



Development of a land use module for the applied economic model NEMESIS : application to european policies

Baptiste Boitier

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Baptiste BOITIER

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devant un jury composé de :

- Jean Paul Charvet, Professeur Émérite de l'Université de Paris Ouest – Nanterre La Défense, Rapporteur
- Daniel Deybe, Expert à la Commission Européenne, Président du Jury
- Gilles Koleda, Directeur des études à COE-Rexecode, Rapporteur
- Paul Zagamé, Professeur Émérite de l'Université Paris 1 – Panthéon Sorbonne, Directeur de thèse

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Development of a land use module for the applied economic
model NEMESIS : Application to European policies

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Chapter 1

General Introduction

1.1 Introduction

Land was integrated into economy theory since its beginning as a fundamental input especially because economies were based predominantly on agriculture. We can measure the extent of land influence, in the history of economic thought, looking at Quesnay's "Tableau Économique" (1759 [399]) which were used by the Physiocrats as an economic model. According to the Physiocrats, the general level of economic activity depends on the level of agricultural activity, other commerce and manufacturing activities were assumed to be unproductive. Richard Cantillon, forerunner of Classical economics, defined land as the source of wealth:

“La Terre est la source ou la matière d'où l'on tire la Richesse ; le travail de l'Homme est la forme qui la produit : et la Richesse en elle-même, n'est autre chose que la nourriture, les commodités et les agréments de la vie” Richard Cantillon (1755 [72])

He proposed to measure the intrinsic value of goods with the quantity of land and labour required to produce it and he argued that labour value is equivalent to land quantity of which the product is allotted to workers. The Physiocrats view of land as the unique source of wealth creation are based on a physical view of land. However, with the development of industry and the decline of land importance with the Industrial Revolution, land became considered as one of the three elementary inputs: labour, capital and land, notably with Adam Smith (1776 [431]) considering land productivity as one of the main conditions for economic growth with labour productivity and commodity transports improvement (Hubacek and Vazquez 2002 [278]). Among Classical economists for whom land stays in the centre of economic theory, we should name Malthus (1798 [347]) who based his theory of population growth according to the limit of land supply. But, with Classical economists, the focus passes from land as main production factor to land rents *i.e.* the money for land services. According Ricardo (1815 [403]) and his land rent theory, previously conceptualised by James Anderson (1777 [12]), marginal products of land are decreasing, due to diminishing returns of labour, coming from non homogeneous quality of land as well as land scarcity. Thereafter, John Stuart Mill (1848 [356]) introduced the concept of land use and especially the competition between uses such as agriculture, mining or residential. Mill also brought in the amenity function of land but he did not consider land as a main production factor (Hubacek and van der Bergh 2002 [277]). For Marx (1867 [351]), land rents were not due to different land quality and land scarcity as for Ricardo and other Classical economists, but as a product of the capitalist society. This Marxist view of land led the reinforcement of the importance of land,

especially in political terms, with the large agrarian reform in Socialist countries such as in Russia in 1917 or Cuba in 1959. We can also note that some years earlier, van Thunen (1826 [468]) introduced a different view of land rents with the so-called van Thunen model, basis of geographical economics. He argued that the land rent is an inverse function of its distance to a city centre. As agricultural products are sold at a unique price in the town wheresoever they come from, land rent is thereby more expensive in an urban fringe than in farther land. Geographical economics were later developed with the Christaller model (1933 [92]) based on the theory of the central place and which describes the hierarchical organisation of a city network. Thereafter, the work of Isard (1956 [291]), Alonso (1964 [9]) and more recently Krugman (1991 [321]) and Fujita (1989 [234]) have theorised the problems of spatial allocation of economic activities either at international level or at intra-national level. These theories are also known as regional science which focuses on localisation models and spatial economy. Thus, by synthesising, land started in the beginning with Physiocrats as the unique production factor, thereafter the first Classical economists considered land as one of the three elementary inputs with labour and capital. Finally, land has disappeared from macro-economic production function which only includes labour and capital as inputs and the analysis of land in economics as mainly focus on localisation of economic activities or on its services in an utilitarian logic.

However, land does not only have an economic function via space for economic activity or residence and productive soil for agricultural products. Land can play societal and spiritual rules. But, land is also at the heart of environment; a function that restores its place in economic analysis. Indeed, with the accelerated economic development since the Industrial Revolution and the accumulation of scientific knowledge, more and more anthropogenic environmental problems were identified. Thereby, environmental consciousness emerges (*e.g.* Hardin 1968 [260] or the first United Nations Conference on the Human Environment at Stockholm in 1972) on many subjects such as Global Warming, soil erosion, waste management, resource depletion or biodiversity. In 1987, following the World Commission on Environment and Development, also known as the Brundtland Commission, a new model of development was lauded. The Brundtland report defines sustainable development as: “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (Brundtland *et al.* 1987 [60]). Worldwide consciousness on sustainable development has prompted numerous governments to consider the environment and implement policies to protect and restore it or prevent future impact. For instance, in European Union since 1970, almost 350 new Directives or amendments of existing Directives, concerning environment protection, have been passed in

European law, of which 180 are still active. Those directives handle numerous environmental problems in which land plays often a non negligible role. Without giving an exhaustive list of environmental problems acting on land, we can enumerate several of them:

- Land and its soil components and its biomass growing on it is, *inter alia*, a carbon sink. And Land Use, Land Use Change and Forestry (LULUCF) has been identified by the United Nations Framework Convention on Climate Change as a major sector for worldwide greenhouse gas accounting. According to the United Nations Framework Convention on Climate Change, LULUCF sector has captured about 2.1 Gigatonne of CO₂ equivalent in 2008 for Annex I countries *i.e.* almost 12% of their total greenhouse gas emissions (UNFCCC 2010 [447]).
- Accelerated rate of soil erosion due to intensive agriculture, urban sprawling or deforestation that, for instance, raises flooding risk or reduces yields for agriculture (EEA 2003 [159]).
- Land is the place of natural habitats for fauna and flora and the space where ecosystem services take place. According to the Millennium Ecosystem Assessment, the actual rate of species extinction is much higher than extinction rate from fossil records (MEA 2005 [354]). This accelerated loss of biodiversity all around the World is mainly due to anthropogenic activities.
- Nutrient surplus for agriculture is a source of groundwater pollution and eutrophication of fresh water but it is also a major source of marine ecosystem perturbation (Likens 2009 [336]).
- And land, particularly biomass growing, like biofuel crops or wood, is a potential huge source of energy to counterbalance the expected depletion of fossil energy as well as a reduction of greenhouse gas emissions. For instance, the European Environmental Agency estimates primary biomass potential even produced with strict environmental constraints, at 190 in 2010 increasing to 295 million tonnes of oil equivalent in 2030 which could represent between 15% and 16% of European Union primary energy requirements (EEA 2006 [160]).

Furthermore, the land use has also re-gained importance since some years through the problems of land availability. On one hand, the rise of World population requires more farmable land to produce food and the recent strong economic development in China or India, countries massively populated, leads to change in eating habits with more meat which requires more land than crops (see *e.g.* Charvet 2009 [82]). On another hand, in some developed countries with already high agricultural productivity but with few available land, the limited land supply requires limitation of land use expansion to avoid strong increase of land price which could affect their economic development.

To summarise, land was at the beginning of economic thought, with the Physiocrats, in the centre of economic analysis but progressively its importance has decreased notably through the development of industrial activities and a more utilitarian view of land that has taken place. Land has kept a place in regional science or spatial economic but, in traditional economics analysis, land was only involved as an input for agriculture often treated as a fixed input. With the emergence of the environment recognition in economics, land via its economic uses has re-gained importance. Land use is actually at the heart of numerous environmental policies of which the European Common Agricultural Policy is a good example because it combines economic and environment especially since its recent reforms.

1.2 Motivation

The subjects examined in this dissertation are based on the consideration presented above. It has been implemented in the context of the 6th Framework Programme of European Commission and especially in the outlines of four Integrated Projects: SENSOR¹, PLUREL², MATISSE³ and THRESHOLDS⁴.

The aim of this dissertation is the construction of a tool for the impact assessment of European policies and especially on economics and the environment. Indeed, the Göteborg European Council and the Laeken European Council in 2001, demanded the consideration of the effects of policy proposals on their economic, social and environmental dimensions which were followed by the establishment, by the European Commission, of impact assessment method for new legislation or policy proposals in economic, social and environmental fields. Similarly in 2008, the French government included in article 39 of the French Constitution the obligation of impact assessment for new legislation (Congrès du Parlement français 2009 [99]). *Ex-ante* policy impact assessment is expected to provide insights on different policy options and thereby help decision makers. It led to the development of a variety of methods and modelling tools with different spatial, temporal and institutional scales (Uthes

1. Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions. SENSOR is supported by the Sixth Framework Programme of the European Union (EU FP6 Integrated Project), Priority Area 1.1.6.3 - "Global Change and Ecosystems". Contract number 003874 (GOCE) - www.sensor-ip.eu

2. The PLUREL project: Peri-urban Land Use Relationships - Strategies and Sustainability Assessment Tools for Urban-Rural Linkages is a European integrated research project within the European Commissions Sixth Framework Programme. www.plurel.net

3. MATISSE (Methods and Tools for Integrated Sustainability Assessment) is supported by the Sixth Framework Programme of the European Union Contract number: 004059 (GOCE) - www.matisse-project.net/projectcomm

4. Thresholds of Environmental Sustainability is an Integrated Project under the European Union's FP6 (Contract No. 003933) - www.thresholds-eu.org.

et al. 2010 [451]).

In this sense, we decided to include, into the New Econometric Model of Evaluation by Sectoral Interdependency and Supply (NEMESIS⁵), land use for a quantitative assessment of European policies. The NEMESIS model is a large macro-econometric applied model for European Union (except Bulgaria and Cyprus) that models each European country individually. The model distinguishes 30 sectors of production and 27 consumption functions. Each production sector is modelled with nested Constant Elasticity of Substitution (CES) production function that includes five production factors: labour, capital, intermediate consumption excluding energy, intermediate energy consumption and knowledge. For consumption, the aggregate consumption is firstly defined, thereafter it is split between durable and non-durable goods which are finally disaggregated into 27 consumption goods. Finally, external trades are subdivided between intra-EU and extra-EU. The former external trade is modelled through a “trade pool” *i.e.* without bi-lateral trades. Furthermore, the NEMESIS model includes three optional modules. The first details the agriculture sector distinguishing agriculture, forestry and fisheries. The agriculture sub-sector is modelled with a transcendental logarithmic functional form and distinguishes two outputs (animal and vegetal) and twelve inputs treated either as flexible or quasi-fixed or fixed (Ngwa Zang and Le Mouél 2007 [367]). Another module disaggregates national sectoral economic variables to regional ones with fixed coefficients. And finally, the last module details energy demand and greenhouse gas emissions. It calculates the energy consumption for each production sector and for households in physical units for eight energy products: fossil energies (coal, oil and gas) and renewable energies (wood, biofuel, biogas and electricity power generation: wind and solar). Those energy sources are modelling with nested CES production functions that link total energy consumption in monetary unit with energy consumption by products in physical units. The NEMESIS model uses are numerous but they mainly focus on R&D policy assessment (*e.g.* Brécard *et al.* 2006 [54], Chevallier *et al.* 2006 [87] and Fougeyrollas *et al.* 2010 [232]) taxation policies (Besson 2007 [33]) and environmental policies (Zagamé *et al.* 2009 [477], CAS 2010 [77]).

Thereby, the NEMESIS model already has interesting features for European policies assessment but the integration of new mechanisms could provide good insights for European policies. Especially, land use, as we described above, interferes in many environmental policies but also on agricultural policies. Consequently, our integration of a land use module in a large applied economic model of European

5. See Appendix B NEMESIS model or Zagamé *et al.* (2010 [476]) for detail description of the model. www.erasme-team.eu/index.php/erasme-nemesis.html

Union such as NEMESIS becomes interesting. There are several kinds of land use models. Mainly, land use models are spatial allocation models more or less detailed and they are generally based on Geographic Information Systems (GIS). For specific land use allocation models or geographical models, even if they differ in terms of scale and mechanisms and if they can be static or dynamic, we can distinguish two categories of geographical models: empirical or statistical ones and rule based models (Heistermann *et al.* 2006 [262]). The former uses past land use change to project future land use whereas the second is based on allocation rules that are not necessary grounded on past land use change but more on expert knowledge or exogenous assumptions for normative analysis. Recently, numerous Agent-Based Models (ABM) for land use change have been developed (Parker *et al.* 2002 [381], Matthews *et al.* 2007 [352]) but they are generally designed for local or even regional analysis. The last groups of model focusing on land use changes are economic ones. Many of them are partial equilibrium models and they focus on global land use change *i.e.* with aggregated World regions (between ten and forty regions). To our knowledge, there is only one dynamic buckled economic model that integrates detailed land use for European Union for which the land use modelling is described in Tabeau *et al.* (2006 [438]). In this context, our introduction of land use in an applied model like NEMESIS appears as relatively innovative and so it could be viewed as a new tool of great interest for European policies assessment.

Thereby, this dissertation will merely focus on applied economic modelling and it will show several applications to European policies. Consequently, the field of this dissertation will be relatively large. For instance, we will address themes related to, *inter alia*, economic analysis (macro-economic and some micro-economic elements), policy analysis with environmental policies or Common Agricultural Policy, sectoral analysis (agriculture), environmental issues (land use, nutrients or biodiversity), energy (energy prices or biofuels), statistics (data collection and harmonisation, construction of databases or econometrics) and obviously economic modelling. The use of those transverse domains has advantages. Mainly, it displays an usefulness of the our modelling for policies assessment. Nevertheless, there are also some disadvantages to address numerous fields. Especially, it does not consistently allow a complete deepening of inherent theories. However, we will try to provide quick but as clear as possible overview of the requisites and, *a minima*, we will refer to the publications.

1.3 Overview

This dissertation is composed of four chapters. The first one describes the land use database construction and explains the construction of the land use module for the NEMESIS model. The second chapter deals with the issues of scenarios for applied modelling through two different applications; one for the so-called *reference scenario* and the second for alternative scenarios. The third chapter presents the construction and the functioning of linkage of four models for sustainable European policies assessment. It also details an application to Common Agricultural Policy partial or complete phasing out with different recycling options for released funds. Finally, the fourth and last chapter presents, after the construction of indicator of agricultural nutrients use, two European policy assessments for biodiversity conservation and for biofuels development.

The **first chapter** is divided into three sections. The first one starts by a presentation of the **land use database** through the different database sources and the assumption made for their harmonisation to reach a complete and coherent database for each European Union country. This land use database distinguishes between four main land use categories, which are subdivided in ten sub-categories: agriculture (arable, grassland and unutilised agricultural land use), built-up areas (housing, commercial and industrial buildings, roads and rails), forest (protected forest and commercial forest) and other land use. In the second section dedicated to agricultural land use, we start by presenting the construction of the **land use asymptote** for agriculture supposing that agriculture has priority to other uses on available lands but only before land conversion into urban, forest or other land use. Later, we briefly explore the studies on agricultural land price determinants to finally detail agricultural land supply modelling in applied economic models. It will lead to a detailed presentation of our modelling of agricultural land price and an analysis of its properties. After choosing the **land supply modelling**, we estimate its parameters with the help of different econometric models. Finally, the third section displays the general methodology for urban land use modelling which converts investments in building into building stocks that are thereafter transcribed into land use through fixed conversion coefficients. Thereafter, buildings are divided into Industrial and Commercial Buildings (I&CB) and housing. The former uses investments from firms addressed to construction sector as a proxy to measure investments in Industrial and Commercial Buildings. Whereas, housing investments is approximated by households investments for which we develop an error correction model estimated with panel data.

In the **second chapter**, several scenarios for the future of European economy will be presented. First of all, a presentation of a typology for development of scenarios elaborated by Kuhlman (2008

[322]) and based on van Notten *et al.* (2003 [457]) is presented. The typology distinguishes four main axis for development of scenarios *(i)* an extrapolating approach based on past trends, *(ii)* an expert knowledge approach using scientific publications or experts studies, *(iii)* an inclusive approach defining several worlds in order to capture the real future and *(iv)* an imaginative approach asking people or experts to imagine the future. Thereafter, we present the construction of the so-called *reference scenario* that will be used as a reference for the policy assessment of the following chapter. **The reference scenario** is grounded on a combination of two of the previous approaches: extrapolating and expert knowledge approach. Thereafter, we display **four alternative scenarios** realised for the European PLUREL project and which are more grounded on imaginative approach even if they take some elements of the others. For *reference scenario* as well as for alternative scenarios, we start by presenting the main drivers. Starting from, the demography and its structure which acts on economy through labour availability or scarcity and social expenditures (such as health or education). Thereafter, we present the assumption about energy price and especially oil price which will constrain more or less the economic development of the whole economy (firms and households) or some economic sectors through energy costs. The third main driver concerns the external demand addressed to European countries. To construct it, we assume some economic projections for twelve World regions that we dispatch in economic sectors using historical data. Finally, we defined R&D investments in European Union which will be a major driver for economic performance of European countries. Furthermore, additional drivers will be defined according to scenarios such as expert projections for agricultural, forestry activity or carbon price. After, economic as well as land use results are discussed and explained and land use change of each scenario is compared with existing projections in the publications.

The policy assessment with the NEMESIS model and the land use module starts in the **third chapter**. However in this chapter, a linkage framework of models will be used for the assessment of a set of Common Agricultural Policy reforms. The **linked models** regroup three sectoral models *(i)* a detailed agricultural model CAPRI (Britz and Witzke 2008 [57]), *(ii)* a forest management model EFISCEN (Sallnas 1990 [412] and Schelhaas *et al.* 2007 [416]) and *(iii)* a detailed model for land use allocation Dyna-CLUE (Verburg *et al.* 2006 [463], Verburg and Overmars 2009 [462]) and one model covering overall sector NEMESIS. Those models have been linked in order to assess European policies looking at sustainable issue. After briefly presenting each model, we provide insights on the relevance of the modelling system for sustainability. Thereafter, a detailed presentation of the models linkage

between the NEMESIS and the CAPRI models underlines its originality. The link between NEMESIS and CAPRI has been designed to take the advantage of CAPRI details on agricultural production and thereby for agricultural land demand and to introduce NEMESIS agricultural land supply flexibility into CAPRI. In order to do this, an iterative convergence process has been implemented between both models for agricultural land use. In a second section, we present the *ex-ante* impact assessment of **a set of Common Agricultural Policy reforms** that emphasises Common Agricultural policy instruments but also its effects on European budget allocation. Indeed on one hand, we will analyse the impact of Common Agricultural Policy phasing out either by market support abolition or by a suppression of direct support to farmers. On another hand, we will look at the effect of two re-allocation options for Common Agricultural Policy released funds either via tax rebate to consumer or subsidies to R&D investments. Finally, we will compare our results with other studies looking at Common Agricultural Policy instruments impact on agriculture and land use and economic effects of re-allocation options.

The **fourth chapter** aims to use the land use module developed for the NEMESIS model for two environmental policies. But before the assessment of both policies, we construct a database on **nutrient use in agriculture** in European countries. With the help of Hansen (2000 [258]), OECD (2007 [374]) and OECD and Eurostat (2007 [376]) studies, we calculate the nitrogen and phosphorus inputs in agriculture in 2008 distinguishing manure, inorganic biological fixation and atmospheric deposit nutrients. Modelling those sources of nutrient input, we thereafter project them for the *reference scenario* up to 2025 and we analyse the results. The second section starts by an overview of European biodiversity conservation policies and particularly the Natura 2000 network on which we lean on for the assessment of two different biodiversity conservation policies. The first policy consists of **an extension of European protected forest** which is implemented by a reduction of available land *i.e.* a shift of the agricultural land asymptote whereas, the second biodiversity conservation policy reaches **an extensification of European agriculture**. This extensification is allowed by a subsidy to farmers for decreasing agricultural land price; subsidy implemented either at national or at European level. Thereafter, we compare our results through the biodiversity conservation cost with other estimates. Finally, the last section displays a normative assessment of the European target of **10% of biofuels** in transports in European Union in 2020. This assessment focuses on the agricultural impact of such biofuel crop development as well as their environmental impact on agricultural land use and nutrients use for which we have slightly modified the modelling to take into account two different options. We

Chapter 1. General Introduction

conclude this section by a critical comparison of our results with existing assessments of European biofuel policies with applied economic models.

Finally, we will conclude this dissertation by a large summary of the main results obtained in the four chapters. We will also proceed to a critical analysis of our findings before finishing by expressing the desirable and desired future researches

Chapter 2

Land use module

2.1 Introduction

In this first chapter we will describe the land use module developed for the large applied econometric model NEMESIS¹ (see Appendix B or Zagamé *et al.* 2010 [476] for description). The increasing demand of *ex-ante* policy assessment at European level, that follows the mandatory assessment of major European policies, has developed the interest for large quantitative tools such as the NEMESIS model. Among all European Commission policies (research and development, taxation, ...), the interest for energy and particularly environmental policies has grown rapidly following the discussions about the Common Agricultural Policies (CAP) reform after 2013 or the post-Kyoto process. However, these environmental policies can have significant impact on land-use and the NEMESIS model was not able to provide insights on this subject. Thus, with the implication of the NEMESIS model in European projects² focusing on environmental policies assessment and particularly for some of them on their land use impact, we decided to implement a land use module in NEMESIS in order to fill this gap. The land use evaluation and prospective imply a large range of scientific fields such as demography, sociology, geology, urban and landscape planning or forestry. It is of course not possible, and not desirable, to take all these research fields into account together in the development of this module. Our more modest objective was to construct a module that links land use and with economics in order to provide interesting indicators for policy makers. Nevertheless, as for every detailed applied modelling, linking an economic model and land use is not simple and implies trade-offs which are of the two following natures:

- a trade-off between the main economic mechanisms used in an applied macro-sectoral economic model and the multiple faces of land use. We choose to emphasise the economic aspect.
- and, as for all quantitative tools, a trade-off between the expected details of the module and available information and, notably, available databases and knowledge.

The major part of this chapter will deal with agricultural land. The choice to put emphasis on **agricultural land** is due to four main reasons:

1. www.erasme-team.eu

2. Notably:

- SENSOR: Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multi-functional Land Use in European Regions. SENSOR is supported by the Sixth Framework Programme of the European Union (EU FP6 Integrated Project), Priority Area 1.1.6.3 - "Global Change and Ecosystems". Contract number 003874 (GOCE) - www.sensor-ip.eu
- PLUREL: Peri-urban Land Use Relationships - Strategies and Sustainability Assessment Tools for Urban-Rural Linkages is a European integrated research project within the European Commissions Sixth Framework Programme. www.plurel.net

- Agricultural lands cover the major part of the area of European countries,
- agriculture is also an economic sector of interest for European Union (EU) insomuch as almost half of its budget is dedicated to the Common Agricultural Policy (CAP),
- agriculture is a sector directly or indirectly concerned by environmental policies. Indeed, environmental policies, such as biodiversity conservation, have direct impact on agricultural activity. In addition, other policies like climate change policies, have indirect impact on agriculture, for instance through biofuels or the reduction of greenhouse gas emanating from animal production,
- and agriculture is a specific sector of NEMESIS for which there is a detailed representation in the model and especially according to its factor demands (Ngwa Zang and Le Mouél 2007 [367] and Ngwa Zang 2008 [366]).

We have also studied **urban land use**. Indeed, even if urban land use is not directly linked to environmental policies and even if it covers less area than agriculture, its importance can be non negligible in certain countries. Furthermore, the urban land, having an increasing popularity, are in competition for land use. Thereby, it can reduce available land for agriculture. It then appears important to take urban land use into account, even if we will only use available NEMESIS economic information to model it. Regarding other land use categories we also deal with forest, transport infrastructures and the unsuitable lands :

- **Forest** is the second land use category in EU, in terms of occupied area, and, as agricultural land, forest is concerned within environmental policies. The forest areas can be divided in two categories, on one hand, a huge part of forest is protected and its evolution is mainly the result of national policies. On the another hand, forest is used for wood products and serves as raw material for forestry. Nevertheless, the forestry sector is more complex than the agricultural one, and especially, the link between forestry and land used requires an important knowledge of national forest exploitation rules as well as knowledge about forest components *e.g.* the tree species and their age. Thus, considering this complexity, we decided to keep forest exogenous. However, we will not totally exclude forest from our analysis insomuch as we linked the NEMESIS model with a specific model for forestry in chapter 4 and we assessed biodiversity policies in forest areas in chapter 5.
- We calculate the land used by **transport infrastructures** in section 2.2, but transport infrastructures cover a very small area in EU and we decided to keep it exogenous. We could link it with the transport sector of NEMESIS, but the dynamic of the transport infrastructures is not

necessary related to the transport sector activity. In fact, even without speaking about public aspects of transport infrastructures policies, there are volume effects (*i.e.* number of passengers per car or number of merchandise per truck) as well as traffic effects (*i.e.* number of cars on a road at certain time) that complicate the link between the NEMESIS transport sector and the land used by transport infrastructures.

- Finally, the **unsuitable lands** that include wetlands, mountainous areas, etc, are also kept exogenous. Of course, we take its into account by quantify them and supposing none conservation for these areas.

Thus, we organise this chapter in four parts. The first part is devoted to the presentation of **land use categories**, and it displays a statistical analysis of European land use with respect to these categories. We explain in this first section which databases we use and how we have compiled them to create a coherent land use database for the NEMESIS model. Thereafter, we present the **agricultural land supply** starting from a short literature survey on land price determinants. Then, we describe some agricultural land supplies used by large applied economic model, comparable with NEMESIS. A short comparison of the different functional forms, used in these models, allow us to present our modelling for agricultural land supply. We thereafter introduce the data used to estimate our model and finally we present and discuss the estimate results. The second section describes the **agricultural land demand** based on agriculture production functions implemented in NEMESIS. We explain which function we chose and why we selected it. Finally fourth section, before a conclusion summarising the overall work on the land use module, presents the **urban land use modelling**. Firstly, we describe the general methodology used to model urban land use and thereafter we detail this methodology for industrial and commercial buildings as well as for housing. An important part of this section is dedicated to the development of an error correction model for housing investment with panel data.

2.2 Land use database

In the section, we present the different data sources used to construct NEMESIS land use. We also perform a brief statistical descriptive analysis in order to display the differences between countries and the extent of each land use underlining the importance of land on different economic activities or on the environment.

2.2.1 Main Land Use categories - CORINE Land Cover 2000

The first database used to build the land use module will allow us to determine total land use and to split it between main land use categories. The CORINE Land Cover 2000 (CLC2000) database (EEA, 2004 [166]) provides land cover³ for EU27 (except Finland, Sweden, Malta and Cyprus) and it is based on the photo-interpretation of satellite images. This database provides three levels of nomenclature, the first level describes four main land categories, the second one, thirteen and the last one, thirty nine (see table 2.2.1). We use the CLC2000 data as basis for the year 2000, in order to have full and coherent data for NEMESIS land use module in 2000, which can not be done with Eurostat (Eurostat, 2004 [199]) or Food and Agricultural Organisation (FAO, 2008 [221]) databases. Nevertheless, we will use the other databases later to define more detailed land use categories.

Box 2.2.1 : Land use and Land cover

The confusion between land use and land cover has been treated since more than 30 years (Anderson *et al.* 1976 [13], Campbell 1981 [71], Di Gregorio and Jansen 2000 [114]) but a recent paper realised by Fisher *et al.* (2005 [226]) allows the establishment of a clear and simple distinction between land use and land cover. Indeed, they defined land cover as “*the physical material at the surface of the earth [...] including grass, asphalt, trees, bare ground, water, etc*” whereas land use is defined as “*a description of how people use the land [...] urban and agricultural land uses are two of the most commonly recognised high-level classes of use*”.

In our study, we will speak about land use and not land cover, even if we will not respect exactly the Fisher *et al.* (2005 [226]) definitions. For instance for agriculture, we will start by using land cover data to define the overall land that could be used for agricultural production. We thereafter will calculate the agricultural land use with the area used by agriculture to produce. For urban land use, we will use the land covered by urban (land cover concept) supposing that this land are used by people as urban areas (land use concept), thereby we will not make the distinction between land cover and land use in this case.

3. See box 2.2.1 for explanation of about the difference between land use and land cover.

Table 2.2.1: CORINE2000 Land Cover Land Nomenclature

1 Artificial surfaces	11 Urban fabric	111 Continuous urban fabric 112 Discontinuous urban fabric
	12 Industrial, commercial and transport units	121 Industrial or commercial units 122 Road and rail networks and associated land 123 Port areas 124 Airports
	13 Mine, dump and construction sites	131 Mineral extraction sites 132 Dump sites 133 Construction sites
	14 Artificial, non-agricultural vegetated areas	141 Green urban areas 142 Port and leisure facilities
2 Agricultural areas	21 Arable land	211 Non-irrigated arable land 212 Permanently irrigated land 213 Rice fields
	22 Permanent crops	221 Vineyards 222 Fruit trees and berry plantations 223 Olive groves
	23 Pastures	231 Pastures
	24 Heterogeneous agricultural areas	241 Annual crops associated with permanent crops 242 Complex cultivation patterns 243 Land principally occupied by agriculture with significant areas of natural vegetation 244 Agro-forestry areas
3 Forest and semi natural areas	31 Forests	311 Broad-leaved forest 312 Coniferous forest 313 Mixed forest
	32 Scrub and/or herbaceous vegetation associations	321 Natural grasslands 322 Moors and heathland 323 Sclerophyllous vegetation 324 Transitional woodland-shrub
	33 Open spaces with little or no vegetation	331 Beaches, dunes, sands 332 Bare rocks 333 Sparsely vegetated areas 334 Burnt areas 335 Glaciers and perpetual snow
4 Wetlands	41 Inland wetlands	411 Inland marshes 412 Peat bogs
	42 Maritime wetlands	421 Salt marshes 422 Salines 423 Intertidal flats

Source: CLC2000

We use the two first levels of the CLC2000 nomenclature to specify the following land use categories of NEMESIS land use module (table 2.2.2):

- “1. Artificial surfaces” are defined as “Built-up Areas”,
- “2. Agriculture areas” are defined as “Total Agricultural Lands”,
- “3.1. Forests” are defined as “Forest”,
- “3.2. Scrub and/or herbaceous vegetation associations”, “3.3. Open spaces with little or no vegetation” and “4. Wetlands” are defined as “Other land Use” or “Nature Conservation” or even “Unsuitable lands”.

Table 2.2.2: CLC2000 and NEMESIS land use correspondence table

CLC2000	NEMESIS main Land categories
1 Artificial surfaces	Built-up Areas
2 Agricultural areas	Total Agricultural Lands
31 Forests	Forest
32 Scrub and/or herbaceous vegetation associations 33 Open spaces with little or no vegetation 41 Inland wetlands 42 Maritime wetlands	Nature Conservation or Other Land Use

For Finland, Sweden and Malta that were not covered by the CLC2000⁴, we use the Eurostat land use database (Eurostat, 2004 [199]). For Finland and Sweden, we use Eurostat Land Use Statistics that are complete for 1990. In this case, the four categories used in NEMESIS are defined as:

- “*Built-up Areas*” refers to “*Built land and related land*” (la_3)⁵,
- “*Total Agricultural lands*” to “*Total Agricultural Land*” (la_1).
- “*Forest*” is equal to “*Total land under forest and other wooded land*” (la_2) less “*Other wooded land*” (la_25).
- And finally “*Nature Conservation*” is the sum of “*Other wooded land*” (la_25), “*Wet open lands*” (la_4) and “*Total dry open lands*” (la_5).

For Malta, we also use Eurostat Structure of agricultural holdings (Eurostat, 2009 [209]) to determine the “*Total Agricultural Lands*” and we take the Luxembourg coefficient for “*Built-up areas*”⁶ and finally we deduce the “*Other Land Use*” as the difference between the total land and the two other categories, insomuch as there is no “*Forest*” in Malta. As Cyprus is not modelled in the NEMESIS model, we left Cyprus out of the study. Thereby, we obtain the land use presented in figure 2.2.1 that displays quite different land use repartition among Member States (MS). For instance, we can observe that “*Total Agricultural Lands*” represent around 60% of France’s total land (*i.e.* 300 000 km²) whereas Sweden and Finland are principally covered by forest with 251 000 km² (62%) and 202 000 km² (68%) respectively. Furthermore, looking at Belgium and Netherlands, we observe that “*Built-up Areas*” represent respectively 20.5% (6 250 km²) and 12% (4 540 km²) of the total lands whereas only 2%

4. These countries are now available on CLC2000 database, but it was not the case at the beginning of this study.

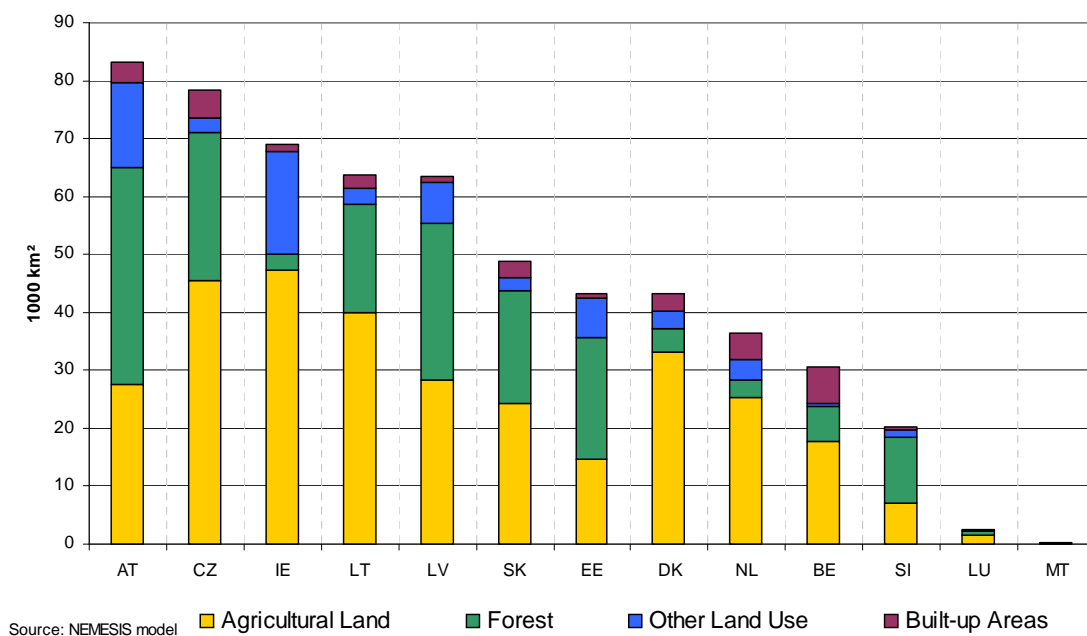
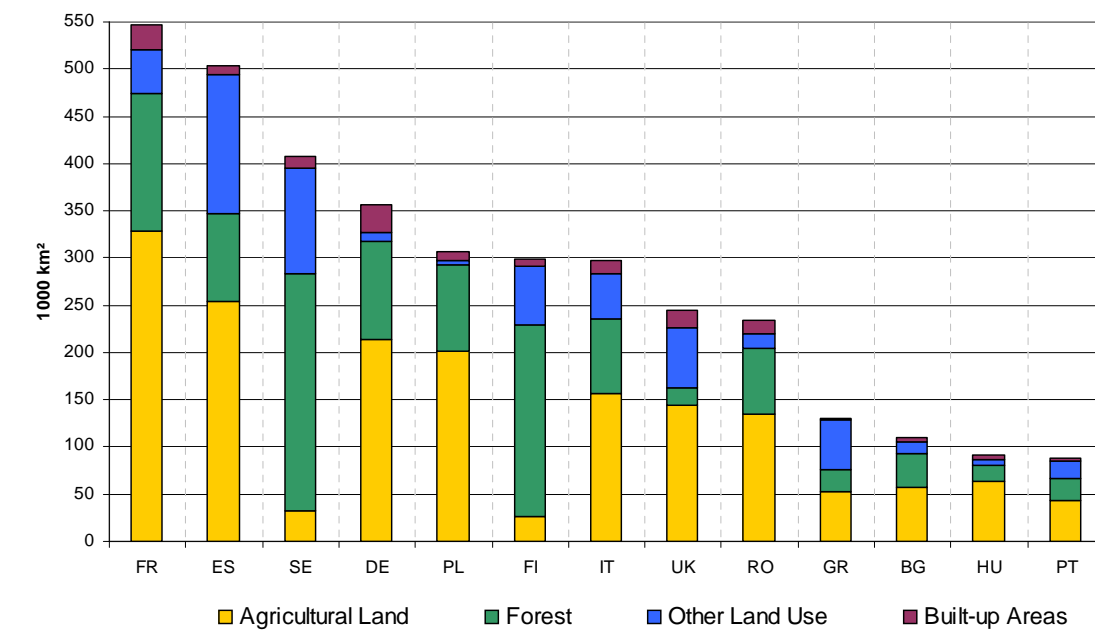
5. Those codes refer to Eurostat Land Use Statistics nomenclature

6. This assumption is relatively rough, but in the absence of data, the similarity in term of size between Luxembourg and Malta lead us to retain this assumption.

Chapter 2. Land use module

(915 km²) of the Estonian territory is covered by “*Built-up Areas*”. All these differences will have important consequences for the land supply and the land price in section 2.3.

Figure 2.2.1: Land Use main categories in thousand km² for NEMESIS Land Use Module in 2000



2.2.2 Land Use Sub Categories

Some of the land categories described in the previous section have to be sub-divided in order to provide better assessment on the impact of economic policies on land use changes. This is particularly the case for “*Built-up Areas*”, which covers Urban land use (housing, commercial and industrial buildings) as well as transport infrastructure, and for the “*Total Agricultural Lands*” for which we have to determine the share of land actually used (as the CLC2000 database provides land cover and not land use). However, there are important restrictions to increase the number of land sub-categories:

- As expressed above, CLC2000 database provides data at a relatively detailed level, but these categories concern land cover and not land use, and we have to calculate the land *used* by agriculture and not only the “*Total Agricultural Lands*” *i.e.* the overall available land for agricultural production. Furthermore, the CLC2000 sub-categories for agricultural land are more oriented by physical aspects than by economics, but our concern is to link economic activities to land use. Therefore, we can not use the CLC2000 database to detail NEMESIS land use.
- Secondly, our goal is to build a module for the NEMESIS model, so we must keep in mind the structure and the functioning of the model, and we have to be able to model each land use sub-category with NEMESIS variables. Thus, for instance it will be useless to detail the agricultural land use too much insomuch as NEMESIS model distinguishes only two agricultural productions: vegetal and animal productions.
- Furthermore, as the NEMESIS model is designed to provide results at country level, we have to keep the NUTS0⁷ level for each land use category. Indeed, if this aggregation level can appear too aggregated, it is important to specify that the NEMESIS land use module must be designed for each EU countries and must stay strongly linked with the model. Thereby, it seems adequate to adopt the country level for the land use module.

The definition of the NEMESIS land use sub-categories is the result of a trade-off between the need of details in order to realise relevant policy assessment, the data restrictions and the consistency with the NEMESIS model. Thus, we have distinguished ten land-subcategories which are displayed in table 2.2.3. In order to build agricultural sub-categories, we use the Eurostat Structure of agricultural

7. NUTS “Nomenclature d’Unités Territoriales Statistiques” is a geocode standard for referencing the subdivisions of countries for statistical purpose. NUTS0 level refers to countries. And for instance, NUTS1 refers to huge regional zone like “Ouest” (FR5) for France, NUTS2 refers to “régions” for France like “Bretagne” (FR52) and NUTS3 refers to “départements” for France like “Morbihan” (FR524). For more detailed on NUTS principles and NUTS region in EU please refers to Eurostat website (http://ec.europa.eu/eurostat/ramon/nuts/introduction_regions_en.html)

holdings database (Eurostat 2009 [209]) which distinguishes 8 land use types :

- “*Utilised Agricultural areas*” divided in: “*Arable Land*”, “*Kitchen Garden*”, “*Total: Permanent grassland and meadow*”, “*Permanent Crops*” and “*Other land*”,
- “*Unutilised agricultural land and other areas*”,
- “*Wooded area*”.

Table 2.2.3: NEMESIS land use disaggregation

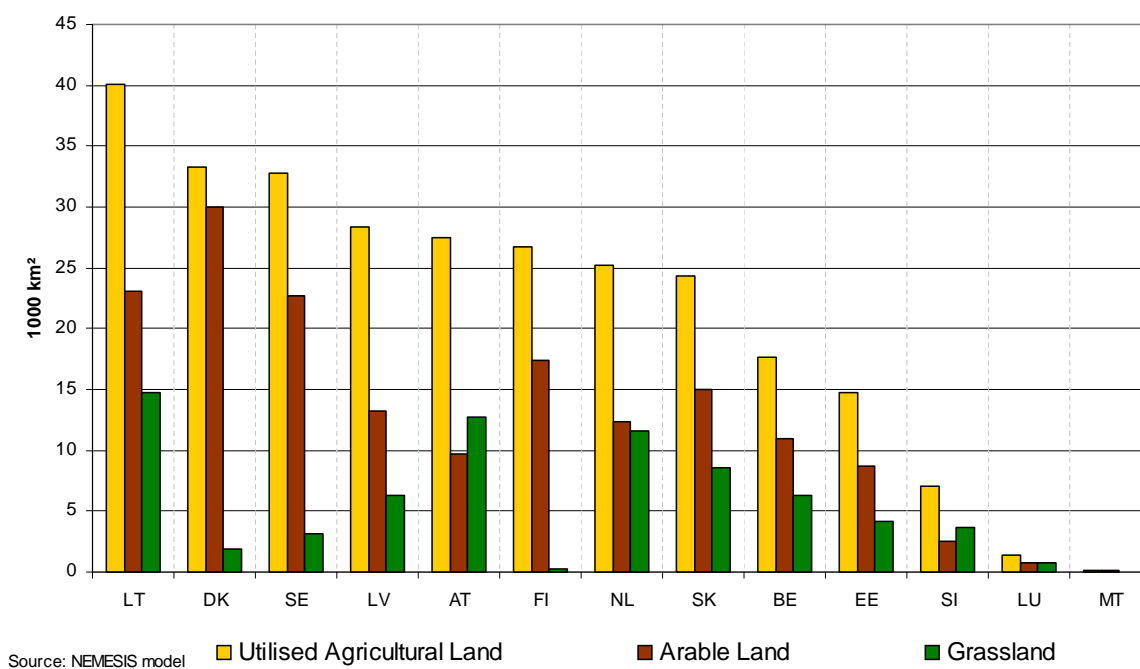
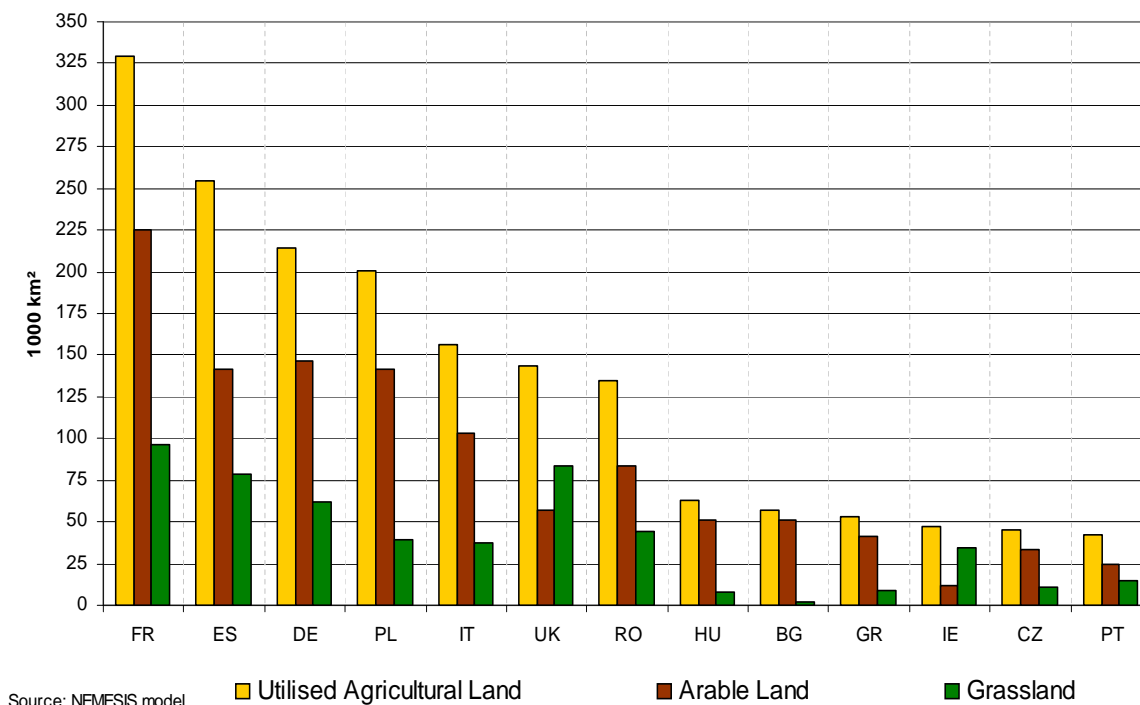
Aggregated Land Use Categories	Intermediate Land Use Categories	Detailed Land Use Categories
Built-up Areas	Urban Land Use	Housing
		Commercial and Industrial Buildings
	Tranports Land Use	Roads
		Rails
Total Agriculrural Lands	Utilised Agricultural Land	Arable Land
		Grassland
	Unutilised Agricultural Land	Unutilised Agricultural Land
Forest	Forest	Commercial Forest
		Preserved Forest
Other Land Use	Other Land Use	Other Land Use

Agricultural land

We start by taking the share of Eurostat “*Utilised Agricultural Land*” in the overall agricultural land of Eurostat and apply it to the NEMESIS “*Total Agricultural Lands*” calculated in the last section which allows us to determine the “*Utilised Agricultural Land*” in NEMESIS. Thereafter, we aggregate “*Arable Land*” and “*Permanent crops*” and we apply its share on Eurostat “*Utilised Agricultural Land*” to NEMESIS’s “*Utilised Agricultural Land*” allowing the calculation of the “***Arable Land***” in NEMESIS. Similarly, we use the difference between the previous land category and NEMESIS “*Utilised Agricultural Land*” to compute the NEMESIS “***Grassland***” category.

Figure 2.2.2 shows the “*Utilised Agricultural Land*” for EU countries in 2000, which is split between “*Arable Land*” and “*Grassland*”. Total EU agricultural lands cover around 1.875 million km² *i.e.* 45% of the EU land, of which 1.28 million km² (68% of the EU lands used by agriculture) is arable land whereas 595 000 km² (32%) is grassland. We can also see that arable land is bigger than grassland in most of EU countries, except in United Kingdom, Ireland, Austria and Slovenia with 83 500 km², 34 000 km², 12 700 km² and 3 700 km² of land occupied by grassland respectively.

Figure 2.2.2: Agricultural land sub-categories (in thousand km²) for NEMESIS land use module in 2000 (1/2)



Built-up Areas

Figure 2.2.3, 2.2.4 and 2.2.5 display the “*Built-up Areas*” sub-categories: “*Housing*”, “*Commercial and Industrial Buildings*”, “*Railways*” and “*Roads*”. Each sub-category was calculated starting from the aggregated “*Built-up Areas*”. For Belgium, Denmark, France and Netherlands, we compute, from the Eurostat Land Use Statistics (Eurostat 2004 [199]), “***Housing***” with the share of “*Residential land*” (la_3_1) and “*Recreational and other open land*” (la_3_9) on “*Built-up and related land*” (la_3). But for the other countries, this data is missing in the Eurostat Land Use Statistics. Nevertheless, regarding this share for the four countries with available data, we can observe that these shares are relatively stable with 47% for Belgium, 45% for Denmark, 42% for France and 53% for the Netherlands. We then calculate the weighted average share of “*Housing*” with the four available countries (44.3%), and apply it to all other countries. Of course this assumption is very important but the lack of data and the incoherence between different data sources, force us to adopt such strong assumptions.

Thereafter, we use the Eurostat Common Questionnaire on Transport Statistics (Eurostat 2004 [197]) which provides for each EU country the length in kilometres of motorways, other roads and railways. So, we have to make some assumptions on the width of each transport infrastructure type⁸. We choose 15 meters for “*Motorways*”, 7 meters for “*Other roads*” and 5 meters for “*Railways*” (using standard gauge or Stephenson gauge). We obtain the lands used by transport infrastructure presented in figure 2.2.4 and 2.2.5. In EU, transport infrastructures cover 26 800 km², of which 25 200 km² by **road** and 1 600 km² by **railways**. The biggest railway network is in Germany with more than 300 km², followed by France and Poland with respectively 220 km² and 160 km². Furthermore, we find the biggest road network in France with 7 000 km² followed by United Kingdom and Poland with respectively 2 900 km² and 2 600 km². We can see that one of the main driver for transports land use is obviously the country area, but it is not the only influential factor, as for instance looking at Bulgaria (110 000 km²), where total area is almost four times bigger than in Belgium (30 500 km²), the land occupied by transports infrastructures is almost eight times more important in Belgium (1 100 km²) than in Bulgaria (151 km²). Finally, we calculate the land used by “*Commercial and Industrial Buildings*” as the balance between the three other sub-categories and the total “*Built-up Areas*”. “*Commercial and Industrial Buildings*” are represented in figure 2.2.3.

8. We used different documents for this purpose (SETRA 2006 [423], EuroRAP 2003 [196])

Figure 2.2.3: Housing and Commercial & Industrial Buildings land (in thousand km²) for NEMESIS land use module in 2000

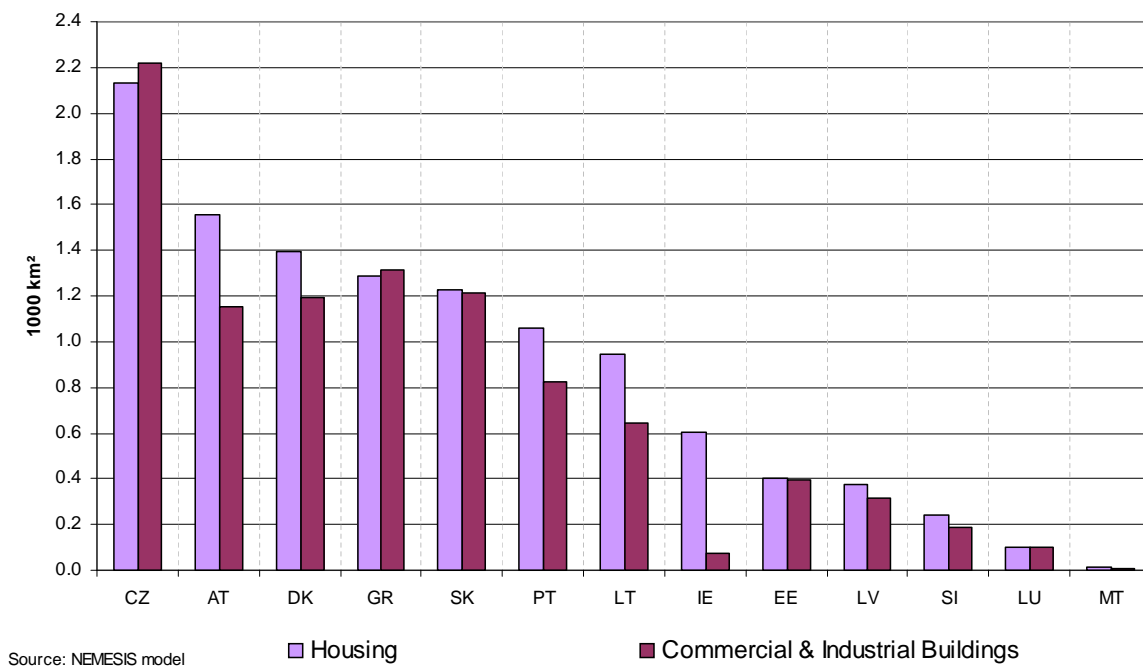
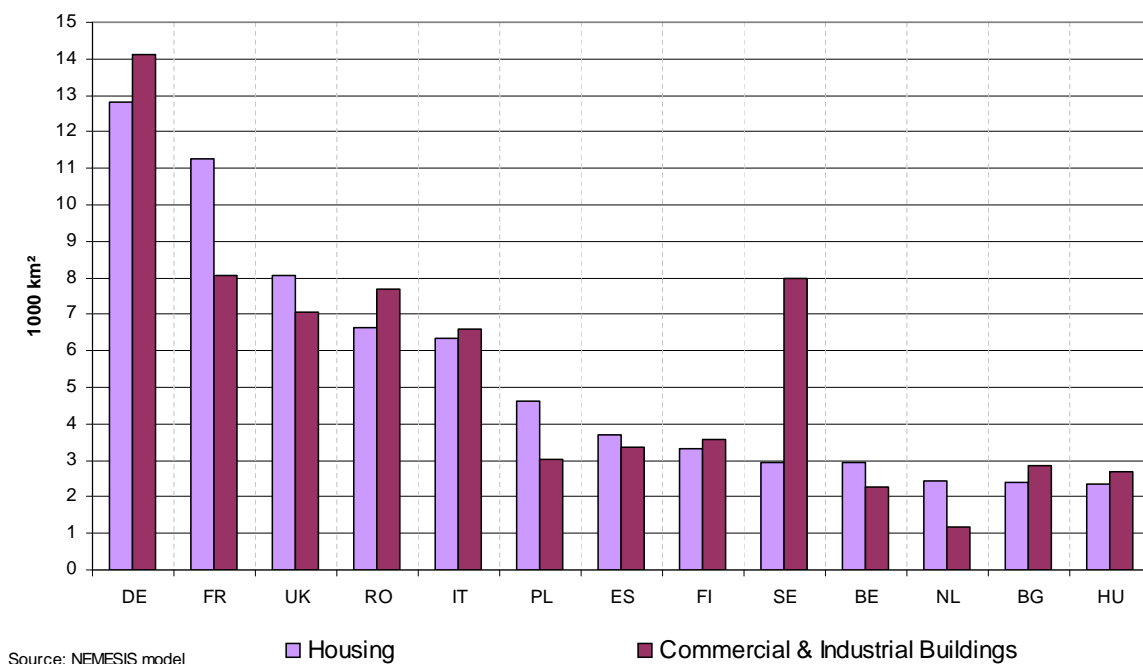
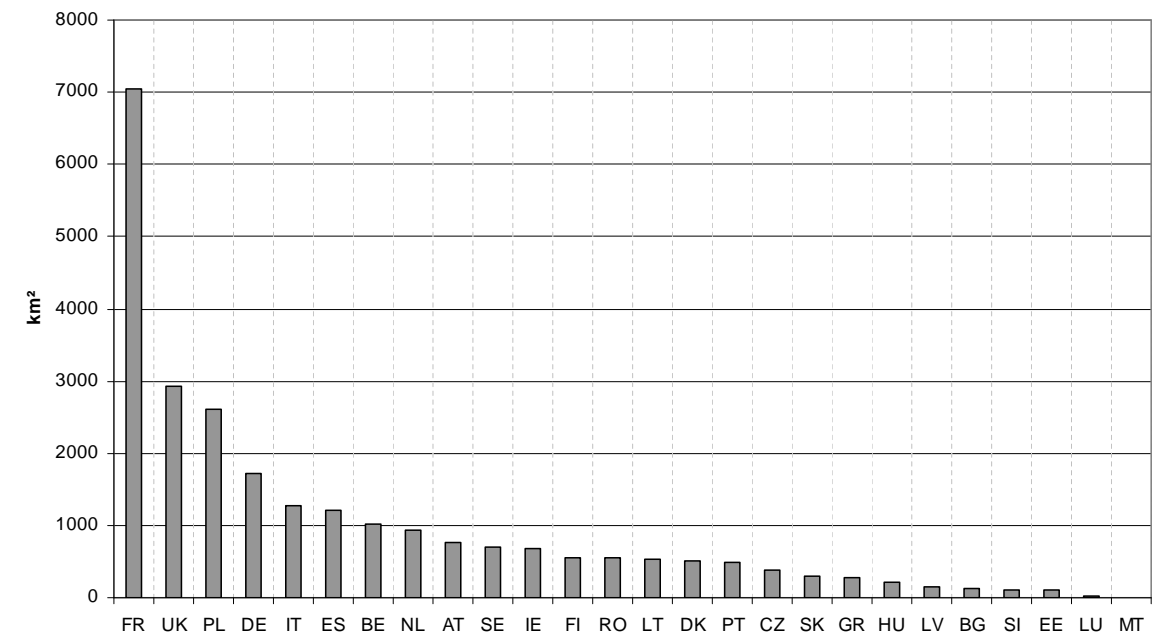
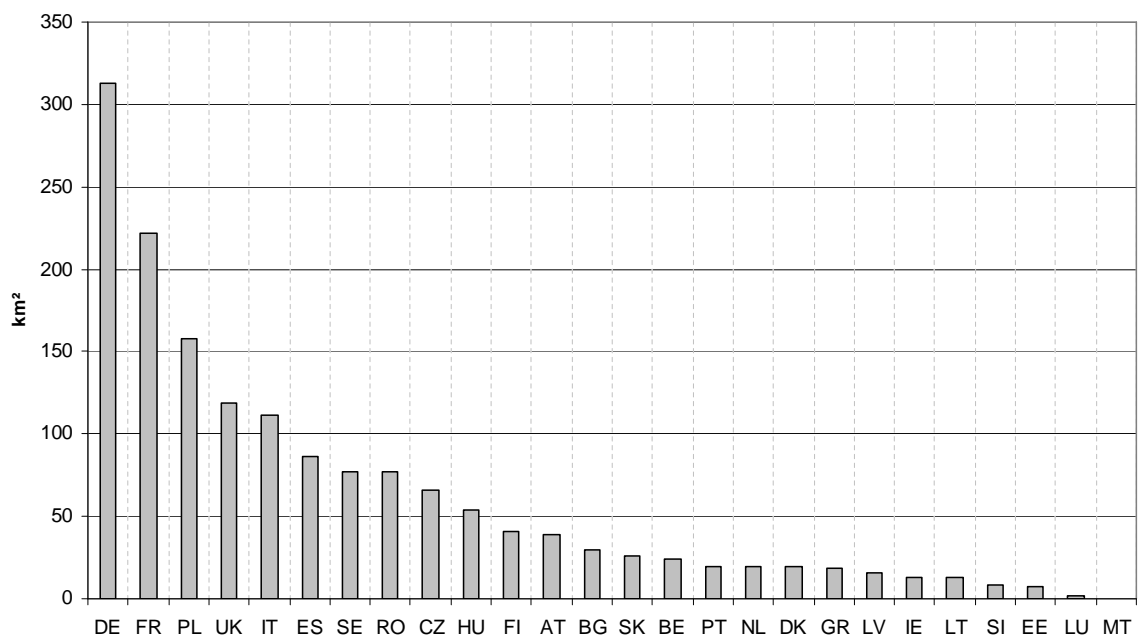


Figure 2.2.4: Road areas (in km²) for NEMESIS Land use module in 2000



Source: NEMESIS model

Figure 2.2.5: Railways areas (in km²) for NEMESIS land use module in 2000



Source: NEMESIS model

Forest

The last sub-categories distinguish the forest available for wood production (that we call “*Commercial Forest*”) and the “*Preserved Forest*”. We use the FAO FRA2000 (FAO 2001 [219]) database to construct both land sub-categories, insomuch as the FAO FRA2000 database distinguishes both forest types.

Figure 2.2.6: Commercial and Protected Forests in thousand km² for NEMESIS Land Use Module in 2000

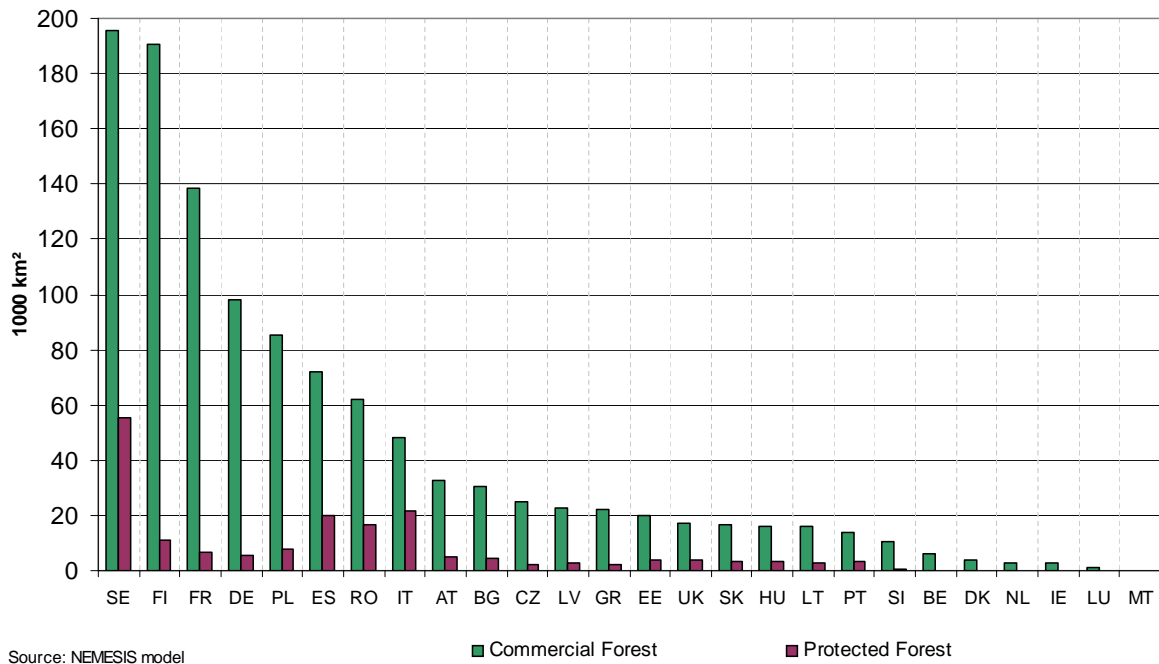


Figure 2.2.6 shows that both Scandinavian countries: Sweden and Finland represent 34% of the total EU forest, with 250 000 km² and 200 000 km² occupied by forest respectively. We can also see that the share of the “*Preserved Forest*” in the total forest is very variable among countries with a maximum of 31% in Italy, following by Sweden with 22% whereas countries like France, Belgium, Denmark and Ireland have less than 5% of “*Preserved Forest*”. In EU, the “*Preserved Forest*” represents more than 4% of the EU area with 183 000 km², and “*Commercial Forest*” covers 1.15 million km² *i.e.* more than 27% of EU lands.

2.3 Agricultural Land Use

In this section, we present the core of the NEMESIS land use module, *i.e.* the supply of agricultural land use. As we saw in the previous section, the agricultural land use covers a major part of the EU land (48%) and can reach 77% of the total land used in a country like Denmark. Furthermore, compared with forest that also covers important areas in EU, agricultural lands are more impacted by economic activities than forest. Thus, we put a particular emphasis on the agricultural land use through the demand emanating from agriculture needs for production and the land supply which is constrained by the land availability. In this section, we will focus on the land supply and especially on the relation between land supply, land rental price, and scarcity of lands. First, we present how we treat the problem of land scarcity, we then focus on the functional form used to model land supply. We then present the econometric estimate results and display the land supply elasticity to land rental price and illustrate its consequences for some EU countries. Finally, we explain how we treat the land demand referring to agriculture production already implemented in the NEMESIS model.

2.3.1 Asymptote

We assume in the NEMESIS land use module that each land type requires different land claims and we treat these land claims hierarchically. After land conversion, available area changes imposing some irreversibilities: “*Built-up Areas*” can not be converted to other land use types. Indeed, it seems unrealistic to suppose a land conversion from built-up area from agriculture in the time horizon of our study *i.e.* 10 to 20 years. Similarly, “*Protected Forest*” and “*Other land*” that are supposed to be protected and therefore stay constant without specific policy change. We then define total available land as the total land minus the land used by “*Built-up Areas*” (urban land and transports Infrastructures), “*Protected Forest*” and “*Other Lands*” (wetlands and unsuitable lands), *i.e.* the existing agricultural land plus the “*Commercial Forest*”. We hence assume that all the “*Commercial Forest*” can be converted to available land, even if in the short term, it can be difficult to convert all the “*Commercial Forest*” in “*Agricultural land use*”. But, as the forest is not protected in the long term, a full conversion could occur. As a consequence, only agricultural land use and “*Commercial Forest*” can be considered as available, and drive the position of the asymptote for land supply (see figure 2.3.1). Once determined the total available land, we assume that the agriculture sector has priority to other uses (Forestry and Built-up Areas) on the available land *i.e.* that available areas are allocated uppermost to agriculture.

We present in figure 2.3.2, two different hypothesis, one including 100% of the “*Commercial Forest*” and another one including only 25% of it. We nevertheless use the first options in the following of our study.

Figure 2.3.1: Land Asymptote in NEMESIS Land Use Module

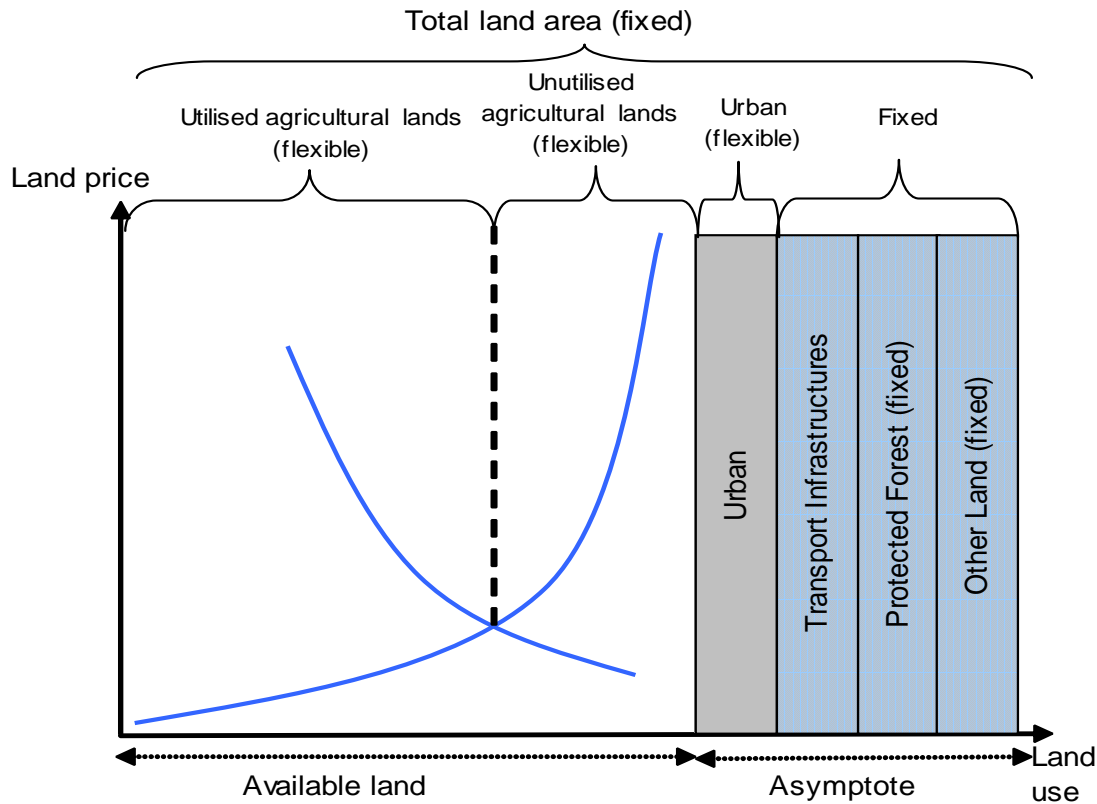
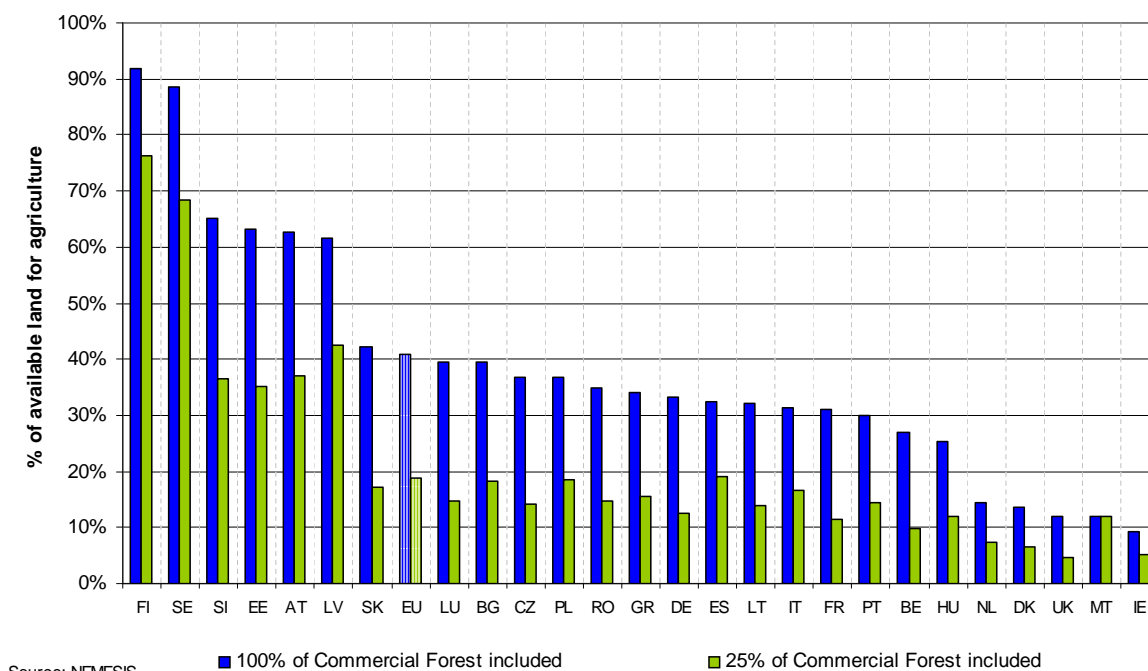


Figure 2.3.2 shows the percentage of unutilised agricultural lands *i.e.* the ratio between the overall potential available lands for agriculture minus lands already used by agriculture and the available land for agriculture. This ratio allows showing the initial position of each EU countries on the supply curve in 2000 in figure 2.3.1, a country like Ireland which have few available lands (4 700 km² *i.e.* less than 10% of the total land available for agricultural⁹) is very close to its asymptote and therefore can not increase too much its agriculture land demand without facing to a strong increase of its land price. At the opposite, Finland or Sweden, that have the biggest share of forest, have important unused

9. When it is not specified, we give the results for the case where we include 100% of the “*Commercial Forest*” in the land available for agriculture. This is also the option that we will keep all long this study.

agricultural land with respectively 92% (200 000 km²) and 89% (202 000 km²) of unutilised agricultural lands. However, looking at the case where only 25% of “*Commercial Forest*” can be convert into agricultural land, Finland and Sweden have, of course, less land available especially in level, but they remain the less constrained countries with still 76% (56 700 km²) and 68% (55 700 km²) of unutilised agricultural lands, respectively.

Figure 2.3.2: Percentage of land available for agriculture including 100% or 25% of Commercial Forest, for EU countries, in 2000



We can identify in figure 2.3.2, three main groups of countries:

- The first one includes countries having more that 50% of land still available for agricultural production, this group is composed of Finland, Sweden, Slovenia, Estonia, Austria and Latvia.
- The second group, the most important, regroups fifteen countries: Slovakia, Luxembourg, Bulgaria, Czech Republic, Poland, Roumania, Greece, Germany, Spain, Lithuania, Italy, France, Portugal, Belgium and Hungary. These countries have between 50% and 25% of unutilised agricultural lands.
- The third group includes, the more constrained countries, with less than 25% of agricultural lands available. It regroups five countries: Netherlands, Denmark, United Kingdom, Malta and Ireland.

Chapter 2. Land use module

In the EU, the unutilised agricultural lands are about 1.3 million km² (40% of total potential available land for agriculture) in the case where the whole “*Commercial Forest*” is potentially available for agriculture. While it represents only 435 000 km² (19% of total potential available land for agriculture) in the case where 25% of “*Commercial Forest*” is included in the potential available land for agriculture. This representation of land use through an asymptote is the basis of the agricultural land use market and especially it is the canvass of the land supply functional form presented in the following sections.

2.3.2 Land supply and land price

We start this section by a short survey starting by giving some historical marks and by excluding some theoretical fields, we thereafter detail a little bit more empirical literature on land prices determinants but we will really focus on literature on land supply within large applied economic model.

2.3.2.1 Historical marks

The links between economics and land use have been studied very early in the economic literature and the amount of theoretical studies is very substantial¹⁰. It begins with Ricardo (1815 [403])¹¹ and the classical theory on land rent which supposes that the more productive lands are used first following by the less one. And he supposes land rent existence by land scarcity and different land qualities. Another economist who made the basis of the land rent theory is van Thünen with the so-called van Thünen model (1826 [468]), basis of geographical economics, and that evaluates the land price by the agricultural returns net of the transportation cost. Geographical economics were later developed with the Christaller model (1933 [92]) based on the “theory of the central place” and which describes the hierarchical organisation of a city network. Thereafter, the work of Isard (1956 [291]), Alonso (1964 [9]) and more recently Krugman (1991 [321]) and Fujita (1989 [234]) have theorised the problems of spatial allocation of economic activities either at international level or at intra-national level. These theories are also known as regional science that focuses on localisation models, on spatial economy, on the analysis of regional public policies and also on environmental management such as land use. Nevertheless, the localisation of economic activities is not precisely our goal. In fact, on one hand, we based our study at a national level substantially reducing the applicability of regional science theories and on the another hand, we should introduce important modifications in the NEMESIS model in order to take into account the problems of economic activities localisation. We should introduce for instance the possibility of international capital and labour mobility, labour being only perfectly mobile inside country and capital being only mobile through the new investments *i.e.* a fixed capital stocks. Unfortunately, the national scale and the absence of international labour mobility limit considerably the possibility to use regional science theories. We have, then, chosen to represent the land use by a demand and supply for uses, without localisation aspects. We have briefly given historical marks on

10. See Hubacek and van den Bergh (2002 [277]) and Pyykkönen (2006 [398]) for a large survey the economic theory of land.

11. We should start from the *Mercantilists* and the *Physiocrats* (see chapter 1 or Hubacek and van den Bergh 2002 [277]).

land economic literature and we gave some limits to our study by explaining why we can not use some theories, then we will now focus on empirical literature and more especially on land prices determinants.

2.3.2.2 Empirical literature on land price determinants

We briefly present now the empirical economic literature on land price determinants. According to Awokuse and Duke (2006 [20]), we can establish three groups in economic literature that explain the farmland price determinants¹².

The first approach, the **present-value model** that is the traditional economic representation to assess land price. Suppose that land price at time t equates present discounted value of its expected future earnings (Burt 1986 [68], Featherstone and Baker 1987 [223]). Nevertheless since Falk (1991 [217]) who invalidates the present value model using Iowa farmland price and rent data over the 1921-1986 sample period, many studies rejected the present value model or bring out its explanatory failure (*e.g.* Engsted 1998 [172]). While Lence and Miller (1999 [332]) and de Fontnouvelle and Lence (2002 [108]) find that, by introducing the transaction cost in the present value model with constant discount rate, the model is robust for short term but not for long term. Nevertheless, the present value model is still a basis of land price studies, and some researchers try to improve it by relaxing some assumptions. Turvey *et al.* (1995 [443]) estimate a time varying discount rates for two Canadian provinces: Ontario and Saskatchewan and they equally bring out the necessity to differentiate incomes from markets and payments from government insomuch as their respective discount rates are different. For the government payment to farmers, Turvey *et al.* (1995) establish the dependency of the discount rates on payments mechanisms and particularly on their expected stability¹³. There is also numerous studies focusing on the improvements of the present-value model through advanced statistical techniques. In this spirit, Tegene and Kuchler (1991 [439]), using data on five US *Corn Belt* states from 1921 to 1989, find that net rents and land price are both integrated of order one and that they are also co-integrated. They suggest using an error correction model for the price land equation. Other statistical techniques such as vector auto-regressive model (*e.g.* Falk and Lee 1998 [218] and Engsted

12. Another and more general distinction is made by Pyykkönen (2006 [398]). He divides the land price literature on:
– studies on land price level and he distinguishes two approaches; the first using the production function approach;
and the second the hedonic (semi-hedonic) prices,
– studies explaining differences in price movements over time.

In spite of the real educational interest of this distinction, we will not adopt it; firstly because it should require a more bigger literature review on land price and secondly because we want to focus more on studies that can be useful for applied economic model. Then, we take more attention on the second group.

13. See Latruffe and Le Mouél (2009 [324]) for a recent survey on the capitalisation effect of the governments supports on agricultural land prices.

1998 [172]) or recent advances in the area of non-stationary panel data (Gutierrez *et al.* 2007 [253]) are also used to improve the present-value model. Thus, the literature on present value model is numerous but its empirical validity does not make consensus, nevertheless its uses and its improvements allow the identification of land prices changes determinants.

The **structural model** tries to identify more land price determinants imposing *a priori* theoretical economic structure. The literature on this field is less important than for present value model. In the main study dealing with structural model by Just and Miranowski (1993 [308]), the authors define a structural model of land price and estimate it with a Seemingly Unrelated Regression (SUR) using data from 1963 to 1986 on three US states: Iowa (Corn belt), Kansas (Wheat belt) and Georgia (Southeast). Their results suggests that their structural model fits the data well and they find that the main determinants of land price changes are the expectation for land price, inflation rate and the real return on alternative use of capital, reducing the importance of others variables such as land tax, credit limit or government payments. Chavas and Thomas (1999 [85]) develop a capital asset pricing model that incorporates risk aversion, transaction cost and dynamic preferences. They underline that with their model there is a statistical evidence of the influence of risk aversion and transaction costs on land prices. The structural model literature is still not the most developed even if it could be very interesting and especially in the framework of the Just and Miranowski (1993 [308]) study that use a rigorous theoretical economic structure.

The **“growth” models** that in addition to the rent from agriculture, incorporate in the price potential land redevelopment, especially in urban land. The studies generally focus on urban fringe or peri-urban and try to examine how the urban and rural forces interact in land prices. The first dealing with this problem is Chicoine (1981 [88]) who establishes the importance of land features, such as the distance to a city centre, on urban fringe farmland price. Thereby, he demonstrates the influence of potential land redevelopment on farmland prices. Many others studies demonstrate the influence of potential land development on farmland prices (*e.g.* Capozza and Helsley 1989 [73], Capozza and Helsley 1990 [74], Shi *et al.* 1997 [426], Plantinga and Miller 2001 [393], Plantinga *et al.* 2002 [392], Cavailhès and Wavresky 2003 [78] and Livanis *et al.* 2006 [339]). These studies use different types of models and different data. For instance, Shi *et al.* (1997 [426]) use a gravity model on fifty two US West Virginia counties from 1950 to 1992. Plantinga *et al.* (2002 [392]) develop a spatial city model with stochastic returns to future land development and estimate it in a national-scale cross-section (2955 US counties). And Cavailhès and Wavresky (2003 [78]) use an optimal allocation model decision

and estimate an equation based on the theoretical model using data on individual land transaction from the french city Dijon. In spite of the different methodology used by the studies, they always demonstrate the importance of the future land redevelopment on the land price.

This empirical studies focus on the land price determinants such as land characteristics (soil quality, etc), macroeconomic variables (inflation, interest rates, etc), institutional regimes (government supports, etc) and spatial localisation of land (neighbourhood, potential development, etc). Thus they provide insights to land price representation in the economic models, even if the “growth” model includes some localisation aspects that we have excluded from our studies, the other determinants could be useful for the modelling of the land supply, however it is interesting to see, in a first time, how large applied economic models represent the land supply or land prices and how they deal with these determinants.

2.3.2.3 Land supply in large applied economic models

Despite the numerous developments of large applied economic models since the 1980’s, very few represent a land market being either sector models (partial equilibrium models) or general economic models (computational general equilibrium or macro-econometric models). In most applied economic models, there is no land representation neither on the demand side or the supply side. The only models that generally represent land as a production factor are those oriented on assessment of agricultural policies and more recently those studying climate change and greenhouse gas emissions from Land Use, Land Use Change and Forestry (LULUCF - see *e.g.* Hertel *et al.* 2009 [270]). But the majority does not represent land supply, they generally suppose that land supply is exogenous and fixed¹⁴. To our knowledge, there are only the Global Trade Analysis Project¹⁵ (GTAP) models and the LINKAGES model (van der Mensbrugghe 2005 [454]) that explicitly model an endogenous land prices¹⁶.

14. Very few model descriptions go further than a fixed land supply. They generally not explain how they deal with the land price. They probably used the fixed land supply as a constraint with an associated shadow price, but none model descriptions mention it explicitly.

15. www.gtap.agecon.purdue.edu

16. The European Forest and Agricultural Sector Optimisation Model (EUFASOM, Schneider *et al.* 2008 [419]) refers to adjustment cost for land use change between forest, crop production, bio-energy and nature reserves plantation. But, the land price is not explicitly modelled. Schneider *et al.* 2008 suppose also that “*limits to agricultural production arise not only from technologies but also from the use of scarce and immobile resources [...], the use of agricultural land, labour, irrigation water, and grazing units is either physically limited by regional endowments or economically limited by upward sloping supply curves for these private or public resources*”. But we do not know if the “*upward sloping supply curve*” is used for land.

The GTAP models

The GTAP community developed several general equilibrium models, starting with Hertel (1997 [269]) and Itakura and Hertel (2000 [292]). Burniaux and Lee (2003 [65]) develop the GTAP-L model by including an endogenous supply for land in the GTAP-E model (Burniaux and Truong 2002 [66]) - an extension of the standard GTAP model for energy and environmental concerns. Burniaux and Lee (2003) use a Constant Elasticity of Transformation (CET) function (see Powell and Gruen 1968 [395] and Shumway and Powell 1984 [427]) to model supply of cropland for different uses, the transformation elasticity allowing the determination of the degree of land mobility. These land supplies coupled with the land demand, resulting of a nested Constant Elasticity of Substitution (CES) function (Arrow *et al.* 1961 [18]), are adjusted to set croplands price.

Golub *et al.* (2006 [244]) divide the land by Agro-Ecological Zones (AEZ), a land database developed by Lee *et al.* (2009 [330]) that separate land into different observed uses and types, and they restrict land mobility across diverse uses. Golub *et al.* (2006) develop five land supply models with different land mobility assumptions. The two first models suppose that land is perfectly mobile either for all AEZs or within an AEZ. Thus, a single land rental price is equated across all uses for all AEZs in the first case, and within each AEZ in the second. The third model is similar to Burniaux and Lee (2003) and uses a CET function for each AEZ while in the fourth model, Golub *et al.* (2006) compute a land heterogeneity index for each AEZ. This index is an average standard deviation of five variables: growing degree day, moisture index, soil carbon density, soil pH and topography. Then, they adjust the elasticity of transformation of the land supply CET function supposing that the relationship between the elasticity of transformation and the heterogeneity index is linear. Nevertheless, the use of the standard deviation as criterion for the index implies that the largest AEZs are also the most heterogeneous, inversely for smallest AEZs. The last model develops a nested land supply based on CET functions. In each AEZ, the land owners allocate, in a first step, their lands between agriculture and forestry in order to maximise the total returns from land and in a second step, land owners allocate the land between cropland and pasture. Golub *et al.* (2006) conclude that the fifth model with the most restrictive land mobility displays the most realistic representation of land supply even if, in their baseline, land rentals in forestry and grazing raise strongly and seem unrealistic. They argue that this problem could be technically overcome by increasing the elasticities of transformation.

Thus, Golub *et al.* (2009 [243]), starting from the fifth land supply model, increase the elasticity

of transformation between agriculture and forestry, being now equal to -1.5¹⁷ according to Songhen and Brown (2006 [433]) estimates whereas the elasticity of substitution between cropland and pasture is equal to -3. Golub *et al.* (2009) also introduce the access possibility to new lands (developed by Gouel and Hertel 2006 [246]) by calculating the net present value of accessing new land, as a positive linear function of the land price expected for a conversion of unmanaged land to managed one and as a negative linear function of the access cost. Thus, the unmanaged lands are converted in lands using activity until that the expected return of land conversion is superior to its conversion cost. Following Gouel and Hertel (2006), Golub *et al.* (2009) represent the marginal conversion cost as a convex function of the share of accessed forest in total forest:

$$C(h_{t+1}) = -\alpha \cdot \ln \left[\frac{\bar{h} - h_{t+1}}{\bar{h}} \right] + \beta + \gamma \left[\frac{h_{t+1} - h_t}{h_t} \right]^2 \quad (2.3.1)$$

Where \bar{h} is the total forest area, h is the accessed forest area, γ a parameter governing the size of the adjustment costs (a near term phenomenon), α a parameter determining the long run elasticity of access cost ($\sigma(h)$ - when, $h = h_t = h_{t+1}$ then $\sigma(h) = \frac{\alpha}{C(h)} \frac{1}{\left[\frac{h}{\bar{h}} - 1\right]}$) and β is a scale parameter. Golub *et al.* (2009) conclude, comparing this model with previous ones, that the possibility of accessing new lands reduces land rent, and smooths changes in land use in the regions where access does not take place. Golub *et al.* (2009) then confirm their model choice developed in Golub *et al.* (2006) *i.e.* a model with nested CET land supply function. But in order to reduce the land rental overmuch increases, they introduce higher elasticity of transformation and allow the possibility to access to new lands¹⁸.

Thus, the GTAP models use several land supply modellings trying to include substitution between land uses with the CET functions being nested or not (Burniaux and Lee 2003, Golub *et al.* 2006 or Golub *et al.* 2009). But, they also include some spatial aspects and some land characteristics either with the definition of the AEZs or with the construction of land heterogeneity indexes affecting the land substitution (Golub *et al.* 2006). Finally they use the present value model with marginal conversion cost to convert unmanaged lands to managed ones (Golub *et al.* 2009) allowing the reduction of the land scarcity and then land prices. Nevertheless, this last model requires the calibration or estimate of several parameters.

17. The elasticity of transformation then is largely superior to -0.25 in Golub *et al.* (2006 [244]). Higher is the elasticity of transformation (in absolute value), more lands are substitutable; when it equates zero, the supply of land is fixed.

18. In their baseline, Golub *et al.* (2009) introduce also land-augmenting technological change.

The LINKAGE model

The LINKAGE model (see van der Mensbrugghe 2005 [454] and box 2.3.2.3 for more details) use a two steps structure for its land supply. The aggregate land supply is allowed according to changes in real aggregate land price, whereas the allocation of land supply across different activities is modelled with CET functions.

Box 2.3.2.3 : LINKAGE model short overview

The LINKAGE model version 6 (van der Mensbrugghe 2005 [454]) is a recursive dynamic applied general equilibrium model developed by The World Bank and OECD for previous version. The model uses the GTAP database that allows to cover 87 regions/countries and 57 production sectors. The production functions are modelled with nested CES functions with different nested structures for crops, livestock and manufacturing and services sectors. All incomes generated by economic activity are assumed to be distributed to consumers. A single representative consumer allocates optimally his disposable income among consumption and saving. The world trade block is based on a set of regional bilateral flows, where importations are imperfect substitutes (Armington 1969 [15] specification) whereas exports are modelled with nested CET functions. The dynamic in the LINKAGE model comes from the capital accumulation, the putty-semi-putty specification (see *e.g.* Johansen 1959 [301], Hogan 1989 [272] or Meijers and van Zon 1994 [355]) of technology and the exogenous change in productivity. The LINKAGE model is used for the World Bank Global Economic Prospects (*e.g.* World Bank 2009 [475]) and trade policy analysis (*e.g.* Lee *et al.* 2009 [329]).

Thus, the aggregate land supply is modelled using a logistic function (equation 2.3.2).

$$L = \frac{L_{max}}{1 + \chi \cdot \exp\left(-\gamma \cdot \left(\frac{P_L}{P_{base}}\right)\right)} \quad (2.3.2)$$

Where L is the aggregate land supply, P_L its associated land price, P_{base} the land price in the base year, χ a scale parameter, γ a parameter for the logistic function and L_{max} the maximum available land for agriculture. In addition, the aggregate land price (P_L) is determined by the CET dual price (equation 2.3.3) when the elasticity of transformation (ϖ) is finite and is a function of the sectors specific (i) land price (P_{L_i}), whereas the sectoral land allocation (L_i - equation 2.3.4) arises from the CET functions¹⁹.

19. There are other equations for the land supply in the LINKAGE model, for an infinite elasticity of transformation (*i.e.* $\varpi = \infty$), but we do not present them here. See van der Mensbrugghe (2005 [454]) for more details.

$$P_L = \left[\sum_i \theta_i \cdot P_{L_i}^{1+\varpi} \right]^{1/(1+\varpi)} \quad (2.3.3)$$

$$L_i = \theta_i \left(\frac{P_{L_i}}{P_L} \right)^{\varpi} \quad (2.3.4)$$

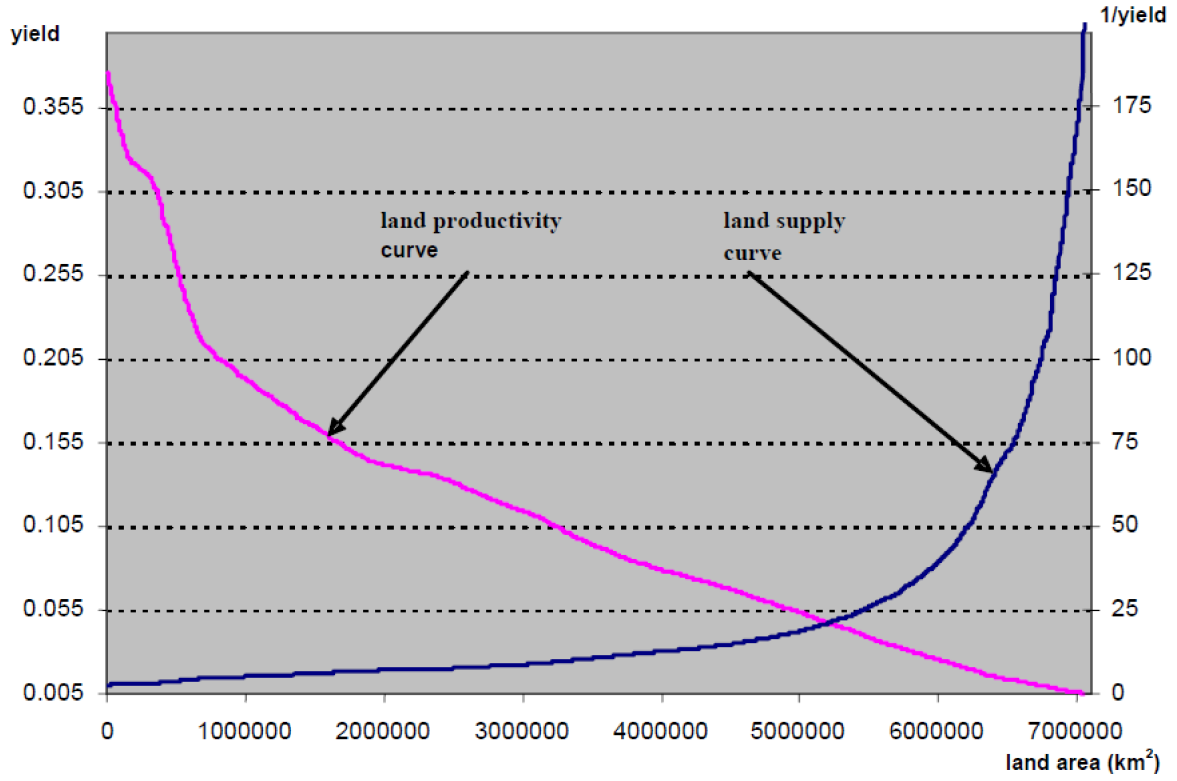
The approach use to model land supply in the LINKAGE model is then relatively similar to the fifth model of Golub *et al.* (2006 [244]) insomuch as it uses a nested approach but the LINKAGE land supply does not use a CET function in the first step of the nested approach but a logistic function. The advantage of the logistic function compared to a CET one is a non constancy of the elasticity with respect to the level of land that allows a better representation of land scarcity. We will present the logistic function properties in following section.

An hybrid modelling approach

The basic idea of Tabeau *et al.* (2006 [438]) was to restore the link between land productivity and its biophysical properties (such as land availability, soil quality and atmospheric conditions) insomuch as they notice the lack of economic models accounting for land availability and particularly the land heterogeneity. Thus, they link the standard GTAP model with the biophysical based modelling framework: Integrated Model to Assess the Global Environment (IMAGE - Bouwman *et al.* 2006 [49]) which integrates information about climate and soil conditions at a grid scale of $0.5^\circ \times 0.5^\circ$ that allow to determine crop productivity at the same scale. Thereby, Tabeau *et al.* (2006 [438]) makes a link between land biophysical information and land rental rates and they estimate a land supply curve using biophysical data from the IMAGE model that calculates the land productivity of each grid cell for each crop and represents them by a index ranges from 0 to 1. They compute the average land productivity of each grid cell by ordering all the grid cells from high productivity to low productivity and by accumulating total area for each productivity level. Therefore, they obtain the land productivity curves (figure 2.3.3). They assume that the land rental price is an inverse function of land productivity and obtain the land supply curve, assuming that the most productive land (*i.e.* the less expensive to bring in cultivation) is first taken into production.

Then Tabeau *et al.* use the following formalisation for the land supply (equation 2.3.5), with L , the land supply, A is the maximal available agricultural land (asymptote), $f(\cdot)$ is an increasing function of land productivity (y) (see equation 2.3.6) and $\beta > 0$ is a parameter.

Figure 2.3.3: Land productivity and land supply curve for Canada (source: Tabeau *et al.* 2006)



$$L = A - \frac{\beta}{f(1/y)} \quad (2.3.5)$$

$$f(1/y) = c_0 + (1/y)^p + \sum_{i=1}^n c_i \cdot (1/y)^{p+i} \quad (2.3.6)$$

Where $c_i \geq 0$ and $p \geq 0$ are positive parameters. And they assume that $1/y$ is equal to the land rental price (r), then:

$$L = A - \frac{\beta}{\left(c_0 + r^p + \sum_{i=1}^n c_i \cdot r^{p+i}\right)} \quad (2.3.7)$$

Supposing that $c_i = 0$, Tabeau *et al.* (2006) compute the elasticity of land supply with respect to the land rental price (ε_L) equates:

$$\varepsilon_L = \left(\frac{\beta \cdot (p+1)}{A} \right)^{1/p} \quad (2.3.8)$$

They compute the A parameter, the asymptote or available lands²⁰ using the IMAGE model. They estimate the parameters c_i and β for 25 countries or regions and they fix the parameters p and n in order to maximise the fit of the regression. Globally, estimate results are relatively good, nevertheless the regression quality decreases when a region is placed on the flat or sloping part of the land supply curve. They introduce this land supply function in the standard GTAP model and compare their results with the GTAP model without endogenous land supply. With the endogenous land supply, the agricultural production is higher and the intensification (land-augmenting technological progress) is lower as the land price calculated with the land supply curve is lower due to the possibility of increasing agricultural land, reducing world agricultural prices. Nevertheless, they find, in countries with scarce lands, a lower agricultural production and intensification insomuch as the consideration of a land supply curve in each country or region leads to a reallocation of agricultural lands between regions: scarce land regions lose competitiveness compared to more “plentiful” land regions. Finally, Tabeau *et al.* (2006) proceed to a sensitivity analysis of the land supply curve by shifting the asymptote (parameter A) by 2.5% lower and higher than estimated. They find that the land supply is sensitive to the asymptote shift especially in scarce land regions, but they also show that the impact on agricultural production is rather low. Indeed, approximately half of the land supply change leads to a change in agricultural production whereas the other half changes the land productivity.

The land supply approach of Tabeau *et al.* (2006 [438]) is very interesting because it combines a land supply based on biophysical data, by the link established with the LINKAGE model, with a land supply function relatively simple (“inverse-L” curve) able to be easily estimated.

Summary

This overview of the literature has emphasised a relative homogeneity of land modelling between applied economic models, the land supply is predominately represented by CET functions that allow substitutions possibilities between agricultural lands however we saw that there are alternative land supply modelling approach. The land supply in the LINKAGE model (van der Mensbrugghe 2005 [454]) is represented by a logistic function that allows the introduction of an upper bond on available land but especially allows an increasing land price elasticity with respect to land supply. And finally, the alternative modelling approach developed by Tabeau *et al.* (2006 [438]) suppose an inverse relationship between land price and land productivity through an “inverse-L” land supply curve.

20. Available lands exclude unsuitable lands, urban areas and protected lands

Looking at land price determinants identified in the empirical survey, we observe that few of them are directly take into account in the land supply modelling of applied economic models. By resuming the four land determinants families, we can summarise their uses in applied models as follows:

- The institutional regimes such as government supports do not enter directly in the modelling framework even if a part could be implemented exogenously in land prices or in the marginal conversion cost functions of Golub *et al.* (2009 [243]).
- The macroeconomic variables are also indirectly integrated through the model locking up and notably the production level or production price in the case of the CET functions. The Golub *et al.* (2009) model that uses the present value model for the implementation of the possibility of assessing new lands, is the only integrating directly macroeconomic variables such as interest rate.
- Localisation aspects, we can mention the Agro-Ecological Zones of the GTAP models (Golub *et al.* 2006 [244]) nevertheless those are very large (18 AEZs for the World) and can not be assimilated with the neighbourhood or land potential development effects, they fit more with the land price determinants like the land characteristics.
- Finally the land characteristics are perhaps more directly used to model land supply with the example of the AEZs (Golub *et al.* 2006) but more particularly with the Tabeau *et al.* (2006 [438]) land supply function. Indeed, they use detailed biophysical land data of the IMAGE model to construct their land supply curve by aggregating them and by establishing an inversed relationship between land price and land productivity. We also mentioned, even if the results are not really convincing, the fourth model of Golub *et al.* (2006) that modify the land elasticity of transformation with an index of land heterogeneity by AEZs.

As we express all through this chapter, the land supply modelling for applied models must deal with the locking up condition, the data availability and the level of analysis. Thereby, it can not fully take into account the empirical results nevertheless interesting case exits like in Tabeau *et al.* (2006 [438]) or with the LINKAGE model.

2.3.2.4 The land supply and land price in NEMESIS

According to the previous section, there are, by generalising, two different approaches to model land supply²¹. The first is based on the **nested CET functions** that allow the introduction of imperfect substitutes between land uses. The CET functions have the advantage of an easy implementation in large applied models insomuch as these properties are well known. Nevertheless, one of these properties, the constancy of the elasticity of transformation with respect to land, is rough. Indeed, if in the case of substitution between different land uses, the CET function is relatively well designed in condition to have robust estimate of the elasticity of transformation. In the case of the aggregate land (the overall uses for agriculture), it seems better to have an increasing land price elasticity with respect to land as long as available lands decline. In addition, the lack of detailed times series data does not enable econometrics estimates of CET functions and unfortunately there are few estimates of its elasticity in the studies except Golub *et al.* (2009 [243]) that generalise Songhen and Brown (2006 [433]) estimates for South Central United States. However using local US estimates of elasticity of transformation and applying it in European countries seems too rough. Moreover, as it is clear that the nested CET functions approach is better designed for land allocation between uses, it is then more adapted for models with numerous agricultural productions and land uses but it is not the case in NEMESIS where agricultural productions are only divided between animal production (livestock) and vegetal production (crops) without distinction between crops productions and animals. We then exclude this approach that is less relevant for the NEMESIS model. The second approach defines an **ad-hoc functional form** for the land supply and estimates or calibrates its parameters. It is the case with the LINKAGE model (van der Mensbrugghe 2005 [454]) that uses a logistic function to model aggregate land supply and in Tabeau *et al.* (2006) constructing a asymptotic curve (“inverse-L” function). Both functional forms seem well designed to represent land supply at an aggregate level and, in order to choose the best representation for the NEMESIS model, we will present in more detail these two functional forms and compare each other by looking at their respective properties.

The logistic function

In order to test the logistic function presented in equation 2.3.2, we impose the following assumptions:

- we suppose that the base year, $P_{base} = P_L = 1$

21. Nevertheless, there are also models that combined both approaches.

- We impose arbitrarily the total land supply (asymptote: $L_{max} = 500$)
- and we calibrate the parameter $\chi (= 6.7)$ and $\gamma (= 3)$ with which we obtain an agricultural land use covering 65% of total agricultural land for the base year ($L_0 = 375$).

With these assumptions, the land supply is increasing with the land price, but the more the land supply is near the asymptote, the less the land price increases land supply (see figure 2.3.4-A, where the red point shows the initial position) *i.e.* the elasticity of land supply with respect to land price (equation 2.3.9) is a decreasing function of the land price (right hand of the figure 2.3.4-B). Hence the land price tends to infinity and the marginal land supply tends to zero.

$$\varepsilon_{\frac{L}{P_L}} = \frac{P_L \cdot \chi \cdot \gamma \cdot \exp(-\gamma \cdot P_L)}{1 + \chi \cdot \exp(-\gamma \cdot P_L)} \quad (2.3.9)$$

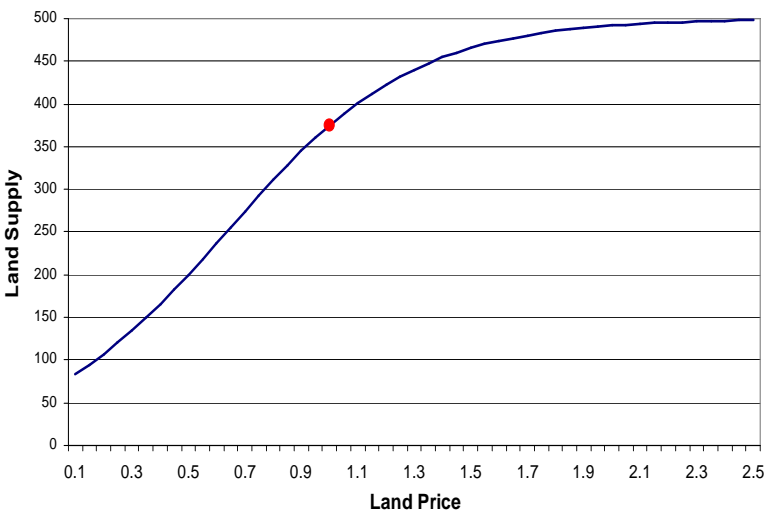
These land supply properties are more easily understandable with the inverse land supply (equation 2.3.10 and figure 2.3.4-C) in which the land price is an increasing function of land supply and where the elasticity of land price with respect to land supply (equation 2.3.11) is a flat-U curve (figure 2.3.4-D). As a result, the more the land is scarce the more the land price increases.

$$P_L = -\frac{1}{\gamma} \cdot \left[\ln \left(\frac{L_{max}}{L} - 1 \right) - \ln \chi \right] \quad (2.3.10)$$

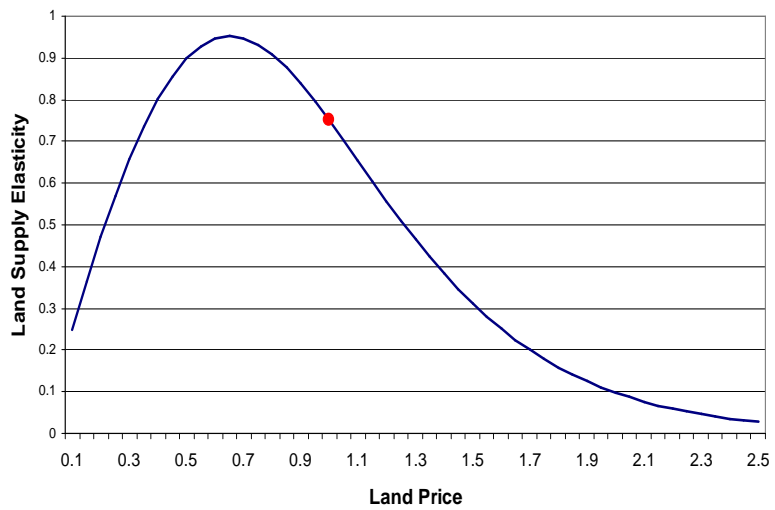
$$\varepsilon_{\frac{P_L}{L}} = \frac{\left(\frac{L_{max}}{L_{max} - L} \right)}{\ln \left(\frac{L_{max}}{L} - 1 \right) - \ln \chi} \quad (2.3.11)$$

Thus, the logistic function presents interesting properties especially with a marginal land supply that decreases when it comes close to the maximum available land (asymptote) allowing a relatively good representation of the land scarcity. But despite its good properties, the logistic function suffers from a relatively weak sensibility of the land price elasticity. To illustrate this weakness, we take the example of some European countries. Supposing that the logistic function is defined with the parameters presented above and taking the land situation of some European countries with the available land calculated in section 2.3.1. In this case, the land price elasticity with respect to land supply is about 1.9%, 2%, 2.1%, 2.6% in Netherlands, Denmark, United Kingdom and Ireland respectively, countries where unutilised available lands are weak, less than 15%. And at the opposite, in Finland and Sweden where there are still more than 85% of available lands for agriculture compared to the used ones, the land price is undefined with these parameters values.

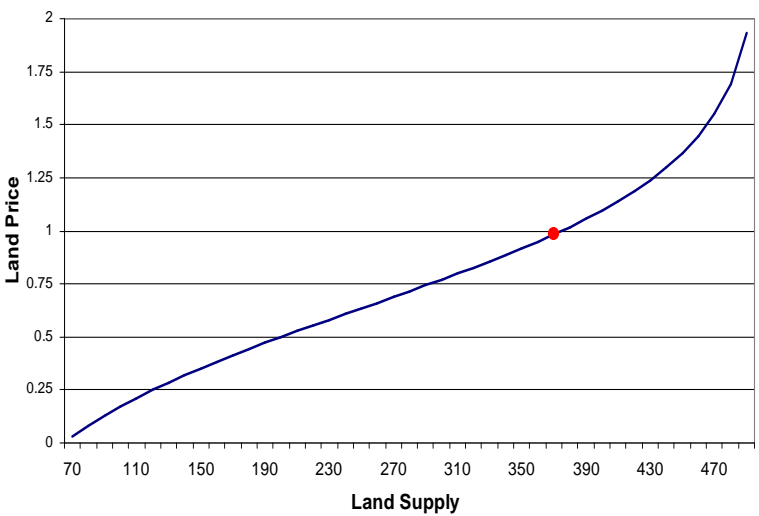
Figure 2.3.4: Logistic land supply properties



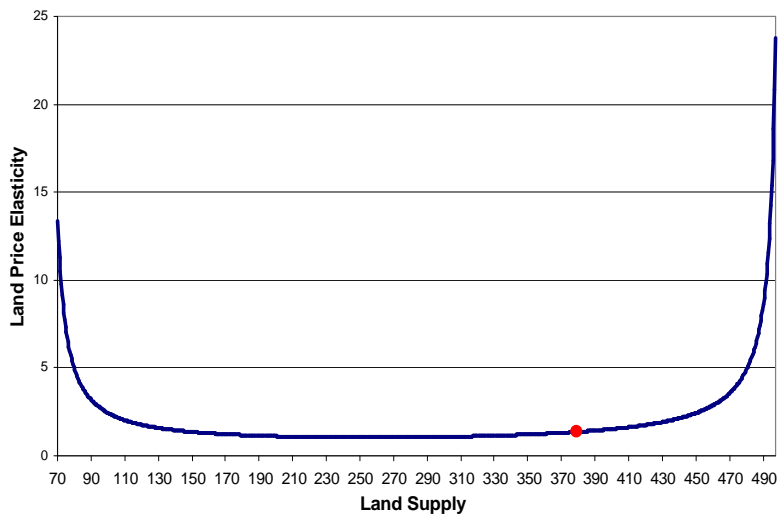
A



B



C



D

Obviously, these results are strongly dependent on the logistic function parameters and the quantification of both parameters is also a problem with the logistic function. Indeed, according to the available data, we can not estimate both parameters (see section 2.3.3) and we must calibrate either one or the other. Now supposing that we calibrate the parameter χ in order to have $P_L = 1$ the base year, in this case we have $\chi(\gamma) = \exp(\gamma) \cdot \left(\frac{L_{max}}{L_{base}} - 1\right)$, where L_{base} is the land supply for the base year. Taking the example of Ireland for a numeric application, we have then $\chi = 2.04$ (always with $\gamma = 3$), $L = 454$ (*i.e.* 9.2% of unutilised lands) and a land price elasticity, for the base year, about 3.6% which is superior to the previous case (2.6%) and seems more realistic according to the land scarcity in Ireland. Now, we have to define the value of the γ parameter nevertheless we must pay heed to its value because there is a problem of existence of the land price function (equation 2.3.10) for some values of the γ parameter. Going back to the example, with the previous parameters values, the land price does not exist for a land supply inferior to 165. Indeed, the land price is positive if $\chi(\gamma) > \frac{L_{max}}{L} - 1$, then for $L < 165$ the land price is negative and does not exist. In order to increase the range of existence of the land price function, we must increase the parameter γ and consequently the parameter χ . In the Ireland case, if the γ parameter is superior to 6.2 ($P_L > 1$ if $\gamma > \ln \left[\frac{L_{base}(L_{max}-L)}{L(L_{max}-L_{base})} \right]$) then the land price is positive for all land supply included between 10 and 500. Nevertheless, as the land price elasticity is a decreasing function of χ parameter and consequently a decreasing function of γ parameter, we now have a lower elasticity that equates 1.75, the base year whereas it was about 3.6 before. Consequently, as we can not estimate both parameters, we must calibrate either one or the other but the calibration implies, in the logistic function, a relationship between the parameters and this relationship requires a compromise between the range of definition of the land price function and the land price elasticity, raising one reducing the other.

To summarise, the logistic function present the advantageous property of a land price elasticity increasing with the land price and all the more so the land supply is close to the asymptote nevertheless the definition of the logistic function is problematic and can lead to undefined land price function. We look, in the next section, at the “inverse-L” function properties and we compare them with the logistics ones.

The “inverse-L” curve

We proceed to the same properties analysis than for the logistic function with the “inverse-L” curve, starting from the functional form of Tabeau *et al.* (2006 [438]) on which we add a parameter on land

price, in order to relax the constrain that $\alpha = 1$, allowing to differentiate the land supply elasticity among EU countries with econometric estimates, we then obtain the following equation 2.3.12:

$$L^s = A - \frac{B}{P_L^\alpha} \quad (2.3.12)$$

Where A , B and α are positive parameters with $B \in [0, A]$, P_L is the land price and L^s is the agricultural land supply. When P_L tend to infinity then L^s tend to A . Thus, A can be thus defined as the maximum land available while if we assume that $P_L = 1$, we obtain that $B = A - L^s$. Thereby, B can be interpreted as the unutilised land. The assumptions made for testing the properties of the “inverse-L” function are the following:

- maximum available land $A = 500$,
- 35% of unused agricultural land ($B = 175$)
- and $\alpha = 1$ (as in Tabeau *et al.* 2006)

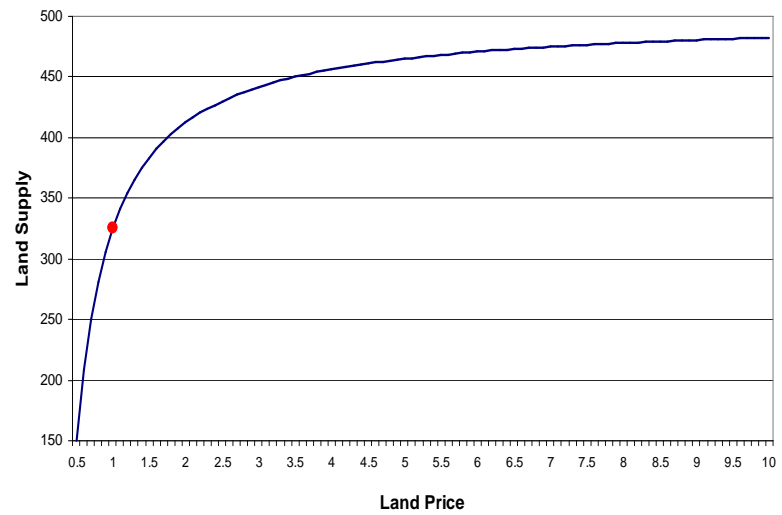
The land supply (figure 2.3.5-A - equation 2.3.12) is an increasing function of the land price with a decreasing marginal land productivity, so the land supply elasticity (figure 2.3.5-B - equation 2.3.13) is decreasing with the land price and tends to zero when the land price tends to infinity. Consequently, the land price (figure 2.3.5-C - equation 2.3.14) and its elasticity (figure 2.3.5-D - equation 2.3.15) are increasing with the land supply and increase all the more so land supply tends to the asymptote. Furthermore, we can see that the introduction of the α parameter allows to have a land price elasticity with respect to land price not only defined by initial position (*i.e.* by A and B)

$$\varepsilon_{\frac{L^s}{P_L}} = \frac{B \cdot \alpha}{A \cdot P_L^\alpha - B} \quad (2.3.13)$$

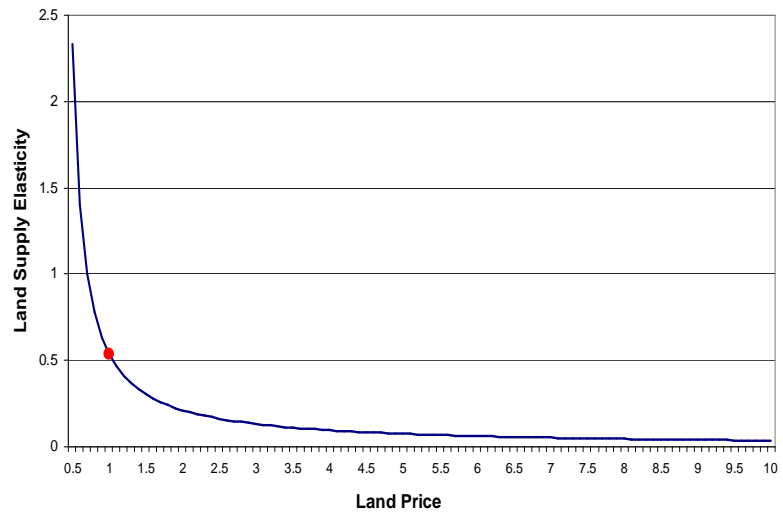
$$P_L = \left(\frac{B}{A - L^s} \right)^{1/\alpha} \quad (2.3.14)$$

$$\varepsilon_{\frac{P_L}{L^s}} = \frac{L^s}{\alpha (A - L^s)} \quad (2.3.15)$$

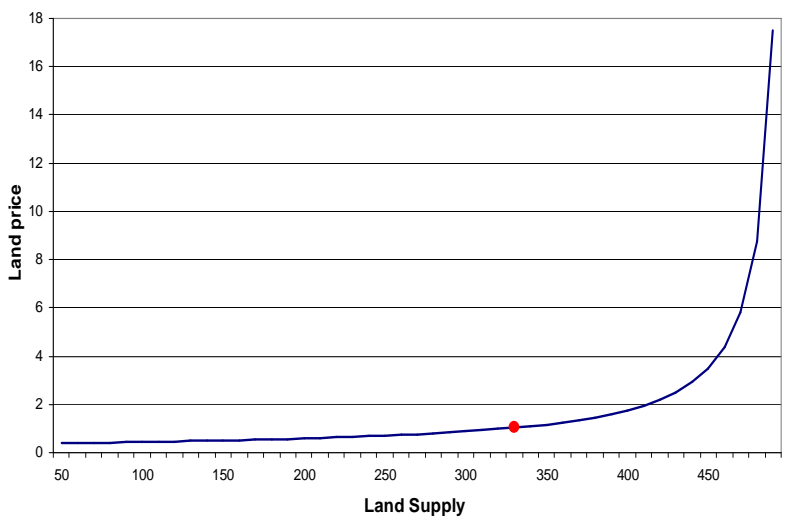
Figure 2.3.5: NEMESIS Land Supply



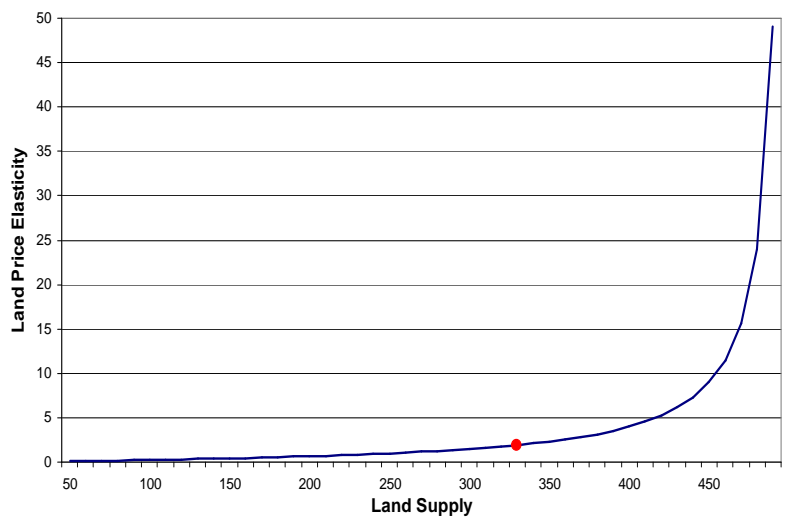
A



B



C



D

By comparing this functional form with the logistic function, we see that there are also some restrictions to have a positive land supply ($P_L > (\frac{B}{A})^{\frac{1}{\alpha}}$). Thus, for a given α , the more the unutilised agricultural lands tend to A , the less the land supply exists ($L^S > 0$) *i.e.* when, the base year, the land supply tends to zero, the land supply will be defined for a land price superior to 1 that is not possible by definition of the B parameter. Taking the example of Finland with 92% of unutilised lands the base year (see section 2.3.1 and figure 2.3.2), the land supply exists ($\alpha = 1$) when land price is included in the range $[0.92; +\infty]$ what is restrictive. And like with the logistic function increasing the land supply range of existence, by a decrease of the α parameter, implies a raise of the land price elasticity. In the Finnish case, in order that land supply exists when land price is included between 0.1 and infinity, the parameter α must equate 0.036 ($\alpha < \frac{\ln(B/A)}{\ln P_L}$) but consequently land price elasticity shifts from 0.09 to 2.41. Thereby, the condition of existence of the land supply implies then a strong raise of the land price elasticity.

Thus, comparing with the logistic function, the “inverse-L” function presents a similar advantage: a land supply elasticity that is decreasing with the land price, and a similar inconvenient *i.e.* a definition problem of the land supply function. Nevertheless, opposite to the logistic function, the existence condition for the “inverse-L” curve mainly concerns countries with important available unutilised agricultural lands like Finland or Sweden whereas for the logistic function it concerns countries with few unutilised lands like Ireland, United Kingdom, Denmark or Netherlands. Furthermore, for the “inverse-L” function, the calibration of the B parameter (χ for logistic function), such as the base year $P_L = 1$, does not imply a relationship with the α parameter (γ for logistic function) as with the logistic function.

Conclusion

According to the structure of the NEMESIS agriculture sector and the available data, we firstly choose to exclude a representation of land supply with a nested CET functions, even if it is *a priori* well designed. Because there are several major problems to adopt this representation with NEMESIS. Firstly, there is a lack of data to estimate the elasticity of transformation between agricultural land and forest (1st level of the nested CET) or a lack of studies on its estimate to calibrate it. In addition to data restrictions, the limited number of agricultural productions in the NEMESIS model reduces the interest to develop a CET land supply for different agricultural productions (2nd level of the nested CET). We decided to focus on the two other functional forms: the logistic and the “inverse-L” functions.

Therefore, we have identified some disadvantages of both functions and particularly the problems of definition of the land supply function. The logistic function is restricted when land supply tends to the asymptote whereas the “inverse-L” curve definition restriction arises when land supply tends to zero. Moreover, the modification of the parameters to enlarge the range of existence of land supply functions, also modify the land supply elasticity with respect to land price. Nevertheless, the existence problem is more complex with the logistic function insomuch as if we calibrate one of the two parameters, the second is then linked with the calibrated one, which is not the case with the “inverse-L” function. Then, according to these restrictions as well as data availability but also looking at the land price elasticities for some credible values of land supply functions parameters, we decide to use the “inverse-L” function instead of the logistic one, even if it can cause some problems with Finland and Sweden. The “inverse-L” curve has some additional advantages compared to the logistic function:

- independence of the uncalibrated parameter with respect to the calibrated one,
- land price elasticity more sensitive, indeed despite diverse parametrisation the logistic function presents a land price elasticity with respect to land supply more flat than the “inverse-L” function (see for instance figure 2.3.4-D and figure 2.3.5-D).
- and a form that can be related to land bio-physical properties and land productivity, as established by Tabeau *et al.* (2006 [438])

Thus, according to these advantages and knowing the disadvantages of the “inverse-L” function adapted from Tabeau *et al.* (2006), we decided to use it for the NEMESIS land use module. The following section presents the econometric estimates of this land supply for European countries and discuss the results.

2.3.3 Econometric results

We present in this section the land supply estimate results. We first describe the database and the data calculation, secondly we present the estimated models and finally we display the estimate results and discuss them.

2.3.3.1 The data

The data used for the estimate comes from different sources: Eurostat (Structure of Agricultural Holdings [209], Selling prices of agricultural products (absolute prices), land prices and rents [203], and Annual National Account [204]) and FADN (Farm Accounting Data Network [144]) database. We use the “*Total Agriculture area*”, “*Land Prices*” and “*Rents*” of the Eurostat Structure of Agricultural Holdings²², the “*Total Utilised Agricultural Area*” and “*Farms Represented*” from FADN and the “*GDP Price index in euro base 2000*” from Eurostat Annual National Account. Nevertheless, the data source disparity imposes some calculations and assumptions to built a coherent data set for estimate.

1. The land use database from Eurostat Structure of Agricultural Holdings, does not provide annual data for the total agricultural area and only the years 1990, 1993, 1995, 1997, 2000, 2003, 2005 and 2007 are available. So, we interpolate linearly the total agricultural land for missing years and we suppose a total agricultural land equal to the first available year before this year for missing years at the beginning of the period.
2. We compute the Agricultural Utilised Area (AUA) by multiplying the “*Total Utilised Agricultural Area*” by the “*Farms Represented*”. In fact, the “*Total Utilised Agricultural Area*” is defined by farms and the “*Farms Represented*” is the number of farms represented in the FADN survey.
3. We computes real land prices and real rents by dividing “*Land Prices*” and “*Rents*” by “*GDP Price index*”.

Thus, we have a data set covering 13 EU countries with data starting from 1990 to 2007 for Denmark and Luxembourg (the longest series) and from 2002 to 2007 for Slovakia, Czech republic and Latvia (the shortest series).

22. Except for France where land prices data come from AGRESTE - Enquêtes sur la valeur des terres agricoles [5], we did not find rents for France.

2.3.3.2 The estimates

We estimate the two following models 2.3.16 and 2.3.17:

$$L_{i,t} = A_{i,t} - \frac{\beta_i}{P_{L_{i,t}}^{\tilde{\alpha}_i^2}} + \varepsilon_{i,t} \quad (2.3.16)$$

$$L_{i,t} = A_{i,t} - \frac{B_{i,2000}}{P_{L_{i,t}}^{\tilde{\alpha}_i^2}} + \hat{\varepsilon}_{i,t} \quad (2.3.17)$$

Where i denotes the country, t the time, $L_{i,t}$ the agricultural utilised area, $A_{i,t}$ the total agricultural land, $P_{L_{i,t}}$ the real land price or real rents, $\tilde{\alpha}_i$ are parameters ($\tilde{\alpha}^2 = \alpha$ from equation 2.3.12) and $\varepsilon_{i,t} \sim iid(0, \sigma^2)$ and $\hat{\varepsilon}_{i,t} \sim iid(0, \hat{\sigma}^2)$ are independent and normally distributed random variables (error terms). In the model 2.3.16, we define the unutilised agricultural land β_i (B in equation 2.3.12) as parameter whereas in model 2.3.17 we impose a fixed value calibrated in 2000 when $P_{L_{i,2000}} = 1$ such as $B_{i,2000} = A_{i,2000} - L_{i,2000}$ ²³. We also test the following hypothesis:

$$\begin{cases} H_0 : \beta_i = B_{i,2000} \\ H_1 : \beta_i \neq B_{i,2000} \end{cases}$$

$$\text{where } t_{\hat{\beta}_i} = \frac{\hat{\beta}_i - B_{i,2000}}{s_{\hat{\beta}_i}}$$

With $t_{\hat{\beta}_i} \sim St(T - K)$ statistic of the null hypothesis that the estimated $\hat{\beta}_i$ is equal to the $B_{i,2000}$ value computes with the normalisation of P_{L_i} to 1 in 2000, with $S_{\hat{\beta}_i}$ the standard deviation of the estimated $\hat{\beta}_i$ parameter and with T the number of year and K the number of estimated parameters. We also constrain α (equation 2.3.12) to be positive by taking the squared value of $\tilde{\alpha}_i$ (equation 2.3.16 and 2.3.17). In addition, we estimate for each country i both models with the real land prices and the real rents using nonlinear least square²⁴. Finally, we also estimate both models with pooled panel data imposing $\tilde{\alpha}_i = \tilde{\alpha}, \forall i$.

23. In the case where the data are not available in 2000, we shift the base year in 2007.

24. All the estimate are done with TSP 5.0 software ([256]), otherwise it will be notified.

2.3.3.3 The estimates results

We estimate both models using different measure for prices: real land prices and real rents. The results for Netherlands are not provided, because despite the data availability, the positive constrain imposed on the $\tilde{\alpha}$ parameter, did not allow an estimate of it.

Estimates using real land price

The results for the model 2.3.16 with real land prices (see table 2.3.1) show that all $\tilde{\alpha}_i$ parameters are significantly different to zero at least at 10%, except for Italy and United-Kingdom. The $\tilde{\alpha}_i$ parameters are estimated between 1.9 for France and 0.37 for Latvia, so the α parameters ranges from 3.6 and 0.14. But with the exception of these two extreme cases, α are generally between 0.4 ($\simeq 0.64^2$) and 1.8 ($\simeq 1.33^2$). The $t_{\tilde{\beta}_i}$ statistics display, except for Belgium, France, Luxembourg and Latvia, that the hypothesis of equality of β_i with its calibrated value in 2000 is rejected. These results imply a coherency problem between the estimated model 2.3.16 and the theoretical one (equation 2.3.12), and we are then obliged to constrain β_i parameter to its value at the base year, $B_{i,2000}$ (the calibrated value), what is done in model 2.3.17. Globally the R^2 are correct (except for Latvia) insofar as there are only two explanatory variables. Italy, Luxembourg and Spain have the highest R^2 with 0.79, 0.77 and 0.75 respectively whereas Denmark and United-Kingdom have lowest R^2 with respectively 0.25 and 0.36.

The estimated $\tilde{\alpha}_i$ are also all significant in the model 2.3.17 except for Italy and their values range between 0.51 for Latvia to 3.65 for United-Kingdom. Thus, the α parameters are included between 0.26 and 13, however the extreme value of α in United-Kingdom seems unrealistic and the very low R^2 (0.07) confirms the bad quality of the estimate. Except for the United Kingdom, estimated values of $\tilde{\alpha}_i$ with the constrained model 2.3.17 are relatively close to those estimated with the model 2.3.16. The same remark applies for the R^2 that do not change so much. The estimate of the constrained model, allow us an estimate for countries with little data as Czech Republic and Lithuania, for which the α parameter is estimated to 0.28 and 0.35 respectively and are both significantly different to zero at 5% level. On the contrary, the constrained model can not be estimated for Ireland due to the positive constraint on $\tilde{\alpha}_i$.

Table 2.3.1: Land supply estimates results with real land prices

Country	Real Land Prices				
	Model 2.3.16			Model 2.3.17	
	$\tilde{\alpha}_i$	β_i	R^2	$\tilde{\alpha}_i$	R^2
BE	1.14** (0.58)	10910 (7791)	0.57	0.79* (0.43)	0.57
CZ	—	—	—	0.53** (0.26)	0.96
DE	1.19*** (0.28)	2428550+++ (113714)	0.44	1.48*** (0.29)	0.5
DK	1.06*** (0.09)	290701++ (15725)	0.26	1.20*** (0.08)	0.31
ES	−1.05*** (0.08)	10237900+++ (468894)	0.75	−0.87*** (0.08)	0.72
FI	0.64*** (0.02)	4724220+++ (25361)	0.48	0.64*** (0.04)	0.54
FR	1.9*** (0.23)	2679880 (198520)	0.57	1.77*** (0.16)	0.56
IE	0.67** (0.28)	481528+ (23648)	0.35	—	—
IT	0.87 (1.44)	7892210++ (228754)	0.79	1.02 (1.08)	0.81
LT	—	—	—	0.59*** (0.12)	0.35
LU	1.33*** (0.21)	8941 (2535)	0.77	1.4*** (0.06)	0.77
LV	0.37* (0.21)	1222370 (143237)	0.04	0.51*** (0.1)	0.16
SE	0.71*** (0.11)	3889230++ (128965)	0.41	0.56*** (0.15)	0.32
UK	0.87 (1.29)	1939140+++ (296075)	0.36	3.65*** (0.54)	0.07

*, **, ***: parameters significantly different to zero at 10%, 5% and 1% respectively
 +, ++, +++: test t_{β_i} , H_0 rejects at 10%, 5% and 1% respectively

Estimates using the real rents

Only nine countries can be estimated with land rents due to data scarcity and like with the real land price, the model 2.3.17 can not be estimated for Ireland. For the model 2.3.16, the $\tilde{\alpha}_i$ parameters (see table 2.3.2) are all significant at least at 5% level except for Germany. They are relatively higher than with real land prices (except for Ireland) that implies a more important sensitivity of land prices than rents. It seems not unrealistic inasmuch as the rents are strongly influenced by a national legal regime whereas land prices coming from land sells market which is less regulated. For instance, the α parameters equal 8.3 in Luxembourg, 4.9 in United Kingdom, 1.7 in Sweden and 0.3 in Hungary. The $t_{\hat{\beta}_i}$ statistics for Germany, Denmark, Finland, Hungary and Sweden are however inferior to their critical values. The equality hypothesis between β_i and $B_{i,2000}$ can not be rejected for these countries, which is in accordance with the theoretical model. Nevertheless, it is important to see that the quality of estimates of model 2.3.16, with the real rents, is relatively modest. In fact, the R^2 are very low for Germany (0.05), Denmark (0.05) and Hungary (0.02), are weak for Finland (0.44), Luxembourg (0.31) and United Kingdom (0.34) but are correct for Ireland (0.73) and Sweden (0.67). Unfortunately these weak R^2 relative the scope of the results.

In the constrained model 2.3.17, the $\tilde{\alpha}_i$ parameters are relatively similar that in model 2.3.16, except for Luxembourg where the $\tilde{\alpha}_{LU}$ value increases strongly and rates 4.6 (*i.e.* $\alpha = 21$) which appears too important. Otherwise, the parameters are all significant at 1% level except for Germany as with model 2.3.16. But, the R^2 are also very close to those obtained with the model 2.3.16.

Table 2.3.2: Land supply estimates results with real rents

Country	Real Rents				
	Model 2.3.16			Model 2.3.17	
	$\tilde{\alpha}_i$	β_i	R^2	$\tilde{\alpha}_i$	R^2
DE	-1.11 (2.71)	3481050 (1033470)	0.05	1.19 (2.98)	0.06
DK	1.62*** (0.18)	279959 (18777)	0.05	1.78*** (0.14)	0.06
FI	0.83*** (0.3)	4898540 (218430)	0.44	0.82*** (0.18)	0.44
HU	0.56*** (0.18)	1826740 (75970)	0.02	0.65*** (0.07)	0.02
IE	0.49** (-0.22)	475519 ⁺⁺ (-22135)	0.73	—	—
LU	2.89*** (1.08)	14790 ⁺ (3024)	0.31	4.62*** (0.72)	0.28
SE	1.30*** (0.12)	3991150 (78799)	0.67	1.22*** (0.16)	0.67
UK	2.2*** (0.54)	1345470 ⁺⁺⁺ (391817)	0.34	2.05*** (0.35)	0.35

*, **, ***: parameters significantly different to zero at 10%, 5% and 1% respectively
⁺, ⁺⁺, ⁺⁺⁺: test t_{β_i} , H_0 rejects at 10%, 5% and 1% respectively

Conclusion

Finally, we briefly present the results (table 2.3.3) of the pooled panel estimate for model 2.3.16 and 2.3.17 with real land prices. We impose, for panel estimate, the equality constraint of $\tilde{\alpha}_i$ for each countries ($\tilde{\alpha}_i = \tilde{\alpha}$, $\forall i$). With the model 2.3.16, the $\tilde{\alpha}$ is equal to 1 and is significantly different to zero at 1% level whereas in the model 2.3.17, its value is of 0.84 and also significant at 1% level. Thus, using panel estimate, the α parameter is close to one (1 or 0.71) and is much less important than with individual estimates in some countries.

Table 2.3.3: Land supply panel estimates

Model 2.3.16	Model 2.3.17
$\tilde{\alpha}$	$\tilde{\alpha}$
1.00***	0.84***
(0.02)	(0.02)

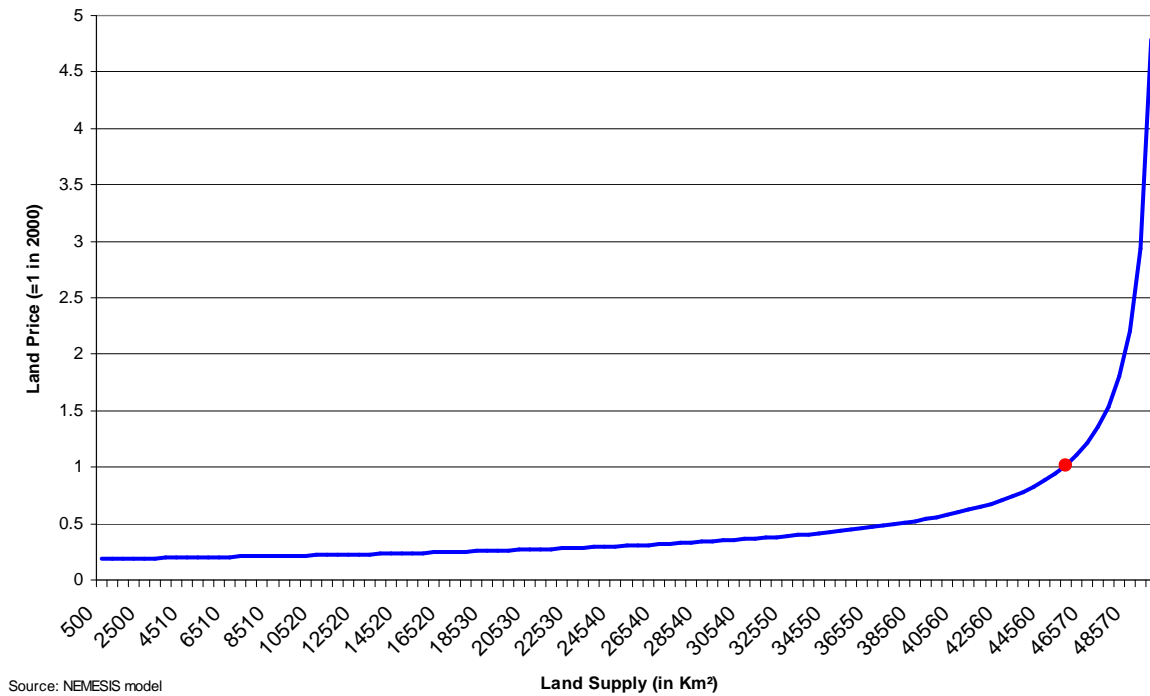
*** parameters significantly different to zero at 1% level

To summarise, using real rents instead of real land prices lead to higher α values than with real land prices. This difference can arise from more stable rents than land prices when the unutilised agriculture area increases, resulting from legal regimes that impose restrictive rules for agricultural land rents in several EU countries²⁵. But it could also just come from the fewer number of samples with real rents than with real land prices that reduces their comparability. To the light of these results, it appears more reasonable to keep the results of estimates with real land prices. As we explained, the α values in the models estimated with real rents are too high and the land supply curve would be very little sloping and then not very elastic with respect to land price. Thus, we retain the estimate results with real land prices. Regarding the results of model 2.3.16 estimated with with real land prices, if we drop the extreme values for France and especially United Kingdom and Latvia, the α parameters are ranged between 0.25 and 2.25 . These values seems relatively correct, nevertheless, the $t_{\hat{\beta}_i}$ statistics rejected the assumption of equality between β_i and $B_{i,2000}$, for more than the half of the estimates. And as we construct our model supposing that β_i is equal to $B_{i,2000}$, we then retain the constrained model 2.3.17 estimates *i.e.* we will introduce the α values of the model 2.3.17 in the NEMESIS model. Indeed, its estimates are relatively good, all parameters, except for Italy, are significant at least at

25. For instance, in France, the State fixes a minimum and a maximum for the agricultural land rents and follows the construction index price. In United Kingdom, before 2006 and the “The Regulatory Reform (Agricultural Tenancies)”, there was a strong legal regime to establish rents and as most of contracts were established before, the rents are still strongly regulated (Henin 2010 [268]).

10% level. Except for the United Kingdom, the α values are in a satisfactory range, between 3.1 in France and 0.26 in Latvia and the R^2 are also correct. It seems then logical to keep these α estimates for the NEMESIS model. Furthermore, we will use the α value (0.71) from panel estimate with the constrained model for countries for which the estimates are not possible as well as for countries for which the estimates are not satisfactory: United Kingdom and Italy.

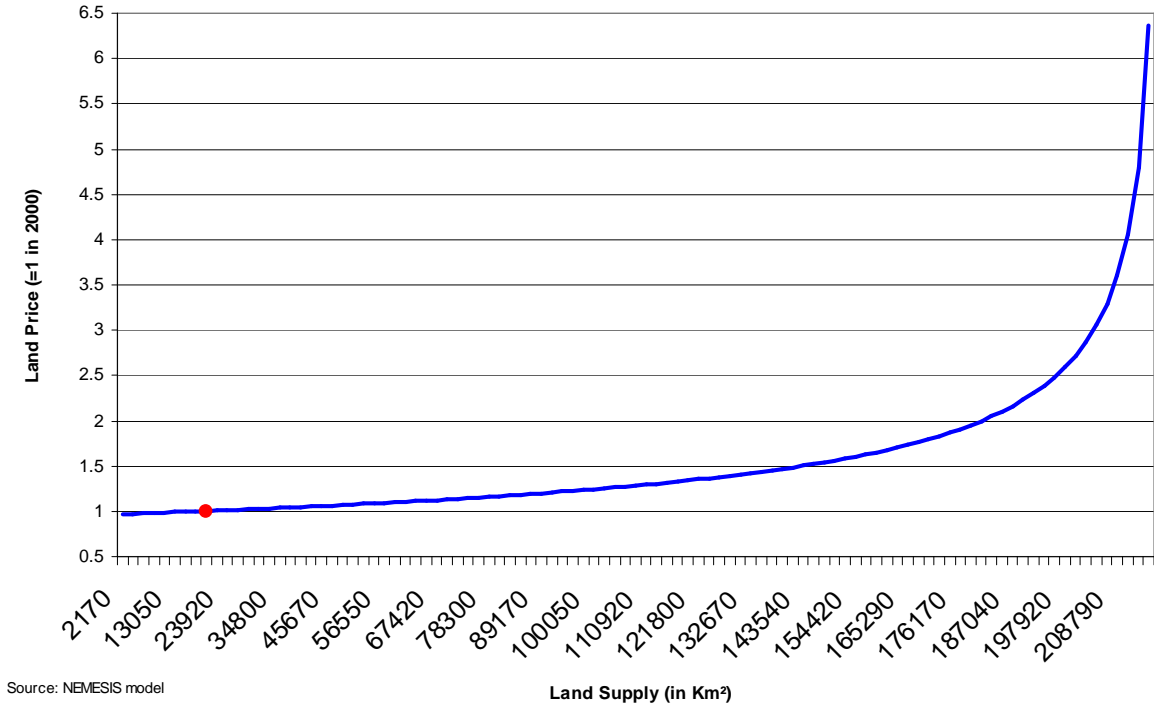
Figure 2.3.6: Ireland land supply in 2000



For illustration, figure 2.3.6 and 2.3.7 display the inverse land supply curve for Ireland and Finland in 2000 according to the estimated α parameter (0.71 and 0.41 respectively) and the calibrated B parameter (4 600 km² and 200 000 km² respectively). These countries are extreme cases, in Ireland the unutilised agricultural land represents 9.2% of total agricultural land whereas it is about 92% in Finland (see figure 2.3.2). The red points represent the initial position of each country on the inverse land supply in 2000²⁶. Thereby, in 2000, Ireland (figure 2.3.6) is in the sloping part of the inverse land supply whereas Finland (figure 2.3.7) is placed in the flat part.

26. The inverse land supply functions are provided in Appendix C, for overall EU countries.

Figure 2.3.7: Finland land supply in 2000



2.3.3.4 Land supply elasticity to land price

We present briefly in this section the land supply elasticity with respect to land price. We provide the elasticities for each EU country, in 2000, using the estimated α parameters and the calibrated B parameters. Equation 2.3.18 displays this elasticity in 2000 where $P_{L_i,2000} = 1 \forall i$.

$$\varepsilon_{P_L^s}^{L^s,2000} = \frac{\alpha_i B_{i,2000}}{A_i - B_{i,2000}} = \frac{\alpha_i B_{i,2000}}{L_{i,2000}} \quad (2.3.18)$$

Table 2.3.4 displays the land supply elasticities with respect to land price. These elasticities are very heterogeneous between EU countries with the highest for Finland and Sweden where an increase by 1% of the land price increases the land supply by 4.7% and 2.5% respectively. In fact, Finland and Sweden have a share of unutilised agricultural land on total land available for agriculture around 90%. This important land availability is traduced by a strong land supply sensibility with respect to land price *i.e.* a weak land price variation increases much more the agricultural land supply²⁷. At the opposite,

27. As exposed in section 2.3.2.4, the land supply of Sweden and Finland can more easily become undefined, we have then pay heed to this problem, and in the case of strong variability of land price, we will reduce the land supply elasticity with respect to land price, we will notify it in this case.

an important group of countries, composed by Malta, Ireland, United Kingdom and Netherlands, for which the unutilised agricultural lands are very weak, have a small land supply elasticity. Therefore, in these countries the land price must increase strongly to increase the land supply. For instance in Ireland, an increase of about 14% of the land price will increase the land supply by 1%. Finally, supposing that the α parameter for EU takes the panel estimated value (0.71), we find a land supply elasticity about 0.49%, and a land price elasticity about 2%.

Table 2.3.4: Land supply elasticities with respect to land price

AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT
1.19	0.23	1.09	0.23	0.36	4.65	1.42	0.36	0.07	0.32	1.29	0.12	0.30

SE	UK	BG	CZ	EE	HU	LT	LV	MT	PL	RO	SI	SK
2.45	0.1	0.46	0.16	1.21	0.24	0.17	0.42	0.10	0.41	0.38	1.32	0.51

Source: NEMESIS model

We have constructed a land supply for agriculture using an "inverse-L" functional form, we have also estimated this functional form and finally, we have provided some illustrative results on the resulting land curves and land supply elasticities. We now briefly present the agricultural land demand that comes from the production function for agriculture in the NEMESIS model.

2.3.4 Agriculture Land Demand

We present in this section the agricultural land demand. The land demand from agriculture is based on the agricultural production functions developed by Ngwa Zang and Le Mouël (2007 [367]) and Ngwa Zang (2008 [366]) and implemented in the NEMESIS model, thus, we will not go into details and we will just present briefly the general methodology²⁸.

Ngwa Zang and Le Mouël (2007) develop a production function for the agriculture sector based on a variable cost function with flexible and quasi-fixed inputs (Samuelson 1953 [413], Diewert 1973 [117], Diewert 1974 [118] and Mac Fadden 1978 [343]) called restricted cost function ($CR(p_x, y, u)$, with p_x a vector of flexible inputs prices, y a vector of outputs and u a vector of quasi-fixed inputs in volume). This restricted cost is described with a transcendental logarithmic (translog) functional form (Christensen *et al.* 1973 [95] and Berndt and Christensen 1973 [30]) and includes 2 outputs: vegetal (Y_A) and animal production (Y_B); 6 flexible inputs: hired labour (LS), energy (EG), fertilisers (E), seeds (S), cattle-food (N) and other intermediate consumptions (CI); 4 quasi-fixed factors (K_1, K_2, K_3, K_4): and 2 fixed factors: land (L) and family labour (LNS). The restricted cost function is then normalised by family labour (LNS) that is used as a proxy for the number of holdings. They also introduce an adjustment delay (λ) to the optimal level to capture the farmers behaviour inertia. Thus Ngwa Zang and Le Mouël (2007) obtains the following normalised restricted cost function (\tilde{C})²⁹:

$$\ln \tilde{C} = \lambda \times \left[\sum_x \gamma_x \times \ln x + \sum_h \sum_m \gamma_{h,m} \times \ln h \times \ln m \right] + (1 - \lambda) \times \ln \tilde{C}_{-1} \quad (2.3.19)$$

With, $x = h = m = P_i, U_{-1}, L_{-1}, Y, t$ and where γ are parameters, P_i are the normalised (by P_{CI}) price of the flexible inputs i ($i = LS, EG, E, S, N$), U_{-1} represents the normalised (by LNS) quasi-fixed inputs ($U = K_1, K_2, K_3, K_4$) at time $t - 1$, L_{-1} the normalised (by LNS) land at time $t - 1$, Y the normalised (by LNS) vegetal and animal production ($Y = Y_A, Y_B$).

Ngwa Zang and Le Mouël (2007) treated the land demand as a fixed factor and did not include the land demand as a control variable for farmers. So, we first try to consider land demand as quasi-fixed factor, and treat it as input in the same manner than Ngwa Zang and Le Mouël (2007). Thereby, at the long term equilibrium, the user cost of quasi-fixed factors must equal the cost reduction induced by an increase of quasi-fixed factor (optimal equilibrium condition). We obtained the following cost

28. See Appendix B for details on the agriculture module of NEMESIS, based on Ngwa Zang and Le Mouël (2007 [367]).

29. We present a simplified version of the normalised restricted cost function developed by Ngwa Zang and Le Mouël (2007). For instance, we omit the second term of Taylor series.

share for the land:

$$S_L = \lambda \times \left[\gamma_L + \sum_v \gamma_{v,L} \ln v \right] + (1 - \lambda) S_{L-1} \quad (2.3.20)$$

With $v = P_i, U_{-1}, L_{-1}Y, t$ and S_L the land cost share and where the γ parameters are given by Ngwa Zang and Le Mouël (2007) estimate results. The parameters values are given in the following table 2.3.5.

Table 2.3.5: Ngwa Zang and Le Mouël (2007 [367]) estimated parameters of the normalised restricted translog cost function

λ	γ_L	$\gamma_{L,E}$	$\gamma_{L,S}$	$\gamma_{L,N}$	$\gamma_{L,LS}$	$\gamma_{L,t}$
0.11	0.8371	0.0051	0.0051	0.0881	-0.0431	-0.0652
$\gamma_{L,L}$	γ_{L,K_1}	γ_{L,K_2}	γ_{L,K_3}	γ_{L,K_4}	γ_{L,Y_A}	γ_{L,Y_B}
0.1068	0.0196	0.01	0.009	0.0277	-0.0457	-0.0517

Nevertheless, the implementation of the equation 2.3.20 in the NEMESIS model provides bad results and especially, there is a strong disconnection between the agricultural production and the land demand. This problem is in line with Ngwa Zang and Le Mouël (2007) assumptions. Looking at the historical data, they observe a disconnection between the land use by agriculture and agricultural production. In this manner, they normalise the restricted cost function by family labour, as a solution to this problem, avoiding structural effect on scale parameters. One way to go ahead this problem should have been to modify the estimated parameters from equation 2.3.20, but as all these parameters are also present in the other equations, it could be inconsistent for the other inputs of agricultural production. Furthermore, as this representation of land demand does not allow to distinguish between grassland and arable land, in addition as we have two types of production and finally as data on grassland and arable land are available, it is preferable to make the distinction between arable land and grassland rather than use the equation 2.3.20 as land demand in NEMESIS. So, we decide to use the following functional form that allow to separates both agricultural land demands:

$$L_{n,i,t}^D = \lambda \left(\frac{C(Y_{n,i,t})}{UCT_{n,i,t}} \right)^\theta + (1 - \lambda) L_{n,i,t-1}^D \quad (2.3.21)$$

With n is the index for grassland (GL) and arable land (AL), t the time index and i the country

index. L^D is the land demand, λ is a adjustment parameter, θ is a positive elasticity parameter³⁰, $C(Y_n)$ is the cost function of the other production factors, where Y is the animal production ($Y = Y_B$) when $n = GL$ and vegetal production ($Y = Y_A$) when $n = AL$. And UCT is the user cost of land. The cost of the other production factors is defined by equation 2.3.22:

$$C(Y_n) = S_{Y_n} \times \tilde{C} \times \sum_v S_v \quad (2.3.22)$$

With

$$S_{Y_n} = \begin{cases} \frac{P_A \cdot S_{Y_A}}{\tilde{C}} & \text{if } n = AL \\ \frac{P_B \cdot S_{Y_B}}{\tilde{C}} & \text{if } n = GL \end{cases} \quad (2.3.23)$$

With $v = P_i, U, t$, S_v is the share of the input v in the total cost \tilde{C} and is the cost shares for agricultural production Y_A and Y_B *i.e.* for vegetal and animal production. Thus, this function depends on the agricultural production level as well as on the other inputs price allowing a trade off between land and other inputs. The user cost of land is defined by equations 2.3.24 and equation 2.3.25 that follow the traditional representation of user cost³¹. We suppose that $r_{i,t}$ is the discount rates at time t , equal to the nominal long term interest rates of country i , $E^{i,t}[P_{L_{i,t+1}}]$ is defined as the expected land price (P_L) at $t+1$, expectation made at period t . And we also suppose that the depreciation rate of the land is null.

$$UCT_{n,i,t} = \frac{P_{L_{i,t}} \left(r_{i,t} - E^{i,t} \left[\frac{P_{L_{i,t+1}} - P_{L_{i,t}}}{P_{L_{i,t}}} \right] \right)}{1 + r_{i,t}} \quad (2.3.24)$$

In addition, we assume identical user costs of land for grassland and arable land (*i.e.* $\forall n$) and static expectations. Thus, the expected land price at $t+1$ is the same as in period t ($E^{i,t}[P_{L_{i,t+1}}] = P_{L_{i,t}}$) and the expected growth rates of the land price in $t+1$ is null ($E^{i,t} \left[\frac{P_{L_{i,t+1}} - P_{L_{i,t}}}{P_{L_{i,t}}} \right] = 0$). We now have the following user cost for land:

$$UCT_{i,t} = P_{L_{i,t}} \left(\frac{r_{i,t}}{1 + r_{i,t}} \right) \quad (2.3.25)$$

30. We have calibrated the θ parameter in order to have robust projections for agricultural lands, in average the θ parameter is about 0.3.

31. This presentation of the user cost is based on Scheryer (2009 [420]) itself inspired by Christensen and Jorgenson (1969 [93], 1973 [94]), Diewert (1974 [120]), Jorgenson (1989 [304]) and Hulten (1991 [279]). In addition, this formulation imposes that investors are risk-neutral.

In this manner, we have a simple form of the user cost of land. It depends on the agricultural land price and on long term nominal interest rate and defined by the opportunity cost of land ($P_{L_{i,t}} \times r_{i,t}$) and by the discounting factor $((1 + r_{i,t})^{-1})$.

To conclude, we presented in this section the land demand implemented in the NEMESIS model based on the agricultural production side developed by Ngwa Zang and Le Mouél (2007). But, as they noticed, when we deal with the land demand as quasi-fixed factors *i.e.* in the same way as for capital goods, we are confronted with structural problems that lead to inconsistent projections either by unrealistic increases or drastic decreases. That is the reason why, we construct a land demand using simple functional form that is however linked with the agricultural production by a cost function of other inputs boiling down to a trade-off between land and other costs of inputs in the production process.

2.4 Urban land use

Even if at a global European level the share of urban land use in total land appears relatively small (3.8% of total land against 44.5% for agricultural land *i.e.* 160 000 km² against 1 870 000 km²), its importance in some countries is not negligible like in Belgium or Netherlands with 17% and 10% of total areas respectively. Moreover, as seen in section 2.3.1, urban land use acts on other land and especially on agricultural land by shifting the asymptote reducing land available for agricultural use when increasing and raising it when decreasing (see section 2.3.1). We choose to use the economic information provided by NEMESIS to model the urban land which is split into two major components: Industrial and Commercial (I&C) buildings on one hand and housing in the other hand. This section is organised in three part. In a first section 2.4.1, we will present the general methodology and the related assumptions used to model both urban lands, section 2.4.2 will deal with the Industrial and Commercial Buildings *i.e.* the urban land used by firms, and finally, section 2.4.3 presents the model developed for housing as well as the modelling of households investments in housing.

2.4.1 Linking urban lands and economics in NEMESIS

We present the general methodology used to link urban lands with the economic activity. Indeed, the urban lands (lands covered by physical buildings such as shops, houses, storehouses, schools, etc) are represented in the NEMESIS model through capital stocks, we can thus define a relationship between the capital stocks and the land occupied by them. We choose to compute density coefficients (c_i) that link the capital stock with the urban lands, representing the number of square kilometre by unit of capital expressed in volume (*i.e.* here by €₂₀₀₀):

$$c_i^n = \frac{L_i^{U_n}}{BS_i^n} \quad (2.4.1)$$

Where $L_i^{U_n}$ represents urban land used by agents n in country i , with $n = H, F$ including households (H) and firms (F)³². It is noticed that both agents (n) allow the distinction between both urban land as Industrial and Commercial (I&C) buildings are owned by firms whereas households invest in housing. Finally, BS_i^n represents the stock of buildings for agent n and in country i . This simple relation can provide a relatively good proxy to link urban land and economic variables, nevertheless, it obliges us

32. Here, we define “firms” as all productive agents *i.e.* the private firms but also the overall public administrations.

to make some assumptions. Firstly, we do not have details on I&C buildings at sectoral level as well as for different household categories, thus we can not define the density coefficients c_i at sectoral level or by households types, and as a consequence we define these coefficients for aggregated agents. In this manner, we lose information and we suppose that there are the same density coefficients for each sector or household what is a strong assumption. The c_i coefficients are then average aggregated coefficients, however we will see in section 2.4.2 that, for I&C buildings, there is more sectoral information coming from the stock of buildings. Secondly, we compute these density coefficients for year 2000 and we assume that they are fixed. Thereby, we suppose that the buildings land density is constant *i.e.* one constant euro invests in 2000 covers the same number of square kilometre in 2000 than in 2025. We tried to relax this assumption but the lack available information and the time to collect them, if possible, lead us to keep density coefficients fixed .

We now present in more details, following the previous methodology, the computation of the density coefficients for each agents as well as the development for the NEMESIS model when it was necessary.

2.4.2 Industrial and commercial buildings

We focus in this section on the density coefficients for Industrial and Commercial (I&C) buildings and more especially on the calculation of building stock. We start by computing buildings stocks at sectoral level ($BS_{s,i}^F$) by using the traditional perpetual inventory method (equation 2.4.2):

$$BS_{s,i,t}^F = I_{s,i,t}^F + (1 - \delta^F)BS_{s,i,t-1}^F \quad (2.4.2)$$

Where $I_{s,i,t}^F$ is the firms investments in buildings in sector s and country i at time t and δ^F is the annual depreciation rate of the buildings stock. The firms investments in buildings ($I_{s,i,t}^F$) at sectoral level are not directly available therefore we use the NEMESIS investment matrix that distributes the investment realised in a sector ($I_{s,i,t}$) between sectors that produce this investment. To identify the investments in buildings, we assume that the investment share addressed to the construction sector ($\theta_{s,const,i}^{inv}$) represents the whole investment in buildings. Thus, the $I_{s,i,t}^F$ is equal to $I_{s,i,t}^F = \theta_{s,const,i}^{inv} \times I_{s,i,t}$. To calculate the $BS_{s,i,t}^F$, we need, in addition to $I_{s,i,t}^F$, an initial stock of building that is calculated by assuming that the investment in buildings grows at a constant rate ($g_{I_i^F}$)³³:

33. The methodology to compute initial capital stock or other stock using perpetual inventory method can be find, for instance, in Guellec and van Pottelsberghe de la Potterie (2001 [252]).

$$BS_{s,i,0}^F = \frac{I_{s,i,0}^F}{1 - \left(\frac{1}{1+g_{I_i^F}} \right) (1 - \delta^F)}$$

Finally, we suppose an annual depreciation rate (δ^F) of 1.8% as recommended by OECD (2001 [372]) representing an average service life of the I&C buildings of about about 40 years. Now, by summing the sectoral stock of I&C buildings, it leads to the national stock of I&C buildings ($BS_{i,t}^F = \sum_s BS_{s,i,t}^F$), and we can now calculate the density coefficients for I&C buildings.

As one can see in table 2.4.1, the density coefficients are very disparate among EU countries. It can be due to different aspects such as economic development, national regulatory regimes, available areas for urban growth but unfortunately also, for some countries, from the relative bad quality of investment data and especially their time horizon. For New Members States (NMS), the sectoral data on investment is recent and does not allow a good estimate of buildings stocks. Looking at table 2.4.1, we can see that in the NMS the density coefficients are often higher than in EU-15³⁴, the density coefficient is about 15 km² per billion €₂₀₀₀, in NMS, whereas it is about 2.2 km² per billion €₂₀₀₀ in EU-15. We can also explain the higher density coefficients in NMS, by the differences on economic development insomuch as economic development tends to increase urban migration and consequently to raise activity concentration. We also observe that countries with large available areas as Finland, Sweden, Estonia or Latvia have also higher density coefficients, indeed the land pressure being less important, these countries can have less dense I&C buildings areas³⁵.

Table 2.4.1: Density coefficients for land used by industrial and commercial buildings (in number of km² per billion €₂₀₀₀)

AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT	SE
1.8	2.6	1.6	1.0	1.3	6.0	1.9	5.3	0.2	1.9	1.8	1.0	2.2	18.6

UK	CZ	EE	HU	LT	LV	MT	PL	RO	SI	SK	EU	NMS	EU-15
3.7	11.2	25.7	28.5	40.3	12.6	0.6	4.9	83.4	3.3	15.8	2.7	15.2	2.2

Source: NEMESIS model

34. In order to well understand the density coefficients, we must keep in mind that higher the density coefficients are, more larger areas are occupied for 1 € of I&C buildings stock.

35. We also observe very high coefficients for Romania and Latvia, we decide to reduce it to 35 in NEMESIS whereas we see that density coefficient for Ireland is very low, we then decide to fix it at 1.

After the presentation of the link between lands occupied by the industrial and commercial buildings and investments in NEMESIS, we now present the link between land used by housing and household investments.

2.4.3 Housing

We will present, in the first part of this section, the link between land used by housing and household investments as done for I&C buildings. Nevertheless, this link required housing investment and as the one used in NEMESIS model is not developed enough, we decided to develop a model for housing investment. Thereby in a second part, we develop a new model of households investments for NEMESIS.

2.4.3.1 Housing and land

As for I&C buildings in section 2.4.2, we construct the households stocks of housing (BS^H) using the perpetual inventory method (equation 2.4.3).

$$BS_{i,t}^H = I_{i,t}^H + (1 + \delta^H) BS_{i,t-1}^H \quad (2.4.3)$$

With $I_{i,t}^H$ the household investments in housing in country i at time t . We note that, for households, the stock of buildings is defined at national level, we do not have further detailed data that could allow to distinguish between households types. Furthermore, as data does not exist on investments in housing by households, we use the Gross Fixed Capital Formation (GFCF) as proxy³⁶, nevertheless as mentioned by Baghli *et al.* (2004 [22]), for France, household investments in housing represent at least 90% of the households GFCF. We compute the initial stock of housing as we did for I&C buildings but with an annual depreciation rates (δ^H) of 1% (OECD, 2001 [372]). Table 2.4.2 displays the density coefficients of housing for European countries. We can see that the density coefficients for housing are very similar than for I&C buildings what seems relatively normal³⁷.

We have now both density coefficients. Nevertheless, we want to improve the modelling of households investments in the NEMESIS model. Thereby in the following section, we present how we develop the households investments modelling for NEMESIS.

36. In reality, we use GFCF of households and non-profit institutions serving households. But, we observed, for countries with the both data, a share of households investments representing more than 95% of total investments.

37. As for I&C buildings density coefficients, we reduce, in NEMESIS, the Romanian and Latvian coefficients to 35.

Table 2.4.2: Density coefficients for land used by housing (in number of km² by billion €₂₀₀₀)

AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT	SE
3.2	4.4	1.0	5.0	2.3	10.7	2.5	2.6	2.0	1.8	1.8	2.6	3.0	12.8
UK	CZ	EE	HU	LT	LV	MT	PL	RO	SI	SK	EU	NMS	EU-15
3.4	17.5	25.0	15.1	39.6	29.4	2.4	12.7	63.0	4.9	24.7	2.7	21.1	2.1

Source: NEMESIS model

2.4.3.2 Modelling housing investments

Methodology³⁸

Household investment was already modelled in the NEMESIS model but in a very rough way, and the implementation of the land use module implies a better modelling of it. In this section, we will present the new formalisation and estimate of household investment in the NEMESIS model.

Either from a theoretical or an empirical point of view, interactions between residential market and macroeconomic are not very well analysed (Leung, 2004 [335]). It explains that the modelling of household investment in large applied economic model is not very developed, or at least is not highlighted compared to other macroeconomic variables. This fact is reinforced by the lack of consensus regarding households investments formalisation, mainly due to national regular regimes but also because of real estate bubbles (Baghli *et al.* 2004 [22]). Furthermore, there are two aspects on housing investments. The first one is associated with the services provided by the housing which can be viewed as a consumption and the second one concerns the wealth effect related with the ownership of housing³⁹. We analyse how some large applied economic models and especially econometrics ones represent the housing investments⁴⁰.

In the INTERLINK model developed by the OECD (Richardson 1988 [404], Egebo and Lienert 1988 [167]) estimate housing stocks for six main OECD countries with a stock adjustment model. In their modelling, the variation of the housing stock is a function of the households real disposable

38. The section depends for a part on a study realised in the ERASME laboratory (Lécina 2008 [327]) and especially for the literature survey.

39. We do not treat the trade-off between buying a housing or renting it (see *e.g.* Arrondel and Lefebvre 2001 [17] or Henderson and Ioannides 1983 [267]). Furthermore, from macroeconomic point of view, the housing investment only concerns new housing purchase, the second hand market is not considered even if it follows the new housing purchase market, as demonstrated by Demers (2005 [112]) for Canada.

40. We do not present the estimate results of these studies but we will use them to compare our estimate results in the following section.

income *per capita*, the real interest rates (in moving average), the relative housing price (either relative price of housing services or relative price of housing investment), the existing housing stock *per capita* at the previous period, the variation of unemployment rate and finally a partial adjustment term⁴¹. For the MIMOSA model⁴², Chauffour and Fourmann (1990 [83]) formalise the investment rate (*i.e.* the ratio between housing investment and housing stock) as a function of households income *per capita* (smoothed variable), real housing investment price (smoothed variable), real interest rate, previous housing stock *per capita* and unemployment rate change. A very similar version of housing investment model was developed for the french economy (Bonnet *et al.* 1994 [44]) in the AMADEUS model (INSEE 1998 [287]), they also estimate the investment rate but they replace households income *per capita* by gross household income and unemployment change by employment variation. Another interesting model is the European HERMES model (1993 [293]) composed by seven individual macro-sectoral models for Belgium, Netherlands, France, Germany, Ireland, Italy and United-Kingdom. Only four models introduce the housing investment in their respective presentation but in one of them, the Dutch model (Mot *et al.* 1993 [359]), housing investment is described as exogenous. According to the French HERMES model (Assouline and Epaulard 1993 [19]), housing investment is described as a model based on the desired housing stock adjusted with the help of an error correction model (Engle and Granger 1987 [171]). This desired housing stock depends on household income, relative price, active population and interest rates. In the Irish HERMES model (Bradley *et al.* 1993 [51]), the housing investment is modelled by the housing investment *per capita* that is a linear function of real personal disposable income *per capita*, government transfers for housing, interest rates and inflation⁴³. Finally, Bosi *et al.* (1993 [45]) use similar housing investment model for the Italian HERMES model. They relate, in logarithmic form, housing investment *per capita* with income *per capita* and relative price of housing investment and they include also a dynamic partial adjustment. More recently, Chauvin *et al.* (2002 [84]) develop an error correction model the Emod.fr model in which they model housing investment rates (the ratio between housing investment and households real disposable income) with real disposable income, unemployment rate and interest rate as explanatory variables. In this case, the use of housing investment rates, in an error correction model, imposes a long term elasticity between household investment and real disposable income equal to one⁴⁴. Finally, in a very recent description

41. All variables are expressed in logarithm except for real interest rate and unemployment rate.

42. See Delessy *et al.* 1996 [111] for a description of the MIMOSA model.

43. All variables are expressed in logarithm.

44. We will specify these properties in the following section.

of the MESANGE model (Klein and Simon 2010 [313]), housing investment is also modelled with an error correction model in which they link for short term, housing investment variation with previous variation, housing investment price variation, real short term interest rate variation (3 month) and unemployment rate variation while in the long term equation, they only keep the link between real disposable income and real long term interest rates (10 years)⁴⁵.

As one can see in the previous descriptions, there are few differences in the explanatory variable used to describe household investment in the applied economic models, even if the endogenous variable is slightly different (investments rates, investment in level and stock of housing, ...). This can be summarised as follows:

- Firstly, real disposable income allows us to take into account the purchase ability as well as the borrowing power of households.
- The purchase of housing, in most cases, requires a long term loan. This aspect is included with the help of interest rates, the payback power being reduced when interest rates increase.
- In addition, socio-economic aspects can also act on the housing investment, and particularly, demography can play a non negligible role, this is why some models use *per capita* variables as explanatory variables.
- The relative housing investment price, generally, the ratio between housing investment price and consumption price, allows the modelling of the traditional substitution effect. But, in the case of housing, which is an asset for the households, the investment price acts also on the expected wealth (insomuch as it follows housing stock price) and this wealth effect can be effectively very important as illustrated by the recent real estate bubble. Thus, housing investment price plays a double role, it increases purchase cost but it also raises expected housing value.
- The general economic context is generally represented through unemployment rate or employment which are relatively important for the household expectations on economic futures and then for their confidence on their payback capacities.
- Finally, other variables such as government subsidies for housing, as in Irish HERMES model (Bradley *et al.* 1993 [51]), can act on the household investment decision. Some of them are already included in the real disposable income, this is the case for instance of transfers. It could also be interesting to include specific variables that could reflect change in regular national regimes

45. All variables are expressed in logarithm except interest rates and unemployment rate.

but as we use a panel of 12 countries, the time required to get good and reliable information constrains us to exclude this option.

According to the modelling, we can see that the most recent studies (Chauvin *et al.* 2002 [84] and Klein and Simon 2010 [313]) use the error correction model that we also choose for NEMESIS because the error correction model allows the distinction between two models: one for short term and a second for long term (equilibrium). Nevertheless, the error correcting model requires a deep examination of variables with numerous econometric time series tests, and especially, it requires unit roots and cointegration tests. Thus, we present in the following sections the data used for the modelling, the unit roots and cointegration tests, followed by the error correction model estimate and finally we display some sensibility analysis on the estimated model.

The data

All economic data used for the estimate come from the Annual Macro-ECONomic database (AMECO 2008 [11]) of the European Commission's Directorate General for Economic and Financial Affairs (DG ECFIN) which provides structured and coherent data on national accounts and especially times series for prices. Population data comes from the Eurostat Population database (Eurostat 2008 [202]). Thus we have the following variables for 12 European countries⁴⁶ from 1995 to 2008:

- Households and Non-Profit Organisation (NPO) real gross fixed capital formation⁴⁷ ($GFCF$) which is the $GFCF$ in value divided by the total economy gross fixed capital formation price (P_{GFCF})⁴⁸.
- The real total economy gross fixed capital formation price (P_{GFCF}^R) which is the ratio between P_{GFCF} and the consumption price (P_{CONS}).
- The household real disposable income (REV^Q) which is the ratio between household disposable income and consumption price.
- Long term and short term real interest rates (TX^{LT} and TX^{CT}) which are the ratio between interest rates and consumption price.
- The number of unemployed people ($UNEMP$).
- And the population divided in 5 age groups, the “very young” (POP^{YY}) between 0 and 4 years,

46. Only EU-15 countries: Belgium, Denmark, Germany, Spain, France, Italy, Netherlands, Austria, Portugal, Finland, Sweden and United-Kingdom.

47. Households gross fixed capital formation and households and NPO gross fixed capital formation in residential are unavailable.

48. Price of households and NPO gross fixed capital formation is unavailable.

the “young” (POP^Y) between 0 and 19 years old, the “medium” (POP^M) between 20 and 39 years, the “medium-old” (POP^{MO}) between 40 and 59 years old and the “old” (POP^O) more than 60 years.

All these variables are transformed in logarithm except for the real interest rates. In the following section, we present the unit root tests and cointegration tests realised on these variables.

Unit root tests and Cointegration tests

We start by presenting the unit root tests followed by cointegration tests. The unit root tests are realised on the variables, in logarithmic form⁴⁹, presented in the previous section. As we will use panel estimate techniques, we use two different unit root tests for panel data⁵⁰: the IPS test (t_{IPS} , Im *et al.* 2003 [285], see box 2.4.3.2-A) and the MW test (t_{MW} , Maddala and Wu 1999 [344], see box 2.4.3.2). Table 2.4.3 displays the IPS tests and the MW test⁵¹. We do not compute IPS test and MW test on a model with a trend for unemployed people and for both interest rates because it seems unrealistic. Logically, these variables can not include a trend even if it could graphically appear for the unemployed. We can see that for variables in logarithm, all the t_{IPS} statistics are inferior to their critical values either with or without trend⁵², except for the “young” population pop_Y for which both t_{IPS} and t_{MW} statistics show an integration of order 0 (*i.e.* $I(0)$) with a trend, *i.e.* pop_Y is trend stationary. In fact, the t_{IPS} and t_{MW} are both higher than the critical values in the case of the model with trend, thus we can reject the hypothesis of unit root existence at 1% level (see boxes 2.4.3.2-A and 2.4.3.2-B).

In general, the both tests t_{IPS} and t_{MW} give the same conclusion but there are several cases where the conclusion can be divergent. In particular, t_{MW} tends to reject more often the null hypothesis of unit root. In this case, we suppose the predominance of the IPS test on the MW test, thus the MW test serves to confirm the IPS test. Therefore, we do not reject the null hypothesis for gross fixed capital formation ($gfcf$), “very young” population (pop_{YY}) and “old” population (pop_O) with the model containing a trend and “medium-old” population (pop_{MO}) for the model with constant. Thus, all variables, except the “young” population are supposed to be at least $I(1)$.

49. Variable in lower case are in logarithm.

50. See Hurlin and Mignon (2005 [280]) for a recent survey of unit root test for panel data. We base our test explanation on this survey.

51. We use as basis a program write by Hall and Cummins (1999 [255]) for IPS test.

52. The critical values for t_{IPS} are -2.32, -2.06, -1.93 at 1%, 5% and 10% respectively for models containing intercepts and are -3.03, -2.74, -2.59 at 1%, 5% and 10% respectively for models with intercept and trend (see table 2 in Im *et al.* 2003 [285]).

Box 2.4.3.2-A : The Im, Pesaran and Shin test (IPS test)

The IPS test (Im *et al.* 2003 [285]) is a unit root test with an assumption of inter-individual dependency. It is based on the Augmented Dickey-Fuller (ADF) tests (Dickey-Fuller 1979 [115], 1981 [116]). It uses the following model:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + \sum_{j=1}^L \beta_{i,j} \Delta y_{i,t-j} + \varepsilon_{i,t} \quad (2.4.4)$$

Where $y_{i,t}$ is the tested variable at time t for country i , $\Delta y_{i,t} = y_{i,t} - y_{i,t-1}$ is the first difference of variable $y_{i,t}$, α_i is a parameter for individual effect, $\beta_{i,j}$ parameters to randomise the error terms, L the number of lag^a, ρ_i the tested parameter for unit root in country i and $\varepsilon_{i,t} \sim N.i.d(0, \sigma_{\varepsilon_i}^2)$ is normally and independently distributed with a variance of $\sigma_{\varepsilon_i}^2$. The IPS test tests the joined null hypothesis of unit root ($\rho_i = 0$) with $\alpha_i = 0$.

$$\begin{aligned} H_0 : \rho_i &= 0, \forall i = 1, \dots, 12 \\ H_1 : \rho_i &< 0, \forall i = 1, \dots, N_1 \\ \rho_i &= 1, \forall i = N_1 + 1, \dots, 12 \end{aligned} \quad (2.4.5)$$

Im *et al.* construct the following statistic (\tilde{t}) that is the mean of the N (number of country) individual ADF statistics (t_i^{ADF} , Dickey-Fuller 1979 [115], 1981 [116])

$$\tilde{t} = \frac{1}{N} \sum_{i=1}^N t_i^{ADF} \quad (2.4.6)$$

Finally, Im *et al.* compute the standardised statistic ($Z_{\tilde{t}}$) that is centred on the first moment ($E[t_i^{ADF}]$) of the individual ADF statistics and divided by the second moment of the same distribution ($Var[t_i^{ADF}]$).

$$Z_{\tilde{t}} = \frac{\sqrt{N} \left(\tilde{t} - N^{-1} \sum_{i=1}^N E[t_i^{ADF}] \right)}{\sqrt{N^{-1} \sum_{i=1}^N Var[t_i^{ADF}]}} = t_{IPS} \quad (2.4.7)$$

The moments $E[t_i^{ADF}]$ and $Var[t_i^{ADF}]$ are computed (see Table 3 in Im *et al.* (2003 [285])) for lag (L) and time horizon (T). Im *et al.* also compute critical values when T and N are small; t_{IPS} being normally distributed when N and T tend to infinite.

^a. The optimal lag is determined with AIC2 (Akaike Information Criterion, Akaike 1974 [7]) as recommend by Pantula *et al.* (1994 [379]).

Box 2.4.3.2-B : The Maddala and Wu test (MW test)^a

The Maddala and Wu test (Maddala and Wu 1999 [344]) is a non parametric Fisher test (1932 [228]) defined as follow:

$$t_{MW} = -2 \sum_{i=1}^N \ln(P_{t_i^{ADF}}) \quad (2.4.8)$$

Where $P_{t_i^{ADF}}$ is the p-value associated with the i^{th} ADF statistic (t_i^{ADF}). $P_{t_i^{ADF}}$ is distributed according to a $\chi^2(1)$. Thus t_{MW} statistic is distributed according to a $\chi^2(2N)$. If t_{MW} is superior to the critical value, then we reject the null hypothesis of unit root for panel countries.

^a. This test was used in Choi (2001 [90]) and in a working paper version in 1999 (Choi 1999 [89]), as precised by Hurlin and Mignon (2005 [280]).

Table 2.4.3: Panel Unit root tests results

	Logarithm ($\ln y$)				1 st Difference ($\Delta \ln y$)			
	Trend		Constant		Trend		Constant	
	t_{IPS}	t_{MW}	t_{IPS}	t_{MW}	t_{IPS}	t_{MW}	t_{IPS}	t_{MW}
$gfcf$	-0.67	47.0***	2.09	21.1	-1.66	57.7***	-2.18*	51.4***
rev^Q	0.93	22.0	-0.47	28.8	-0.95	37.2*	-1.98*	41.6***
p_{gfcf}^R	-0.26	30.8	-1.84	30.5	0.32	19.2	-2.23**	48.5***
$unemp$	—	—	-0.42	31.3	—	—	-2.38***	50.1***
pop	7.24	19.2	3.1	18.6	5.79	21.4	-2.56***	61.4***
pop_{YY}	-0.40	51.7***	0.29	31.6	-2.08**	47.4***	-0.88	51.2***
pop_Y	-4.14***	92.8***	-0.07	42.5**	—	—	—	—
pop_M	2.4	22.2	1.67	27.5	-2.69***	60.9***	1.76	20.2
pop_{MO}	0.21	28.7	-1.0	54.7***	-2.22***	66.6***	-0.81	34.1*
pop_O	-0.56	77.2***	5.70	7.3	-2.75***	70.8***	-1.67	78.8***
$TX^{LT(a)}$	—	—	-0.3	20.3	—	—	-2.17**	37.5*
$TX^{CT(a)}$	—	—	-0.7	21.9	—	—	-1.12	28.0

*, **, ***: hypothesis H_0 reject at, respectively, 10%, 5%, 1% confidence level.

^(a): variable not transform in logarithm.

Looking at variables in “log-1st difference”, t_{IPS} and t_{MW} show that all variables are, except for short term interest rates, integrated of order one either in the model with trend or the model without trend. In fact, the t_{IPS} and t_{MW} for gross fixed capital formation, real disposable income, unemployed people, total population and long term interest rates are all superior to their critical values at least at a 10% level of confidence. We then conclude that these variables are $I(1)$ while, the “very young”, “medium”, “medium-old” and “old” populations are $I(1)$ with trend. It can be surprising but as the time horizon covers only 14 years, it can be possible that the variation of these variables include a trend. The only variable being neither $I(1)$ or $I(0)$ is the short term interest rate. When we perform the IPS test and MW test on the 2nd difference, it appears that short term interest rate is $I(2)$. This result seems a little unrealistic but in order to avoid spurious regression and as we do not want to introduce it in 1st difference on the long term relation, we exclude this variable for the error correction model.

We have identified the integration order of the variables, we now need to test the cointegration (Engle and Granger 1987 [171]). As explained by Kennedy (2003 [312]), dropping a variable in the cointegration can be disastrous for the cointegration and Kennedy recommend to use the cointegration

test starting from the most general specification. Thus, we use Pedroni tests⁵³ (1999 [382], 2004 [383] - see box 2.4.3.2-C) for cointegration with panel data, starting from the overall variables and gradually excluding some of them to finish with our final cointegration vector⁵⁴.

Box 2.4.3.2-C: The cointegration Pedroni tests (1/2)

The Pedroni (1999 [382], 2004 [383]) tests regroup seven cointegration tests for panel data with multiple regressors^a. They are based on the following model:

$$y_{i,t} = \alpha_i + \delta_i t + \sum_{m=1}^M \beta_{m,i} x_{m,i,t} + \varepsilon_{i,t} \quad (2.4.9)$$

With i the country ($i = 1, \dots, N$), t the time ($t = 1, \dots, T$) and m the number of regressors ($m = 1, \dots, M$). $y_{i,t}$ is the endogenous variable, $x_{m,i,t}$ is the m^{th} regressors and $\varepsilon_{i,t} \sim N.i.d(0, \sigma_{\varepsilon_i}^2)$ is the error term. Pedroni built seven statistics, with four based on within dimension and three on between dimension. The seven statistics are based on the same null hypothesis of no cointegration:

$$H_0 : \rho_i = 1 \forall i \quad (2.4.10)$$

with $\hat{\varepsilon}_{i,t} = \rho_i \hat{\varepsilon}_{i,t-1} + u_{i,t}$

With $\hat{\varepsilon}_{i,t}$, is the estimated error term. The alternative hypothesis are different when it concerns within dimension (equation 2.4.11) or between dimension (equation 2.4.12), the former allowing the existence of heterogeneity between country:

$$H_1 \rho_i = \rho < 1 \forall i \quad (2.4.11)$$

$$H_1 : \rho_i < 1 \forall i \quad (2.4.12)$$

The four Pedroni tests based on the within dimension are:

- Non-parametric test (panel ν - statistic) based on variance ratio:

$$T^2 N^{3/2} Z_{\nu N, T} = T^2 N^{3/2} \left(\sum_{i=1}^N \sum_{t=1}^T \hat{L}_i^{-2} \hat{\varepsilon}_{i,t-1}^2 \right)^{-1} \quad (2.4.13)$$

- Non-parametric test (panel ρ - statistic) based on the Phillips-Perron (1988 [388]) ρ statistic:

$$TN^{-1/2} Z_{\rho N, T-1} = TN^{-1/2} \left(\sum_{i=1}^N \sum_{t=1}^T \hat{L}_i^{-2} \hat{\varepsilon}_{i,t-1}^2 \right)^{-1} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_i^{-2} (\hat{\varepsilon}_{i,t-1} \Delta \hat{\varepsilon}_{i,t} - \hat{\lambda}_i) \quad (2.4.14)$$

- Non-parametric test (panel t - statistic) based on the Phillips-Perron t statistic:

$$Z_{tN, T} = \left(\hat{\sigma}_{N, T}^2 \sum_{i=1}^N \sum_{t=1}^T \hat{L}_i^{-2} \hat{\varepsilon}_{i,t-1}^2 \right)^{-1/2} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_i^{-2} (\hat{\varepsilon}_{i,t-1} \Delta \hat{\varepsilon}_{i,t} - \hat{\lambda}_i) \quad (2.4.15)$$

- Parametric test (panel t - statistic) based on the augmented Dickey-Fuller t statistic:

$$Z_{tN, T}^* = \left(\hat{s}_{N, T}^{*2} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_i^{-2} \hat{\varepsilon}_{i,t-1}^{*2} \right)^{-1/2} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_i^{-2} \hat{\varepsilon}_{i,t-1}^* \Delta \hat{\varepsilon}_{i,t}^* \quad (2.4.16)$$

^a. For details, please see Pedroni (1999 [382], 2004 [383]) or Hurlin and Mignon (2007 [281]).

53. See Hurlin and Mignon (2007 [281]) for a recent survey on cointegration test for panel data. The presentation of Pedroni tests is based on this survey.

54. The Pedroni tests are realised with WinRATS 7.0 (Enders 2003 [170]) and with a program developed by Pedroni (2007 [384]).

Box 2.4.3.2-C: The cointegration Pedroni tests (2/2)

The three Pedroni tests based on the between dimension are:

- Non-parametric test (panel ρ – *statistic*) based on the Phillips-Perron ρ statistic:

$$TN^{-1/2} \tilde{Z}_{\hat{\rho}N, T-1} = TN^{-1/2} \sum_{i=1}^N \left(\sum_{t=1}^T \hat{\varepsilon}_{i,t-1}^2 \right)^{-1} \sum_{t=1}^T \left(\hat{\varepsilon}_{i,t-1} \Delta \hat{\varepsilon}_{i,t} - \hat{\lambda}_i \right) \quad (2.4.17)$$

- Non-parametric test (panel t – *statistic*) based on the Phillips-Perron t statistic:

$$N^{-1/2} \tilde{Z}_{tN, T-1} = N^{-1/2} \sum_{i=1}^N \left(\hat{\sigma}_i^2 \sum_{t=1}^T \hat{\varepsilon}_{i,t-1}^2 \right)^{-1/2} \sum_{t=1}^T \left(\hat{\varepsilon}_{i,t-1} \Delta \hat{\varepsilon}_{i,t} - \hat{\lambda}_i \right) \quad (2.4.18)$$

- Parametric test (panel t – *statistic*) based on the augmented Dickey-Fuller t statistic:

$$N^{-1/2} \tilde{Z}_{tN, T-1}^* = N^{-1/2} \sum_{i=1}^N \left(\sum_{t=1}^T \hat{s}_i^{*2} \hat{\varepsilon}_{i,t-1}^2 \right)^{-1/2} \sum_{t=1}^T \hat{\varepsilon}_{i,t-1} \Delta \hat{\varepsilon}_{i,t} \quad (2.4.19)$$

The asymptotic distributions of these seven Pedroni statistics are normally distributed for which Pedroni (2004) gives the two first order moments. Furthermore, Pedroni (1999) provides the two first order moment to normalised the seven statistics. The normalised statistics follow a normalised and centred normal distribution.

We tested different regressors and we find traditional variables as in Chauvin *et al.* (2002 [84]) and Klein and Simon (2010 [313]) which regroup the five following variables:

- the households real disposable income (rev^Q),
- the real price of gross fixed capital formation (p_{gfcf}^R),
- the long term interest rates (TX^{LT}),
- the unemployed people ($unemp$) and
- the total population (pop).

Table 2.4.4: Results of Pedroni cointegration tests

	$\nu - stat$		$\rho - stat$		$t_{PP} - stat$		$t_{ADF} - stat$	
	Trend	Constant	Trend	Constant	Trend	Constant	Trend	Constant
Within	-1.43*	-1.06	3.39***	2.59***	-7.59***	-4.37***	1.97**	-2.69***
Between	–	–	4.76***	4.19***	-9.36***	-5.26***	-3.58***	-4.61***

*, **, ***: hypothesis H_0 rejected at, respectively, 10%, 5%, 1% confidence level.

The results of Pedroni tests for these variables are provide in table 2.4.4. The seven Pedroni tests show the rejection of the null hypothesis of no cointegration, except for $\nu - stat$ in the model without constant. And looking at the $t_{PP} - stat$ and $t_{ADF} - stat$ statistics allowing heterogeneity

between country (between dimension) and being, the more robust for small panel dimension (Pedroni 2004 [383]), we can observe that the statistics are all significant at 1% level of confidence. Thereby, there is a cointegration relationship between the households gross fixed capital formation (*gfcf*) and the following variables: rev^Q , p_{gfcf}^R , TX^{LT} , $unemp$ and pop .

To summarise, we realised unit root tests, the results show that all the variables, except the “young” population and the short term interest rate, are integrated of order 1. Thereafter, we realised cointegration tests on variables integrated of order 1 and we find that there is a cointegration relationship between households gross fixed capital formation and households real disposable income, real gross fixed capital formation price, long term interest rate, the unemployed and total population. Consequently, with these results, it is possible to develop an error correction model (Engle and Granger, 1987) which we do in the next section.

Model estimate and results

We estimate an error correction model (Engle and Granger 1987 [171]) with the cointegrated variables presented above. Thus, we have two models, one for long term relationship and a second for short term relationship. The long term relationship is defined by the general model 2.4.20 whereas the short term equation is defined by general model 2.4.21.

$$\begin{aligned} gfcf_{i,t} = & \alpha_i + \delta_i t_i + \beta_i^{rev^Q} rev_{i,t}^Q + \beta_i^{p_{gfcf}^R} p_{gfcf,i,t}^R + \beta_i^{pop} pop_{i,t} \\ & + \beta_i^{unemp} unemp_{i,t} + \beta_i^{TX^{LT}} TX_{i,t}^{LT} + \varepsilon_{i,t} \end{aligned} \quad (2.4.20)$$

$$\begin{aligned} \Delta gfcf_{i,t} = & \mu_i + \theta_i^{rev^Q} \Delta rev_{i,t}^Q + \theta_i^{p_{gfcf}^R} \Delta p_{gfcf,i,t}^R + \theta_i^{pop} \Delta pop_{i,t} \\ & + \theta_i^{unemp} \Delta unemp_{i,t} + \theta_i^{TX^{LT}} \Delta TX_{i,t}^{LT} + \theta_i^{res} \hat{\varepsilon}_{i,t-1} + u_{i,t} \end{aligned} \quad (2.4.21)$$

As, we use panel data, we impose identical parameters for each country for long term and short term equations (see equation 2.4.22) except for intercepts (α_i and μ_i) and trend (δ_i). $\hat{\varepsilon}$ are estimated residuals from long term relationship.

$$\begin{aligned} \beta_i^U &= \beta^U \quad \forall i \\ \theta_i^Z &= \theta^Z \quad \forall i \end{aligned} \quad (2.4.22)$$

Where $U = rev^Q, p_{gfcf}^R, pop, unemp, TX^{LT}$ and $Z = rev^Q, p_{gfcf}^R, pop, unemp, TX^{LT}, \hat{\varepsilon}$.

We also estimate the models 2.4.20 and 2.4.21, either keeping free the long term relationship between households gross fixed capital formation and households real disposable income (β^{rev^Q}) and gross fixed capital formation real price ($\beta^{p_{gfcf}^R}$) or constraining those relationships. Table 2.4.5 displays the estimated results of both models, with and without constrained parameters.

Looking at the **unconstrained models**, we can see that parameters of the long term model are all significantly different to zero except for population. The long term elasticities of households gross fixed capital formation ($GFCF$) with respect to households real disposable income (REV^Q) is equal to 0.52. If this elasticity can appear relatively good, this result supposes a progressive decrease of the ratio between household investment in level and their income in level *i.e.* the share of household investment in their budget tends to decline. Thus, we can not keep this results, and we must impose, as in the studies presented above (for instance in Chauvin *et al.* 2002 [84]), the long term relationship for households real income. In addition, the elasticity of households gross fixed capital formation with respect to households gross fixed capital formation real price (P_{gfcf}^R) is estimated to 1.47. This positive and superior to unity value of price elasticity can be quite surprising. However, as we mentioned above, housing is a spending for households but it is also an asset, as a consequence, an increase of investment price increases purchase cost but raises also the anticipated value of the asset. Thus, as our data cover the 1995 to 2008 period, it includes the recent real estate bubbles that occur in most of the EU-15 countries, and an elasticity of 1.47 can represent the bubble effect of the housing price. Nevertheless, the introduction of such a parameter value in a economic model such as NEMESIS would lead to misleading results, therefore we constrained this elasticity at -0.5%, value in adequacy with those estimated in the literature. For instance, Egebo and Lienert (1988 [167]) find elasticities of -0.45% for France, -0.56% for United Kingdom and -0.44% for Italy while Chauffour and Fourmann (1990 [83]) find elasticities about -0.4% for France, -0.4% for Italy and -0.3% for West Germany. More recent studies, imposed an elasticity or exclude the real price of housing investment of their models in order to avoid such results.

In the **constrained models**, all parameters are significantly different to zero, at least at 10% level except for long term interest rate in the short run relationship and population in the long run one. Regarding the effect of the long term interest rate, the null parameter seems not so surprising, and even using the short term interest rate does not provide better parameters estimates, consequently we keep the hypothesis that long term interest rate has no impact at short term. The parameter estimates

for the population appears to be strong in the short run (+3%)⁵⁵, but does not influence household investment in the long run. The unemployed elasticity is negatively related to housing investment with a short term elasticity of -0.28% and a long term elasticity a little bit lower with -0.13%. For household investment prices, the positive short term elasticity (1.2%) represents the bubble effect where households anticipate the increase of the value of their assets, while in the long run the more traditional behaviour dominates and explains the negative parameter value (-0.5%). Finally, an increase of 1% of households real disposable income raises the households gross fixed capital formation about 0.66% at short term and 1% at long term.

Table 2.4.5: Estimates results of households gross fixed capital formation error correction model

Model 2.4.20 (Long Term)			Model 2.4.21 (Short Term)		
	Unconstrained	Constrained		Unconstrained	Constrained
β^{rev^Q}	0.5196*** (0.3574)	1 ^(a) –	θ^{rev^Q}	0.7575*** (0.2896)	0.6633** (0.2809)
$\beta^{p_{gfcf}^R}$	1.4731*** (0.3465)	-0.5 ^(a) –	$\theta^{p_{gfcf}^R}$	1.6091*** (0.3707)	1.2401*** (0.3523)
β^{pop}	-0.2841 (0.5338)	-0.4065 (0.5736)	θ^{pop}	3.0925** (1.2115)	3.2721*** (1.1696)
β^{unemp}	-0.1398*** (0.0475)	-0.1309*** (0.0411)	θ^{unemp}	-0.2502*** (0.0502)	-0.2849*** (0.0494)
$\beta^{TX^{LT}}$	-0.0178*** (0.0068)	-0.0143* (0.0074)	$\theta^{TX^{LT}}$	-0.0074 (0.005)	-0.0067 (0.0048)
			θ^{res}	-0.5418*** (0.0882)	-0.5302*** (0.0739)

*, **, ***: parameter significantly different to zero at 10%, 5%, 1% respectively.

^(a): fixed parameters.

We tried to individualise some coefficients either in long term or short term model, but due to our limited sample (168 obs.) and the increasing number of parameters, the results are globally disappointing, few coefficients being significant. The only parameter providing relatively good results when individualised, it is the adjustment parameter (θ_i^{res}), which estimates are given for short term

55. We will limit the short term effect at 1.5% in the implemented version of housing investment in NEMESIS to keep a certain stability even at short term.

equation in table 2.4.6.

Table 2.4.6: Estimates results for short term model with individualised adjustment coefficients

Individualised adjustment parameter: θ_i^{res}		Fixed parameters	
BE	-0.5005**	θ^{revQ}	0.523*
DK	-0.7661***	$\theta^{p_{gfcf}^R}$	1.2497***
DE	-0.2594	θ^{pop}	4.0173***
ES	-0.7418**	θ^{unemp}	-0.228***
FR	-0.3308	$\theta^{TX^{LT}}$	-0.006
IT	-0.3787		
NL	-0.5545*		
AT	-0.1028		
PT	-0.4417		
FI	-0.5214**		
SE	-0.7269***		
UK	-0.6318***		

*, **, ***: parameter significantly different to zero at 10%, 5%, 1% respectively.

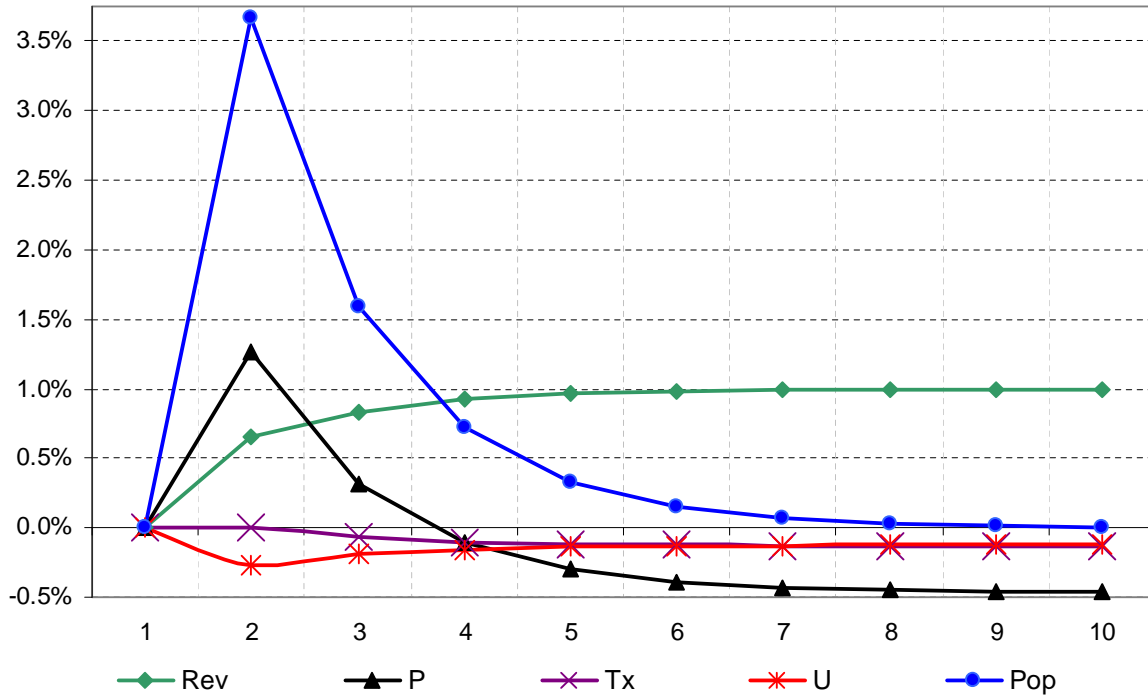
We observe that the other coefficients are close to their value with common adjustment parameters. The short term elasticity is a little bit lower for real disposable income and unemployed people, stronger for population and still not significant for the long term interest rate. Now looking at the individualised adjustment coefficients, we first see that all are negative. But the coefficients for Germany, France, Italy, Austria and Portugal are not significant at 10% level. And we can also see that the range of significant coefficients is confined between a minimum of -0.5 in Belgium and a maximum of -0.77 in Denmark. To analyse the effect of adjustment parameters as well as the effects of short and long term parameters, we realise a sensibility analysis by introducing standard stocks in the error correcting model.

Sensibility analysis

We make a sensibility analysis of the housing investment error correction model estimated in the previous section by introducing shocks on one variable and keeping the other ones fixed. Figure 2.4.1 and 2.4.2 display the model responses to a permanent shock of 1% on each variable with the exception of long term interest rates which had been raised by 1 point of percentage permanently. Figure

2.4.1 presents the responses for common adjustment parameters (-0.53) whereas figure 2.4.2 compares results with individualised adjustment parameter of Denmark (-0.77) and Austria (-0.10) with common parameters case for 1% shock on real disposable income.

Figure 2.4.1: Sensibility analysis with common adjustment coefficient



With $Rev = rev^Q$, $P = P_{gfcf}^R$, $Tx = TX^{LT}$, $U = unemp$ and $Pop = pop$.

We can see in figure 2.4.1, in accordance with estimate results, a short term effect of population very strong but decreasing progressively to reach zero at long term. Thus, population rise has only a transitory effect on households gross fixed capital formation. On the contrary, the real disposable income shows a moderate short run effect on housing investment. The first year, household investment increases by about 0.6% and tends to 1% (as imposed) in the long term. Furthermore, the real price of housing investment has a particular dynamic. First of all, a raise of 1% of investment price pushes housing investment up to 1.25% which can be viewed as a transitory bubble effect. Secondly, the short term positive effect declines to reach its long term equilibrium of -0.5% (as constrained). Thus a perpetual shock on housing investment real price plays, in the short term, a bubble effect but this bubble effect progressively declines to finally reduce housing investment. Looking at the unemployment effect, we observe a bigger short term shock (-0.3%) than the long term with -0.13%. Finally, as demonstrated

by estimated parameters, short term effect of the long term interest rates is null, and long term effect starts one year after the introduction of the shock, to reach -0.15% in the long term.

Figure 2.4.2: Model response to 1% shock on households real disposable income: Comparison according to adjustment coefficients

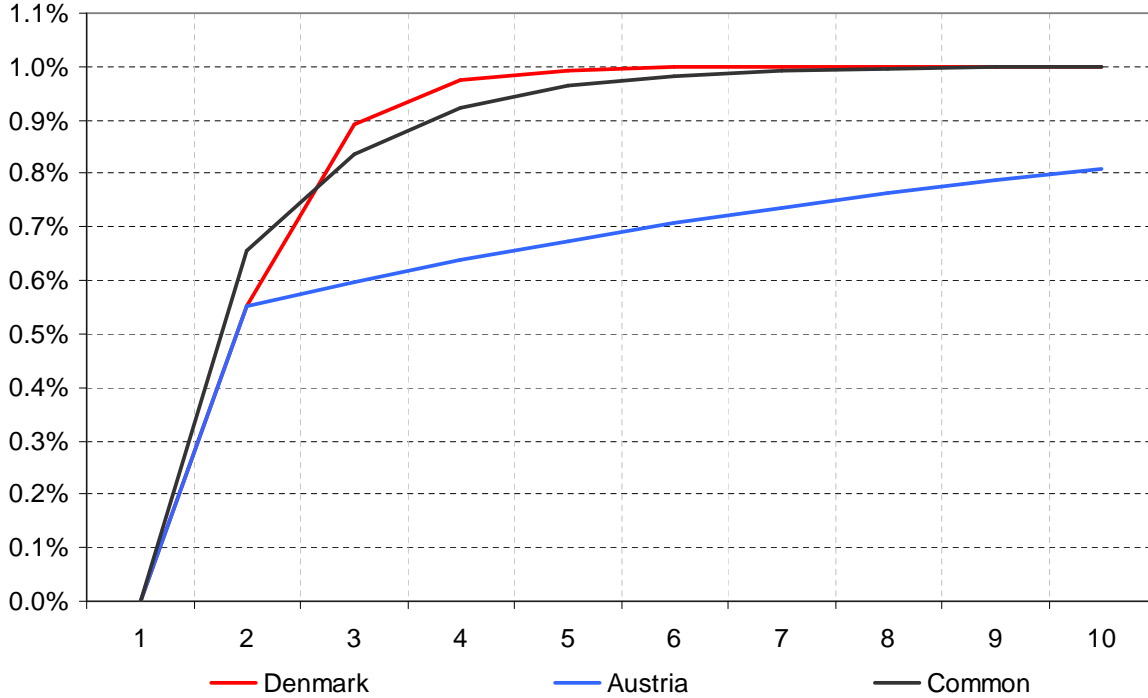


Figure 2.4.2 shows the effect of different adjustment parameters on the response dynamic. Denmark, where the adjustment parameter is the higher with -0.77, tends more rapidly to its long term equilibrium, therefore the Danish average adjustment decay is about 0.3 years *i.e.* 50% of the adjustment of the long term equilibrium is done in 4 months. At the opposite end of the scale, the average adjustment is about 9 years for Austria, where the adjustment coefficient equals -0.1 thereby, full adjustment is not still realised at $t + 10$. For the common adjustment parameter (-0.53), the average adjustment decay is 0.9 year.

We have displayed the responses of the error correction model for different variables and for different adjustment parameters and we showed their respective importance. We keep, for the implementation in the NEMESIS model, the estimated coefficients except for the short term effect of population. In fact, the estimated value of this parameter seems too strong and so we decided to reduce it to 1.5%, *i.e.* a little bit higher than the unity and we still suppose that its long term elasticity is null. Similarly,

we impose a null short term effect of long term interest rate and finally we take the individualised adjustment parameters for estimated countries and we use the common adjustment parameter for not estimated European countries.

Concluding Remarks

We have now an endogenous model for households investments. This model is an error correcting model that determines housing investment in each European country according to its prices, households real disposable income, total population, the unemployed and long term interest rate. With the housing investment for each European country, we can calculate their housing stock using a perpetual inventory method. And finally, we can determine the national land used by housing by using the density coefficients that link national housing stock with its land use.

2.4.4 Summary

We summarise here the development realised to implement urban land use in the NEMESIS model. Our aim was to link NEMESIS economic information with urban land use. We have then supposed that we can link the area occupied by buildings with the stock of buildings. The stock of buildings is defined as a share of the capital stock of each economic agent and it corresponds to investments in buildings or housings. We have then computed density coefficients that define the number of square kilometres of land occupied by buildings for 1 €₂₀₀₀ of building stock. Nevertheless, the use of temporally fixed density coefficients leads to the strong assumption of temporal fixed relationship between land occupied by buildings and its stock. Even, if these coefficients must be relatively stable, the density coefficients will probably change in the next decades and especially for NMS. Indeed, the density coefficients are relatively higher in NMS than in the EU-15, traducing lower density. With the economic convergence it could be possible that NMS coefficients tend to EU-15 ones, nevertheless the lack of data or the complexity of their collection, do not allow us to overcome this hypothesis. We computed the density coefficients for each European country and for firms and public administrations and for households. The coefficient are very heterogeneous between country but are very homogeneous between firms and households. The density coefficients are computed at macro-level for both agents, however the firms stocks of buildings are computed with sectoral investments and according to the heterogeneous dynamic of sectoral investments, it can provide a land use dynamic not only driven at macroeconomic level. For households, we did not have information by households type and we only

kept macroeconomic dynamic. Nevertheless, to have its macroeconomic dynamic, we should develop an endogenous housing investment. We choose, in accordance with the literature, an error correction model that gives short term and long term elasticities. We should impose some of these long term elasticities to keep a coherency for the NEMESIS model, indeed we have imposed an unitary elasticity of housing investment with respect to households real disposable income and we have also fixed the long term elasticity with respect to real price of housing investment at -0.5. The others elasticities kept free and provide relatively good results. We estimated our error correction model in panel with common parameters except for adjustment parameters which have been individualised.

We have now developed the urban part of our land use module and we can introduce it in NEMESIS. The evolution of urban land use is not negligible for NEMESIS insomuch as it shifts on the asymptote and therefore acts on the agricultural land use through available land and land price.

2.5 Conclusion

We presented in this chapter the construction of a land use module for the NEMESIS model. In this respect, we described the functional forms or models used for this module, we also displayed their estimates and we showed their analytical properties with some sensibility tests. In fact, we started, in a first section, by building an homogeneous database on land use for each European country. Thus, we created, from the CLC2000 database, four main land use categories: built-up areas, agricultural land, forests and other land. Starting from this four land use categories, we sub-divided three of them using Eurostat databases and some assumptions. We sub-divided built-up areas between urban land use, including industrial and commercial buildings and housing, and transport infrastructures, with land used by railways and roads. The agricultural land was also divided in utilised agricultural land that includes grassland and arable land. Finally, we distinguished commercial forests to protected ones. This database shows an heterogeneity between European countries, for instance land repartition in Belgium is relatively balanced with 58% of agricultural land, 24% of built-up areas, 21% of forests whereas in Sweden, forest covers 68% of overall land and only 9% for agriculture. And on average for the EU, agriculture covers 48% of total areas, forest 32% and built-up areas 5%, the rest 15%, are unsuitable lands. Even, if it was only the description of a database, this section confirmed the importance of the land use for assessing European sustainable policies. Indeed with respect to European countries heterogeneity, the impact of such policies can be relatively different among countries.

The second section, referring to the importance of agricultural land displayed in the previous section, presented the modelling of agricultural land supply and demand. We started by presenting and constructing the agricultural land asymptote. This asymptote gives the limits for agricultural land expansion and allows the recognition of land scarcity, it is constructed to deal with land claims in a hierarchical manner. The agricultural land has a priority compared to others land uses on available lands, but after land conversions, land priority order changes, there are some irreversibilities: built-up areas can not be converted into other land-use types that shift the asymptote and reduce available land for agriculture. We, then, chose a “L-inverse” functional form for agricultural land supply. This functional form, despite its simple specification, allows us to take into account heterogeneous situation of land scarcity for European countries and it establishes a link between physical land properties and land productivity as demonstrated by Tabeau *et al.* (2006 [438]). Thereafter, we studied the properties of this functional form and we estimated it for countries with available data. The calculation of land supply elasticity with respect to land prices displays a range between 4.5% for Finland, where unused

land by agriculture is very large, and 0.07% in Ireland for which unused agricultural land covers less than 10% of total land available for agriculture. For EU, land elasticity is about 0.5% *i.e.* 1% increase of land price raises land supply by 0.5%.

The following sub-section focused on agricultural land demand that is based on NEMESIS agricultural production functions developed by Ngwa Zang and Le Mouél (2007 [367]), and we also used a functional form for its modelling. The land demand is divided in two land demands. On one hand, the grassland is determined by a trade-off between land claims for animal production, coming from NEMESIS production functions, and the grassland user cost, whereas arable land results from a trade-off between land claims for vegetal production and the arable land and the user cost. Thus, the confrontation of land supply and land demand, will allow us to establish a land price and lands used by agriculture.

Finally, the last section emphasised the modelling of urban land use. We chose to use buildings stocks, calculated with investment addressed to construction sector, to model urban land use. In fact, we calculated land density coefficients (number of km² by 1€₂₀₀₀ of buildings stock) linking building stocks with occupied lands by buildings and we constructed these coefficients for two urban land use types: industrial and commercial buildings and housing. For industrial and commercial buildings, we used sectoral buildings stocks constructed with the NEMESIS sectoral investments flows and for housing, we calculated national stocks of housing with housing investment. In addition, we have defined a model for housing investment that we specified and estimated with an error correction model. We imposed some long term properties such as long term housing investment elasticity with respect to households real disposable income equals to unity and we displayed some short and long term properties of housing investment modelling. For instance, with constrained and estimated parameters, we found a positive impact, in the short term, on housing investment of its real price and a negative impact in the long term, thereby housing investment model can display some transitory real estates bubbles.

To conclude, all those developments allow the implementation of the land use in the NEMESIS model. We now have a land market for agriculture, and a modelling framework for urban land use which are linked together through the asymptote for agricultural land. We must now use this land use module for assessment of European policies, however we must first establish one or several reference scenarios on which we will implement the policies. Indeed, reference scenario is essential for policy assessments and can have consequences on quantitative policy assessments results. Chapter 3 presents the importance of reference scenarios and gives some examples.

Chapter 3

Scenarios

3.1 Introduction

There are several ways to use quantitative tools like the NEMESIS model, it can be used for forecasts, for projections¹, for *ex-post* assessment or for *ex-ante* assessment. In the particular cases of NEMESIS, the three last uses are the more suitable inasmuch as the size of the model and the required information for its database do not really allow the realisation of forecasts. In our studies, we want to realise *ex-ante* assessment but it should be compared to a reference case excluding the policies that will be assessed. Consequently, we must have a projection on the future on which the *ex-ante* study will refer. Therefore, we present several projections grounded on scenario-based studies literature.

Before presenting how we construct our scenario for the *ex-ante* assessment, we introduce the concept of scenario and typology or methodology of scenarios. There are, in the literature, several definitions for scenarios, we retained two of them that are relatively general and can be applied to several disciplines but also because they are simple and clear. Scenarios can be defined as “*plausible stories about how the future might unfold, constructed using qualitative and/or quantitative models and information on current and past conditions*” (Biggs *et al.* 2007 [40]) or more simply “*scenarios are descriptions of possible futures that reflect different perceptions on the past, the present and the future*” (van Notten *et al.* 2003 [457]). The use of scenarios by decision-makers, consultants and researchers is now relatively current and common in numerous sectors and disciplines such as political decision making, business planning or environmental management (EEA 2000 [165], van Notten *et al.* 2003 [457], Ringland 2006 [406]). And consequently, there are in the literature many scenarios typologies or recommendations to construct scenarios², we retained the typology presented by Kuhlman (2008 [322]) and based on van Notten *et al.* (2003) that is well suitable for quantitative analysis and for social, economic and environmental oriented scenario-based studies. The typology developed by Kuhlman is relatively general and allows a good understanding of alternative ways that might be used to construct scenarios by focusing on the methodology, nevertheless scenarios are generally not grounded on a singular approach but on a mix of two of them or even more. Kuhlman (2008) distinguishes the four following approaches:

1. We make, here, the distinction between projections and forecasts. The last ones are supposed to provide the exact information as close as possible of the real future, forecasts are then more for short term or even at medium term where uncertainties are less important. At opposite, projections are more for long term where uncertainties are high and there is no obligation to be as close as possible of what will be exactly the future.

2. For scenarios typologies, see, *inter alia*, Ducot and Lubben 1980 [122], Amara 1981 [10], Inayatullah 1990 [286], Mannermaa 1991 [348], Duncan and Wack 1994 [124], Godet and Roubelat 1996 [239], Marien 2002 [350], van Notten *et al.* 2003 [457] or Börjesson *et al.* 2006 [58]

- *Extrapolating approach* also called business-as-usual scenarios and based on the extrapolation of existing trends. They assume that past trends will be replicated in the future. An extrapolating scenario is not a statement of what is likely to happen, but only what will happen if recent trends continue to operate.
- *Expert knowledge approach* or expert judgement approach: rather than assuming a simple continuation of past trends, in this approach experts are consulted, scientific publications or expert studies are used to define the most likely developments of driving forces. These judgements and expertise are used to define future evolutions of key assumptions and drivers with a better valuation than in other approaches. This approach aims to describe a likely future rather than merely a possible one.
- *Inclusive approach*: it consists of defining a set of possible worlds, in the hope of capturing a range wherein the real future will be contained. Commonly, several dimensions are defined along which the future may vary, leading to multi-dimensional scenarios limited by the likelihood of parameter variations.
- *Imaginative approach*: that asks people or experts to imagine things that might come to pass. People or experts construct scenarios starting from general assumptions on futures and imagining possible consequences that might result from them.

By referring to this typology, we find numerous recent examples of scenario-based studies grounded in one of these approaches even if they not use one of them exclusively. For instance a good example of scenario using the inclusive approach is the Intergovernmental Panel on Climate Change (IPCC) Special Reports on Emissions Scenarios (SRES - IPCC SRES 2001 [289]) that, on the basis of four families of scenarios, has realised 41 different scenarios. The advantage of this approach is that it can determine what the future will be. Nevertheless, the multiplication of scenarios reduces the readability of the scenarios and increases the complexity to disseminate their conclusions. The inclusive approach raises the change to find the real future but its interest declines with the increase in the number of scenarios. The imaginative approach was, for instance, implemented in the European PRELUDE project (EEA 2007 [157]) which distinguishes five scenarios³, starting from key drivers and uncertainties, they thereafter use participatory method (stakeholders panel) to examine the possible chain of consequences of such drivers on each scenario. The imaginative approach is interesting to answer

3. These scenarios are called: *Great Escape - Europe of contrast*, *Evolved Society - Europe of harmony*, *Clustered Networks - Europe of structure*, *Lettuce Surprise U - Europe of innovation*, and *Big Crisis — Europe of cohesion* and are presented in EEA 2007 [157] .

to potential problems that might arise but it does not directly attempt to know how the real future will be. The extrapolating approach is the more current approach notably in economic and sectoral perspectives (*e.g.* BFP 2008 [36], EC 2008 [152] or EC 2009 [146]). It is more easily acceptable by policy-makers than other approaches because it uses the actual situation to provide a dynamic view of the future but the extrapolating approach is also questionable because it does not implement future known or expected breaks in trends. The expert knowledge approach is generally not used as complete background of scenarios but it comes most of time as a complement of the three other approaches either to cut or refine the scenarios in the extrapolation approach because of knowledge about arising breaks or to give borders in imaginative approach avoiding unrealistic scenarios or to reduce the scope of inclusive approach by excluding some scenarios.

The implementation of these approaches in the construction of scenarios passes by the definition of drivers *i.e.* a prime mover or a force which is not caused by something else that does not exist in reality. But for quantitative tools such as NEMESIS, drivers are identified as exogenous variables and model parameters. Nevertheless, we must pay heed to the quantification of the drivers that can be causally related such as short term economic development and oil price. Indeed, an accelerated economic growth at short term will inevitably tend to raise oil price and inversely a sudden oil price rise will constrain economic development in importer regions. Similarly, when scenarios or related storylines cover several fields, a conflict can arise between the outputs or mechanisms of the quantitative tools used to assess those scenarios and the scenarios storylines that already defined these outputs. For instance, GDP is an output of economic models but it is generally predefined in the storylines. Thus, these constraints must be taken into account limiting somewhat the scope for the scenarios implementations in the quantitative tools.

Referring to the previous approaches and taking into account the different questions coming with the implementation of scenarios in quantitative tool, we present in this chapter the *reference scenario* on which the policy assessments will be based which are presented in chapter 4 and 5 and we also display four “alternative scenarios” developed for a European research project. For all these scenarios, we will define the main drivers of the NEMESIS model *i.e.* the European population and its structure, energy prices and particularly oil price, the World demand *i.e.* the demand addressed to EU countries resulting from World economic development and R&D investments that even if they can be endogenous in the model NEMESIS, will be defined. Other parameters or exogenous variables required by some scenarios, will also be clarified. The first section of this chapter presents the *reference scenario* through

its drivers and its results. This scenario is defined as a mix between the extrapolating approach and the expert knowledge approach. A huge part of the *reference scenario* comes from the NEMESIS database and the econometric relationships which are grounded in empirical facts and thereby generally reflect past trends. But another part of the *reference scenarios* uses expert knowledge, and particularly models projections on NEMESIS drivers such as population or oil price, or on NEMESIS economic sectors like agriculture or forestry. The second section proceeds in the same manner by presenting the drivers for each of the four alternative scenarios and by displaying and discussing some interesting results. Nevertheless, the alternative scenarios are based on storylines defined by a consortium of a European research project on peri-urban relationships. The consortium referred, as a basis to define the scenarios, to the four IPCC SRES families which would suppose the use of the inclusive approach to construct the scenarios, but as the consortium has introduced some “shocks” on each scenario and has established the chain of consequences, we suppose that the alternative scenarios are grounded on the imaginative approach.

3.2 Reference scenario

3.2.1 Introduction

This section presents the *reference scenario* that will be used for the policy assessments presented in chapter 4 and 5⁴. The *reference scenario* is based on a mix between extrapolation and expert-judgement approaches. Some drivers will be reproduce trends such as R&D investments and other scenario assumptions are based on expert knowledge, such as demography or forestry production. Indeed, there are important available forecasts or prospective studies that can be used to quantify NEMESIS drivers or some NEMESIS outputs. The *reference scenario* is then composed with such external studies but also with drivers extrapolation. The *reference scenario* was developed in 2008. The last available year of historical data is at best 2007. Firstly, we present the drivers and assumptions for the *reference scenario*. Drivers such as demography, oil price or external trades are explained and commented. Similarly, we present the implementation in the model of the expert judgements. And on a second section, we display and comment the *reference scenario* outputs, on one hand, looking at economic results and on another hand looking at the land use results.

3.2.2 *Reference scenario*: drivers and assumptions

3.2.2.1 Demography

Demography is an important driver for the NEMESIS model. Firstly, it acts on labour market by increasing or decreasing labour force which acts on wages and then on prices and competitiveness inside or outside EU. Secondly, population and its age structure are important determinants for several NEMESIS variables. For instance, public education expenditures are linked with population younger than twenty five years old whereas food, drink and tobacco household consumption is related to the total population. Thus, the population is an important exogenous driver for the NEMESIS model and must be defined carefully. The demographic data, for *reference scenario*, comes from the EURO-POP2004 Medium (or baseline) projection scenario (Eurostat 2007 [198])⁵. The medium scenario of EUROPOP2004 is a trend extrapolation scenario for fertility rate, mortality rate and migration. The fertility rates and migration are supposed to be stable and the life expectancy is supposed to raise but

4. This scenario was developed for the European integrated project SENSOR, 6th Framework Program, DG Research, European Commission (www.sensor-ip.eu).

5. The Eurostat population projections were updated in 2009 (EUROPOP2008) which contain only one scenario.

tends to slow down compared to historical data (see Eurostat 2006 [200]). EUROPOP2004 projections provide population by sex and age (1 year) for each EU country from 2004 to 2050. For NEMESIS, we aggregate the projections in four age groups: zero to fourteen years old ($[0 - 15[$), fifteen to twenty four ($[15 - 25[$), twenty five to sixty four ($[25 - 65[$) and more than sixty five years old ($[65 - +[$). We use historical population data up to 2007 and we take the growth rate of EUROPOP2004 projections to extrapolate population until 2025. Figure 3.2.1 displays the growth rates of total population by sex between 2000 and 2025 for EU-27. The male and female population growth rates is positive until 2021 for females and 2025 for males. Consequently, the total population increases until 2023. Nevertheless, the growth rates decline progressively between 2005 and 2025, starting from 0.31% for males and 0.24% for females and reaching -0.01% and -0.03% in 2025 respectively. Thus, the average growth rates between 2005 and 2025 are about 0.12% for males, 0.08% for females and 0.1% for total population.

Figure 3.2.1: EU population annual growth rates in *reference scenario*

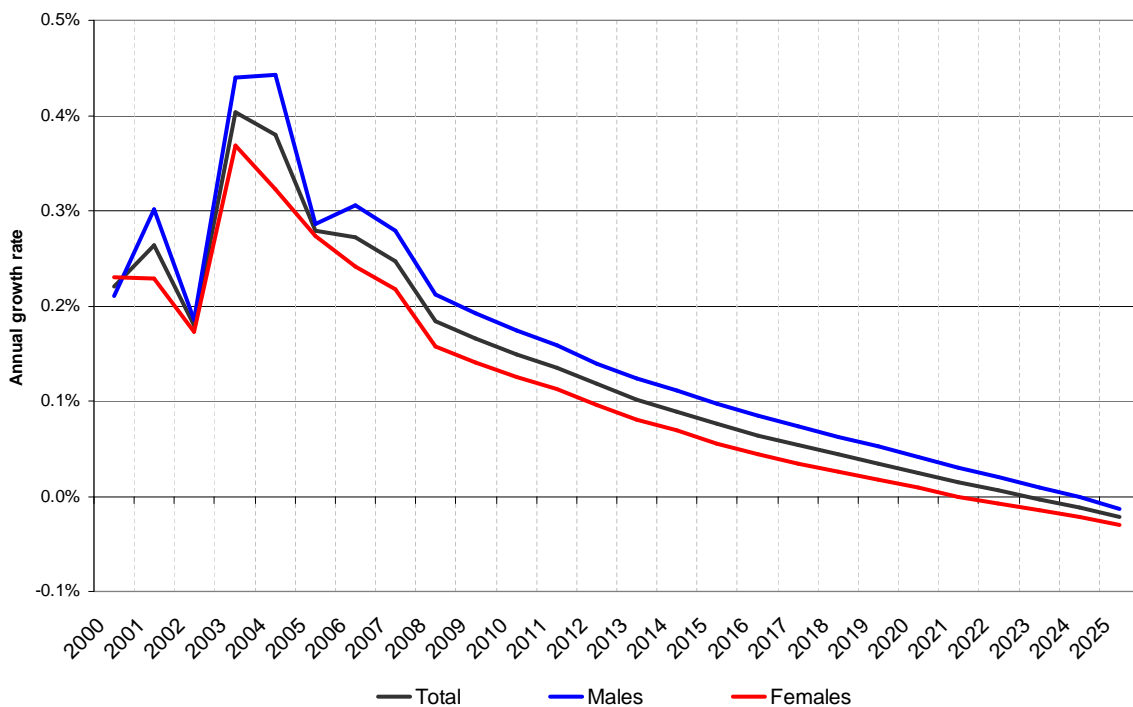


Table 3.2.1 shows the EU population by sex and age groups in 2005 and 2025. We can see that the **total population increases weakly** (1.8%), females population raises by 1.4% and males population increases by 2.2%. Nevertheless, the relative stability of the population hides strong variations between age groups. Looking at table 3.2.1, we observe an elderly total population, the young (under 15 years

old) decrease by -9.2% and population between fifteen and twenty four years old decreases by 16%. These observations are visible for females and males with a loss of 8.7 million persons younger than twenty five years. The medium age population ($[25 - 65[$) decreases slightly between 2005 and 2025 (-1.6%) with a loss of 4.3 million persons whereas old population ($[65 - +[$) rises to 111.6 million in 2025 *i.e.* an increase about 37%.

Table 3.2.1: EU population by age groups and sex in 2005 and 2025 for *reference scenario* (in millions)

Sex	Age groups	2005	2025	% change
Total	[0 – 15[	79.5	72.2	-9.2%
	[15 – 25[	62.7	52.6	-16.1%
	[25 – 65[	268.0	263.7	-1.6%
	[65 – +[	81.2	111.6	37.4%
	Total	491.5	500.1	1.8%
Females	[0 – 15[	40.8	37.1	-9.0%
	[15 – 25[	30.7	25.7	-16.4%
	[25 – 65[	134.4	131.5	-2.2%
	[65 – +[	47.9	63.0	31.5%
	Total	253.8	257.3	1.4%
Males	[0 – 15[	40.8	37.1	-9.0%
	[15 – 25[	32.0	27.0	-15.7%
	[25 – 65[	133.6	132.2	-1.0%
	[65 – +[	33.3	48.6	45.7%
	Total	239.7	244.9	2.2%

Consequently, we observe an **elderly European population** between 2005 and 2025. These structural changes of European population could have huge economic consequences, especially on labour market and could raise the inflationary pressures in Europe through the decline of labour force. However, we must look at population structure in each EU country because there are important heterogeneity between EU countries, as displays by table 3.2.2. Table 3.2.2 shows the Old Age Dependency Ratio (OADR - *i.e.* persons aged 65 years and over compared with persons 15-65 years old) for each EU-27 countries in 2005 and in 2025. We observe that in all countries the OADR is increasing between 2005 and 2025 confirming the elderly of European population. The OADR raises by 10.7 points for

EU passing from 24.6% to 35.3%. Globally, the OADR is lower in New Member States (NMS) than in EU-15 in 2005 and 2025 but it grows slightly more in NMS (+11.5 points) than in EU-15 (+10.4 points). In Italy, Finland and Germany, the OADR reaches two persons aged 65 years and over for 5 persons aged between 15 and 64 years old, whereas the OADR ratio is about one old person for 4 persons 15-64 years old, in Ireland and Romania which is not even to Italian, Finish or German level in 2005.

Table 3.2.2: Old age dependency ratio for EU-27 in 2005 and 2025, for *reference scenario*

	2005	2025		2005	2025
AT	23.6%	34.5%	CZ	19.8%	35.0%
BE	26.3%	36.5%	EE	24.1%	31.3%
DK	22.6%	33.8%	LV	24.1%	30.7%
DE	27.8%	39.3%	LT	22.5%	29.2%
FI	23.8%	41.6%	HU	22.6%	34.3%
FR	25.3%	36.9%	MT	19.2%	33.8%
GR	26.8%	35.5%	PL	18.7%	32.8%
IE	16.5%	25.2%	SI	21.7%	35.8%
IT	29.4%	39.7%	SK	16.3%	28.1%
LU	21.2%	27.7%	RO	18.3%	24.7%
NL	20.7%	32.5%	BG	24.7%	36.6%
PT	25.2%	34.7%	NMS	19.8%	31.3%
ES	24.5%	33.6%	EU-15	25.9%	36.3%
SE	26.4%	36.5%	EU27*	24.6%	35.3%
UK	24.4%	33.2%	NO	22.4%	31.5%

*: EU-27 except Cyprus.

To conclude, the demography in the *reference scenario* tends to slightly increase (+1.8%) between 2005 and 2025. However, its growth hides a strong structural evolution of the European population; the number of young persons (less than 25 years) decreases by about 17 million between 2005 and 2025 whereas old persons (more than 65 years old) increase by about 30 million during the same period. An ageing population is common at all EU countries, but with a heterogeneous degree.

3.2.2.2 Oil price and other raw material prices

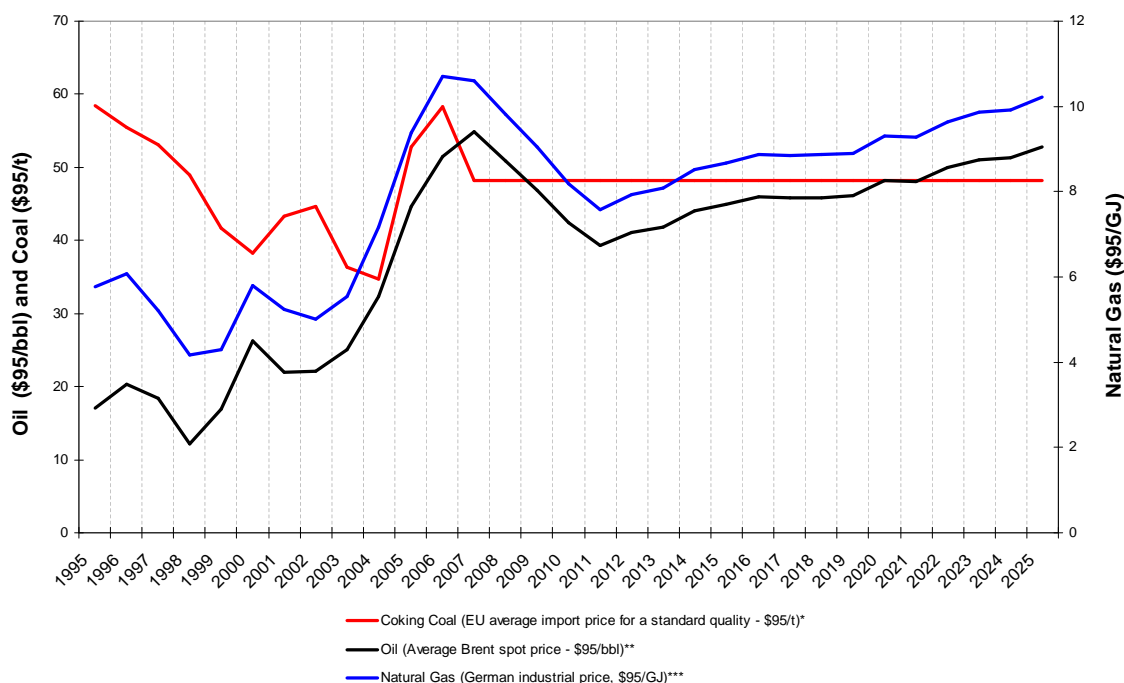
We present in this section oil, coal and gas prices. The prices of energies are important drivers for the NEMESIS model insomuch as they affect costs and price for all economic agents through transportation costs, heating costs or production costs. The **oil price** projections were realised in 2007 and do not take into account the important fluctuations that arose in 2008 and 2009. The oil price projections come from the PROMETHEUS model (Kouvaritakis *et al.* 2007 [316]) which is a stochastic model of the world energy system developed by the Energy - Economics - Environment Modelling Laboratory (E³M - Lab) at the National Technical University of Athens (NTUA)⁶. This model provides different scenarios on oil price, associated to a probability to be confronted with a higher barrel price than the profile of price given. The trend of the oil price integrated in NEMESIS corresponds to a situation where there is 50% chance that the barrel becomes more expensive *i.e.* the medium projection. **Gas prices** is generally the results of long contract between suppliers and buyers where gas price is indexed on oil price⁷. Thus, we make the assumption that gas price follows the oil price. For **coal prices**, we suppose that it stays constant between 2007 and 2025, in real terms, even if the demand increases, the known available resources are still very large and we suppose thereby that the coal price in 2007 reflects a long term equilibrium.

Figure 3.2.2 displays the oil, coal and gas price for *reference scenario*. The oil price is about 54.9 \$₁₉₉₅ per barrel in 2007 and decreases progressively to reach 39.3 \$₁₉₉₅ in 2011. Thereafter, between 2012 and 2025, oil price rises slightly and is equal to 52.8 \$₁₉₉₅ in 2025. As supposed, the gas price follows the same evolution than the oil price starting from 10.6 \$₁₉₉₅ per GigaJoule (GJ) in 2007 and reaching 10.2 \$₁₉₉₅ in 2025. Finally, coal price stays constant between 2007 and 2025 at 48.1 \$₁₉₉₅ per tonne. IEA (2007 [284]) projections distinguish three scenarios: a medium scenario in which oil price is around 50\$₂₀₀₅ (*i.e.* around 36\$₁₉₉₅) in 2014 and 59\$₂₀₀₅ (*i.e.* 43\$₁₉₉₅) in 2030, a high scenario where oil price reaches 100\$₂₀₀₅ (*i.e.* 72\$₁₉₉₅) in 2030, and a low price scenario reaching 39\$₂₀₀₅ (*i.e.* 28\$₁₉₉₅) in 2030. Thus comparing with the IEA (2007) oil price projections, our *reference scenario* projection is close to the medium scenario and included in the range of IEA medium and high scenarios. It allows us to validate the oil price projection up to 2025, for projection realised in 2008.

6. www.e3mlab.ntua.gr

7. Even if those kind of contracts are not used in all EU countries and if they tend to decline and according to the weak information on future gas price, it seems better to keep this assumption.

Figure 3.2.2: Oil, Coal and Gas prices for *reference scenario*



For historical data: *Source: EC - DG ENERGY and own calculation, **Source: IEA and own calculation, ***Source: Eurostat and own calculation.

To summarise, we have for *reference scenario*, relatively stable energy prices, which will not change too much their impact on European economy, and will allow the development of intensive energy sector such as transports.

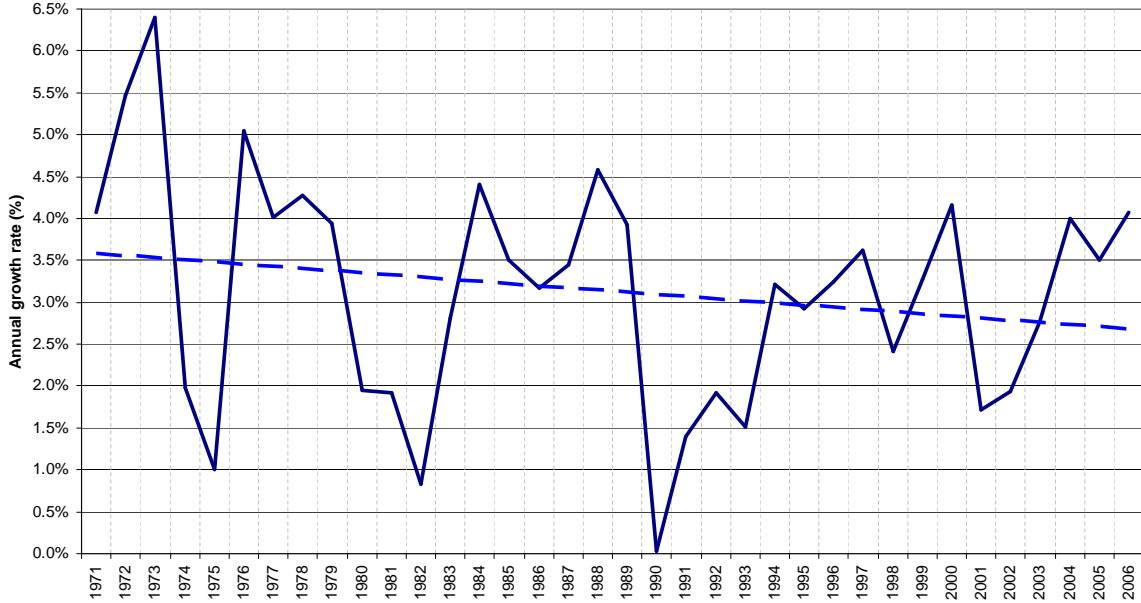
3.2.2.3 World Demand

World demand, *i.e.* demands for goods and services addressed by non EU countries to EU countries, is the major exogenous driver for economic performance. It determines the contribution to growth of external trade in each European country. To determine the world demand for NEMESIS, we use the GDP growth rates of 12 world regions⁸ as an indicator of the demand addressed to EU countries supposing a certain stability of the GDP share addressed by each World region to EU. We extrapolate these 12 regional GDP from 2007 up to 2025, using the historical GDP growth (UNSTAT 2007 [446]). Even if from 1996 to 2006 World economic growth displays an increasing trend (see figure 3.2.3), the

8. U.S.A., Japan, Brazil, Asian OPEC, India, Russian Federation, China, America, other European countries, Africa, other Asian countries and Oceania.

long term World GDP growth rates between 1971 and 2006 draws a slow downward trend. We took into account this downward trend to project the 12 regional GDP up to 2025.

Figure 3.2.3: World GDP growth rates between 1971 and 2006 (GDP at market prices in \$₉₀)



Source: UNSTAT

Table 3.2.3 displays historical and projected growth rates. The projected World GDP growth rate between 2005 and 2010 is on average about 3.6% and it decreases slightly until 2025 with an average growth rate of 3.2%, 3% and 2.8% for 2010-2015, 2015-2020 and 2020-2025 respectively. The regional GDP dynamics are similar, *i.e.* characterised by a progressive slowdown of growth between 2005 and 2025, but with important disparities in the GDP level of each regions. For instance, Chinese GDP growth rates decline from 9.3% for 2005-2010, to 5.3% for 2020-2025 whereas Japan average GDP growth rate is more stable passing from 2.3% to 1.9%.

Thus, after with the projected GDP for each region and with the share of each of the 12 regions in the exports of each EU countries⁹, we construct national indexes for world demand (see equation 3.2.1).

$$ID_{i,t} = \prod_{j=1}^{12} IGDP_j^{S_{i,j}^{EXP}} \quad (3.2.1)$$

9. For, bilateral trade data, we use the CHELEM database (2007 [79]) developed by the CEPII.

Table 3.2.3: Historical and projected GDP growth rates for 12 World regions, for *reference scenario*

	90-95	95-00	00-05	05-10	10-15	15-20	20-25
Africa	1.5%	3.5%	4.5%	5.1%	4.1%	3.6%	3.2%
America	2.4%	3.4%	2.8%	4.2%	3.6%	3.3%	3.1%
USA	2.4%	3.9%	2.6%	3.0%	2.4%	2.2%	2.1%
Brazil	1.8%	2.6%	2.5%	3.5%	3.5%	3.3%	3.1%
Asia	7.1%	4.4%	4.8%	5.0%	4.3%	4.0%	3.7%
China	10.8%	9.0%	9.3%	9.3%	7.1%	6.1%	5.3%
India	5.2%	6.1%	6.4%	7.7%	6.3%	5.8%	5.2%
Japan	2.1%	1.1%	1.7%	2.3%	2.1%	2.0%	1.9%
Asian OPEC	3.7%	3.4%	5.0%	5.4%	3.6%	3.2%	2.9%
Rest of Europe	-23.6%	1.9%	2.7%	3.7%	3.2%	3.0%	2.8%
Russian Federation	-9.1%	0.6%	6.8%	6.0%	4.7%	4.2%	3.9%
Oceania	2.6%	3.7%	3.1%	3.2%	2.8%	2.6%	2.5%
World	1.8%	3.3%	3.0%	3.6%	3.2%	3.0%	2.8%

Historical data: source UNSTAT

Where $ID_{i,t}$ is the World demand index for EU country i at time t , $IGDP_j$ is the GDP growth index of region j and $S_{i,j}^{EXP}$ is the exports share from region i to EU country j ¹⁰. We calculate World demand indexes at national level for each EU country with equation 3.2.1 and we also construct sectoral World demand indexes for each country ($ID_{i,s,t}$). To compute these sectoral indexes (see equation 3.2.2), we re-balance the national indexes by the ratio between average growth rates of national exports by product from CHELEM database ($\bar{g}_{i,s}^{EXP}$) and the total one (\bar{g}_i^{EXP})¹¹. There is no data for exports of services on CHELEM database, we then suppose that indexes for services follow the national index.

$$ID_{i,s,t} = ID_{i,t}^{\left(\bar{g}_{i,s}^{EXP}/\bar{g}_i^{EXP}\right)} \quad (3.2.2)$$

To summarise, as World demand plays an important role in the economic performance of EU countries, we have constructed World demand indexes for each EU country and each NEMESIS sector up to 2025. These indexes are based on World GDP projections decreasing slightly between 2005 and 2025 and on sectoral dynamic stemming historical data on products exports. Thus, the calculated indexes show that trade will stay relatively stable but the situation of each countries and each sectors on international markets will deviate more or less from its global trend.

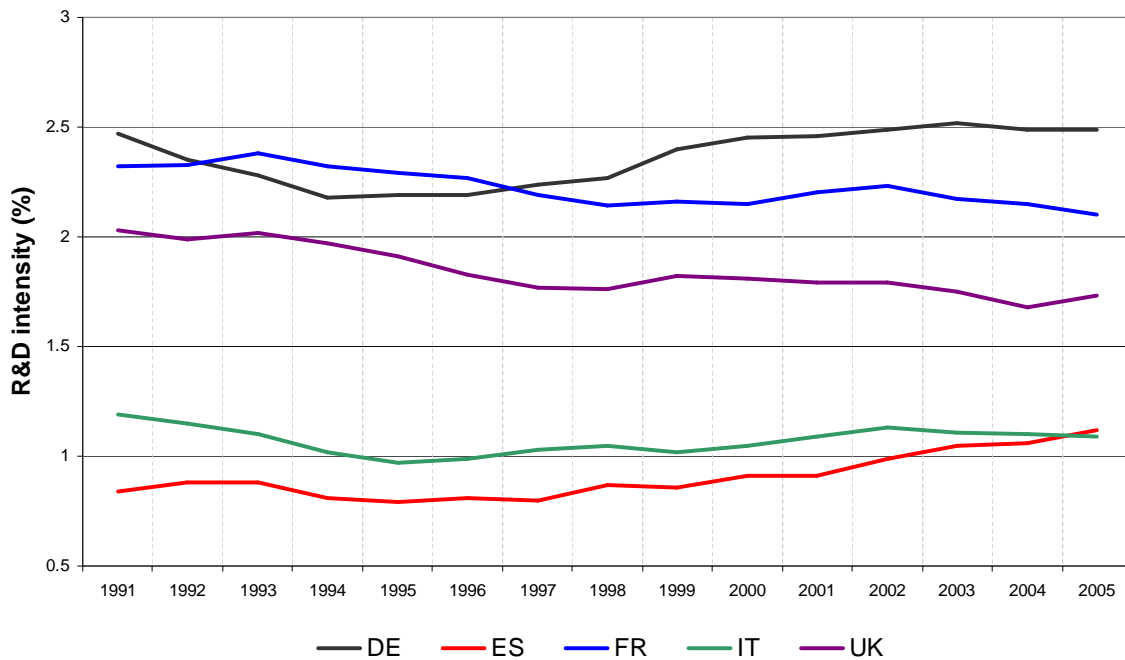
10. We use the last available share in the CHELEM database, *i.e.* for *reference scenario* 2005.

11. CHELEM database (2007) provides national exports for 11 different goods between 1995 and 2003.

3.2.2.4 Research and Development

As established by the new economic growth theories (see *e.g.* Aghion and Howitt 1997 [2] or Barro and Sala-i-Martin 2003 [26]), technological progress, coming from new organisational techniques or new technologies, is a major source of long term growth. In addition, the endogenous economic growth theories give a driving role to investments in Research and Development (R&D) for innovations. And as the NEMESIS model integrates further aspects of these theories of endogenous economic growth (see Brécard *et al.* 2006 [54], Chevallier *et al.* 2006 [87]) and especially as it takes as source for innovation the sectoral investments in R&D, it is important to look carefully at R&D investments in the *reference scenario*. Although NEMESIS has an endogenous decision for R&D investments, we impose a predefined trajectory for R&D investments to keep the existing tendency on R&D investments for *reference scenario*.

Figure 3.2.4: R&D intensity for five European countries from 1991 to 2005



Source: Eurostat - Statistics on research and development (2007 [201])

Looking at figure 3.2.4, we see that the R&D intensities (*i.e.* the ratio between national R&D investments and GDP) for the 5 main European economies¹², are relatively stable between 1991 and

12. In 2005, the cumulative investment in R&D of Germany, Spain, France, Italy and United Kingdom represents 76.2% of the EU-15 total R&D investment and 74.3% for EU-27 (Eurostat, 2007 [201]).

2005. For France and United Kingdom, R&D intensities are decreasing slightly starting from 2.3% and 2% in 1991 and reaching 2.1% and 1.7% in 2005 respectively. For Spain, R&D intensity raises from 0.84% in 1991 to 1.12% in 2005, while for Germany and Italy, despite some fluctuations, there is no clear trend for R&D intensity between 1991 and 2005. According to the weakness or the absence of real tendency for R&D intensity in European countries, we suppose that R&D investments follow the GDP growth rate, keeping the R&D intensities constant. This assumption implies, a priori, a stability of the technological progress coming from R&D investments and then a stability for economic growth coming from innovations. Consequently, the European Lisbon Strategy (2000 [183]) is not achieved and especially the European Barcelona objective of 3% for R&D intensity (2003 [185]).

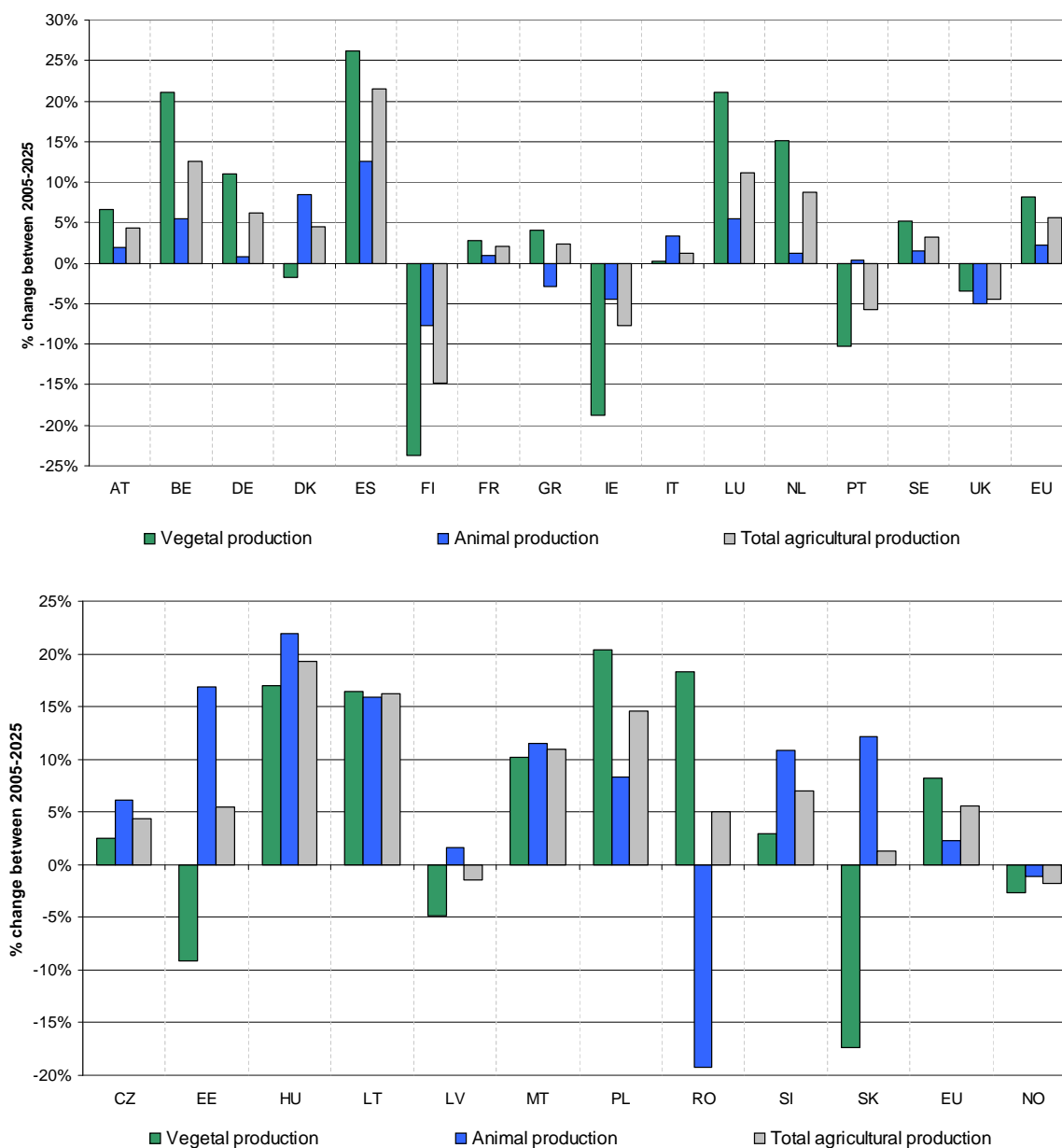
3.2.2.5 Agriculture

We present in this section the assumptions made for the projection of the agriculture sector which is not an exogenous driver for NEMESIS but for which we used expert knowledge for projections up to 2025. In fact, the policies assessment that we want to achieve with the *reference scenario* concern for a non negligible part the agricultural sector. It is then very important to have an consistent projection for agricultural production up to 2025. To make these projections, we used the expertise of the Common Agricultural Policy Regionalised Impact Modelling System (CAPRI) model¹³ (Britz and Witzke 2008 [57]). The **CAPRI model** is a partial equilibrium model and it offers detailed depiction of agricultural sectors at NUTS2 level in the EU. Agricultural production comes from the maximisation of gross added value of representative regional farms subject to technological constraints. As CAPRI is more specialised and more detailed than NEMESIS for agriculture production, we used the CAPRI model results for vegetal and animal production, that were re-aggregated by CAPRI, for NEMESIS needs, from physical to monetary units.

Figure 3.2.5 displays the percentage change of agriculture production in Europe, over 2005-2025 period, for *reference scenario*. Of course, these projections for vegetal and animal production are the results of aggregation of detailed agriculture production from CAPRI model and hide a disparity of evolution between these detailed agricultural productions as for instance an increase of pig and poultry meat production and a decrease of beef and sheep meat production.

13. The CAPRI model (www.capri-model.org) is one of the sector model that will be embodied in the models linkage used for some sustainability assessments, chapter 4. See also chapter 4 for a more detailed description of the CAPRI model.

Figure 3.2.5: Agricultural production change between 2005 and 2025, for *reference scenario*



Source: CAPRI model and NEMESIS model

Regardless, we can see that, on average in the EU, total agricultural production grows by about 5.6% between 2005 and 2025, pulled-up by vegetal production which increases by about 8.2% whereas animal production only grows about 2.2%. The annual growth rate of the agricultural production in

EU between 2005 and 2025 is then relatively weak, around 0.3%¹⁴. There are also quite important differences between New Member States (NMS) and EU-15, with respectively 11% and 5% rise of agriculture production for 2005-2025 period. The difference between NMS and EU-15 is stronger for vegetal production (15.5% and 7.4% respectively) than for animal production (5.3% and 1.9% respectively). There is then a catch up of NMS relatively to EU-15. Furthermore, because of the link between NEMESIS and CAPRI, we made the assumption that the NEMESIS imports of agriculture products from the rest of the World ensure the coherency between agriculture production, calculated by CAPRI, and demand for agriculture calculated by NEMESIS. For instance, in case of a decrease in agricultural production without change in demand for agriculture products inside Europe, imports from the rest of World increases such as equilibrium between supply and demand of agriculture products is satisfied, at national and European levels. With these projections of agriculture projection based on expert knowledge, we have consistent agricultural production projections for the *reference scenario* what is important insomuch as it will drive the agricultural land use.

3.2.2.6 Forestry

The forestry activity is the last assumption realised for the *reference scenario*. Even if we suppose a fixed forest area between 2005 and 2025 in the *reference scenario*, forestry is an strategic sector for land use and will be important for linked models in chapter 4. Thereby, we also use expert knowledge to project forestry. These projections are based on Food and Agriculture Organization of the United Nations (FAO) forecasts for 2025 (FAO, 2005 [220]). The FAO forecasts are based for a part on GDP projections that were not fully compatible with the NEMESIS GDP. We then corrected FAO projections taking into account the difference between FAO GDP projections and NEMESIS ones¹⁵.

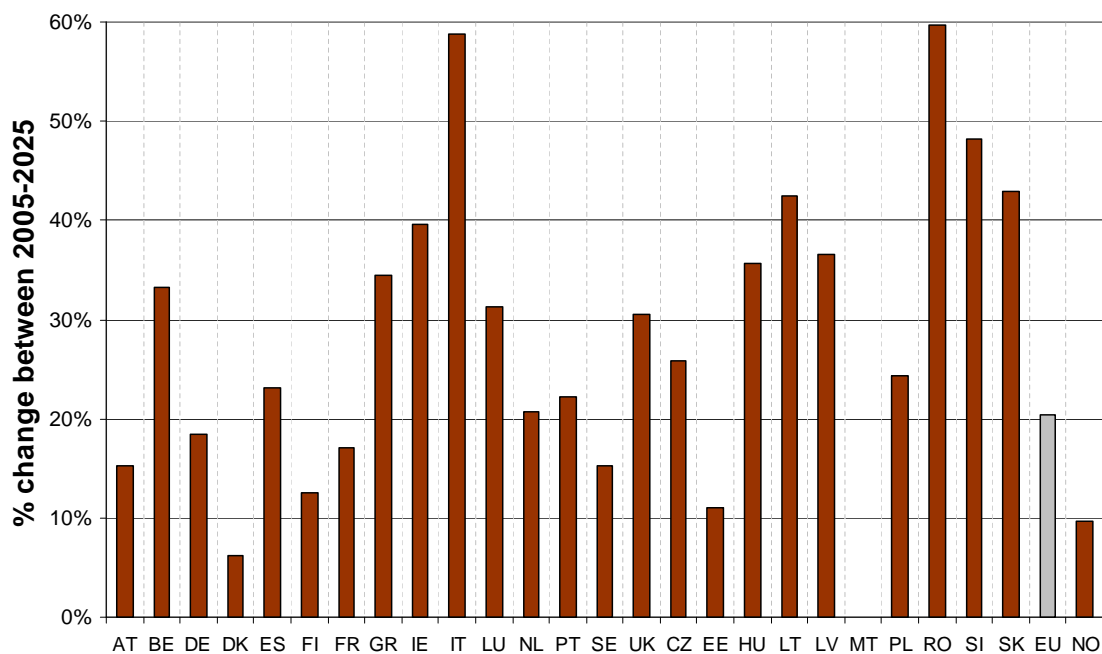
Figure 3.2.6 displays the forestry production evolution between 2005 and 2025 in *reference scenario* for each EU country. For all EU countries, the forestry production is increasing, except for Malta for which there is no forest. On average, European forestry production increases, in volume, about 20% between 2005 and 2025, the higher growth of forestry production comes from Romania, for which the production rises by 60%. Countries with important land use occupied by forests, like Sweden and Finland have a moderate growth of the forestry production, around 15% *i.e.* less than the EU

14. And especially, if we compared annual growth rate of EU agricultural production with EU GDP growth rate (see section 3.2.3), consequently the agriculture share in overall European GDP falls.

15. As we need NEMESIS GDP, the FAO forecasts corrections for forestry activity were realised after a first simulation of the *reference scenario*.

growth. Nevertheless, Sweden and Finland still represent more than 30% of the total European forestry production in 2025. Furthermore, we have validated these corrected forestry projections, with the European Forest Information SCENario (EFISCEN) model (Sallnäs 1990 [412] and Schelhaas *et al.* 2007 [416]) EFISCEN¹⁶. We have provided NEMESIS projections for forestry production to EFISCEN that have validated these projections by comparing them with the available forest resources.

Figure 3.2.6: Forestry production evolution between 2005 and 2025 in *reference scenario*



Source: FAO 2005 [220] and NEMESIS model

16. The EFISCEN model (www.efi.int/portal/completed_projects/efiscen/) is a large-scale forest resource model that assesses the supply of wood and projects forest resource development. And EFISCEN model is also another sector model that will be used for policy assessments in the chapter 4. See chapter 4 for a more detailed description of the EFISCEN model.

3.2.3 Economic results for *reference scenario*

After a presentation of the main exogenous drivers for the NEMESIS model and both sectoral projections based on expert knowledge, we display and discuss in this section at EU and national levels, the evolutions of GDP, employment and sectoral production.

3.2.3.1 GDP growth in EU-27

European growth, in the beginning of the simulation is supported by two main pillars. The first one is the finalisation of the transition and integration of NMS, and the second one follows the labour force scarcity that arises from elderly European population and as a consequence, in the long run, the decline of labour force. In fact, at the beginning of the period, economic growth is important, and European GDP growth reaches 2.5% on average for 2005-2010, and 2.4% for 2010-2015 (see table 3.2.4). After 2015, population trends, characterised by elderly population, weigh more on growth and these trends are foreseen to continue after 2020 implying a net decrease of labour force at the end of the period. This labour force scarcity increases wage pressure, but wage rise is not high enough to sustain private consumption that slows down progressively due to population decrease. Hence, household consumption growth slightly decreases from 2015 to 2025. At the same time, wage pressure increases inflation, even if prices increase is partially limited by the labour productivity growth. Also, the strength of World economic growth is foreseen to continue after 2015 but with a slight slowdown. These trends for the after-2015 period then imply a slowdown of European economic growth, especially in NMS, but economic growth will stay dynamic with for EU GDP 2.3% annual growth on average over 2015-2020 and 2020-2025 periods. The productivity gains limit the increase of production costs and thus prevent a deep loss of competitiveness on external trade which is a traditional effect of wage pressure. Hence, European exports are sustained, on the one hand by the important World demand (mainly during the first part of the projection) and on the other hand by maintained competitiveness. European imports which largely depend on the evolution of European internal demand, are limited by the maintained European competitiveness. Finally, net European exports (exports less imports) bring a positive contribution to the development of European GDP during the whole projection period. NMS observe a higher growth, contributing to a certain convergence within the EU for levels of GDP per capita. This can be mainly explained by higher efficiency improvements in these countries with their integration in the EU market.

Table 3.2.4: Average GDP growth rates in EU countries for *reference scenario*

	05-10	10-15	15-20	20-25
AT	2.3%	2.1%	2.1%	2.0%
BE	2.3%	2.2%	2.2%	2.2%
DE	1.8%	1.9%	1.9%	1.8%
DK	2.3%	2.2%	2.2%	2.6%
ES	3.4%	2.9%	2.6%	2.3%
FI	3.2%	2.6%	2.6%	2.5%
FR	2.2%	2.2%	2.2%	2.2%
GR	3.7%	3.4%	3.1%	3.0%
IE	4.7%	4.0%	3.6%	3.3%
IT	1.5%	1.6%	1.7%	1.7%
LU	4.5%	3.8%	3.6%	3.7%
NL	2.7%	2.5%	2.4%	2.4%
PT	1.6%	2.2%	2.4%	2.5%
SE	3.3%	3.0%	2.9%	2.8%
UK	2.5%	2.4%	2.4%	2.4%
EU-15	2.3%	2.3%	2.2%	2.2%
EU	2.5%	2.4%	2.4%	2.3%
CZ	4.9%	4.0%	3.6%	3.4%
EE	9.0%	6.6%	5.3%	4.8%
HU	2.9%	2.9%	2.9%	3.0%
LT	7.0%	5.4%	4.6%	4.3%
LV	8.6%	6.6%	5.7%	5.2%
MT	2.2%	2.9%	3.4%	3.4%
PL	4.8%	4.6%	4.3%	4.2%
RO	5.6%	5.0%	5.0%	4.9%
SI	4.5%	3.8%	3.4%	3.2%
SK	6.1%	4.9%	4.3%	4.1%
NMS	5.0%	4.5%	4.2%	4.0%
EU	2.5%	2.4%	2.4%	2.3%
NO	2.5%	2.5%	2.6%	2.6%

Source: NEMESIS model

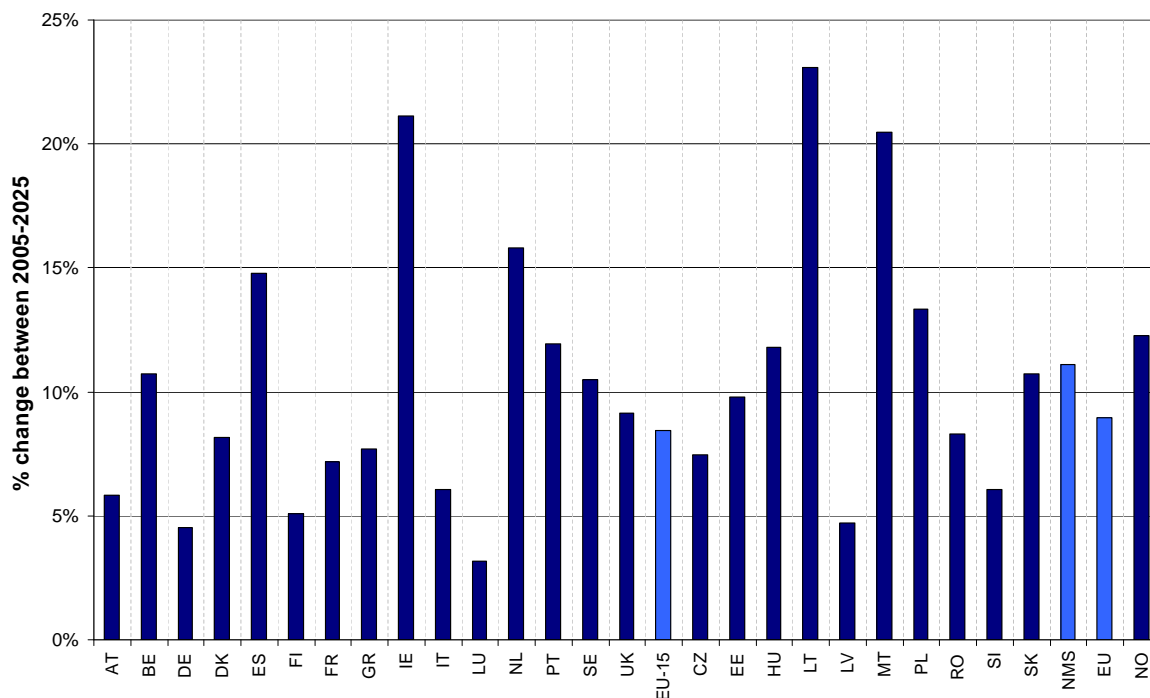
One can see in table 3.2.4 that GDP in NMS grow two times faster than in EU-15 for the periods 2005-2010, with 5% per year against only 2.3%, and 2010-2015 with 4.5% growth per year against again 2.3%. After 2015, growth in NMS stays high, but slows down progressively, to reach 4% on average for the period 2020-2025, against 2.2% for EU-15 countries. For individual countries, contrasts for GDP evolutions are again more striking, with for example, for the entire 2005-2025 period about,

6.4% growth per year in Latvia against only 1.6% in Italy which is the European country where GDP growth rate is the weaker until 2025. Differences in national GDP growth rates are more important for NMS, where it establishes between 3% on average for countries such as Hungary and Malta and 5% or more, for Estonia, Latvia, Lithuania and Romania. Contrasts are less important for EU-15 countries, even if some small countries as Luxembourg, Ireland, Greece and Sweden, are expected to over-perform the rest of EU-15, with GDP growth rates close or superior to 3%, against only 2.2% to 2.3% in average for EU-15.

3.2.3.2 Employment growth in EU-27

The results of *reference scenario* for employment are displayed in figure 3.2.7. One can see that employment growth between 2005 and 2025 stays limited in both EU-15 (8%) and NMS (11%). The labour scarcity due to European elderly population, induces a raise in real wage and a continued improvement of labour productivity that is supposed to increase about 50% in EU-27 between 2005 and 2025, that is to say at a rate close to 2% per year.

Figure 3.2.7: Employment growth, between 2005 and 2025, in EU countries for *reference scenario*



Source: NEMESIS model

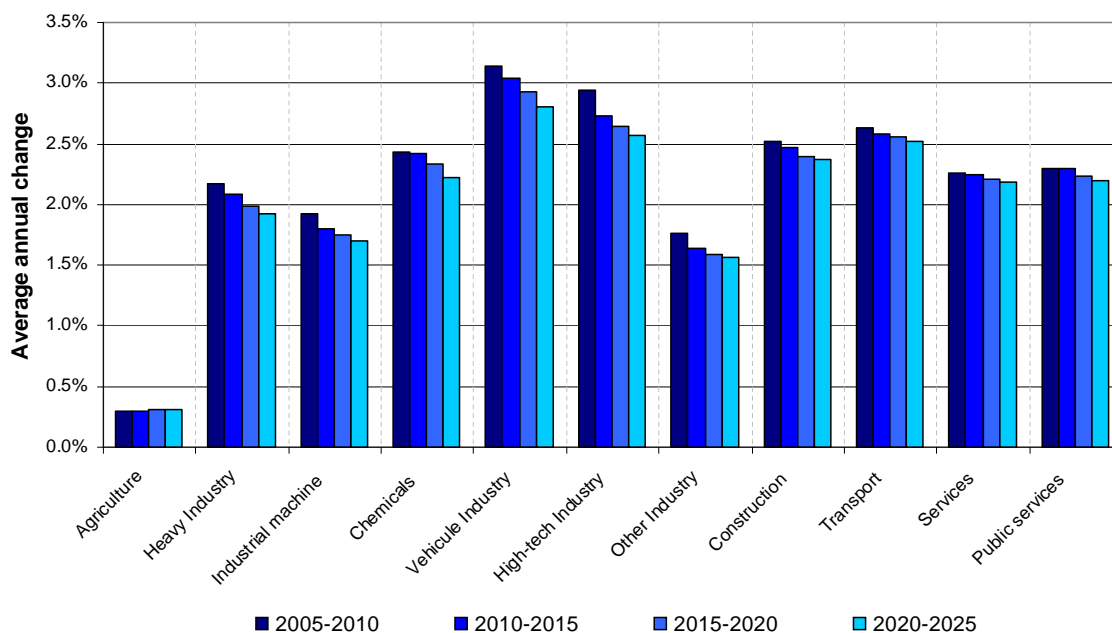
Labour productivity increases faster in NMS, partially due to technological production catch-up.

These employment evolutions, taking into account the decrease in labour force, allow a progressive reduction of unemployment in Europe over 2005-2025 period. In some countries, such as Italy, Netherlands or Portugal, the fall of working age population is compensated by rises in participation in labour market of the working age population, to be able to respond to the needs of labour market. In NMS, for countries as Romania and Poland, part of the need in labour is satisfied by increasing labour productivity inside agriculture sector *i.e.* the decline of agricultural employment.

3.2.3.3 Sectoral growth in EU-27

We complete and finalise the overview of the economic results of *reference scenario* by displaying sectoral results at European level. For EU industrial sectors, the most dynamic sectors, in *reference scenario*, are “Transport equipments” and “High-tech industries”, with annual growth rates that establish about 2.5% to 3% in average over 2005-2025 (figure 3.2.8). These sectors benefit from the strong attractiveness of their products for European consumers and foreign customers. The increase in labour productivity enables firms hold down their production costs and maintain their market shares with respect to their trade partners. Moreover, the activity of the “Transport equipments” sector benefits, especially in NMS, from the strong growth of transport demand allowing by the moderated oil price.

Figure 3.2.8: European sectoral production growth, between 2005 and 2025, in *reference scenario*



Source: NEMESIS model

At the opposite end of the scale, sectors included in “Other industry” group, covering “Food, drink and tobacco”, “Textile and clothes”, “Paper and printing”, “Rubber and plastic” and “Industrial machines”, displays a moderate production growth about 1.6%. These performances can be explained by the weakness of internal demand but more particularly by their disadvantageous positions on foreign markets dominated by more cost competitive World regions.

Regarding service activities, transport is the most dynamic sector in EU-27, with a production growth rate of about 2.3% to 2.5% for the period 2005-2025. “Services” industries (including “Communications”, “Bank and finance”, “Health and education”, etc.) also experience a sustained growth, and benefit from the rise of household expenditures. For other sectors, “Public services” and “Construction”, production growth is driven by the general level of GDP in EU-27, while the evolution for agriculture sector reflects CAPRI assumptions, that were discussed in section 3.2.2.

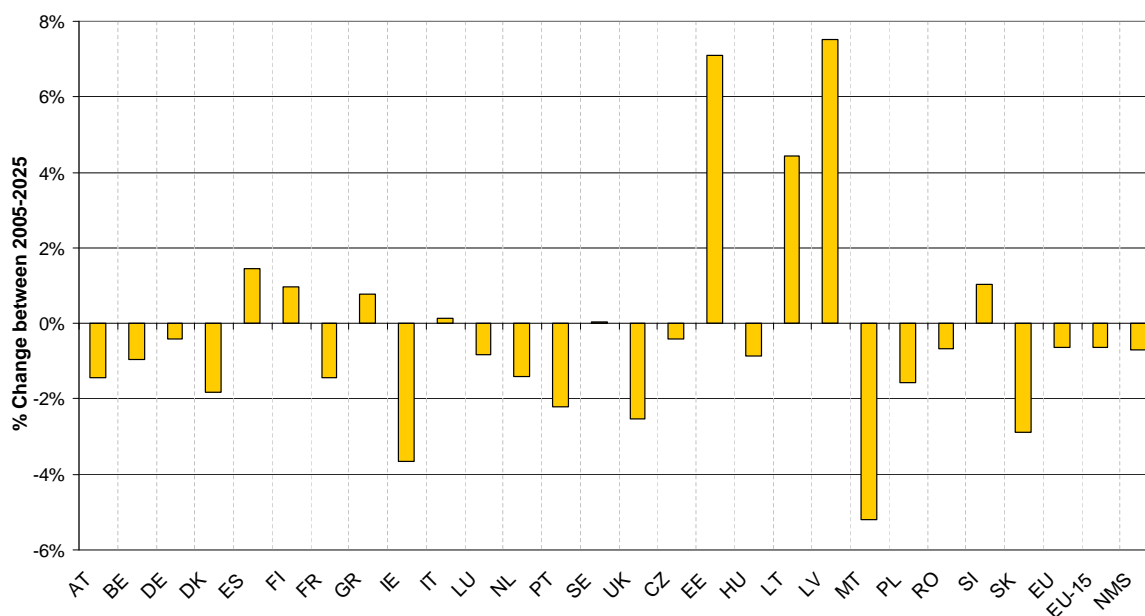
3.2.4 Land use results for *reference scenario*

We present, in this section, the land use change in EU countries, for *reference scenario*, which is driven by three main factors¹⁷. Change in agriculture production and change in agricultural yields determine land used by agriculture sector. Change in GDP *per capita* influences the development of urban land use, but the initial availability of land also plays an important role. The more land is used by agriculture, the more land price is elastic, as it becomes increasingly difficult to make additional land suitable for agriculture. The development of urban land use also pushes up land price, by restricting land availability for agriculture. In return, it reduces future urban land use, by increasing construction price and consequently prices of housing and Industrial and Commercial (I&C) buildings. Thereby, it is evident that no significant increase in land use should be expected for 2025, compared to 2005, in countries, like Ireland, the Netherlands, Denmark or the United Kingdom, with limited forested area, and nearly no land availability in 2005. In this sense, figure 3.2.9 displaying total land use change per country in 2025, shows total land use, measured here as the sum of areas used by agriculture and urban lands, decreasing by 3.6% in Ireland, 2.5% in United kingdom and 1.8% in Denmark due to a fall in land used by agriculture about 4% (1 700 km²), 4% (5 300 km²) and 2.9% (950 km²) respectively (see figure 3.2.10). In these three countries, the loss of agricultural lands is not compensated by urban expansion, 10% (70 km²) in Ireland, 12% (300 km²) in Denmark and 10% (1 500 km²) in United Kingdom. We

17. We have also use experts knowledge of CAPRI team to take into account some change in agricultural production that are hidden by the two agricultural production aggregates of NEMESIS.

have a similar but less profound situation in Netherlands with lands occupied by urban increasing about 250 km² (7%) and area used by agriculture decreasing of 600 km² (2.7%), reducing total land used of 350 km² (1.4%) in 2025 compared to 2005.

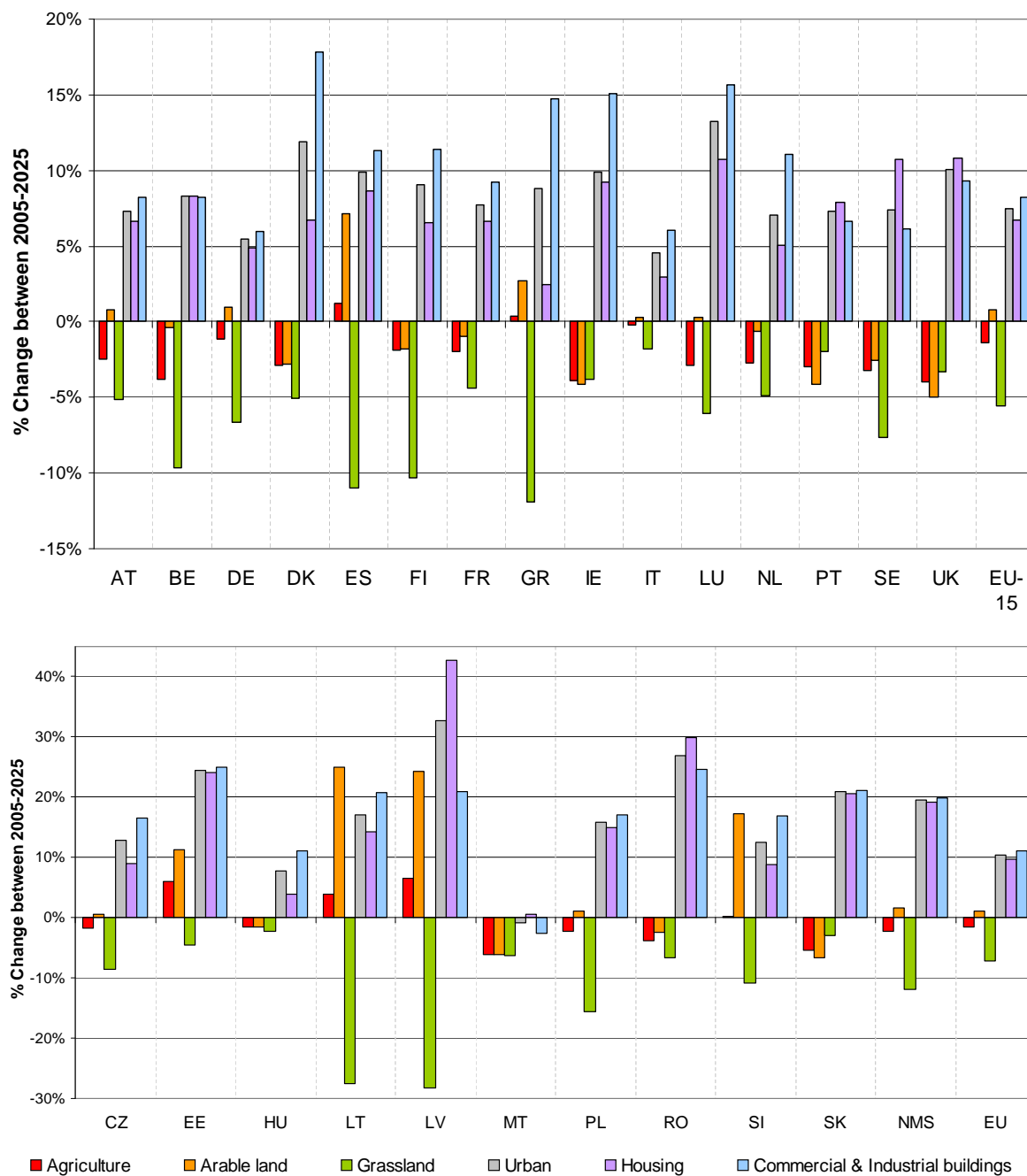
Figure 3.2.9: Land used change between 2005 and 2025, in *reference scenario*



Source: NEMESIS model

One can see on figure 3.2.10 for the whole Europe, but equally for EU-15 and for NMS, that the total area used is not expected to change much in 2025 compared to 2005 (-0.6% *i.e.* 12 750 km²). Results by country show however noticeable changes in total land use in some EU-15 countries, with a maximum increase of 1.4% in Spain, a decrease about 2% in Portugal, and until 3.6% in Ireland. Change in total land use is particularly important for some NMS countries that should experience very high economic growth in the next 20 years. There is notably an increase of 7.1% (900 km²) of total land use in Estonia, and a rise of respectively 4.4% (1 700 km²) and 7.5% (1 400 km²) in Lithuania and Latvia. As illustrated by figure 3.2.10, and already quoted above for Ireland, United Kingdom, Netherlands and Denmark, in all countries most important evolutions reflect substitutions between land use categories, with a strong substitution of urban land to land used by agriculture.

Figure 3.2.10: Land used by category change between 2005 and 2025, in *reference scenario*



Source: NEMESIS model

Inside the agricultural area, we find most often a decrease in grassland, and increase in arable land. The most important substitutions between land use categories are finally found for Lithuania and

Latvia, which are also among the countries that experience the most important increase in total land use. If we compare evolutions for EU-15 countries and for NMS, we find that urban area is expected to grow about 19.6% (7 400 km²) in NMS, against only 7.5% (8 900 km²) for EU-15. Grassland area is expected to decrease by 11.9% (16 700 km²) in NMS and 5.6% (25 100 km²) in EU-15. For arable land, we have an increase of 1.6% (5 500 km²) in NMS and 0.8% (7 200 km²) in EU-15, while total agriculture area decreases by 2.3% (11 200 km²) in NMS and 1.4% (17 900 km²) in EU-15. Given growth of agriculture production in the *reference scenario* (see section 3.2.2), agriculture yields are consequently expected to continue to grow in Europe, and notably in NMS.

To summarise, the first observation, that comes from the land use change of the *reference scenario*, is the global stability of European land use (agriculture plus urban) which is declining slightly -0.6% *i.e.* 12 800 km² of land abandoned. The second noticeable result concerns the substitution between agricultural land and urban land. In fact, urban area increases in all European countries, 10.4% (16 300 km²) for EU, whereas agricultural land decreases in the majority of EU countries with a loss of 1.6% (29 100 km²) at European level. And finally, the last main results for land use is the decrease of grassland in overall European countries that results from the modification of the component of animal production where there is a decrease of beef production (-6% between 2005 and 2025 in EU) and sheep and goat production (-26%) requiring important grassland and an increase of pig (+11%) and poultry production (+17%) requesting much less grassland. Indeed, these results for animal production do not appear in the aggregate animal production of the NEMESIS model but with the expertise of CAPRI team, we took it into account for land use.

3.2.5 Concluding remarks

We have presented in this section the *reference scenario* that will be used for the policy assessment in chapters 4 and 5. This scenario is mainly founded on a mix between the extrapolation approach and the expert judgement approach. A huge part of the *reference scenario* comes from the NEMESIS database and the econometric estimated relationships which are grounded in empirical facts and thereby generally reflect past trends. But another part of the *reference scenario* uses expert knowledge, and particularly models projection for NEMESIS drivers such as population or oil price, or for NEMESIS economic sectors such as agriculture or forestry.

We have displayed the economic results that show a robust economic growth in all EU countries, with 2.4% in annual average for the EU, and particularly in the NMS, with 4.4% in annual average. The GDP growth is driven in part by the external demand that is relatively strong and especially dynamised by developing countries such as Brazil, the Russian Federation, India and China but also by the internal dynamic of the EU market with the catch-up of NMS. This economic growth is also characterised by an moderated employment growth (+9% *i.e.* 18.5 millions new jobs between 2005 and 2025) and thereby by an important progress of labour productivity limiting the loss of competitiveness that could result in the decrease of active population. And finally, economic growth is the result of a strong production growth of sectors like services, transports which is not constrained by the oil price, or high-tech sectors, and they compensate the moderating activity growth of agriculture, heavy industry or industrial machines. For the land use, the *reference scenario* allows us to find several tendencies:

- an urban land use growth for the overall EU countries, with an increase of 16 300 km² (10.5%) of land covered by urban in 2025 compared to 2005. This urban expansion is mainly driven by economic growth and consequently it is larger in the NMS.
- a decline of agricultural land in a majority of EU countries (-29 100 km² for EU *i.e.* -1.6%) with a little less in terms of land abandonment in NMS than in EU-15.
- a strong decrease of grassland in all EU countries (-7% for EU *i.e.* -41 700 km²), in part, due to weak animal production growth (2.2% between 2005 and 2025) and land productivity gains, but particularly coming from a decline of beef and sheep production in favour of pig and poultry production that are less land intensive.

Comparing the *reference scenario* results with other studies on European future land use, we also observe a substitution effect between urban and agricultural land use. For instance, despite the heterogeneity of their scenarios based on imaginative approach and for which there is always structural

change in several trends, the PRELUDE project (EEA, 2007 [157]) presents increasing urban areas and decreasing agricultural lands in 2035 in almost all scenarios. Urban area growth is less important in the PRELUDE scenarios than in the *reference scenario*, but looking at urban land use projections of the MOSuS project (Prieler 2005 [397]) where urban land is expected to increase about 20% in EU-15 between 2000 and 2020, urban expansion in the *reference scenario* is ranged in the middle of PRELUDE scenarios and MOSuS one. Thereby the *reference scenario* results for urban land use seems realistic. In addition, the agricultural land abandonment are generally more important in the PRELUDE project than in the *reference scenario* what can be partially explained for agriculture by difference in time horizon. But, its weakness of agricultural land abandonment is also remarkable when we compare the results with the SCENAR2020 (Nowicki *et al.* 2006 [369]) project for which there is a scenario relatively close to the *reference scenario*. In fact, Nowicki *et al.* (2006) find a loss of 114 000 km² (6.3%) of agricultural lands in 2020 compared to 2005 *i.e.* three times more than in the *reference scenario*. A part of this difference for agricultural land abandonment comes from a bigger decline of arable land¹⁸. Indeed, in SCENAR2020, arable land decreases by about 8% and its decrease is especially large in the big EU-15 countries such as France, Germany or Italy. The main reason for these differences stem from different assumptions on land productivity¹⁹, for which SCENAR2020 supposes an increase about 1.2% per year whereas the *reference scenario* assumes a rise of 0.4% per year. Even if our crop yield evolution seems weak, it is relatively difficult to project it. In a recent study, the Directorate General for Agriculture and Rural Development (DG AGRI) of the European Commission (EC 2009 [146]) displays average annual land productivity at about 0.6% between 2009 and 2015²⁰ which is still higher than in the *reference scenario* but much closer. We keep these land productivities knowing that they are weak compared to other studies. Thus, even with noticeable but explainable differences, the land use results for *reference scenario* are not in contradiction with others studies on future European land use and we can then conclude that we have consistent land use results.

18. We can not do the same comparison for grassland insomuch as Nowicki *et al.* (2006 [369]) use the concept of land cover and not land use and thereby consider that abandoned agricultural land becomes, at least temporally, grassland.

19. Land productivity raise is calculated as the difference between agricultural production growth rate and land used by agriculture, it is then a “seeming productivity” that can also include substitution effects or composition effects.

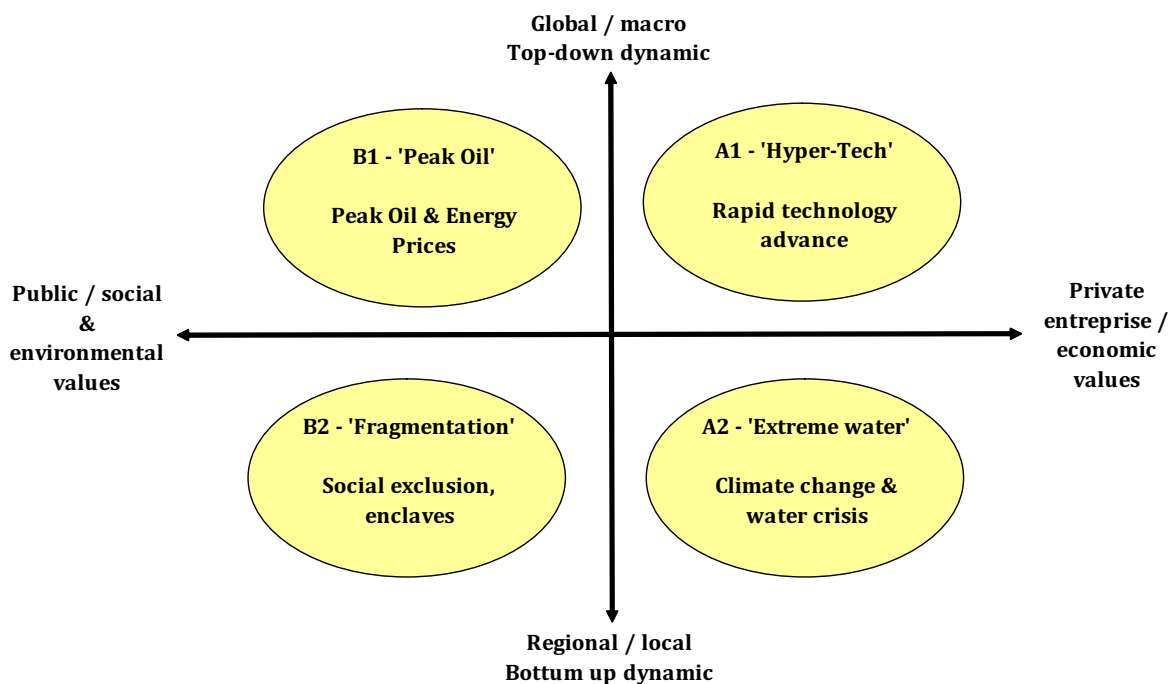
20. See table A.1 and table A.8 in EC 2009 [146].

3.3 Alternative scenarios

3.3.1 Introduction

We present in this section four alternative scenarios, following mainly the imaginative approach and developed for the Peri-urban Land Use RELationships (PLUREL) project ²¹ and realised in 2008. These four scenarios are based on the Special Report on Emissions Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC) families (IPCC 2001 [289]) and they have later been updated and modified to fulfil the objectives of the PLUREL project. Thus, we have defined and organised the four following scenarios as presented in the figure 3.3.1:

Figure 3.3.1: Alternative scenarios framework



Source: Ravetz *et al.* (2008 [401])

The complete storylines are available in Appendix D but we can summarise the four alternative scenarios as follows:

- A1 – ‘hyper-tech’ (globalised private sector dynamic). A world of rapid economic growth, global

21. The PLUREL project is a 6th Framework Program project (see www.plurel.net). The construction of the four alternative scenarios was realised in PLUREL Module 1 which regroupes, in addition to the ERASME laboratory, the International Institute for Applied Systems Analysis (IIASA), the University of Manchester and the University of Edinburgh. See Ravetz *et al.* (2008 [401]) for additional detail on those scenarios.

population that peaks in the mid-century, and the rapid spread of more efficient technologies. Investment in Research and Development (R&D) is high and nations share knowledge and pool resources in a global research market place. Energy prices are moderated because supply is driven by new developments in renewable energy production and nuclear fission. Technological advance is characterised by a rapid acceleration of information and communication technology (ICT) which transforms home and work

- A2 – ‘extreme water’ (localised private sector dynamic). A more heterogeneous world, of self reliance and preservation of local identities. Economic development is primarily regionally-oriented and per capita economic growth and technological change more fragmented. The scenario is subtitled ‘water world’, leading to rapid increase in flooding and drought risks and sea level rise.
- B1 – ‘peak oil’ (globalised public sector dynamic). A future of environmental and social consciousness – a global approach to sustainable development, involving governments, businesses, media and households. Economic development is more balanced with rapid investment in resource efficiency, social equity and environmental protection. This scenario is driven by the real possibility of ‘peak oil’, leading to rapid rises in energy prices, with many social and economic effects.
- B2 – ‘fragmentation’ (localised public sector dynamic). Europe sees a fragmentation of society, in terms of age, ethnicity and international distrust. The voter-strong elderly population becomes increasingly dependent on the younger generation, but the working-age population is disinclined to transfer their resources to the old. This scenario explores the implications for a breakdown of society, with growing inter-generational conflicts.

The four scenarios cover several fields such as economics, socio-economy, environment, socio-cultural aspects, energy and politics. Furthermore, the time horizon of the alternative scenarios is not precisely defined and goes further than 2025, the last year of projections for NEMESIS. Thus, we can not take into account all these aspects with the NEMESIS model, and consequently we focus on the economics by using the classical drivers of the model, even if we have introduced several additional assumptions. Firstly, we slightly modify the **density coefficients** (see chapter 2 section 2.4) to follow alternative scenarios storylines. More precisely we modify the marginal density coefficients *i.e.* the density coefficient applied to new investments on Industrial and Commercial (I&C) buildings and on housing. We have increased the density in A1 - “hyper-tech” by diminishing the marginal density coefficients by 5% in 2025 compared to 2007 (*i.e.* a slight decrease of 0.3% per year) and in B1 - “peak oil” scenario by reducing about 10% marginal density coefficients (*i.e.* a decrease of 0.6% per

year). Thereby, in the A1 - “hyper-tech” scenario, the investments on Industrial and Commercial (I&C) buildings and on housing in 2005 must increase by 5% to use the same area as in 2007. In A2 - “extreme water” and B2 - “fragmentation” we have reduced the density. Marginal density coefficients are increased by 0.6% per year in A2 - “extreme water” and 0.3% per year in B2 - “fragmentation”. These changes of density coefficients coupled with drivers of urban land use will have non negligible impacts on urban land use change for each alternative scenario. Secondly, we introduce in B1 - “peak oil” and B2 - “fragmentation” scenarios, a taxation on CO₂ emissions coming from energy consumption²². We based our **carbon price** on the evaluation of the EU climate and energy package (EP, 2008 [174]) realised by Capros *et al.* (2008 [75]) with the PRIMES model (E³Mlab 2008 [126]). They find a carbon price of 30€₂₀₀₅ per tonne of CO₂ to reach the European CO₂ emissions target in 2020. We have applied a CO₂ tax of 17€₂₀₀₅ in 2008 on oil, coal and gas consumption²³ with a carbon price that progressively reaches 30€₂₀₀₅ in 2025. Thereby, we have a lower carbon price than in Capros *et al.* (2008) but as we also have lower economic growth, it partially counterbalances the weakest carbon price. We will not reach exactly the European climate and energy package but at least, we will have a constrain on CO₂ emissions. Furthermore, we redistribute the CO₂ tax to each economic agent by a lump-sum *i.e.* a green cheque.

We focus and display thereafter the more traditional NEMESIS drivers, as for *reference scenario*.

3.3.2 Drivers

3.3.2.1 Population

The population projections come from IIASA (Skirbekk *et al.* 2007 [430]) which have made specific population projections for each alternatives scenarios. The main assumptions for population are provided in table 3.3.1, where “High” indicates a upper value than past trends, “Low” a lower value and “Medium” a following of past trends. Looking at table 3.3.1 we can expect a trend growth of EU population up to 2025 in A2 - “extreme water” and B2 - “fragmentation” scenarios, with medium value for the three main driver of population. In A1 - “hyper-tech” scenario, European population is expected to grow due to a low mortality rate, nevertheless this growth is defined by an elderly European

22. The NEMESIS model includes a detailed module for energy and GHG emissions, and computes endogenous CO₂ taxes or permit prices according to a CO₂ emissions reduction targets or allowance (see Zagamé *et al.* 2010). Nevertheless, in 2008, this module was not finished and particularly CO₂ emissions calculation did not exit, consequently we use external study to compute the CO₂ tax.

23. We have used the following emissions factors: 4.118 tCO₂/toe for coal, 2.349 tCO₂/toe for gas and 3.043 tCO₂/toe for oil.

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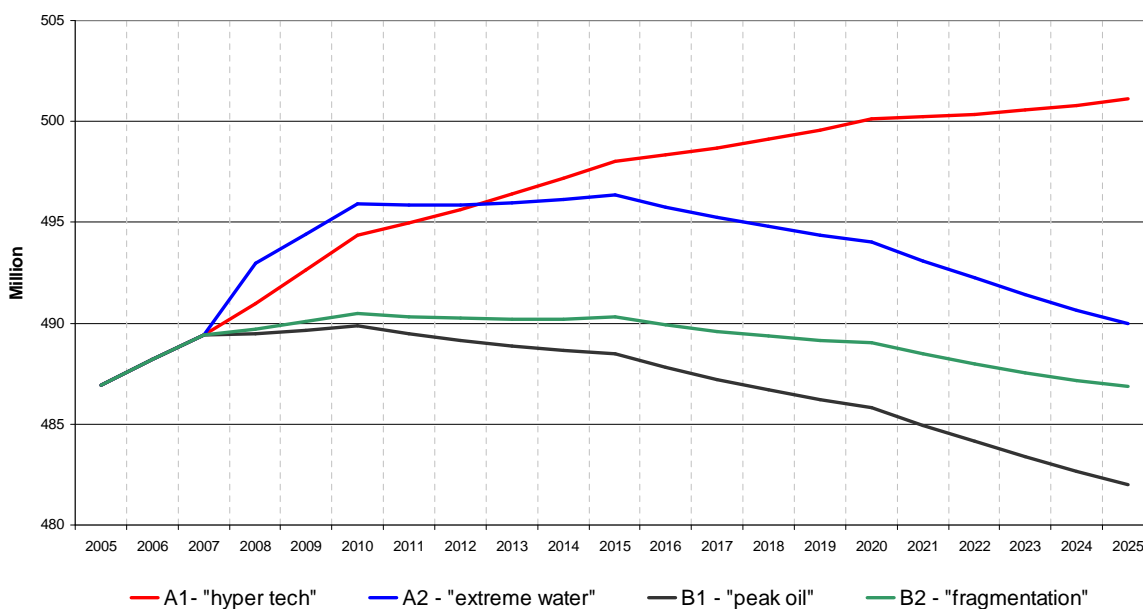
population. Finally, the B1 - “peak oil” scenario will display a decline of European population because of low fertility and high mortality rates which are not compensated by international migration.

Table 3.3.1: Population assumptions for alternative scenarios

	A1	A2	B1	B2
	“hyper-tech”	“extreme water”	“peak oil”	“fragmentation”
Population growth	Medium-High	Medium	Low	Medium
Fertility	Medium	Medium	Low	Medium
Mortality	Low	Medium	High	Medium
Migration (international)	Medium	Medium	Low	Medium

Source: Ravetz *et al.* (2008 [401])

Figure 3.3.2: Total European population projections, for alternative scenarios



Source: NEMESIS model

Figure 3.3.2 confirms the expected results on European population projections, according to the table 3.3.1 assumptions. From 2005 to 2025, European population stays relatively constant in A2 - “extreme water” and B2 - “fragmentation” scenarios, even if we observe a slight increase in the first one, with a 3 million persons more but there is, as in the trends, an ageing European population. European population increases significantly in A1 - “hyper-tech” scenario (+2.9%), starting from 487

million in 2005 and reaching 501 million persons in 2025. This scenario is driven by the low mortality rate. Finally, we observe a loss of 4.9 million persons in Europe between 2005 and 2025 in the B1 - “peak oil” scenario.

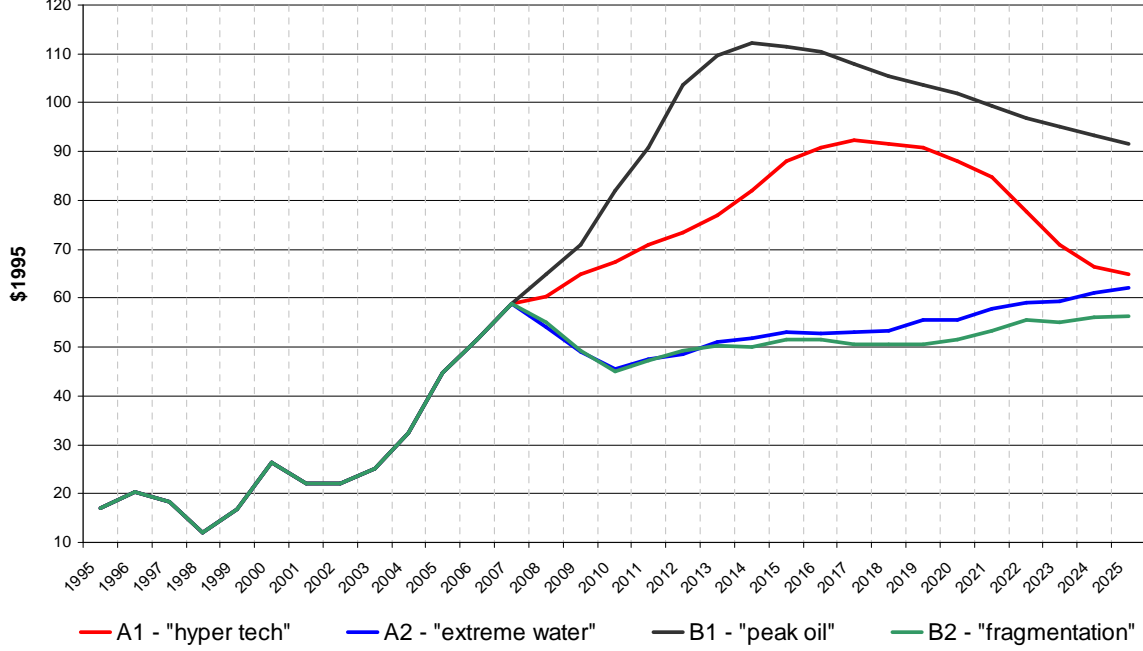
3.3.2.2 Oil, gas and coal prices

Figure 3.3.3 presents the oil price profile, in constant dollar 1995 ($\$_{1995}$), for the four alternative scenarios. From 1995 to 2007, oil price reflects the historic of the average Brent spot price per barrel. The A1 - “hyper-tech” storyline defines a world where “global cooperation and high economic growth lead to innovation and rapid technological development” and where “energy prices decline because supply is driven by new developments in renewable energy production and nuclear fission”. So, figure 3.3.3 shows an oil price which increases rapidly in between 2007 and 2020, and reaches $92\$_{1995}$ in 2017 that is to say around 160 current dollars. In this first step, the rapid rise of World economic growth leads to pressure on the oil market pushing up the oil price. In the longer term, efforts devoted to development of new energy technologies based on renewable and nuclear fission push down the price of non fossil energy sources. Oil demand is consequently decreasing and combined with an oil efficiency rise, oil price falls to $62\$_{1995}$ in 2025. The B1 - “peak oil” scenario reproduces a similar picture to A1 - “hyper-tech”. But in this scenario, the oil price increase is not only due to high economic growth, but also to supply restrictions. Oil price increases from $58\$_{1995}$ in 2007 to $112\$_{1995}$ in 2015 *i.e.* from 86 to 195 current dollar. But in the B1 - “peak oil” scenario, there is a high level of environmental and social consciousness and particular effort is devoted to increase resource efficiency through incentive systems, allowing the rapid development of cleaner technology. Thereby, the oil price decreases progressively after 2015 to reach $92\$_{1995}$ in 2025. A2 - “extreme water” and B2 - “fragmentation” scenarios show oil price profiles more grounded on PROMETHEUS projections (Kouvaritakis *et al.* 2007 [316], see also oil projection for *reference scenario*, figure 3.2.2 in section 3.2.2). In these scenarios, oil price increases progressively between 2010 and 2025. In B2 - “fragmentation”, where there are higher environmental concerns, oil price is slightly inferior to A2 - “extreme water”, with $62\$_{1995}$ in 2025, versus $56\$_{1995}$ for B2 - “fragmentation”.

With regard to gas price, as for *reference scenario*, we suppose a gas price indexed on oil price. Thereby, in B1 - “peak oil” scenario gas price is about $10.6\$_{1995}/GJ$ in 2007 and reaches a maximum of $20\$_{1995}/GJ$ in 2015 whereas it is between $10\$_{1995}/GJ$ and $12\$_{1995}/GJ$ in the three of other alternative scenarios. For coal price, we suppose a constant price about $48\$_{1995}$ per tonne in all alternative

scenarios, as for *reference scenario*.

Figure 3.3.3: Oil price projections for alternative scenarios



Source: NEMESIS model

3.3.2.3 World Demand

The World demand projections for alternatives scenarios use the same methodology as for *reference scenario* (see section 3.2.2) nevertheless in addition to the computation of the world demand index (see equation 3.2.1), we constrain World GDP projections to square with the IPCC-SRES GDP (IPCC, 2001 [289]) on which each alternative scenario is based.

$$\prod_{i=1}^{12} \left(ID_{i,t,s}^{S^{GDP}} \right)^{\rho_s} = ID_{t,s}^{IPCC-SRES} \quad (3.3.1)$$

Where $ID_{i,t,s}$ is the demand index coming from region i at time t for alternative scenario, s , $S_{i,t}^{GDP}$ is the share of the GDP of region i in the World GDP, $ID^{IPCC-SRES}$ is the index of World GDP from IPCC-SRES for alternative scenario s and ρ_s is a parameter that allows the calibration of GDP per region on World GDP from IPCC-SRES. Thereafter, we compute the sectoral World demand index, using the CHELEM database (CHELEM, 2007 [79]), as for the *reference scenario* (see equation 3.2.2).

Table 3.3.2 summarises the difference of the World demand in 2025 between alternative scenarios

taking as a basis the B2 - “fragmentation” scenario in 2025. Thus, looking at table 3.3.2, World demand in the A1 - “hyper-tech” scenario, for which it is the highest, is, for the EU, 27% higher in 2025 than in the B2 - “fragmentation” scenario. By hierarchical order, the highest World demand stems for A1 - “high-tech”, follows by B1 - “peak oil” (13% more than in B2 - “fragmentation”) despite the transport costs resulting from high oil price. Thereafter, comes the B2 - “fragmentation” scenario and finally the lowest World demand is reached in A2 - “extreme water” scenario (7% less than in B2 - “fragmentation” scenario).

Table 3.3.2: Alternative scenarios World demand index comparison (base 100 in 2025 in B2 - “fragmentation”)

	A1 “hyper-tech”	A2 “extreme water”	B1 “peak oil”	B2 “fragmentation”
EU-15	126	93	112	100
NMS	129	94	114	100
EU-27	127	93	113	100

Source: NEMESIS model

3.3.2.4 R&D investments

According to the storylines, the alternative scenarios are also differentiated by their respective degree of innovation and technological development and as the NEMESIS model, with its representation of technological change (see Brecard *et al.* 2006 [54] or Chevallier *et al.* 2006 [87]), can take into account these aspects, we decided to define the profile of R&D investments using the National Action Plans (EC 2005 [137]) for the European Lisbon Strategy (EU 2000 [183]). In fact, in the A1 - “hyper-tech” scenario where rapid economic growth is pushed up by the development of new technologies, we suppose R&D investment growing more rapidly than for other scenarios and reaching the objectives of the National Action Plan (see table 3.3.3). However, the objectives are often too ambitious for 2010 according to the 2005 situation. Therefore, we have decreased the objective for 2010 and we have fixed a long term objectives of 3.5% of R&D intensity for EU in 2030. Table 3.3.3 shows the R&D intensity of EU countries in 2005, the 2010 targets and the projections for 2010 and 2025 in A1 - “hyper-tech” scenario. We can see that, expect for countries where the 2010 target is attainable such as Austria or Germany, the projection for 2010 is always inferior to the target however the effort is still important in many EU countries. For instance, the R&D intensity in France must go up to 2.8% in 2010 what is very

ambitious regarding the historical trend which is stable since 1990 (see figure 3.2.4 in previous section 3.2.2). The effort is more progressive for countries without a target for 2010, mainly for the NMS.

Table 3.3.3: R&D intensity and 2010 target, in A1 - “high-tech” scenario

	2005*	Target 2010**	2010	2025
AT	2.41%	3%	3%	3.4%
BE	1.84%	3%	2.5%	3.2%
DE	2.48%	3%	3%	3.4%
DK	2.45%	> 3%	3%	3.4%
ES	1.12%	2%	1.8%	2.6%
FI	3.48%	4%	4%	4.4%
FR	2.13%	3%	2.8%	3.3%
GR	0.58%	1.5%	1%	2.0%
IE	1.26%	2.5% (2013)	1.7%	2.6%
IT	1.10%	3%	1.8%	2.6%
LU	1.57%	3%	2.5%	3.2%
NL	1.73%	Top 5 of EU	2.3%	3.2%
PT	0.81%	–	1.1%	2.0%
SE	3.80%	1% (public)	3.9%	4.3%
UK	1.76%	2.5% (2014)	2.1%	2.7%
CZ	1.41%	1%(public)	1.9%	2.7%
EE	0.93%	1.9%	1.9%	2.3%
HU	0.94%	–	1%	2.0%
LT	0.76%	2%	2%	2.7%
LV	0.56%	1.1% (2008)	1.1%	2.0%
MT	0.54%	–	1.2%	1.8%
PL	0.57%	2.2%	1%	2.3%
RO	0.41%	–	0.5%	1.4%
SI	1.46%	3%	2.2%	3.1%
SK	0.56%	–	0.6%	1.5%
NO	1.52%	–	1.9%	2.7%

*: Source Eurostat 2007 [201],

** : Source EC 2005 [137]

otherwise own calculation

A2 - “extreme water” is also characterised by technological development but to a lesser extent than in A1 “hyper-tech” scenario. Thus, we supposed a continuous R&D effort with an higher convergence of R&D effort inside European Countries, NMS and southern countries continuing to be the most ambitious with respect to their relative R&D target. R&D intensity converges to 3% in 2050 horizon in all EU countries expect for Malta, Poland and Romania that reach 2.5% and Sweden and Finland

with 4% of R&D intensity in 2050. For instance, R&D intensity is respectively about 2.5%, 2.7%, 1.7%, 1.8% and 2.2% in France, Germany, Italy, Spain and United Kingdom in 2025. For B1 - “peak oil” and B2 - “fragmentation”, we suppose a constant R&D intensity in 2025 compared to 2005 as in the *reference scenario*.

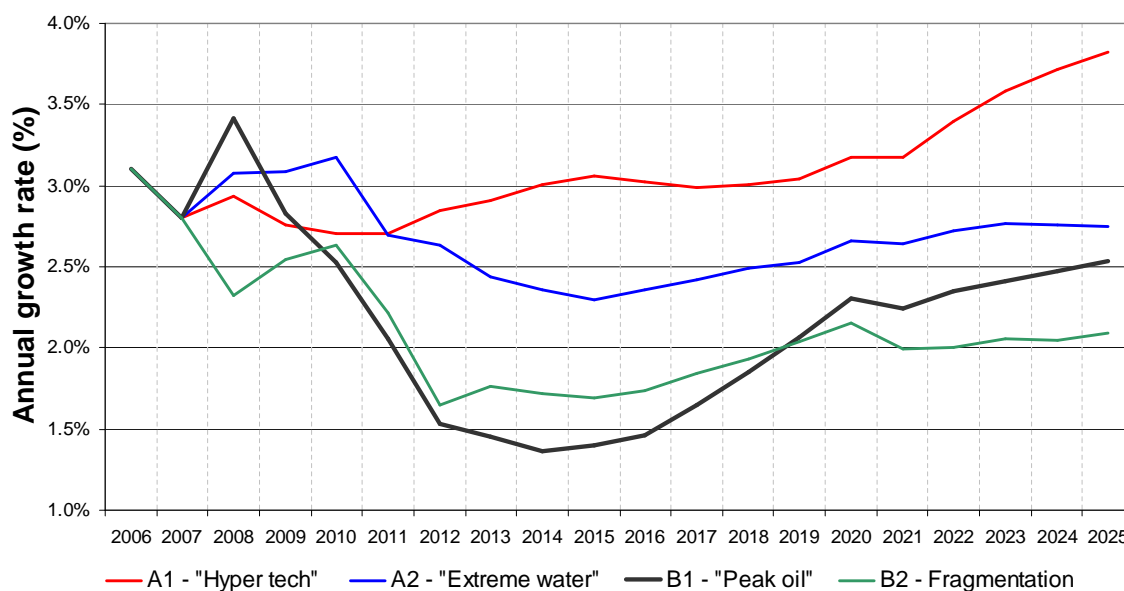
3.3.3 Economic results for alternative scenarios

We have presented and discussed the drivers of the four alternatives scenarios that depict different futures for the European economy following the imaginative approach. We now assume the NEMESIS results for those scenarios starting from general economic results and concluding with land use results.

3.3.3.1 Economic growth

Figure 3.3.4 displays the European real GDP growth rate. There is a huge difference between the scenarios, in 2025, European GDP growth rate is about 3.8% in **A1 - “hyper-tech” scenario**. R&D investments realised by European countries boost European economic performance. In this scenario, European GDP growth rate is relatively similar to other scenarios until 2012 but progressively, innovation effects start and push European GDP growth up to 3% until 2020. And after 2020, the complete effects of R&D investments take place; GDP growth rate reaches 4.6% in 2025 versus 4.4% in the rest of the world, thus between 2008 and 2025 European real GDP increases about 70%. In fact, in this second phase, innovation effects through process and quality goods improvements boost external trade as well as internal consumption. On the contrary in **B2 - “fragmentation” scenario**, European GDP grows at 2.1% in 2025, driven by a moderated World demand, a increase cost of fossil energy and investment in R&D weak according to the GDP evolution. Furthermore, in the B2 - “fragmentation” scenario, European population is relatively constant, but with an ageing European population, people under 25 years old diminishing and as the [0-25[age group is an important driver of household expenditure, household consumption is reduced. Thus, the combined effects of a weak investment in R&D, a weak external demand, a high fossil energy cost and a weak internal consumption constrain the European economic growth that stays in the range of 1.6% and 2.1% between 2012 and 2025.

Figure 3.3.4: European GDP growth rate in alternative scenarios, 2006-2025



Source: NEMESIS model

In the **B1 - “peak oil” scenario**, we can see that European GDP growth is important in 2008 and 2009. The initial relatively good performance of EU economy can be explained by an external demand that is relatively strong and by the fact that there is no requirement for financing additional R&D activity that allows continued competitiveness. In fact, there is no additional R&D investment in the B1 - “peak oil” scenario compared to the A1 - “hyper-tech” and to a lesser extent to A2 - “extreme water scenario” where the financing of R&D investment through capital and labour investment increases firms production costs, and thereby reduces temporally their competitiveness. But after 2010, the combination of the inflationary impact of high oil price and carbon price reduces B1 - “peak oil” European GDP growth rate. Indeed, European GDP growth rate starts at 3.4% in 2009 to reach 1.4% in 2015 when the oil price is at its maximum, 112\$₁₉₉₅, *i.e.* around 195 current dollars in 2015. Economic growth restarts going upward after the oil inflationary shock due to a decrease of oil price but also because firms have adapted *via* substitution between oil and other non-fossil energies such renewable energies and substitution with other production factors such as capital or labour. Consequently, the European GDP growth reaches 2.5% in 2025. In the **A2 - “extreme water” scenario**, where oil price decreases until 2010, the European GDP growth rate is higher than in A1 and B2 scenarios. After 2010, European GDP growth rate in A2 - “extreme water” is relatively steady, fluctuating between

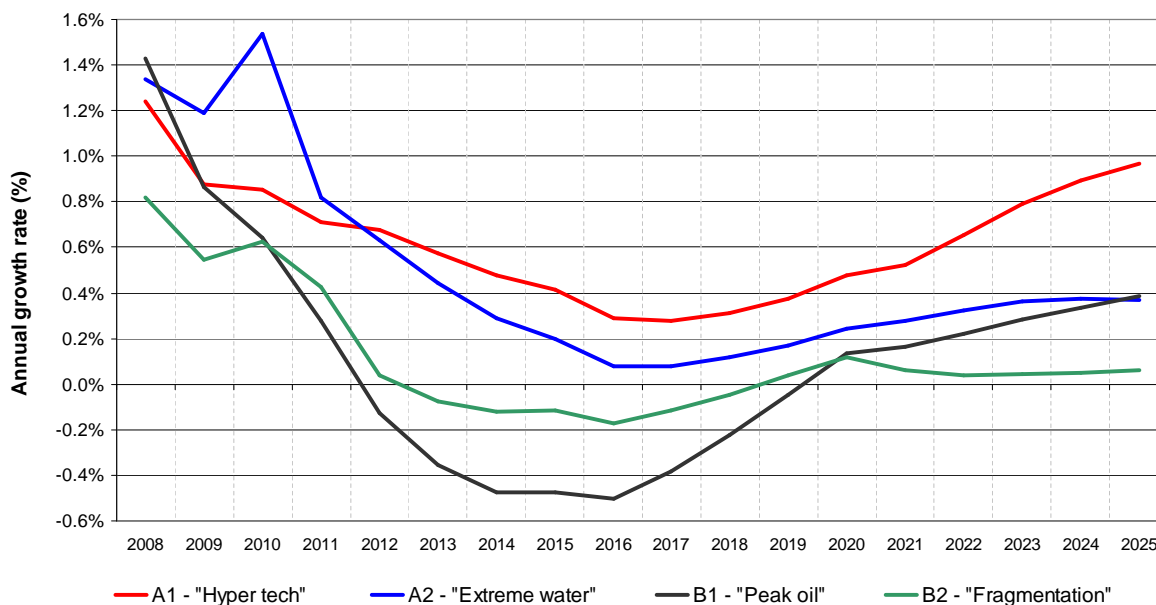
2.3% to 2.8%. Its relative stability, between 2010 and 2015, is due to the weakness of oil price that counterbalances the cost of R&D investment. Nevertheless after 2015, it is the opposite, economic growth gains, due to firms' R&D efforts, are lessened by the increase of oil price and by the weakness of external demand.

To summarise, in the A1 - "hyper tech" and A2 - "extreme water" scenarios where R&D investments grow faster than GDP, the financing of these investments reduces the competitiveness of European economy at first. Whereas in the B1 - "peak oil" scenario where external demand is strong, the economic growth is important, the first two years, before declining because of oil price increase. It is not the case in the B2 - "fragmentation" scenario, where economic performance in other parts of the world is too weak to maintain high economic growth. But in a second phase, when R&D investments produce their effects on internal demand and external competitiveness, as in the A1 - "hyper-tech" and A2 - "extreme water" scenarios, European GDP increases faster and enables strong economic development in EU. In B1 - "peak oil" scenario, the economic growth is maintained by the decrease of oil price and finally European GDP growth stays relatively stable in the B2 - "fragmentation" scenario still affected by weak internal and external demands. Thereby, between 2008 and 2025, the European GDP increases by 70% in A1 - "hyper-tech", 55% in A2 - "extreme water" and 40% in B1- "peak oil" and B2 - "fragmentation".

3.3.3.2 Employment

We continue by presenting economic results with European employment. Figure 3.3.5 displays European employment annual growth rates for the four alternative scenarios. As we can see, employment grows relatively quickly at the beginning of the period in all scenarios. This is mainly due to the initial situation of the European economy. In fact, most European countries have a higher number of unemployed people and then new workers are relatively easy to find for firms. But year after year, labour becomes scarcer, putting pressure on wages and increasing labour productivity, and finally reducing the employment growth rate. Effectively, the labour market is also stressed by population structure on which growth rate of the [25-65[age group, *i.e.* age group of labour force, decelerates until 2015 to decrease thereafter.

Figure 3.3.5: European employment growth rate in alternative scenario, 2008-2025



Source: NEMESIS model

As figure 3.3.5 shows, European employment growth rate follows GDP growth rate. In fact, the A1 - “hyper-tech” scenario has the highest employment growth from 2012, and the B1 - “peak oil” scenario has the weakest one in 2020 with regard to European GDP. But, the difference between the European GDP growth rate in each scenario is higher than for European employment growth rate. This could be firstly explained by wage which induces substitution and variation of production factors and secondly by the increase in labour productivity which is reinforced in the scenarios A1 - “hyper-tech” and A2 - “extreme water” under the effect of R&D investments. In fact, looking at table 3.3.4, in both scenarios with strong R&D investments, the productivity²⁴ is always higher than in the two other scenarios and is also increasing, starting from 1.9% and 2.3% in average between 2010 and 2015 and reaching 2.4% and 2.8% between 2020 and 2025 for A2 - “extreme water” and A1 - “hyper-tech” respectively. Whereas the labour productivity in B1 - “peak oil” and B2 - “fragmentation” scenarios are relatively stable and are included in the range of 2.1% and 1.8% which is yet higher than historical trend in EU labour productivity. Indeed, looking at EU labour productivity since 1998, we observe an average

24. The labour productivity is calculated as the difference between GDP growth rate and employment growth rate. It is then a “seeming productivity” that can also include substitution effects or composition effects as for instance if the share of a labour intensive sector increase in the national GDP.

annual growth of 1.4%. Thereby, we suppose that labour productivity will increase in all alternative scenarios through the labour force scarcity.

Table 3.3.4: Average annual European labour productivity in alternative scenarios

	2010-2015	2015-2020	2020-2025
A1 - “hyper-tech”	2.3%	2.7%	2.8%
A2 - “extreme water”	1.9%	2.4%	2.4%
B1 - “peak oil”	1.8%	2.1%	2.1%
B2 - “fragmentation”	1.8%	2%	2%

Source: NEMESIS model

3.3.4 Land use results for alternative scenarios

We now present the land use results for alternative scenarios, we start by examining agriculture land use referring to agricultural productions and yields.

3.3.4.1 Agricultural land used

Table 3.3.5 displays the results for agricultural production²⁵, land use and land productivity²⁶ for the EU in alternative results. It appears that agricultural land use is weakly variable between the alternative scenarios with a minimum loss of 15 300 km² (*i.e.* 0.8%) in A1 - “hyper-tech” and a maximum loss of 27 200 km² (-1.5%) of land used by agriculture, in B2 - “fragmentation”. On the contrary, the difference between scenario is relatively important for agricultural production. Indeed, in the A1 - “hyper-tech” scenario, where economic growth and external demand is the highest, the total agricultural production increases by about 15% between 2007 and 2025 in the EU whereas in the B2 - “fragmentation” scenario characterised by a weak GDP growth and a moderated external demand, the total agricultural production rises only by 3.6%.

25. For agricultural production, we started with the production of *reference scenario* on which we have calibrated the NEMESIS model. Thereafter, we have let free the model mechanisms for each alternatives scenarios. In other words, for the same assumptions than in the *reference scenario* (except for agriculture), the model will give the same agricultural production than in the *reference scenario*.

26. As in footnote 24, the land productivity growth is computed as the growth rate of agricultural/vegetal/animal production minus the land used by total agriculture/arable land/grassland. It is then a “seeming productivity” that can also include substitution effects or composition effects as for instance if the share of pork meat increases in the aggregate of animal production.

Table 3.3.5: Agriculture productions, land uses and land productivity in alternative scenarios, (% change between 2007 and 2025)

		A1 “hyper-tech”	A2 “extreme water”	B1 “peak oil”	B2 “fragmentation”
Total agricultural production	EU	15.2%	8.1%	4.7%	3.6%
	EU-15	14.4%	7.4%	4.2%	3.4%
	NMS	22.3%	14.1%	9.0%	5.2%
Vegetal production	EU	12.3%	9.0%	5.1%	5.5%
	EU-15	11.1%	8.1%	4.3%	5.0%
	NMS	22.6%	17.5%	12.1%	10.3%
Animal production	EU	19.1%	6.8%	4.1%	1.1%
	EU-15	18.8%	6.4%	3.9%	1.3%
	NMS	21.9%	9.9%	5.2%	-0.9%
Total agricultural land	EU	-0.8%	-1.2%	-1.3%	-1.5%
	EU-15	-0.6%	-1.0%	-1.0%	-1.3%
	NMS	-1.5%	-1.9%	-1.9%	-2.1%
Arable land	EU	1.5%	1.3%	1.3%	1.0%
	EU-15	1.3%	1.0%	1.1%	0.8%
	NMS	2.0%	1.8%	1.8%	1.6%
Grassland	EU	-5.8%	-6.4%	-6.6%	-6.8%
	EU-15	-4.4%	-5.0%	-5.2%	-5.3%
	NMS	-10.3%	-11.1%	-11.0%	-11.5%
Total agricultural land productivity	EU	16.1%	9.3%	5.9%	5.1%
	EU-15	15.0%	8.3%	5.2%	4.7%
	NMS	23.8%	15.9%	10.8%	7.4%
Arable land productivity	EU	10.8%	7.8%	3.9%	4.5%
	EU-15	9.8%	7.0%	3.3%	4.2%
	NMS	20.6%	15.7%	10.3%	8.7%
Grassland productivity	EU	24.9%	13.2%	10.6%	7.9%
	EU-15	23.2%	11.4%	9.1%	6.7%
	NMS	32.2%	21.0%	16.2%	10.5%

Source: NEMESIS model

In the A2 - “extreme water” scenario, where the economic growth is relatively important but where the external demand is weak, agricultural production grows about 8.1%, demonstrating the predominance of EU economic growth as driven for agricultural production even if the external trade is a non negligible driver and if the household income elasticity for agricultural goods is relatively weak compared with other products. The difference in the range of change in alternative scenarios for agricultural production and agricultural land use can only be explained by the difference in land productivity between scenarios. Table 3.3.5 shows these productivities for the four scenarios. It displays for A1 - “hyper-tech” and A2 - “extreme water”, land productivities relatively high with an increase of 16% and 9% respectively between 2007 and 2025 *i.e.* an annual average growth of 0.9% and 0.5% respectively. The high land productivity in these two scenarios stems from R&D investments which are

more important in these scenarios than in the two others for which land productivity grows respectively of 6% and 5% in B1 - “peak oil” and B2 - “fragmentation”.

Regarding table 3.3.5, the productivity increases more for grassland than for arable land, this difference can be explained by the same reason as in the *reference scenario* *i.e.* a change in the composition of the animal production aggregate. Effectively, the share of beef, sheep and goat meat production decreases in favour of pork and poultry meat that are less land intensive. Another observation on the difference between alternative scenarios is the relatively weaker arable land productivity in B1 - “peak oil” scenario than in other scenarios. It can be explained by the high oil price in this scenario that has two different impacts on agriculture production. Firstly, as energy is a production factor in agriculture (around 7.5% of total input cost in EU in 2005 (FADN 2009 [144])), there is a substitution between land and energy in favour of arable land reducing the arable land “seeming” productivity. And secondly, as land productivity gains are generally associated with a rise of fertiliser uses especially in vegetal production and as there is a strong link between oil price and fertiliser price due to energy needs for fertiliser production, the vegetal production tends to be less land intensive in the B1 - “peak oil” scenario. Finally comparing the results between EU-15 and NMS, we observe that agricultural land use change in NMS is always stronger than in EU-15. We also observe the same for agricultural production rise and agricultural land productivity.

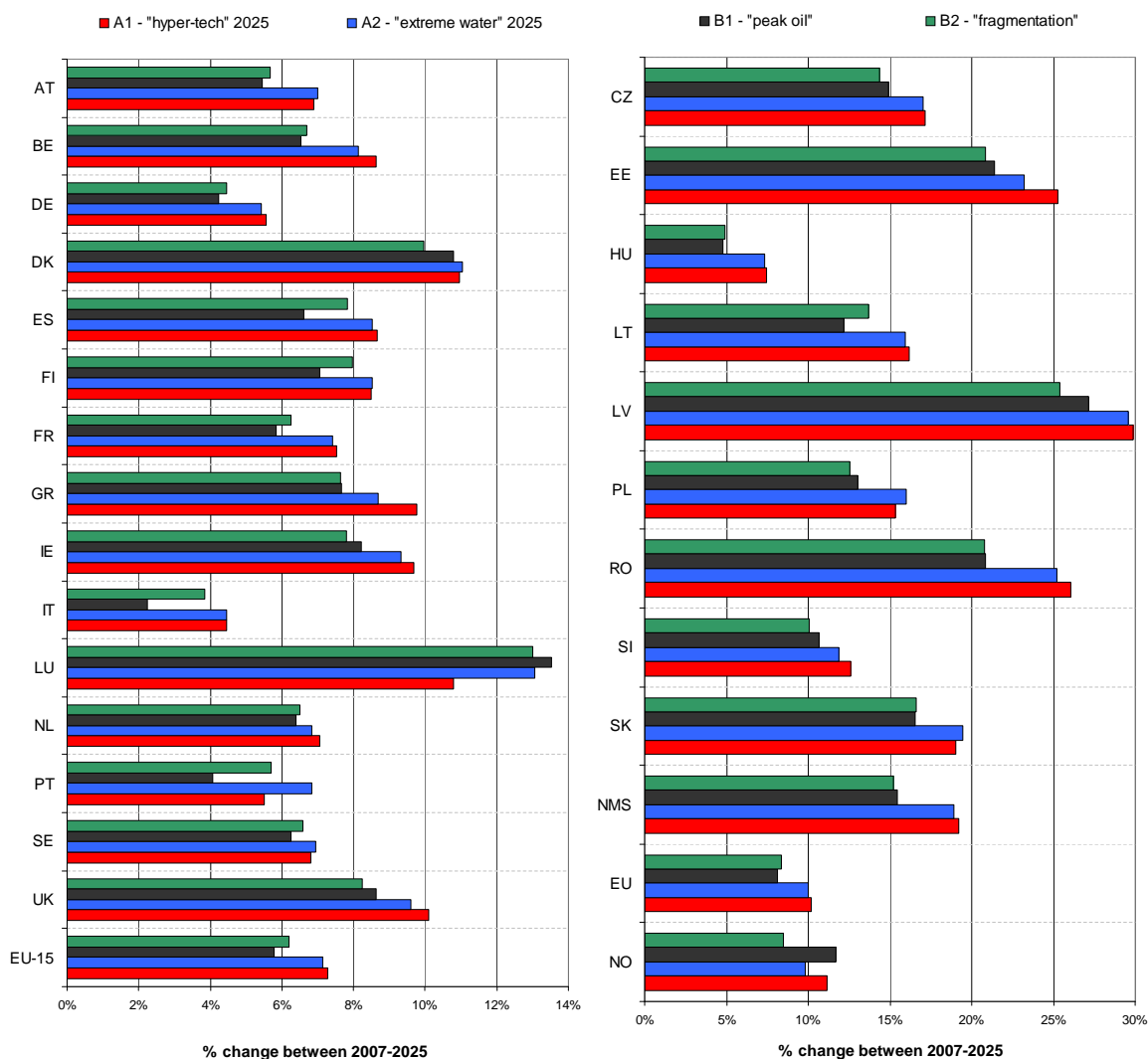
3.3.4.2 Urban land use

We now look at the urban land use change for the alternative scenarios. Figure 3.3.6 displays the urban land use evolution in each of the alternative scenarios between 2007 and 2025. We can see three noteworthy results: an urban expansion in all scenarios and EU countries, a growth driven by economic activity and a certain convergence among alternative scenarios. Looking at general urban land use change, we firstly observe an increase of urban land use in all scenarios, at European level urban land use rises about 10% (*i.e.* around 16 000 km²) in A1 - “hyper-tech” and A2 - “extreme water” scenarios and about 8% (*i.e.* around 13 000 km²) in B1 - “peak oil” and B2 - “fragmentation” scenarios. Comparing the EU countries, economic growth is still the main driver of urban land use leading to a higher urban expansion in NMS (between 15% and 20% according to the scenarios) than in EU-15 (between 5% and 8%). For instance, countries characterised by strong economic growth like Romania,

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Estonia and Latvia²⁷ see urban expansion higher than 20% between 2007 and 2025 whereas urban land grows less than 5% in a country like Italy where the GDP growth rate is weak.

Figure 3.3.6: Urban land use change in alternative scenarios, between 2007 and 2025



Source: NEMESIS model

Finally looking at the difference between country, despite the heterogeneity between economic development in alternative scenarios, there is a convergence in the results among scenarios and particularly between A1 - "hyper-tech" and A2 - "extreme water" scenarios and between B1 - "peak oil" and B2 - "fragmentation" scenarios. The convergence can be explained, in part, by assumptions on marginal

27. We must also note that these countries are characterised by high density coefficients *i.e.* a high number of km² used by urban lands for 1 million €₂₀₀₀ of I&C buildings and housing stock.

density coefficients. Indeed, as presented in section 3.3.1, we modified the density coefficients that link new investments on housing and on Commercial and Industrial (I&C) buildings with the land occupied by them. In A1 - “hyper tech” and B1 - “peak oil” scenarios, the density of new investments was increased between 2007 and 2025 by about 5% and 10% respectively whereas it was reduced by 5% and 10% in B2 - “fragmentation” and A2 - “extreme water” respectively. Consequently, the differential of economic growth between A1 - “hyper-tech” and A2 - “extreme water” scenarios is partially compensated by the rise of density in A1 - “hyper-tech” and the diminution of the density in A2 - “extreme water”. The same mechanisms arise for B1 - “peak oil” and B2 - “fragmentation” scenarios but to a lesser extent insomuch as new investments are weaker than in the two other alternative scenarios. Nevertheless, the consequences of density changes stay relatively moderating and it can not fully explain the results. The capital productivity stemming from R&D investments is another explanation for the convergence of urban land use among scenarios. In A1 - “hyper-tech” and to a lesser extent in A2 - “extreme water” characterised by a rapid technological development, the productivity gains also arise on building investments. Even if it is less important than for other capital types, it reduces the land occupied by buildings for the same level of economic development. And finally the last mechanism that contributes to a convergence between the alternative scenarios, is the land supply (see section 2.3) and especially the shift of the asymptote from right to left due to the expansion of urban land use. Consequently, for a constant agriculture land use, urban expansion pushes the land price up and then the investment price in housing or I&C buildings through construction price. Thus, the trade off between land supply and land demand through land price tends to stabilise the urban land use evolution between scenarios.

3.3.5 Concluding remarks

We summarise here the main results and associated mechanisms previously examined for the four alternative scenarios. From an economic point of view, the difference between alternative scenarios comes from the difference in the main NEMESIS drivers that can be summarised as follows:

- World demand, weak in A2 - “extreme water”, moderating in B2 - “fragmentation” and strong in A1 - “hyper-tech” and B1 - “peak oil”, is an important contributor to economic development in EU countries, by creating export outlets for EU firms.
- R&D investments, strong in the A1 - “hyper-tech” scenario, accelerated in A2 - “extreme water” and following trend in B1 - “peak oil” and B2 - “fragmentation”, play on European competitiveness, after a phase of maturation, by raising productivity and good quality. Then, it boosts the economic growth in scenarios where R&D efforts are strong. Furthermore, the productivity gains limit inflation inside the EU that could occur with labour force scarcity and then contribute to GDP growth.
- energy cost is also an important factor for economic performance, notably in the B1 - “peak oil” scenario. Energy prices, boosted by a high oil price and a carbon price of about 30€/tCO₂ in 2025, constrain economic development in EU countries by increasing transportation costs, heating costs and production costs.

The combination of these three drivers, in addition to the demography, in the four alternative scenarios determines the EU countries economic performance. Indeed, with powerful R&D investments, a strong World demand and a moderated oil price at the end of the simulation period, the economic growth in A1 - “hyper-tech” scenario is very important with an average growth rate of EU GDP of about 3.5% between 2020 and 2025. Despite R&D investments growing more quickly than GDP, the economic growth in A2 - “extreme water” scenario is relatively stable at around 2.6% per year penalised by a weak World demand. Whereas, B1 - “peak oil” and B2 - “fragmentation” display a GDP relatively weak growth rate with 2% in annual average. The first scenario is constrained by a high oil price reaching 200 current dollars and the second is penalised by a moderating World demand and by a high cost of fossil energy.

To summarise the land use results, we refer to table 3.3.6 showing the real agricultural land price and total land use change in EU between 2007 and 2025 in each alternative scenario. We can observe a relative stability of total land use in the overall scenarios. This stability is characterised by an abandonment of agricultural land and especially grassland and an increase of urban land use. It is

all the stronger even if factors such as capital productivity gains, density coefficients and land price tend to homogenise urban land use change. According to agricultural land, land abandonment is less large in scenario with strong economic growth despite powerful land productivity gains in these scenarios. On one hand, urban expansion shifts the land asymptote and reduces potential available land for agriculture and on another hand, the land productivity gains and the moderated development of agricultural production reduce land used by agriculture. Thus, it diminishes the potential land scarcity due to urban growth. The cumulative effect of urban expansion and agricultural land abandonment is relatively neutral on real agricultural land price which grows by about 2.3% in A1 - “hyper-tech”, 0.9% in A2 - “extreme water” and 0.4% in B1 - “peak oil” scenarios and decrease by 0.2% in B2 - “fragmentation” scenario.

Table 3.3.6: Change in real agricultural land price and total land use in alternative scenarios, between 2007 and 2025

		A1	A2	B1	B2
		“hyper-tech”	“extreme water”	“peak oil”	“fragmentation”
Real agricultural land price	EU	2.3%	0.9%	0.4%	-0.2%
	EU-15	2.1%	0.8%	0.2%	-0.2%
	NMS	3.0%	1.4%	1.1%	-0.2%
Total land use	EU	0.0%	-0.3%	-0.5%	-0.7%
	EU-15	0.0%	-0.3%	-0.5%	-0.5%
	NMS	0.0%	-0.3%	-0.6%	-0.9%

Source: NEMESIS model

Finally, comparing alternative scenarios results for land use with other studies and especially with EURURALIS²⁸ (Klijn *et al.* 2005 [314]) that also creates several prospective scenarios mainly based on the imaginative approach, there appear noticeable similarities, despite some differences. In EURURALIS which is composed of four scenarios based on IPCC SRES (2001 [289]) as for alternative scenarios, the evolution of urban land use between 2000 and 2030 is between 5% and 15% for three scenarios *i.e.* in the range of our four alternative scenarios. Nevertheless, the scenario based on A1 IPCC SRES (close to A1 - “hyper-tech”) shows more important urban expansion with more than a 25% rise between 2000 and 2025. This difference in A1 IPCC SRES comes from the storyline definition and interpretation for

28. www.eururalis.eu

which they suppose strong economic growth with urban sprawling whereas we supposed an economic growth with a slightly urban concentration. For agricultural land use, EURURALIS shows larger land abandonment with some scenarios going as far as -15% between 2000 and 2030, only the A2 IPCC SRES is relatively close to our results with a 2% loss of agricultural land. Grassland decreases also strongly (from -5% to -15%) in EURURALIS but arable land does not increase slightly as in alternative scenarios. It decreases by about 10% except in A2 IPCC SRES in which it stays stable. Thus, despite a slightly higher vegetal production in EURURALIS (from +15% to +25% between 2000 and 2030), arable land is decreasing resulting from widely superior land productivity in EURURALIS than in our alternative scenarios even in R&D driven scenarios. Consequently, we find again that our arable land productivity is weak compared to other studies as in *reference scenario* even in A1 - “hyper-tech” and A2 - “extreme water” scenarios where land productivity is however strongly increasing, our trend productivity seems then slightly underestimated.

3.4 Conclusion

We have presented in this chapter the drivers and the economic and land use results for the *reference scenario* and alternative scenarios. The *reference scenario* is grounded on extrapolating approach and expert knowledge approach insomuch as it uses trend drivers and external studies for other drivers or some NEMESIS outputs. The second scenarios use the imaginative approach by introducing some shocks on the IPCC SRES families, with a set of drivers relatively contrasted between scenarios.

The *reference scenario* is characterised by an ageing European population that stays relatively stable, a strong and continuous World economic development, a moderated oil price and a stable R&D intensity throughout the simulation period. With these drivers, the *reference scenario* displays robust economic growth in the EU, with 2.4% of GDP average annual growth rate, it also shows a catch-up of NMS with 4.4% of economic growth in average annual growth rate. The decrease of active population in most of EU countries does not constrain economic development so much, indeed, high labour productivity avoids inflationary pressure and reduces employment needs which increase by about 18.5 million between 2005 and 2025 (*i.e.* +9%). Land use results of *reference scenario* point out an urban expansion in the overall EU countries with a rise of more than 10% (16 000 km²) of lands covered by urban. Urban sprawling is particularly strong in NMS because of more rapid economic development. We also observe a decline of agricultural land use of about 1.6% (-29 000 km²) between 2005 and 2025 and especially a strong abandonment of grassland (-7% *i.e.* 42 000 km²) due to a decline of high land intensive animal production such as beef or sheep in favour of poultry or pork. Nevertheless, comparing the agricultural land abandonment in the *reference scenario* with similar studies, we observe a weak decrease of agricultural land in the *reference scenario* that comes from a weaker arable land productivity maintaining arable land relatively stable with a slight rise of 1% (13 000 km²).

For alternative scenarios, we observe that economic results are mainly influenced by technological development, World demand and energy prices. The A1 - “hyper-tech” and A2 - “extreme water” scenarios where R&D investments grow faster than GDP display strong economic growth pushed up by productivity gains. Furthermore, GDP growth is reinforced in the A1 - “high-tech” scenario because of an important World demand. In B1 - “peak oil”, economic growth is deeply constrained by high energy prices and especially oil price. Whereas in the B2 - “fragmentation”, GDP growth is weak due to low external demand and high fossil energy prices. For land use, alternative scenarios are not as differentiated than for economics. The land productivity gains, the land supply curve and to a lesser extent the assumptions on density coefficients tend to stabilise land use change among scenarios. For

instance, despite higher agricultural production in A1 - “hyper-tech” than in B2- “fragmentation”, land used by agriculture is relatively close in both scenarios. The land productivity gains counterbalance the agricultural land needs in the A1 - “hyper-tech” scenario. In addition, the larger expansion of urban lands in A1 - “hyper-tech” than in B2 -“fragmentation” reduces available land for agriculture and tends to increase agricultural land prices (asymptote shifts from right to left) reducing agricultural land demands. Thus, the conjunction of both mechanisms equilibrate land claims among alternative scenarios, we observe an agricultural land abandonment of between 1.5% (-27 000 km²) and 0.8% (-15 000 km²) characterised, as in the *reference scenario*, by a decrease of grassland and a slight rise of arable land. As for the *reference scenario*, the trend arable land productivity is weak compared to other studies and despite the increase of land productivity growth in scenarios with high technological development (reaching 1.3% per year between 2020 and 2025 in A1 - “hyper-tech”), it does not allow the observation of the same land abandonment than in other studies. It just allows the counterbalancing of the rise of agricultural production.

To summarise, the alternative scenarios, even if they will not be used in the next chapters, give some interesting insights on the mechanisms of the NEMESIS model and their consequences on land use. For instance, we saw the importance of technological development that boosts GDP growth in the EU and to a lesser extent agricultural production. Nevertheless, the rise in land claims, due to agricultural production growth and urban sprawling coming from economic development, is counterbalanced by productivity gains in agriculture reducing thereby the pressure on agricultural land price. We also saw the role of the land supply and the asymptote presented in chapter 2 that tend to stabilise land use change by increasing agricultural land prices with the raise of land used by agriculture but also with urban expansion.

Finally, we have shown that the *reference scenario*, despite weak arable land productivity is relatively close to other studies in terms of urban expansion and land abandonment and especially for grassland. Therefore and as the *reference scenario* is relatively neutral in terms of assumptions for the future insomuch as it is mainly grounded on past trends and on expert knowledge for key drivers and for agriculture and forestry, we decided to use the *reference scenario* as a basis in the following chapters.

Chapter 4

Linked models for Sustainability Assessments: Application to CAP reform

4.1 Introduction

The European policy refers more and more to *ex-ante* impact assessment based on models whatsoever the research fields. It is mainly true with policies that could have strong consequences on the environment or the economy. The *ex-ante* impact assessments are all the more interesting that economic issues of new policy proposal are large and concern policies on which European Union (EU) has a political power. In this sense, the Common Agricultural Policy (CAP) is obviously primary concerned, all the more as its expenditure represents around 50% of the EU budget *i.e.* around 0.4% of European GDP for an agriculture sector accounting for less than 2% of the EU added value. According to the importance of the CAP on EU policy (in budget but also from a historical point of view), and despite the recent reforms tending to reduce CAP expenditure, criticisms from Member States (such as United Kingdom, Sweden and the Netherlands) against the CAP will lead to a reexamination of the CAP budget beyond 2013. The likely changes in CAP expenditure will have huge consequences on the agricultural policy itself, however it also requires an examination to anticipate the macro-economic and environmental impact.

For that reason, the use of a tool with a precise description of the agriculture sector as well as agricultural policy instruments, seems necessary. These tools also must be able to take into account the economic feedback of changes in the agriculture sector but also its economic consequences on EU budget as well as the impact of its re-allocation. Finally, as agriculture is the main user of European land, it is essential to consider the problems of land use. According to those considerations within the framework of the EU integrated projects SENSOR¹, a linked models framework was developed including four different models: a detailed model for agriculture (CAPRI), for land use (Dyna-Clue), for forestry (EFISCEN) and for the overall economy (NEMESIS). The methodology developed with the model linkage is original in several ways (*i*) it includes three sector models of prior interest for *ex-ante* impact assessment of CAP reform: agriculture, land use and forest, (*ii*) a macro-economic model, covering those three sectors allowing the transmission of sectoral impact in the overall economy and gives macro-economics feedback to sector models, (*iii*) macro-economic model allow impact assessment of policies funds, transfers between objectives or between economic agents, (*iv*) finally, the linked models implement a combination of common model variable calibrations reaching joint equilibrium for strategic common model variables.

1. SENSOR : Sustainability Impact Assessment -Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions. Project Reference 003874 (www.zalf.de/home_ip-sensor/index.html).

This chapter aims to present this original linked models through a short presentation of each model, an explanation of the common models variables and an illustration of its functioning. Furthermore, the second objective of this chapter is the *ex-ante* assessment of CAP reform with the linked models² and focusing on environmental and economic impact. The first section is then devoted to explaining the model linkage through its relevance to sustainability impact assessment. We will start by briefly describing each model, thereafter we will explain the functioning of the linked models and we will finish by showing the relevance of the linked models, by exhibiting some results for the land use model and the forestry model. The second section presents an analysis of the implementation of the linked models for CAP reform. The analysis starts by a representation of the CAP context. Thereafter, it focuses on economic effects of 1st Pillar CAP policy instruments and EU budget re-allocation³.

2. The linked models were designed for policy assessment and not only for CAP reform however the main study concerned CAP reform

3. The work presents in this chapter were realised by a consortium including ERASME team from France, LEI Wageningen UR from Netherlands, Alterra Wageningen UR from Netherlands and European Forest Institute from Finland. The work presents in the first section of this chapter gave rise to an article submitted to Ecological Modelling (Jansson *et al.* 2010 [299]) and on which the first section is based. The second section takes a leaf of Jansson *et al.* (2008 [300]) a draft paper on the CAP reform results.

4.2 Linked models description

4.2.1 Introduction

Ex-ante sustainability impact assessment has become increasingly important as a tool to support decision making (*e.g.* Giljum *et al.* 2008 [237], van Ittersum *et al.* 2008 [455]). It is understood as a formal procedure to analyse potential effects of new policies before their adoption and to identify possible economic, environmental and social effects of proposed policies with respect to sustainable development (Tscherning *et al.* 2008 [442]). In this respect, assessing the impact of policies on land use is particularly important, insomuch as land use change has been one of the most important drivers of change in terrestrial ecosystem services (Millennium Ecosystem Assessment - MEA 2005 [354], Foley *et al.* 2005 [230]). Therefore it provides insight on how the policies will affect the environment and the goods and services it supplies (Schröter *et al.* 2005 [421], Rounsevell *et al.* 2006 [409], Schulp *et al.* 2008 [422], Verkerk *et al.* 2009 [466]). Analysis of land use change responses to policies requires an integration of the analysis across different sectors influencing land use. Although cross-sector modelling approaches enable capturing important interactions between sectors, they bring modellers to a classical dilemma: a model with great scope is desired in order to include all sectors of interest, but great scope tends to come at the expense of details. Moreover, state-of-the-art of modelling methods for one sector are not necessarily the most suitable for others. Therefore it requires methodological compromise (Offermann 2008 [377]). Due to this trade-off between scope and detail, models tend to specialise in one or the other. Most of the current modelling approaches for sustainability impact assessment focus on the agricultural sector, given the high impact of the agricultural sector on land use (Meijl *et al.* 2006 [456], van Ittersum *et al.*, 2008, Piorr *et al.*, 2009 [391]). Consequently, these approaches do not or cannot fully integrate the social, economic and environmental impact of policy induced land use changes across and within different land use sectors.

To resolve the dilemma, it is possible to use a combination of models representing the individual sectors. Such a multi-model approach across different scales was successfully adopted in the EURURALIS project (Verburg *et al.* 2006 [464], Verburg *et al.* 2008 [461]), in the LUMOCAP project (van Delden *et al.* 2010 [453]) and at a lesser extent by Britz *et al.* (2010 [56]). However in these studies, the focus is mainly on the agricultural sector and feedback between models were implemented to a limited extent. A more integrated approach could be achieved by using, one specialised sector model for each sector of interest, linked to a model spanning all sectors. In that way, the advantages of

detailed sector models could be exploited. At the same time, the interactions between the sectors via competition for shared resources such as land are captured by the aggregated model. The aim of the study presented in this paper is to develop such a linked system of models, allowing the integrated impact assessment of land use policies on specific sectors and on all sectors together. Three sectors of significant importance for land use are modelled including forestry, agriculture and urban land use. To this end four models are linked. Two are detailed sector models for agriculture (CAPRI) and forestry (EFISCEN). One is a European economy-wide econometric model (NEMESIS) with a land use module that includes, at a national scale, a model for the urban area and agricultural land (see chapter 2). In addition, a land use model (Dyna-CLUE) spatially allocates land use down to a 1 km² grid resolution to allow environmental impact assessment and provides data on land availability at regional scale to others models.

The linked models system served as a basis to assess *ex-ante* sustainability impacts of land use change using a broad set of indicators covering the economic, social and environmental dimensions of sustainability. This section provides a description of the linked models system, with emphasis on how the models work together. The indicators, computed by the linked models system, have been described by Farrington *et al.* (2008 [222]), Petit *et al.* (2008 [385]) and Bach *et al.* (2008 [21]). Firstly, we describe the involved models, focusing on aspects that are relevant for the linkage, secondly we describe how the models are linked and finally we illustrate the advantages of the link as well as its effects on some indicators.

4.2.2 Overview of the models

4.2.2.1 The agricultural sector model CAPRI

The **Common Agricultural Policy Regionalised Impact modelling system CAPRI**⁴ (Britz and Witzke 2008 [57]) is a partial equilibrium model that offers a detailed representation of the agricultural sector at regional level⁵, with around 250 regions and 50 agricultural products (primary crop and animal outputs as well as selected processed commodities). Agricultural production in European regions are determined by mathematical programming models, which maximise gross added value of representative regional farms subject to technological constraints for fertilisation, feeding, set-aside and land availability, and non-linear cost terms. The non-linear term is derived from positive mathematical

4. www.capri-model.org

5. More precisely at NUTS2: Nomenclature of Territorial Units for Statistics level 2.

programming (Howitt 1995 [275], modified as in Heckeles and Britz 2005 [261] and Jansson 2007 [298]), and provides flexibility to allow the model to reproduce historically observed production behaviour in each region. Regional endowments of arable and grassland are exogenous in CAPRI, whereas land rents are endogenous. One contribution of this work is to make land endowments endogenous via a link with the NEMESIS model. The market for agricultural products is modelled at Member State (MS) level in the EU and for about 40 regions in rest of the world, represented by 18 bilateral trading blocs with their own agricultural trade policy instruments. The primary processing sectors dairy and oil seed crushing are explicitly modelled. The final demand model is fully consistent with conventional micro-economic theory (Generalised Leontief expenditure system - Diewert and Wales 1987 [121]). It treats products of different geographical origins as imperfect substitutes in a two-stage budgeting system (Armington 1969 [15], Hertel 1997 [269]). In particular, the aggregate household has a fixed budget and demands a rich set of agricultural products at endogenous prices, but only one aggregate representing all other commodities, traded at a fixed price. In the linked system, both total consumer expenditure and the price index of the aggregate commodity are made endogenous via a link with NEMESIS. The contributions of CAPRI to the overall objectives of the modelling system are the specific implementation of many agricultural policy instruments and delivering highly differentiated results for agriculture in European regions, including indicators such as nutrient balances and greenhouse gas inventories.

4.2.2.2 The forest resource model EFISCEN

The **European Forest Information SCENario model**⁶ (**EFISCEN** - Sallnäs 1990 [412], Schelhaas *et al.* 2007 [416]) is a large-scale forest resource model that assesses the supply of wood and projects forest resource development (Nabuurs *et al.* 2007 [364]). EFISCEN uses forest inventory data (Schelhaas *et al.* 2006 [417]) as input, which include the forest area, average growing stock volume and average annual increment by age-class and forest types. Forest types are defined by regions, ownership classes, site-classes and species (groups). Based on the input data, the state of the forest is described in matrices for each forest type, in which area is distributed over age and volume classes. During simulations, forest area moves between matrix cells, describing different natural processes (*e.g.* ageing, increment, mortality) and human actions (*e.g.* forest management, afforestation, deforestation).

6. www.efi.int/portal/completed_projects/efiscen

tion). As outputs, EFISCEN projects forest area, stem wood volume, increment, age-class distribution and removals for every five year time-step. With the help of biomass expansion factors, growing stock volume is converted into whole-tree biomass and subsequently to whole-tree carbon stocks. Information on litterfall rates and felling residues is used as an input into the soil module YASSO (Liski *et al.* 2005 [338]), which is dynamically linked to EFISCEN and delivers information on forest soil carbon stocks. The EFISCEN model contributes to the modelling system by assessing the supply of wood under different land use policies.

4.2.2.3 The economy-wide econometric model NEMESIS ⁷

The **NEMESIS economic model** is a detailed macro-econometric model specified for each of the EU-27 (except Bulgaria and Cyprus and plus Norway) countries. The dynamics of NEMESIS result from interactions between countries and economic activities through the exchange of goods, services and knowledge. Most NEMESIS equations are estimated econometrically from a special database constructed for the model. NEMESIS is the model that links the sectoral models together insomuch as it spans all sectors and particularly the agriculture (CAPRI), the forestry (EFISCEN) and the land use (Dyna-CLUE). Agriculture is modelled through cost minimisation using a transcendental logarithmic cost function (Ngwa Zang and Le Mouél 2007 [367]) that covers two agricultural productions: animal and vegetal, 6 flexible inputs and 4 quasi-fixed inputs and 2 other inputs ⁸ whereas forestry is modelled as other NEMESIS sectors, with a profit maximisation according to the demand addressed to it. And finally, the land use is divided between three main land use categories ⁹:

- agricultural land, subdivided between grassland and arable land, for which agricultural sectors determining land demand and supply. The land demand resulting from a trade-off between the needs for agricultural production and its cost compared to other inputs whereas the land supply stems from an “inverse-L” curve pushing up land price with scarcity of unutilised agricultural lands. Furthermore, total usable agricultural land expansion are bound by an asymptote composed by built-up areas, non commercial forests and unsuitable lands.
- Urban areas reflect the expansion of housing and industrial and commercial buildings stocks

7. Please refers to Appendix B (or Zagamé *et al.* 2010 [476] - www.erasme-team.eu) for a detailed description of the NEMESIS model, this section being oriented to the linked models.

8. These both last inputs are lands (arable and grassland) modelled as presented in section 2.3.4, and family labour that follows agricultural incomes. A decline of agricultural incomes reduces the family labour: farmers leaving agriculture activity to move to more lucrative activities.

9. See section 2.3 for details.

that are converted into land with the help of fixed density coefficients (*i.e.* number of km² per constant euro of buildings stock). In addition, urban expansion or decline shifts the asymptote either by reducing usable land for agriculture or by increasing it.

- Other land uses are composed by forests, transport infrastructures and other land *i.e.* all unsuitable land such as wetlands, mountains, etc. These lands are also components of the asymptote but they are supposed to be exogenous in this study. Then, they are either fixed or determined by policies or expert knowledge.

Besides its land use module, an important feature of NEMESIS for linked models system is its endogenous technical progress. A knowledge variable inside the supply block allows the integration of new theory of economic growth (see *e.g.* Aghion and Howitt 1998 [2] or Barro and Sala-i-Martin 2003 [26]) taking into account knowledge spillovers (Brécard *et al.* 2006 [54] and Chevallier *et al.* 2006 [87]). Econometrically estimated functions and knowledge spillovers matrix relate R&D spending to sectoral knowledge and finally factors productivities and quality of consumer goods.

4.2.2.4 Spatial disaggregation of land use: Dyna-CLUE

Dyna-CLUE¹⁰ (Verburg *et al.* 2006 [463], Verburg and Overmars 2009 [462]) is a dynamic model with annual time steps that project **land use changes to a high-resolution geographic grid**. Apart from allocating the aggregated land use change as given by NEMESIS, it also simulates internal reconfiguration of land use, in response to competition between land use types and the (re-)growth of natural vegetation. Dyna-CLUE bridges the gap between the outputs of the NEMESIS model at a national level and the input requirements at sub-national level of the CAPRI and EFISCEN models by distributing the land use on Member State (MS) level given by NEMESIS to a 1 km² grid for 17 land cover types. Furthermore, the high-resolution land allocation results provide information for the computation of sustainability impact indicators since the actual location of land use change is of prime importance for the effects on several impact indicators such as carbon sequestration and habitat fragmentation. The spatial explicit approach also allows the analysis of spatial policies such as nature reserves (*e.g.* the EU Natura2000 scheme¹¹) and location specific policies such as the compensation of farmers in Less Favoured Areas. The model simulates the competition between land uses accounting for location conditions, current land use and changes in land claims for the

10. www.cluemodel.nl

11. See chapter 5.

different land uses. The spatial allocation rules are based on a combination of empirical analysis of current land use patterns (Wassenaar *et al.* 2007 [469]), neighbourhood characteristics (Verburg *et al.* 2004 [460]), and scenario specific decision rules (Verburg *et al.* 2006 [463]). The spatial allocation rules are configured separately for each country to account for the country-specific context and land use preferences. Changes in natural vegetation are the result of both net changes in the other sectors as provided by the NEMESIS model and locally determined processes of re-growth of natural vegetation (Verburg and Overmars, 2009). After abandonment of agricultural land re-growth of natural vegetation is determined by the local growing conditions (soil and climate conditions), population and grazing pressure and management. The possibilities to convert natural vegetation into agricultural land or residential/industrial land depend on the location and the type of natural area. Path-dependent dynamics arise from the combination of top-down allocation of agricultural and urban demand and bottom-up simulation of the (re-)growth of natural vegetation.

4.2.2.5 Relevance of the modelling system for sustainability

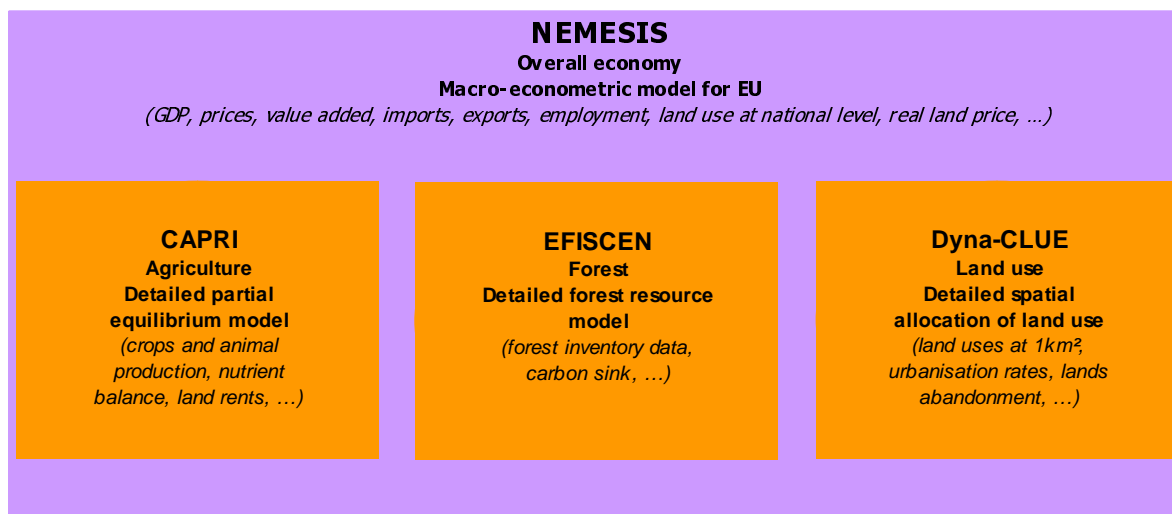
Sustainability is frequently analysed along social, environmental and economic dimensions. The combination of models described above gives rich information related to the latter two. In total, the model chain yields more than two thousand output variables, each of them computed in a spatially explicit manner (*i.e.* at country level for NEMESIS, at NUTS2 for CAPRI, at country to regional level for EFISCEN and at 1km pixel level for Dyna-CLUE) that are potentially interesting for analysis of sustainability issues.

- NEMESIS yields more than one thousand variables of which the majority are economic ones, like prices, production and consumption of different commodities (30 for production and 27 for consumption), gross domestic product per MS in real and nominal terms, different price indexes, households and government expenditures, R&D spending and technical progress and employment. The results from NEMESIS are important for computations of many economic indicators, but also useful for evaluating social impact of policy changes (*e.g.* via employment effects across production sectors - Brécard *et al.* 2006 [54] and Chevallier *et al.* 2006 [87]).
- From CAPRI, results include land use for different crops, herd sizes for different animal categories, nutrient balances on soil level, emissions of greenhouse gas from agriculture, food trade and degrees of self-sufficiency in calories and protein for MS, income statements for agriculture broken down into quantities and prices of goods produced and consumed, and expenditure on agricultural

- policies. The results from CAPRI contribute to the computation of economic indicators (for the agricultural sector) and environmental indicators relevant to water quality and climate change.
- From EFISCEN, more than eight thousand variables are derived. They include basic forest inventory data (area, growing stock, increment, deadwood), roundwood removals and logging residues for different species groups (broadleaves, conifers, mixed) and age-classes, as well as carbon contents of wood and soil. The EFISCEN results can be used to compute various environmental indicators, *e.g.* related to biodiversity (Verkerk *et al.* 2010 [466]), carbon storage (Eggers *et al.* 2008 [168]) and forest fires (Bach *et al.* 2008 [21]).
 - Dyna-CLUE supplies 17 variables corresponding to areas of 17 land-cover classes. Some of the Dyna-CLUE outputs can be considered as direct indicators for sustainability, such as the urbanisation rate or the rate of abandonment in agricultural areas, but most of the Dyna-CLUE outputs serve as input to other models (either the sector models as CAPRI and EFISCEN, or external models and indicators that compute effects on *e.g.* biodiversity - Verboom *et al.* 2007 [459] - or carbon sequestration - Schulp *et al.* 2008 - based on the land use pattern).

Figure 4.2.1 summarises the models involved in the linkage by shortly mentioned their types, sector of application and outputs.

Figure 4.2.1: Models for linkage: type, sector and output



4.2.3 Linked models

4.2.3.1 Overview

In spite of the capabilities of the individual models, there is an added value in linking the different models to achieve a consistent modelling system in order to be able to detect externalities or synergies between sector-specific developments. On one hand, macro-policies and inter-sector interactions are implemented in NEMESIS. Their effects must thus be communicated downstream to the sector models to capture these effects consistently. On the other hand, sector specific policies and detailed behaviour are only implemented in the sector models. To compute the effects of such policies on other sectors and the economy as a whole, the sector models must also communicate upstream, where the effects can be distributed to all sectors. The latter link is also required in order to obtain a reaction across all sectors consistent with macro-economic changes. Thus, **bi-directional linkages** are required. The models cannot be integrated in a single model, because of their different purposes, specification and computing software. Instead of a simultaneous solution, an iterative re-calibration solution for the linked system is used, as described by Böhringer and Rutherford (2009 [38]) and by Grant *et al.* (2006 [248]).

The links between the upstream model NEMESIS and the downstream model CAPRI differ depending on the direction that is considered. CAPRI takes changes in some of the variables of NEMESIS as given, links them to exogenous parameters and computes a new partial solution for agriculture. In the opposite direction, the output variables of the downstream model are endogenous also to the upstream model. For example, CAPRI computes agricultural production, which is also endogenous in NEMESIS, making the linking complex. There are several options for implementing such an upstream link. The first option is to **delete the relevant equations** from the upstream model and replace these by parameters, exogenous variables or (first order) approximations from the downstream model (Böhringer and Rutherford 2009 [38]). Alternatively, the original equation is maintained in the upstream model, and **iteratively calibrated** to the outcomes of the downstream model. We apply a **mixed approach**, where most overlapping variables in NEMESIS are simply fixed to the results from CAPRI (*i.e.* the first option). Only in the case of land prices, a more complex approach is opted for where, *ceteris paribus*, the agricultural land demand function in NEMESIS was iteratively re-calibrated to always replicate the most recent results of CAPRI. We suppose that the agricultural production (an important overlapping between NEMESIS and CAPRI) is better evaluated in CAPRI according to its detailed agricultural productions. As CAPRI considers the NEMESIS consumer expenditures

exogenous, the iterative calibration is chosen for agricultural lands. Furthermore, agricultural land use is exogenous in CAPRI. With the iterative calibration of the agricultural land in CAPRI, it allows the introduction of a “flexible” supply in CAPRI. To facilitate convergence, a weighted average of previous iteration outcomes is used instead of only the outcome of the last iteration. In that way, the effects of large shocks, like a new policy, in one model are transmitted to the model at the other end of the link over several consecutive iterations instead of in one large chunk, which in turn reduces oscillations and the risk of non-convergence.

The link between the Dyna-CLUE model and the other models is relatively straightforward. Dyna-CLUE receives a preliminary land claim at national level from the coupled NEMESIS-CAPRI system. This preliminary land claim is based on the assumption that land use change is distributed evenly over all NUTS2 regions (*i.e.* CAPRI computation units) within a country. This is a simplification that is modified after running Dyna-CLUE which downscales the national scale change in agricultural area to spatial patterns. Dyna-CLUE will, for instance, predict that abandonment will dominantly happen in marginal regions, while urbanisation is confined to certain other regions. After running Dyna-CLUE with the preliminary national land use claims, Dyna-CLUE outputs are aggregated to NUTS2 units, and reported back to CAPRI. Now, CAPRI and NEMESIS iterate once more, this time with modified land use distributions in the NUTS2 areas. Adjusted regional distributions of land change tend to affect variables such as land price and the use of agricultural inputs. Overall land claims, however, were not found to be affected strongly by this feedback, so that a single iteration with the Dyna-CLUE model was sufficient.

Apart from feeding back sub-national land use distributions to the CAPRI-NEMESIS combination, Dyna-CLUE outputs are also input to the EFISCEN model. As EFISCEN uses regions that do not coincide with national borders, it needs the spatial patterns of changes in forest area simulated by the Dyna-CLUE model aggregated to the EFISCEN regions. Regardless of the aggregate amount of land under forest, sub-national dynamics cause forest to disappear at some locations, *e.g.* due to urbanisation, while new forest may develop at other locations, *e.g.* as result of agricultural abandonment. The new locations are often of different quality than the forests that have disappeared. For this reason, EFISCEN needs to know the exact location of all dynamics in forest area, rather than the aggregated amount of forest area.

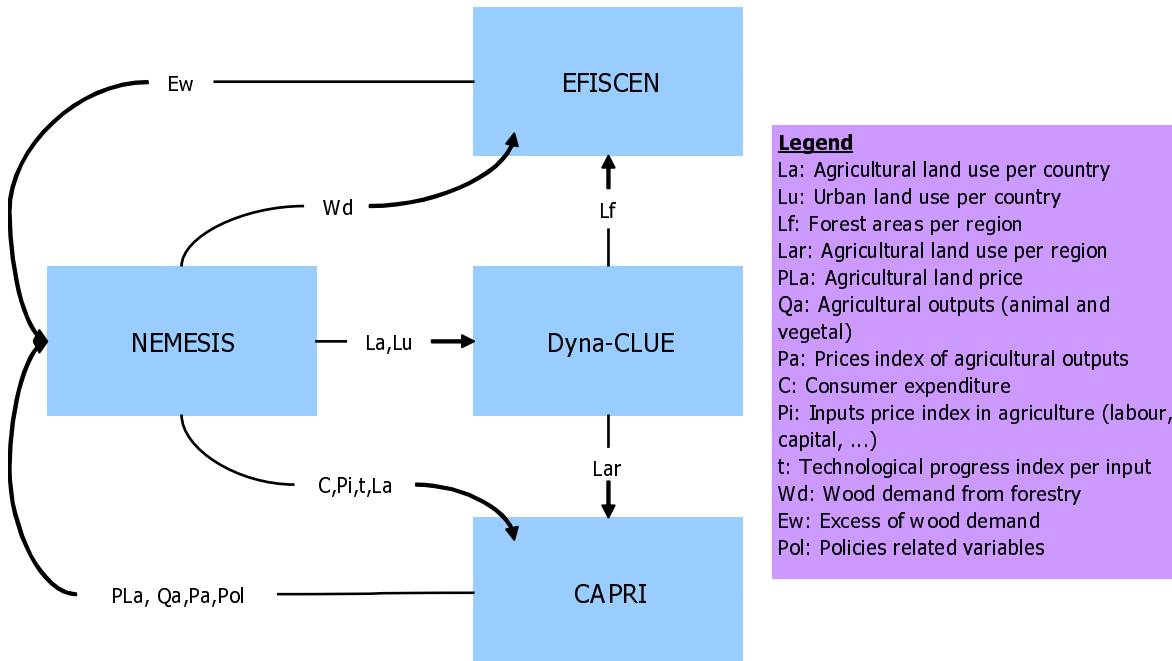
In addition, a special aspect of the linked models is related to the construction of a consistent

scenario, *i.e.* a simulation outcome that serves as a reference to evaluate other simulation outcomes¹². Due to differences in spatial detail, data sources and definition of variables, it was not possible to reach identical results for overlapping variables in the *reference scenario*. To prevent this from causing trouble, the whole system is calibrated by effectively fixing the relative differences between models. In practice, this means that models are links in terms of percentage change and not in absolute values. For instance, a calibration of NEMESIS agriculture productions, with CAPRI outputs (using this methodology), were realised for the *reference scenario* (see section 3.2.2).

4.2.3.2 Linked models for consistent land balances

As mentioned in the previous section, the land balance is the most important means of interaction between the models. Hence, it is appropriate to describe it in greater detail. Figure 4.2.2 summarises the linkages between the models through exchange variables. The iteration between the models can start with any of the models in the chain nevertheless in practice, the chain starts with the CAPRI model.

Figure 4.2.2: Scheme of variables exchanges in the linked models



12. NEMESIS main results for *reference scenario* are presented in section 3.2.3.

From NEMESIS, CAPRI takes into account the vector of agricultural input price indexes Pi ¹³, the technical progress indexes vector per input t , the consumer expenditure vector C (in volume *i.e.* €₂₀₀₀) and the land constraints (La). CAPRI uses also the adjusted regional distribution of agricultural lands (Lar) per NUTS2 unit which is, for the first iteration derived from the current land cover distribution and thereafter uses Dyna-CLUE results. The received data is used to calculate new sets of input prices for input not produced by the agricultural sector, consumer prices (influencing the relative prices of agricultural commodities), land rents and technical coefficients relating to the input requirements and yields of crops and animals in CAPRI. After finding a (new) solution, CAPRI prepares aggregated results for NEMESIS and aggregates the agricultural land price (PL) to the MS level. It also computes gross production of agriculture (Qa) for vegetal and animal products, price indexes (Pa) of agricultural outputs and some variables related to policies relevant for other models (Pol)¹⁴.

NEMESIS uses this information (*i.e.* PL , Qa , Pa and Pol) to recalibrate its land demand function for agriculture, which leads to the replacement of its equations for agricultural outputs and prices equations by constants corresponding to the results (Qa , Pa) from CAPRI¹⁵. The land demand functions for agriculture in NEMESIS (La_n^i with $n = GL, AL$ *i.e.* grassland and arable land or animal production and vegetal production for Qa) is determined by equation 4.2.1. For each iteration i , $UCT_n^i(PL^i) = PL^i \left(\frac{r}{1+r} \right)$ is the user cost of land with PL^i the land price and r the nominal long term interest rate. In addition, $C^i(Qa_n^i)$ represents the cost of other agricultural inputs that is a function of Qa^i . The parameter θ steers the elasticity of land demands whereas c^i is a calibration parameter¹⁶.

$$La_n^i = c^i \left(\frac{C^i(Qa_n^i)}{UCT_n^i(PL^i)} \right)^\theta = c^i \left(\frac{C^i(Qa_n^i)}{PL^i \left(\frac{r}{1+r} \right)} \right)^\theta \quad (4.2.1)$$

As agricultural land prices per country (PL^i) are kept endogenous variables in both CAPRI and NEMESIS, an iterative procedure is required to find the land price that is consistent with the solutions of both models. Therefore, when NEMESIS begins iteration i , the land demand is shifted in such a way that, if equation 4.2.1 were considered alone, then the land demand (La^{i-1}) and other input costs

13. Inputs include labour, capital, energy, etc. And they exclude inputs from agriculture.

14. In the scheme, policy variables come from CAPRI. However they could come from other models according to the policy assessed. But in practice, as the model linkage were used for agricultural policies (CAP reform, see section 4.3), the Pol variable is affected to CAPRI.

15. In practice, as CAPRI is static and NEMESIS dynamic, we introduce progressively in NEMESIS the CAPRI outputs, such as the change in 2025 is the same in both models.

16. In order to simplify and to focus on the linkage, we simplify the NEMESIS land demand function that also includes a partial adjustment to long term optimal level of land demand. (see section 2.3.4).

$(C^{i-1}(Qa_n^{i-1}))$ sent to CAPRI in iteration $i - 1$, would have resulted from the land price that CAPRI computed in iteration i using precisely that data. In other words, NEMESIS agricultural land demand is shifted such that with the CAPRI land price of the i^{th} iteration, NEMESIS provides the same land demand that in $i - 1^{th}$ iteration, *ceteris paribus*. This implies solving equation 4.2.1 for c^i as shown in equation 4.2.2:

$$c^i = La_n^{i-1} \left(\frac{C^{i-1}(Qa_n^{i-1})}{PL^i \left(\frac{r}{1+r} \right)} \right)^{-\theta} \quad (4.2.2)$$

NEMESIS is then solved including the re-calculated parameter c^i from equation 4.2.2 in equation 4.2.1, with agricultural outputs Qa_n and price indexes Pa fixed to the last solution of CAPRI. Thus, the exchange between NEMESIS and CAPRI continues until land price is reached that solves both models¹⁷.

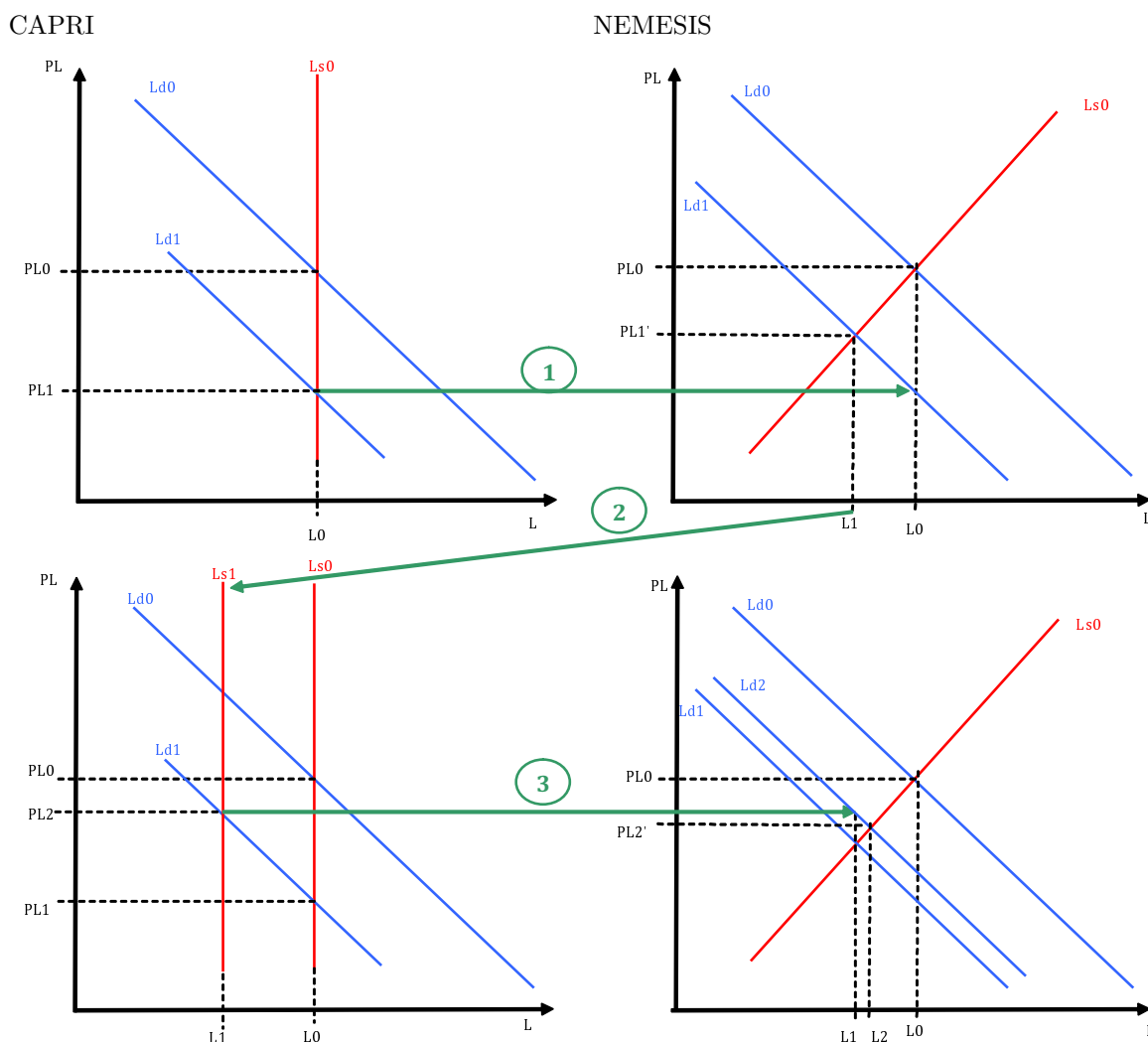
Figure 4.2.3 illustrates the linkage between CAPRI and NEMESIS models with a representation of land market in NEMESIS on right side and in CAPRI on left side, where Ls is the land supply which is fixed in CAPRI (*i.e.* vertical), with Ld the land demand and PL the land price¹⁸. Supposing that we are initially, in the *reference scenario*, at equilibrium $(L0, PL0)$ and assuming a shock induces by the implementation of a new policy. Therefore, the land demand in CAPRI shifts (from $Ld0$ to $Ld1$ in figure 4.2.3) leading to a new land price equilibrium in CAPRI: $PL1$. This new land price is given to NEMESIS, which calibrates its land demand ($Ld0$ to $Ld1$), as explained above, *i.e.* in order to have, with the new CAPRI land price $PL1$, the same land demand than with the previous land market equilibrium $(L0)$. The new land demand ($Ld1$) is then confronted in NEMESIS with its land supply ($Ls0$) that leads to a new land market equilibrium: $L1$ and $PL1'$. Thereafter, NEMESIS sends CAPRI the new land equilibrium $(L1)$ and CAPRI moves its land supply from $Ls0$ to $Ls1$ such as $LS1 = L1$. The CAPRI solution with this new land endowment provides a new land price ($PL2$) which is transmitted to NEMESIS. And the exchange process continues until both models reach an equilibrium¹⁹. Figure 4.2.3 then shows that the link between CAPRI and NEMESIS allows the introduction of a “flexible” land supply in CAPRI and allows the nicety of the NEMESIS land demand.

17. In practice, when the change of aggregated land price PL between two consecutive iterations is less than 1%.

18. Figure 4.2.3 is a simplification of land market in both models, that are in reality more complex.

19. As illustrated by figure 4.2.3, the equilibrium does not mean the same land price in the both models but none change in both models between two iterations. Thereby, as we will see in section 4.3, we will have two different land price equilibrium but only one for land quantity.

Figure 4.2.3: Linkage between CAPRI and NEMESIS: Illustrative scheme



In practice, the link between both models is implemented through a FTP (File Transfer Protocol) server allowing the execution of numerous simulations without manual manipulations that allow the running of eighty simulations during one week. In order to do this, the models check on the server, three different files every three minutes:

1. one indicating the identity of the simulation,
2. one allowing models to know if a new solution was found by one of the models and if it was added on the server,
3. and finally one including all the exchanged variables.

Going back to figure 4.2.2 and according to other models, EFISCEN receives national demand for wood (Wd) from NEMESIS and forest area (Lf) from Dyna-CLUE where Wd is converted into physical units and Lf in changes in forest area which are then added or subtracted from the forest area in EFISCEN. EFISCEN assesses whether the demand for wood can be satisfied and projects forest resource development. Feedback (Ew) is sent from EFISCEN to NEMESIS as a percentage deviation between Wd from NEMESIS and the wood removals calculated by EFISCEN on a national level. Thereafter, NEMESIS uses these results from EFISCEN to constrain Wd so that it cannot exceed the demand for which EFISCEN was run and all wood that cannot be harvested according to EFISCEN, was imported from outside EU in NEMESIS.

4.2.4 Linked models impact

4.2.4.1 Introduction

In order to investigate the linkage and interactions between the models and to display the added value of the coupled models, we illustrate the modelling framework with the help of a scenario on which the European Common Agricultural Policy (CAP) is abolished²⁰ after 2013 and where the EU budget from the “1st pillar” of the CAP is dedicated to financially support investment in R&D in the EU. We analyse what would have been the results of the simulation if each model had been run only once without the iterative feedback between CAPRI and NEMESIS which is done by looking at the outcome of the first iteration. We analyse impacts on land price, nitrate surplus, agricultural land use and GDP, which are outputs of CAPRI and NEMESIS. Thereafter, we focus on results obtained from the joint simulation of several models. For example, we focus on carbon sequestration by forest biomass in the EU (excluding Bulgaria, Cyprus, Greece and Malta). The impact on this indicator is estimated by EFISCEN, but based on changes in the demand for wood as projected by NEMESIS and on changes in the forest area as projected by Dyna-CLUE. To illustrate the importance of the Dyna-CLUE model, we also show results for agricultural land use at country level computed by NEMESIS and we compare them to re-calculated and disaggregated results from Dyna-CLUE²¹.

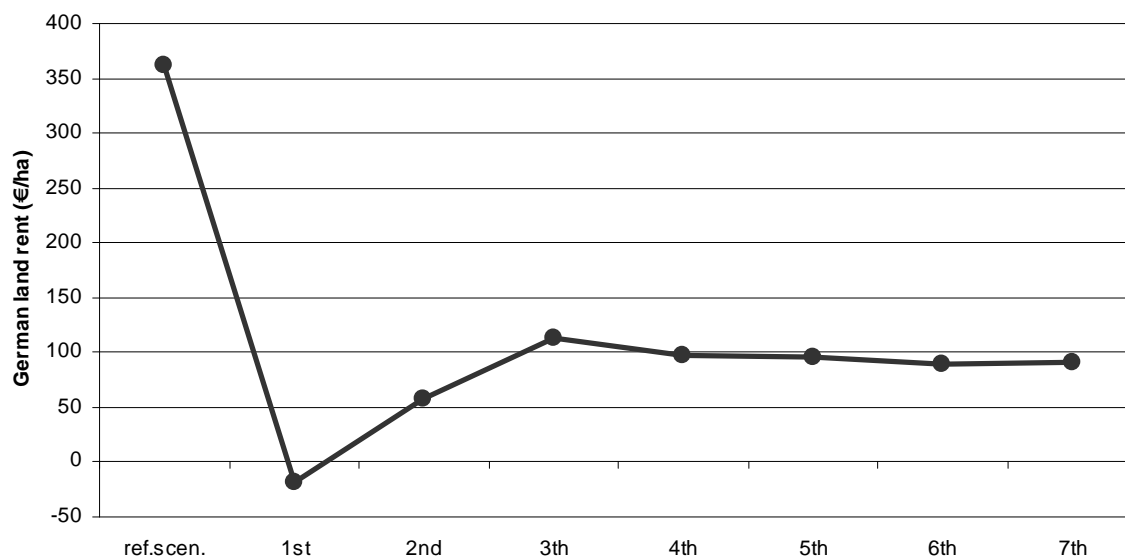
20. More detailed on the CAP reform and the economic results will be give in section 4.3. The goal of this section is just to show the added value of the linkages using CAP reform as illustration.

21. All results refer to the year 2025 and are generally expressed in percentage change with respect to (w.r.t.) the *reference scenario* (see section 3.2).

4.2.4.2 Impact of model feedback

Figure 4.2.4 shows the average land rent in Germany (€/ha) at the start of the simulation and in each of the seven iterations up to convergence of the models. The graph shows that in the first iteration, the land rent in CAPRI turned negative. This result can be explained given that several hundred euros of direct payments per hectare are removed as result of the policy reform and inasmuch as total agricultural land is fixed. If CAPRI had been used in isolation this would have been the simulation result. Figure 4.2.4 shows how the land rent adapted in the consecutive iterations through land contraction (due to increased land use by other sectors at lower prices and due to the stimulus of R&D spending) and demand for agricultural commodities increasing (from other sectors that expand and from consumers due to GDP increases). This makes it clear that for land rents and related land areas used by different sectors, the linked models matter. Significantly different results are then obtained after iterative convergence. Land rents influence sustainability indirectly through changes in land use by agriculture and by other sectors and the changes in agricultural prices. These changes in land rent reflect changes in the agricultural production mix which becomes more extensive in terms of input use and yields. Production intensity directly influences sustainability.

Figure 4.2.4: Agricultural land rents for Germany for seven linkage iterations



Source: CAPRI model

For instance, table 4.2.1 analyses the result from CAPRI on nitrate surplus per hectare, aggregated

over model regions. In the initial iteration, the average nitrate surplus per hectare was reduced by 3%, whereas it was reduced by 4% after convergence which corresponds to a relative difference of 25% in model results.

Table 4.2.1: Projected change in average nitrate surplus per ha compared to the *reference scenario*

	iteration 1	iteration 7
Average nitrate surplus per ha	-3.04%	-4.02%
(% change w.r.t. <i>reference scenario</i>)		

Source: CAPRI model

Another illustration of the importance of interactions between the models for policy analysis is shown in table 4.2.2 that displays the change in total agricultural land in the EU calculated with the linked models system (7th iteration), with CAPRI “stand alone” and with NEMESIS “stand alone” (*i.e.* taking the CAPRI link variables for the 1st iteration but without shifting the land demand in NEMESIS). For CAPRI, the land area stays at the initial level since there is no change in land supply simulated in this model whereas the CAP reform introduced in CAPRI leads NEMESIS to a new equilibrium for agricultural land after a decrease of 1% relative to the current area. Finally, with the linked system of models, the decrease in agricultural area amounts to 2.6%. This final common equilibrium for agricultural land in CAPRI and NEMESIS emphasises the complementarities existing between those two models. CAPRI is better suited than NEMESIS to compute changes occurring in land demand, simulating the production of 50 different agriculture products by representative farms operating at NUTS2 level. By iteratively shifting agricultural land demand in NEMESIS according to CAPRI results for land rents, NEMESIS takes advantage of CAPRI superiority to compute agricultural land rents.

Table 4.2.2: European agricultural land use change in models with and without linkage

Model setup	Agricultural land use change (deviation w.r.t. <i>reference scenario</i>)
CAPRI “stand alone”	0.00%
NEMESIS “stand alone”	-0.97%
Linked models (7th iteration)	-2.58%

Source: CAPRI and NEMESIS models

However, NEMESIS simultaneously considers interactions with agricultural land supply and all other sectors of the economy. The result of this interaction is utilised by CAPRI allowing the introduction of a land supply flexibility in it. The focus of the link is on land use insomuch as it is the most important channel of interaction between the modelled sectors. Nevertheless, many other indicators are less affected by the interactions between the models and in particular, the importance of the linkages for the whole of the economy is smaller. Table 4.2.3 shows change of real GDP in the initial iteration of the CAP reform scenario and in the final equilibrium for this scenario. A calculation of the average change in GDP growth across Member States reveals that the aggregate growth (over the period from 2005 to 2025) is 0.14 percentage point smaller (*i.e.* 6%) after iterations than after the initial shock, with a 2.28% increase of GDP instead of 2.42%. Thus, without the iterative link, the simulated GDP growth would have been slightly higher. The slight difference is due to the smaller drop in agricultural land price, which affects demands in NEMESIS. This small difference arises from the quasi independence of the overall economy according to what happens inside the agricultural sector, indeed the added value of agriculture represents less than 2% of total European added value.

Table 4.2.3: European GDP change in 1st iteration and in 7th iteration

	1 st iteration	7 th iteration
GDP (deviation w.r.t. <i>reference scenario</i>)	+2.28%	+2.42%

Source: NEMESIS model

Since Dyna-CLUE and EFISCEN are only solved after convergence between CAPRI and NEMESIS, no results from those models are available for the intermediate iterations. Selected integrated results involving those models in particular are discussed in the following section

4.2.4.3 Integrated model impact

Besides the possibility to include relevant feedback between the different models, the linked models also allow the assessment of impact using results from different models. The impact of the simulated financial reforms on carbon sequestration in forest biomass is shown in table 4.2.4. According to the projections, European forests remain a carbon sink of 61 244 Gg carbon under baseline development in 2025. Financial reform leads to an increase in the demand for wood, which explains the smaller sinks projected in Finland, Luxembourg, Roumania and Sweden in the financial reform scenario. However, reduced deforestation and increased afforestation and natural forest expansion compensate for this in

other countries, resulting in a net gain in the forest biomass sink. Overall, the forest biomass sink of the 23 EU countries would increase by 1 373 Gg carbon equivalent (2.2%) in 2025 as a result of the assumed financial reforms.

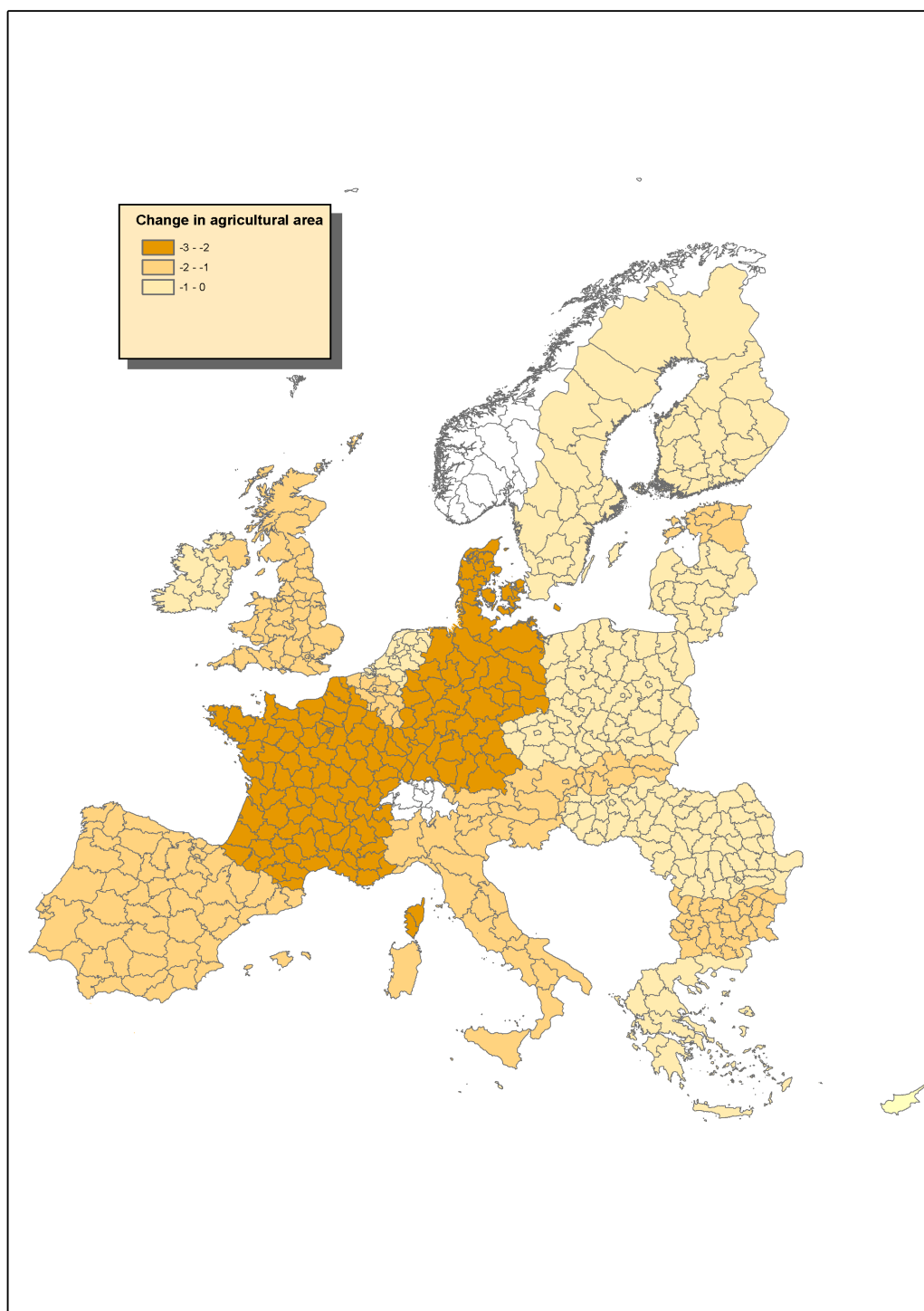
Table 4.2.4: Carbon sequestration by forest change in 2025

	Carbon sequestration (Gg) (deviation w.r.t. <i>reference scenario</i>)		Carbon sequestration (Gg) (deviation w.r.t. <i>reference scenario</i>)
AT	57	LT	128
BE	164	LU	-1
CZ	83	NL	63
DK	32	PL	87
EE	13	PT	5
FI	-39	RO	-97
FR	90	SK	35
GE	326	SI	6
HU	98	ES	160
IE	5	SE	-52
IT	48	UK	114
LV	50	EU-27*	1373

Source: EFISCEN model

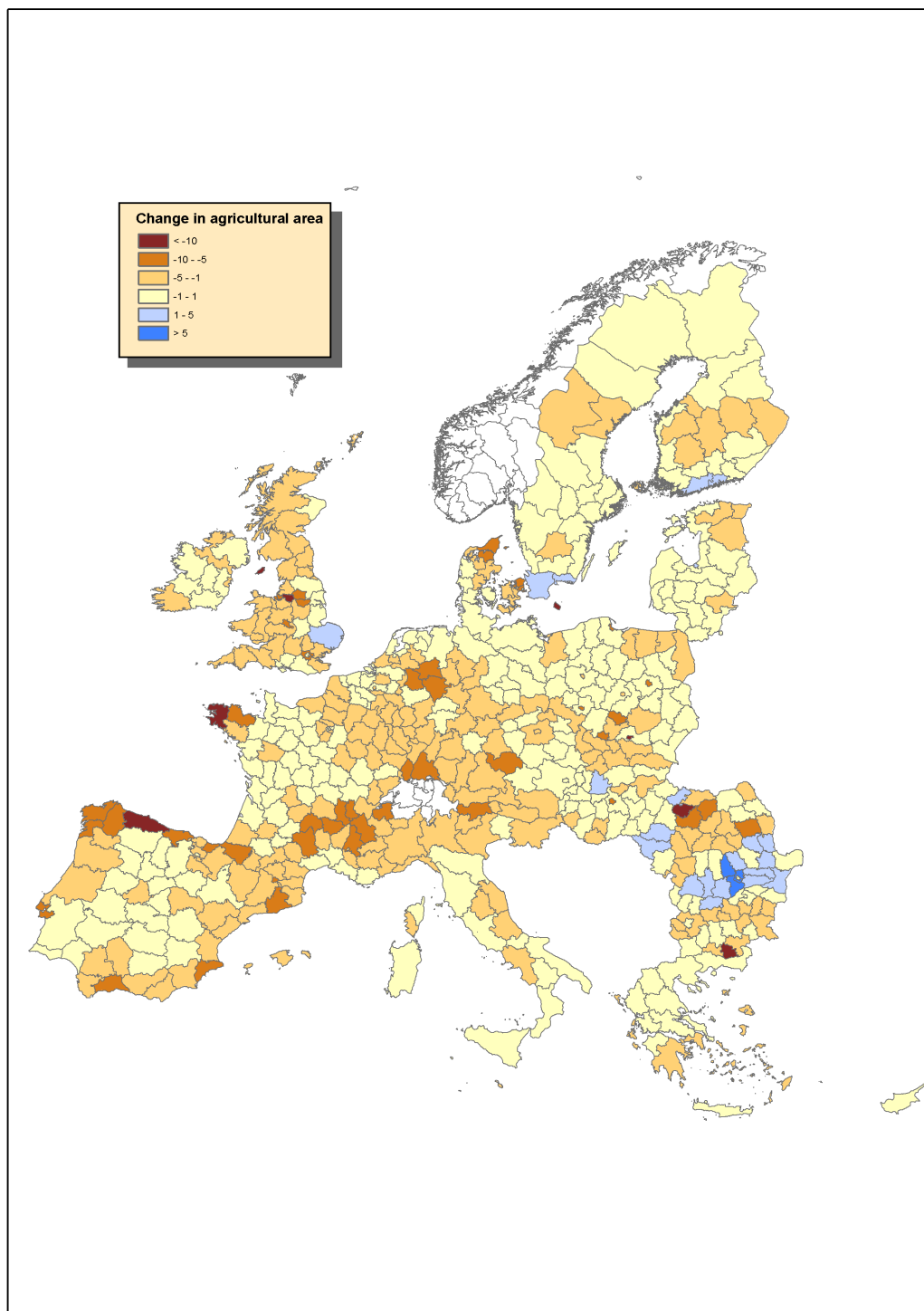
Figures 4.2.5 and 4.2.6 illustrate the importance of Dyna-CLUE in the model chain. The first map (figure 4.2.5) shows agricultural area change (including pasture) at national level coming from NEMESIS. The second map (figure 4.2.6) shows the same national agricultural area change after processing with Dyna-CLUE and aggregation to in European regions. Clearly, land is highly heterogeneous across 466 regions, so that not all regions react in a similar way, and some regions may even react in a qualitatively different way than the country as a whole.

Figure 4.2.5: Agricultural land change in NEMESIS in 2025 (National level)



Source: NEMESIS model with map representation by Dyna-CLUE model.

Figure 4.2.6: Agricultural land change in Dyna-CLUE in 2025 - re-calculation and disaggregation of NEMESIS land use changes (NUTS3 level)



Source: Dyna-CLUE model.

4.2.5 Discussion and concluding remarks

Economic, agricultural and environmental policies tend to have a wide range of side-effects on others sectors. Sustainability impact should be studied throughout all involved sectors. This section has introduced an approach of consistent use a set of existing models to analyse the sustainability impact of such policy changes. The short examples of results for CAP reform scenario illustrate, for instance, that impact on agriculture without macro-economic feedback could lead to erroneous results: the entire economy and land use system are affected, mainly via shared land resource. Furthermore, focusing on the agricultural sector alone would not yield insights into the macro-economic implications or the implications for forestry. These interactions suggest that advanced sector models or generalised multi-sector models cannot individually analyse such policy scenarios as well as a consistently linked system. Many existing modelling frameworks that aspire to include all sectors of the economy either focus on specific sectors or use weak top-down linkage between models (*e.g.* SCENAR2020 project: Nowicki *et al.* 2006 [369]; EURURALIS project: van Meijl *et al.* 2006 [456] and Verburg *et al.* 2008 [461]; INSEA project: Kraxner *et al.* 2007 [319], LUMOCAP project: van Delden *et al.* 2010 [453]; Helming and Banse 2008 [265]; Britz *et al.* 2010 [56]) but none implemented a linkage framework like the one presented in this chapter *i.e.* with bi-directional exchanges (downstream and upstream) and with the seeking of a common equilibrium for a fundamental variable: the land market. By the comparison between outcomes of an initial iteration with the models and the final fully converged results, we observe the advantage of allowing stronger iterations between the models to ensure a full consistency of results for land-use, forestry, agriculture, economic and environmental indicators.

We conclude this section with a discussion of some shortcomings of the current approach. Although, it seems theoretically possible to link all variables where there is an overlap between model output and especially where the output of one model serves as input in another, only a part of such links could be implemented to ensure a manageable and operational system. Nevertheless, this omission may lead to harmonisation bias and potential for error propagation. Some of the potential problems due to omitted links are the following:

- External trade, endogenous in both NEMESIS and CAPRI: the removal of NEMESIS agricultural production for CAPRI one does not dispense keeping equilibrium between resources and uses in NEMESIS and therefore external trade and especially imports from the rest of the World ensure this equilibrium.
- Aggregated agricultural input use, endogenous in both NEMESIS and CAPRI, despite the exo-

genous agricultural production in NEMESIS, we kept the NEMESIS input demands.

- Finally, the demand for wood cannot always be satisfied in each country individually. EFISCEN does not capture international trade in wood products within or outside Europe. For simplicity, we assumed that wood that cannot be harvested according to EFISCEN will be imported from outside EU by NEMESIS. Incorporating more dynamic international trade in Europe within EFISCEN based on NEMESIS would allow dynamically projecting wood supply and enhancing our results.

The magnitude of the possible errors due to omitted linkage could possibly be quantified by computing the difference between overlaps. We argue that the links implemented in this study represent the most important interactions in terms of the sector model share in total resource endowment, and that the additional benefits of further integration would be diminishing even if not necessarily negligible. In particular, as it is argued above, land is a key resource for sustainability impact assessment that is shared among sectors, whereas *e.g.* labour and capital balances are more fully accounted for by sectors that are only modelled as part of NEMESIS. However valuable the results of the linked model system, the process of developing it has also shown how much effort is involved in linking up large scale systems, where detailed knowledge of all components is required. In particular, the technical overhead required in terms of software development was larger than expected even if it does not appear in the linked models description.

4.3 Common agricultural Policy reforms: Application with the linked models

4.3.1 Introduction

In 2005 there was considerable debate in the European Council of Ministers on the long-term EU budget (known as the financial perspective) for the period 2006-2013. There was considerable pressure from several Member States (MS) to further reduce or even to abolish the Common Agriculture Policy (CAP), while there was a British proposal to spend the funds that would be released towards achievement of the Lisbon Agenda (*e.g.* by spending them on Research & Development - R&D). These proposals were unsuccessful but the debate is still on going²² and will be much more impassioned with the recent economic recession and the connected problems of public debt sustainability. Recently, the Commissioner Dacian Cioloş opened, in April 2010, a public debate on CAP reform beyond 2013. This debate must lead, before December 2010, to a first proposal from the European Commission that will be followed later by proposition on CAP financial perspective. The CAP budget debate will be probably a source of divergence among MS with several major issues:

- The importance of the CAP budget according to other budgets (nearly half of total EU budget in 2008).
- The repartition of the budget between the CAP objectives²³ and particularly between the 1st Pillar (direct and market supports) and the 2nd Pillar (competitiveness, environment and rural development).
- The direct decoupled income support of the CAP is difficult to justify *vis-à-vis* taxpayers and consumers and especially according to the repartition based on 2000-2002 criteria²⁴. Furthermore, these supports are also criticised in the achievement their objectives (*e.g.* Sahrbacher *et al.* 2007 [411], Ekman and Rabinowicz 2007 [169]).
- The trade-distorting effects of the CAP are an obstacle to the trade liberalisation process (WTO)

22. See *e.g.* the European Institute for Environmental Policy website dedicated to the future CAP budget: www.cap2020.ieep.eu, the report of the Académie d'Agriculture de France (Bazin *et al.* 2010 [28]) or the Conference called "From the CAP to Competitiveness: The Common Agricultural Policy and the European Budget" and organised by The German Marshall Fund of the United States, the Groupe d'Économie Mondiale (Sciences Po) and the Association of Swedish Chambers of Commerce at Brussels in June 2009 (<http://www.cap2020.ieep.eu/2009/6/26/cap-to-competitiveness>).

23. There are several studies that propose the inclusion, the ending or the modification of several CAP objectives, see *e.g.* Bureau and Mahé (2008 [63]) or Bazin *et al.* (2010 [28]).

24. Problems exposed by Commissioner Dacian Cioloş during its speech for the opening of the public debate on CAP reform beyond 2013 at Copenhagen, the April 26th 2010 [98])

- World Trade Organization) which is generally supported by EU institutions at least in the long term.
- The slow progress of the Lisbon Agenda (*e.g.* EC 2010 [151], Kuhlman 2008 [322]) and the need of economic growth to diminish the effects of the financial crisis on employment and private and public finances.

In this section, we specify and investigate a policy reform that jointly addresses some of those issues. In order to do this, we use the linked models presented in previous section (section 4.2). The policy change consists of (i) a complete/partial removal of the direct income support in CAP 1st Pillar; (ii) a radical trade liberalisation removing agricultural border protection unilaterally for the EU versus all third countries; and (iii) transfer of the funds thus released either to R&D subsidies for overall economic sectors or to general tax refunds. The scenarios are quantitatively analysed for the year 2025, and are evaluated against the *reference scenario* (see section 3.2) where currently decided policies are extended.

The hypothesis underlying the exercise is that the common budget currently used for (partially) decoupled income support in agriculture could contribute substantially to the goals of the Lisbon agenda or the new Europe 2020 strategy (EU 2010 [192]). Furthermore, the agricultural sector will suffer from a substantial income loss, but this loss is likely to be small compared to the economic growth induced by the increased R&D spending. The assessment requires a detailed agricultural analysis for direct effects of the reform, and a macro-economic analysis of the effects of increased R&D spending. We may expect bi-directional feedback effects. On the one hand, the expected changes in the agricultural sector may be sufficient to influence the rest of the economy. On the other hand, the changes in the rest of the economy invoked by the R&D spending will also affect agriculture. In order to take such feedbacks into account, the system of linked models is used, which includes several sector models: agriculture (CAPRI), forestry (EFISCEN), land use (Dyna-CLUE) and a macroeconomic one (NEMESIS) covering all those sectors as well as other economic sectors²⁵.

25. Only results from CAPRI and NEMESIS will be used and commented, here, to clarify the study.

4.3.2 Scenarios definition

The CAP was introduced by the Treaty of Rome in 1957 and has been reformed progressively up to 2003 reform and 2008 CAP “Health Check”²⁶. Despite the numerous criticisms from some MS in 2005, on the share of CAP in EU budget and on EU budget priorities, the CAP budget for 2007 to 2013 was adopted and it still gives huge funds for the European agricultural policy (EU, 2006 [187]). Nevertheless the emphasis on the questioning of CAP budget should imply important consequences for CAP budget beyond 2013.

4.3.2.1 The context

Before describing in detail the scenarios implemented with the linked models, we start by presenting the present situation of the CAP budget in order to have some crucial keys as well as some order of magnitude (see table 4.3.1)²⁷.

Table 4.3.1: EU expenditures in 2008.

	€ Billion	Share of total EU budget
1. Sustainable growth	45.6	39.1%
2. Prevention and management of natural resources	54.8	47.0%
- Market related expenditure and direct aids (1 st Pillar) of which	43.3	37.2%
- Direct supports to farmers	36.8	31.6%
- Market supports	6.5	5.6%
- Rural development (2 nd Pillar)	10.5	9.0%
- Other	1.0	0.8%
3. Citizenship, freedom, security and justice	1.3	1.1%
4. The EU as a global player	7.3	6.3%
5. Administration	7.3	6.3%
6. Compensation	0.2	0.2%
Total	116.5	100%

Source: EC, 2009 [148].

26. For a detail CAP history and for actual CAP functioning, please refers to Bureau 2007 [64] or Loyat and Petit (2008 [340])

27. For a recent detailed description of the CAP mechanisms, see Jomini *et al.* 2010 [303].

In 2008, the overall EU expenditure²⁸ was about €116.5 billion (*i.e.* 0.93% of EU-27 GDP) divided in six headings of which two main items: Prevention and management of natural resources with €54.8 billion (*i.e.* 47% of total EU expenditure) corresponding to the CAP; and sustainable growth with €45.6 billion (*i.e.* 31.9% of total EU expenditure). The CAP expenditures following the both “pillars” are split as follows:

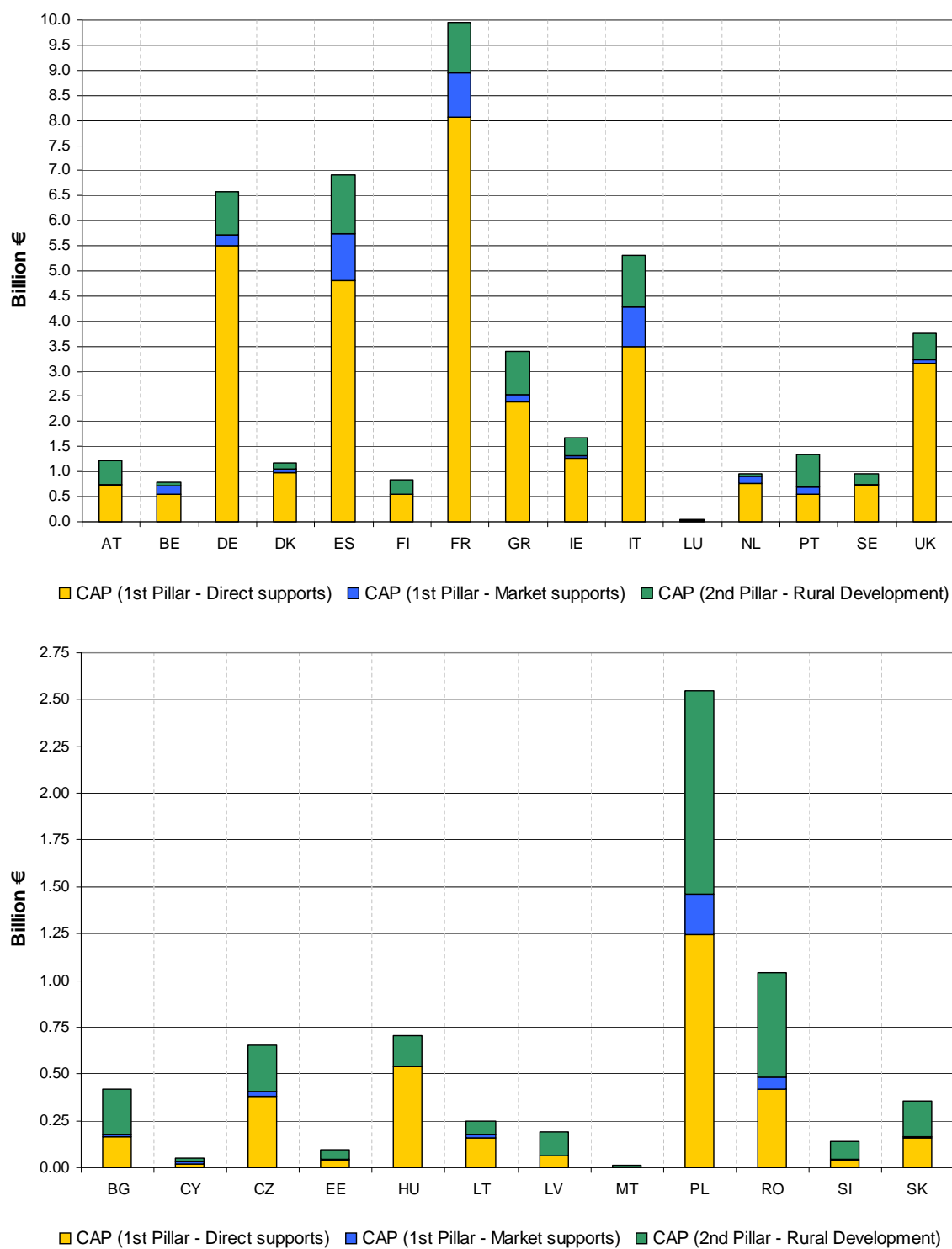
- **1st Pillar** corresponding to market support mechanisms and direct supports to farmers with 37.2% of EU total expenditure *i.e.* **€43.3 billion**,
- **2nd Pillar** supporting rural development initiatives with **€10.5 billion** (9.0% of EU total expenditure).

Looking at these number, the CAP budget is still the largest expenditure of EU and especially as the market and direct supports still represent more than 80% of the CAP budget. Nevertheless, the share of the 2nd Pillar in total CAP expenditure has increased significantly since 2000 passing from 10% to reach almost 20% in 2008. This moving from market and direct supports towards environmental and rural development is generally admitted in the publications as a the long term strategy *i.e.* beyond 2013 (see *e.g.* Bureau *et al.* 2007 [62], Bureau and Mahé 2008 [63], Brady *et al.* 2009 [52] or Bazin *et al.* 2010 [28]). Indeed the 2nd Pillar concerns European public goods more directly and therefore it is more in accordance with the subsidiarity principle (Brady *et al.* 2009 [53]). According to the Special Eurobarometer n°336 (EC 2010 [150]), this orientation also reflects the European citizens preferences on CAP objectives that emphasise environmental protection, food supply security and quality, health and safety of agricultural products.

Now, looking at CAP Pillars expenditures by MS level (figure 4.3.1), we observe a relative heterogeneity in the repartition of both Pillars in 2008. On average for EU-27, 1st Pillar for direct support represented 72% of total expenditures, 1st Pillar expenditures for market support covered around 8% and the 2nd Pillar accounted for 20% of European agricultural policy expenditure. But, direct supports to New Member States (NMS) represented much less with 50% (*i.e.* €3.2 billion) whereas they reached 72% (€36.8 billion) in EU-15. Market supports were also, proportionally, a more important resource for EU-15 (8% *i.e.* €3.7 billion) than for NMS (5% *i.e.* €0.3 billion). Consequently the share of the CAP expenditures for the 2nd Pillar was bigger in NMS (45% *i.e.* €2.9 billion) than in EU-15 (17% *i.e.* €7.7 billion).

²⁸. The data used are expenditures, consequently they can exhibit differences with the budget at least for variables in level.

Figure 4.3.1: CAP expenditure in 2008 by Member State



Source: EC, 2009 [148].

The difference is explained by the axis of both Pillars and especially as one axis of the 2nd Pillar is enhancing competitiveness mainly through capital grants that are much more necessary and successful in NMS (Brady *et al.* 2009 [53]). But it could also come from historical payments, the basis of the Single Payment Scheme (SPS)²⁹ that NMS do not use³⁰. Nevertheless direct payments to NMS increases gradually following the 10-year phasing-in scheme (EC, 2009 [148]).

Table 4.3.2 compares the extent of CAP expenditure in MS. In EU-27 average, total CAP expenditure represented, in 2007, 17.3% of the European agricultural production, and 1st Pillar expenditures for direct supports accounted for 20.1% of European gross farmers income. As implied by the previous results, direct supports covered only 8.8% of farmers income in NMS³¹ and 22% in the EU-15. This difference is less marked for agricultural production (for which the ratio includes overall CAP expenditures) where CAP accounted for 18.1% in EU-15 and 12.8% in NMS. Finland, Greece, Ireland, Portugal and Lithuania were the bigger receivers of CAP funds compared to production, in 2007, with respectively 29%, 35.3%, 38.2%, 49.5% and 33.7%. But, looking at GDP criteria, the spending in Finland was in the EU-27 average (0.41%) with 0.45%. The share in GDP of CAP funds received in 2008 were about 0.4% in EU-15 and 0.65% in NMS. Greece, Ireland, Portugal and Lithuania were still among the main receivers (1.42%, 0.92%, 0.8% and 0.77% respectively) but other countries appears also as important receivers according to their GDP as for instance Latvia (0.81%), Bulgaria (1.23%) and Roumania (0.75%). On the contrary, countries like the Netherlands, Denmark, Cyprus or Malta have received little funding with regard to their agricultural production with only 5%, 11.6%, 10.9% and 8.3% respectively. The results are confirmed for the Netherlands and Malta, looking at the share of the CAP expenditures on GDP, with respectively 0.16% and 0.18%. Finally, we also observe that CAP funds in Luxembourg accounted only for 0.13% of its GDP but as the added of agriculture in GDP is very weak, the CAP funds still reached 21% of its agricultural production.

29. SPS is implemented according to (i) the “historic” model on “*which payment entitlements are based on individual historic reference amounts per farmer*” (Austria, Belgium, Ireland, Italy, Portugal, UK-Scotland, UK-Wales, France, Greece, Netherlands and Spain), (ii) the regional model where “*flat rate payment entitlements are based on amounts received by farmers in a region in the reference period*” (Malta and Slovenia) and (iii) a hybrid model that combined the two others approaches either in a static (Denmark, Luxembourg, Sweden and UK-Northern Ireland) or a dynamic (Germany, UK-England and Finland) framework (EC, 2008 [155]).

30. NMS use a transitory scheme: Single Area Payment Scheme (SAPS) which is based on a uniform payment per hectare, up to a national ceiling.

31. We must note that the table 4.3.2 use 2007 data for agricultural production and gross farmers income and therefore the funds received by Romania and Bulgaria were yet weak. But for GDP, table 4.3.2 uses 2008 data, allowing a better evaluation of the CAP extent in both countries.

Table 4.3.2: Extent of CAP expenditure in member states

CAP share in:	AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT	SE	UK
- Gross domestic product*	0.43%	0.23%	0.26%	0.50%	0.64%	0.45%	0.51%	1.42%	0.92%	0.34%	0.13%	0.16%	0.80%	0.28%	0.21%
- Agricultural production**	21.2%	13.1%	16.9%	11.6%	20.7%	29.0%	19.8%	35.3%	38.2%	13.2%	21.0%	5.1%	49.5%	25.6%	20.3%
- Gross farmers income***	17.6%	15.9%	26.3%	24.1%	21.0%	21.6%	26.0%	26.7%	35.1%	12.4%	19.5%	8.1%	33.9%	34.5%	34.6%

CAP share in:	BG	CY	CZ	EE	HU	LT	LV	MT	PL	RO	SI	SK	EU-15	NMS	EU-27
- Gross domestic product*	1.23%	0.30%	0.44%	0.60%	0.64%	0.77%	0.81%	0.18%	0.70%	0.75%	0.38%	0.55%	0.39%	0.65%	0.41%
- Agricultural production**	0.0%	10.9%	16.1%	18.8%	17.2%	33.7%	17.9%	8.3%	14.9%	0.1%	19.9%	21.4%	18.1%	12.8%	17.3%
- Gross farmers income***	0.0%	6.6%	15.8%	10.5%	17.9%	13.7%	10.0%	2.3%	9.2%	0.0%	8.5%	13.3%	22.0%	8.8%	20.1%

*: GDP and CAP expenditure in value for 2008, sources: EC 2009 [148] and Eurostat 2009 [204].

**:Agricultural production and CAP expenditure in value for 2007, sources: EC 2009 [148] and FADN 2009 [144].

***:Gross farmers income and CAP expenditure only included direct supports in value for 2007, sources: EC 2009 [148] and FADN 2009 [144].

To finish our analyse of the CAP financial context, we must also present the resources coming from CAP and especially from agricultural duties (€1.7 billion in 2008) and sugar levies (€0.9 billion) for which 25% are kept by the EU for collection costs. The revenues coming from agricultural duties and sugar levies remained relatively stable between 2004 and 2008 representing around 2.2% of total EU resources. Therefore, the “net” CAP expenditures in 2008 for market support were about €4 billion *i.e.* 9% of the total CAP expenditures.

We have presented briefly in this section the financial context of the current CAP on which the CAP reform scenarios are based and which are described in the following section.

4.3.2.2 CAP reform scenarios

We start our analysis with the *reference scenario* presented in section 3.2 on which we have implemented a set of political shocks referring to CAP instruments. In practice, nineteen scenarios were simulated based on combinations of those three instruments *(i)* a removal of market supports, *(ii)* a cut of direct supports about 25%, 50% and 100%, *(iii)* and recycling of released funds through either tax rebate or subsidies to R&D.

The **removal of market supports** consists in an unilateral liberalisation, including: Most Favoured Nation (MFN) bound tariff rates down by 90%, trigger prices and minimum border prices removed and lowered by 50% respectively, consumption subsidies down by 90%, intervention and export subsidies abolished, sugar and dairy quotas lifted³². In the *reference scenario*, the market supports are kept identical to the ones of 2008. **Direct supports** include the Single Payment Scheme (SPS) and Single Area Payment Schemes (SAPS) and the remaining coupled payment of the 1st Pillar except the ones under article 69³³ which are not modelled in CAPRI³⁴. In the *reference scenario*, the direct supports to farmers, in 2025, result on the application of this CAP framework leading to a total amount of €40.5 billion.

The released funds coming from market supports removal and/or cut in direct supports are either **transfers to consumer** through a lump sum (called *Tax rebate* scenarios) or to sectoral subsidies to **R&D investments** (called *R&D investments* scenarios). In *Tax rebate* scenarios, in order to focus on

32. All these instruments are detailed in the CAPRI model (Britz and Witzcke 2008 [57]) that implements those instruments in CAP reform scenarios.

33. Article 69 (EU 2003 [184]): “Optional implementation for specific types of farming and quality production”

“Member States may retain up to 10 % of the component of national ceilings [...]. In this case [...] the Member State concerned shall make, on a yearly basis, an additional payment to farmers in the sector or sectors concerned by the retention. [...]”

34. Idem footnote n°32.

the effect of policy instruments and to avoid re-allocation effects, we have allocated the released funds to MS according to the CAP expenditure so that they should received without the implementation of the scenarios *i.e.* there is no re-allocation of funds coming from the CAP between MS and between *Tax rebate* scenario and the *reference scenario*. In the *R&D investments* scenarios, the allocation of saved funds from CAP reform are not returned to MS directly, but are instead used to increase the R&D efforts in each country proportional to the country's GDP. These funds are thereafter split between the NEMESIS sector³⁵ with respect to their R&D intensity *i.e.* the ratio between sectoral R&D investments and its production in the *reference scenario*. This scheme was retained for *R&D investments* scenarios to avoid disproportionate transfers according to GDP and R&D investments in the *reference scenario* even at the expense of re-allocation effects.

In the following section, we present the results of the CAP reform with the linked models. In a first part, we will briefly focus on the impact of both instruments: market supports and direct supports where released funds are given back to MS via *Tax rebate*. Whereas in the second part, we will present and discuss the economic results of both CAP budget re-allocation through two “extreme” scenarios: an unilateral liberalisation of European agriculture with a complete removal of direct supports to farmers (*i.e.* an abolition of the CAP 1st Pillar) either recycling through *Tax rebate* or subsidies to *R&D investments*.

35. See NEMESIS sectoral nomenclature in Appendix B.

4.3.3 Instruments effects

The simulations realised with the linked models allow in first of all the assessment of potential impact on agricultural productions and prices, land use and the overall economy of both 1st Pillar main instruments: the direct supports to farmers (SPS and SAPS) and the market supports (imports duties, exports subsidies, market interventions, quotas, ...).

4.3.3.1 Agriculture

Table 4.3.3 displays the impact on agriculture of the CAP reform with *Tax rebate*, for EU in 2025 and for a policy introduced from 2013. The percentage refers to the difference with respect to the *reference scenario*. Nine scenarios are presented on which four include removal of direct supports of about 25%, 50%, 75% and 100% without abolition of markets supports (left side of the table 4.3.3) and five scenarios with abolition of market support combined with either none suppression of direct support or progressive removal (*i.e* 25%, 50%, 75% and 100% - right side of table 4.3.3).

The agricultural production at European level is little impacted by **the removal of the direct supports**, with a decline about only -1.8% of the total agricultural production in 2025 for a complete removal of direct supports. Vegetal production is slightly more affected with -2.5% that the animal production with -1.2%. Indeed, the decoupled payments have little influence on production in the CAPRI model, a conclusion in accordance with the literature on the potential coupling of decoupling. Bhaskar and Beghin (2009 [37]) have released a survey on the coupling mechanisms of decoupled payments in theoretical and empirical papers. They conclude despite some channels of potential coupling of decoupled payments³⁶ that the magnitude of the channels on agricultural production is very small³⁷.

The production of cereals, grain maize, soft wheat or fodders (between -4% and -5.5%) are slightly more affected by the removal of direct supports than fruit, vegetable and sugar beet (between -0.5% and -1.5%). Whereas for animal production, the range of impact between production types is weaker, beef and veal meat are the more concerned with a decrease of about -2.6%, at opposite milk and eggs and poultry meat are not very sensitive to a removal of direct support with respectively a production loss of -0.6% and -0.7%.

36. Bhaskar and Beghin (2009 [37]) identify five major coupling channels of decoupled payments: risk faced by farmers, credit constraints, labour allocation, lands market and farmers expectation on future payments.

37. Nevertheless, Féménia *et al.* 2010 [229] have discussed the wealth effects with actualisation and show that the coupled effects can be probably more higher than previously estimated.

Table 4.3.3: CAP reform agricultural results at European level, in 2025, *Tax rebate* scenarios

	Market supports continued				Market supports abolished				
	Removal of direct supports				Removal of direct supports				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
<i>%: Difference w.r.t. reference scenario</i>									
Total agricultural production*	-0.58%	-1.03%	-1.50%	-1.78%	-0.69%	-1.23%	-1.65%	-2.09%	-2.41%
- Vegetal production*	-0.89%	-1.48%	-2.10%	-2.47%	-1.16%	-1.98%	-2.52%	-3.18%	-3.62%
(a) Fruits and vegetable**	-0.38%	-0.73%	-1.08%	-1.27%	0.04%	-0.32%	-0.66%	-0.96%	-1.17%
(b) Cereals (barley, durum wheat, oats, ...)**	-2.07%	-3.30%	-4.64%	-5.39%	0.28%	-1.58%	-2.70%	-4.14%	-5.05%
(c) Oil seeds (sunflowers, rape seeds, soya, ...)**	-0.92%	-1.48%	-2.13%	-2.55%	0.67%	-0.31%	-0.86%	-1.50%	-1.91%
(d) Sugar beet**	-0.44%	-0.62%	-0.78%	-0.91%	-14.50%	-15.27%	-15.54%	-15.90%	-16.14%
(e) Grain maize**	-1.15%	-2.53%	-3.54%	-4.12%	-2.39%	-3.77%	-4.66%	-5.70%	-6.43%
(f) Soft wheat**	-1.67%	-2.62%	-3.54%	-4.16%	-0.60%	-2.04%	-2.87%	-3.94%	-4.68%
(g) Fodders (maize, root crops, ...)**	-1.86%	-3.16%	-4.33%	-4.87%	-2.15%	-3.98%	-5.14%	-6.44%	-7.18%
- Animal production*	-0.32%	-0.64%	-1.00%	-1.21%	-0.30%	-0.59%	-0.91%	-1.18%	-1.39%
(a) Beef and veal meat**	-0.72%	-1.40%	-2.12%	-2.63%	-8.67%	-9.51%	-10.30%	-11.10%	-11.78%
(b) Sheep and goats meat**	-0.47%	-0.70%	-1.00%	-1.14%	-2.70%	-3.18%	-3.42%	-3.71%	-3.91%
(c) Poultry meat**	-0.32%	-0.43%	-0.64%	-0.74%	-1.80%	-1.92%	-2.03%	-2.08%	-2.12%
(d) Pork meat**	-0.55%	-0.87%	-1.28%	-1.52%	0.86%	0.76%	0.60%	0.54%	0.50%
(e) Milk and eggs**	-0.04%	-0.28%	-0.50%	-0.62%	2.78%	2.53%	2.25%	2.01%	1.82%
Agricultural products prices*	0.61%	1.02%	1.56%	2.06%	-9.63%	-9.75%	-9.07%	-8.57%	-8.76%
- Vegetal products prices*	0.64%	0.97%	1.46%	1.93%	-5.32%	-5.36%	-4.72%	-4.18%	-4.19%
- Animal products prices*	0.62%	1.19%	1.88%	2.50%	-15.67%	-15.81%	-15.05%	-14.51%	-14.93%

*: in volume (monetary unit - €₂₀₀₀), source: NEMESIS and CAPRI models. **: in volume (ton), source: CAPRI model.

The results for agricultural production are little differentiated between the EU-15 and NMS³⁸ with a decline of -1.9% and -1.7% respectively. Nevertheless regarding country level, they appear to be more contrasted. For instance, the total agricultural production falls by -9.2% in Finland and -4.5% in Lithuania and stays stable in Slovenia and Romania (+0.2). In other countries like France, Spain, Germany or United Kingdom, the production decrease is close to the European average (-2.8%, -1.8%, -2.4% and -0.9% respectively). Globally, the biggest recipient countries of CAP supports such as Greece, Portugal or Ireland (according to their agricultural production) are little impacted by the removal of direct supports. These surprising results can be explained by the slow down of structural change implied by the direct supports based on land, playing as a barrier to entry, as found in the literature (*e.g.* Sahrbacher *et al.* 2007, Bureau and Mahé 2008). Therefore the removal of direct supports tends, in the medium and long term, to speed up the shake-up of farms and push up the competitiveness of these farms.

The removal of direct support for farmers also have a slight effect on agricultural product prices, at European level, vegetal product prices increase by about +1.9% and animal products of +2.5%. According to a demand for agricultural products with very weakly elastic prices, this raise of agricultural product prices results, on one hand, in the decrease of agricultural supply in Europe, and on the other hand, on continued market supports.

In the case of **an unilateral liberalisation** of European agriculture (suppression of market supports), agricultural production is also only slightly impacted, the EU production declining about -0.7% with -0.3% for animal production and -1.2% for vegetal production. These results are relatively surprising. With the fall of market protection, we expect a significant reduction of agricultural production. Three mechanisms explain these results:

- The fall of vegetal product prices (-5.3%) reduces the input cost for animal production, fodder products representing a high share in feedstuffs (about 50% to 70%). This decrease of production costs lowers the negative impact of market support cuts on protected animal production, like beef meat that decreases by about -8.7%. In turn, it increases the competitiveness of less protected animal products like pork or poultry of which the share in total animal production has already raised in the *reference scenario* (see section 3.2).
- The aggregation of animal and vegetal products production hides strong re-allocation between

38. See Appendix E for detailed results at EU-15, NMS and national level.

agricultural production types. The high protected products such as sugar and beef meat are strongly penalised by the liberalisation. Their production goes down by -14.5% and -8.7% respectively whereas the production of fruit, vegetables, oil seeds, pork and poultry meat that are little or not protected are then weakly impacted and even benefit of the suppression of market supports (0%, +0.7%, -1.8, +0.9% respectively). For milk, the removal of quotas allows an increase of the production of 2.8% which is characterised by a strong heterogeneity between MS, milk production increases strongly about +17.9% in Greece, +9.9% in Romania and +5.9% in United Kingdom and decreases slightly in Poland (-0.6%) and Sweden (-1.6%) therefore the suppression of milk quotas allows a re-allocation of the milk production among MS.

- The aggregates (animal, vegetal and total production), for NEMESIS needs, are in a monetary unit which through composition effect distorts aggregate results compared to by-products production which are in physical units.

According to agricultural price products, the fall of -9.6% in EU results from the convergence of EU prices to World prices, then animal product prices decrease (-15.7%) more than vegetal products (-5.4%).

Finally, the **combined effects of market and direct supports suppression** provide similar results, a small change in agricultural production (-2.6%) and a strong decrease of agricultural products prices (-8.7%)³⁹. We will not go into detailed results for agriculture but it is important to comment and explain the difference between MS. Indeed, there is a strong heterogeneity among MS, some European countries profit by CAP reform (Ireland, Netherlands, Malta), others are very little affected like Greece or Denmark whereas countries, like Finland, Sweden, Latvia and France, are more penalised by the CAP reforms.

For Ireland and the Netherlands the benefits of the CAP reform come from the composition of their agriculture production that provides for almost half of dairy products (45% for Netherlands and 47% for Ireland in 2025 in the *reference scenario*, in €₂₀₀₀). We saw that the dairy sector has benefited, in terms of production volume, from the liberalisation and especially from the dairy quotas suppression. Nevertheless, the benefits are very heterogeneous among European countries, indeed the abolition of dairy quotas have strong re-allocation effect among MS because of the estimation of quota rents in the *reference scenario*. The quota rents reflect differences in marginal cost, a lower marginal cost meaning

39. See figure 4.3.3 in the following section 4.3.4.

an higher dairy quota rents (Witzke and Tonini 2008 [473], Réquillart *et al.* 2008 [410]). Therefore, the combination of a huge share of dairy products in total production with high dairy quota rents in the *reference scenario*, pushes up agricultural production in the Netherlands and Greece⁴⁰. At the opposite and, the “losers” of the milk quota abolition are those with low dairy quota rents *i.e.* high marginal costs, like Finland, Italy and Sweden that lose -15%, -4% and -2.5% of their dairy production while it increases by +6% and +7% in the Netherlands and Greece. Furthermore, in the Netherlands, more than 17% of the total agricultural production stems from pork meat which also benefit from the CAP reform. It is also pork meat in addition to poultry meat that push up the production in Malta, where both products represent more than 40% of its agricultural production in 2025 in the *reference scenario*. With regard to Greece, even though it is one of the biggest receivers of European agricultural funds whatever the criterion (GDP, agricultural production or farmer incomes - see table 4.3.2), its total production decreases only by -0.3%. This is partially explained by dairy quota rents, but also because of the size of its fruit, vegetable and olive oil production that covers more than 70% of its total agricultural production of which are little or none affected by the CAP reform. Similarly the slight loss of production in Denmark can be explained by the share of 40% of pork meat in its total agricultural production. And finally France is penalised by a production composed of products for which the production falls with the CAP reform like -18% for beef (representing 13% of its total agricultural production in 2025 in the *reference scenario*), -9% for maize (with a share of 5%) and -6% for wheat (with a share of 10%). In addition, weak competitiveness compared to other MS such as for dairy products leads to loss of market share in the EU and the rest of the World.

4.3.3.2 Agricultural land use

The removal of direct support to farmers impacts heavily on agricultural land use and especially on agricultural land price. Indeed, as identify in the literature (*e.g.* Gohin 2006 [240] or Sharbacher *et al.* 2007 [411])⁴¹, the land-based decoupled payments, are either fully or partially capitalised in land prices. Then, whatever the degree of capitalisation, decoupled payments increase land price. The linkage modelling framework, implemented for those assessments, allows the distinction of direct supports impacts on land prices either with a complete **capitalisation** (from CAPRI model) either without capitalisation (NEMESIS model). Indeed, as presented in section 4.2, the convergence framework on

40. Please see IPTS 2009 [290] for description of dairy quota rents in CAPRI.

41. See Latruffe and Le Mouél 2009 [324] for a survey on the effects of public support on agricultural land prices.

land market implemented between CAPRI and NEMESIS lead to a convergence on land quantity (or more precisely in variation terms) allowing the introduction of land supply flexibility in CAPRI and a better representation of land demand in NEMESIS. Nevertheless, this convergence does not lead to a same equilibrium (in terms of variation) for land prices and therefore individual model characteristics on land valuation are kept. Thereby, table 4.3.4 displays two different land price variations: one including a full capitalisation effect of direct supports on land prices (from CAPRI) and, another, not including (from NEMESIS). Even if the extent of direct supports capitalisation into land price ranges (*e.g.* Weersink *et al.* 1999 [469], Duvivier *et al.* 2005 [125], Latruffe *et al.* 2008 [323] or Ciaian and Kancs 2009 [96]) between an elasticity of 0.1 and 0.65 (Latruffe and Le Mouél 2009 [324]), our modelling allows to capture the range of the potential consequences on land prices of an abolition of direct supports to farmers. Nevertheless, the linkage framework (or at least its implementation) have a negative impact to assess the arable land and grassland. In fact, the shifting of land demand in NEMESIS is done identically for both agricultural lands. This tends to homogenise their responses to a external shock. Consequently, we will focus on the total agricultural land use rather than both sub-categories.

Table 4.3.4 displays the consequences on agricultural land use and prices of the CAP reform policies again for *Tax rebate* scenarios. **Land price with capitalisation** effect falls by -21% for a complete removal of direct supports and about -4.7%⁴² for the liberalisation with direct supports maintained. If we exclude the capitalisation effect on land price, the land price decreases respectively about -7.3% and -1.6%. Therefore, the effect of the capitalisation is about -13% on land price whereas the effect of land scarcity and land requirement declines by about -7% on land price. Looking at MS, the results are relatively contrasted either with or without capitalisation⁴³. For instance in Hungary, land price with capitalisation decreases about -41% while land price without capitalisation falls about -10% after a complete suppression of direct supports. At the opposite end, in Spain the price falls by -17% and -9% respectively. This fall of land price comes with **an abandonment of land used by agriculture**, the incentives, stemming from direct supports to farmers, to maintain active lands, even without production activity, disappear. Then, EU agricultural land decreases by about 2.1% (38 000 km²) under direct supports suppression and 2.6% (47 000 km²) without market supports.

42. There is also, in CAPRI, a capitalisation on land rents of market supports such as quotas (see Britz and Witske 2008 [57] for details).

43. Detailed tables for MS in Appendix E or figure 4.3.2 in section 4.3.4 for a complete CAP reform.

Table 4.3.4: CAP reform results on land use at European level, in 2025, *Tax rebate* scenarios

<i>%: Difference w.r.t. reference scenario</i>	Market supports continued				Market supports abolished				
	Removal of direct supports				Removal of direct supports				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
Land used by agriculture*	-0.45%	-1.02%	-1.61%	-2.13%	-0.27%	-0.84%	-1.38%	-1.95%	-2.63%
- <i>Arable land</i> *	-0.46%	-1.04%	-1.64%	-2.17%	-0.21%	-0.78%	-1.34%	-1.92%	-2.61%
- <i>Grassland</i> *	-0.42%	-0.97%	-1.54%	-2.04%	-0.40%	-0.96%	-1.47%	-2.02%	-2.69%
Agricultural land price (with supports capitalisation)**	-6.65%	-13.18%	-20.12%	-20.83%	-4.65%	-10.11%	-17.51%	-24.80%	-30.98%
Agricultural land price (without supports capitalisation)*	-1.64%	-3.63%	-5.66%	-7.34%	-1.60%	-3.65%	-5.49%	-7.99%	-9.53%

*: Source NEMESIS model. **: Source CAPRI model.

At MS level, the results of the *Tax rebate* scenario are more contrasted with important land abandonment in countries with relatively numerous unutilised agricultural lands ⁴⁴ (such as Estonia, Latvia or Lithuania) or where agricultural structural changes are relatively important (such as Greece and Portugal). Indeed, total agricultural land used in Slovenia, Portugal, Latvia, Lithuania and Greece falls by more than -4% and reaching even -9% in Estonia. On the contrary, countries with few unutilised lands are less sensitive to land price variations ⁴⁵ and then they loose less agricultural land. The total agricultural land abandonment is about -1.8%, -1.4%, -0.8%, -0.5% and -0.1% in the Netherlands, Denmark, the United Kingdom, Ireland and Malta respectively. Globally, CAP reform does not have huge consequences on land intensity of agricultural production, the production decreasing by -2.4% while total European agricultural land use falls about -2.6%.

4.3.3.3 Economy

The assessment of CAP reform, as we see, displays no negligible consequences on agriculture markets and on land use, however, the change also has larger effects on the overall economy. Table 4.3.5 displays the economic impact of the progressive removal of CAP direct supports and/or an European unilateral liberalisation of the agriculture.

The effects of the **suppression of direct supports** on GDP are very weak. The income loss in agriculture by farmers is passed on households and therefore the macroeconomic consequences are very weak. Nevertheless, the impact on agricultural employment ⁴⁶ is more significant. The number of jobs in agriculture decreases by -320 000 (-3.6%) in Europe for a removal of 25% of direct supports and reaches -760 000 (-8.6%) for a complete suppression. This loss of employment in agriculture is mainly caused by the fall in agricultural incomes about -3.6% in the first case to -13.8% for a complete suppression of direct supports. The income from agricultural production are too weak for a part of farmers that leave the agricultural activity and change to others sectors. Effectively as noticed for France (Delame 2006 [110]), a huge part of farmers income comes from non-agricultural activities either from wages and salaries outside the agriculture sector or from land property income. Thereby, with the fall of agricultural incomes and land property incomes, numerous farmers leave the agriculture sector. The impact on total employment is quasi null.

44. See section 2.3.1.

45. The elasticity of the land supply with respect to land price is decreasing with the land scarcity (see section 2.3.2.4).

46. The agricultural employment includes salaried and family labour. In the *reference scenario*, the agricultural employment decreases about 5.9 billion (*i.e.* 40%) between 2005 and 2025 representing the trends (see for instance

Table 4.3.5: CAP reform results on economy at European level, in 2025, *Tax rebate* scenarios

%: Difference w.r.t. reference scenario	Market supports continued				Market supports abolished				
	Removal of direct supports				Removal of direct supports				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
GDP*	-0.01%	-0.01%	-0.03%	-0.04%	0.54%	0.56%	0.53%	0.53%	0.57%
Consumption Price*	-0.03%	-0.06%	-0.08%	-0.10%	-0.16%	-0.22%	-0.23%	-0.27%	-0.31%
Exports Price*	-0.02%	-0.03%	-0.04%	-0.05%	-0.27%	-0.30%	-0.30%	-0.32%	-0.35%
Total employment^{*(a)}	-332 (-0.15%)	-474 (-0.22%)	-641 (-0.29%)	-768 (-0.35%)	225 (0.12%)	103 (0.05%)	-62 (-0.03%)	-198 (-0.09%)	-306 (-0.14%)
- Agricultural employment^{*(a)}	-320 (-3.64%)	-478 (-5.34%)	-634 (-7.23%)	-759 (-8.65%)	-751 (-8.55%)	-966 (-11.01%)	-1083 (-12.34%)	-1248 (-14.22%)	-1436 (-16.36%)
Farmers income**	-3.57%	-7.33%	-10.96%	-13.78%	-11.18%	-15.9%	-18.92%	-22.55%	-26.36%

*: Source NEMESIS model. **: Source CAPRI model. ^(a): in thousands (1st line)

The fall in agriculture production passes on to other economic sectors through production factor demands and, therefore, counterbalances the households income re-allocation. In addition, the rise of agricultural products prices reduces European competitiveness slightly. However **liberalisation**, thanks to the decrease of agricultural products prices, increases European economic activity. In the case of liberalisation without removal of direct supports, the GDP increases by +0.54% and the total European employment rises by about +225 000. But, the fall of agricultural production and particularly agricultural products push income from agriculture down (-11%) and then reduce the employment in agriculture by -750 000, to a similar extent than with the complete suppression of direct supports. The **combination of both agricultural supports** leads to a stronger income loss for farmers (-26%) who leave the agricultural sector. The number of workers in agriculture then falls about -1.4 million (*i.e.* -16%). This decrease is partially compensated by the increase of economic activities in other sectors but the effects on total employment are still negative with a loss of -0.14% (-300 000 jobs). Looking in MS detail, it appears that the majority of the employment loss comes from two European countries: Poland and Romania. Indeed, agricultural employment in those countries still represents a non negligible part of the national employment even if it has already strongly decreased in the *reference scenario* between 2005 and 2025, passing from 3.5 million in each country in 2005 to 1.9 million in Poland and 1.6 million in Romania in 2025. The phasing-out of the CAP reform increases the destruction of these jobs by about -470 000 in Poland and -245 000 in Romania *i.e.* 50% of the European agricultural employment loss while they represent only 10% of the European employment and 4% of the European GDP in 2025.

4.3.4 Comparative results for two re-allocation of released funds from CAP

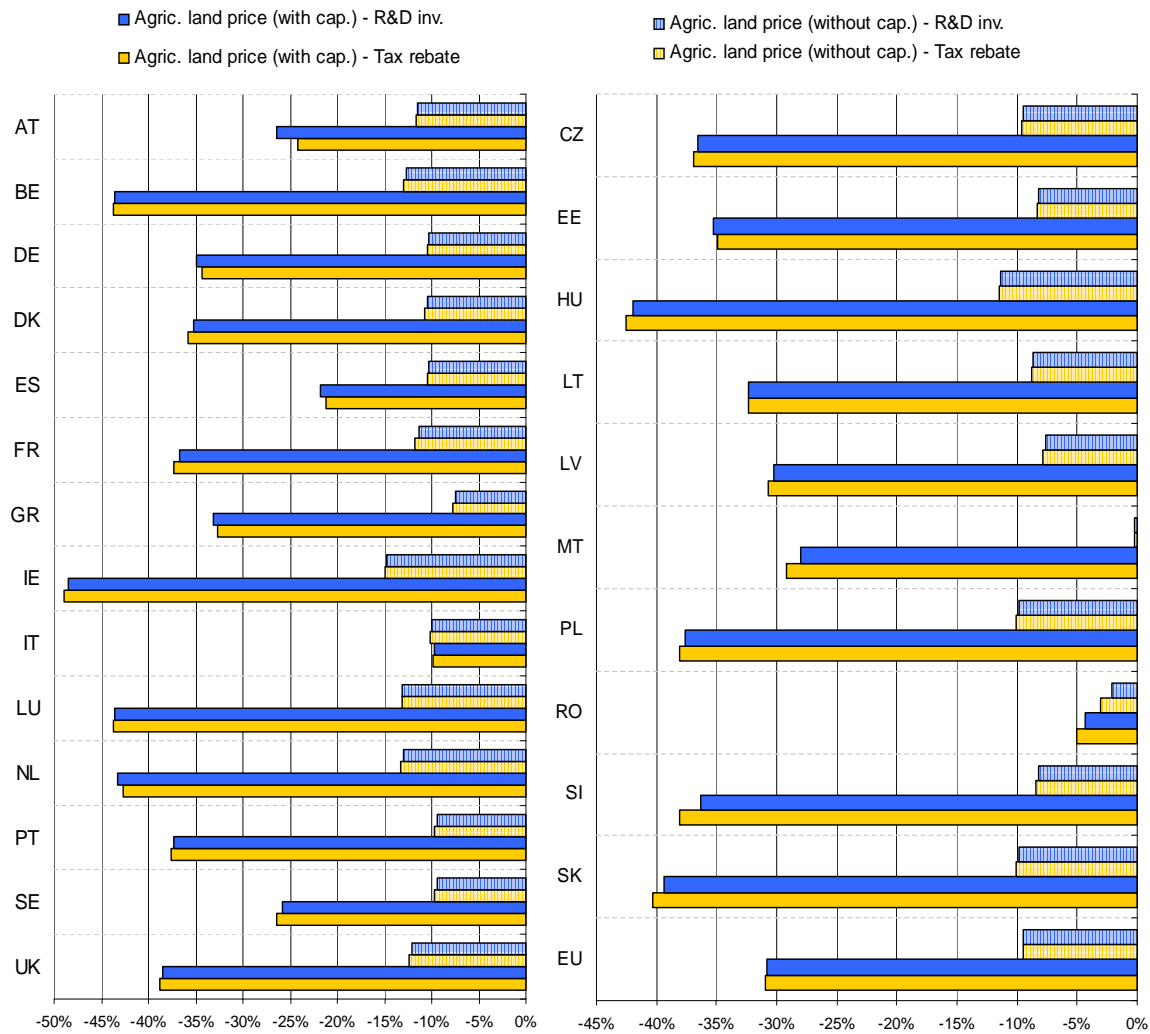
1st Pillar abolition

This section presents the results for “extreme” CAP reforms: a complete removal of direct supports and a suppression of market supports, with either a re-allocation of funds to consumer via a *Tax rebate* or a subsidy at MS to increase the *R&D investments*. Therefore, the aim is to give insights to the current European debate on the priority of European budget. The comparison is then between a continuation of actual CAP policy, the *reference scenario*, or a suppression of the CAP either with a tax rebate, *i.e.* a diminution of the European budget, or with an increase of investments in research and technological development, in line with the Lisbon strategy (EU, 2005 [137]) or the new Europe 2020 strategy (EU 2010 [192]) and as pointed out, for instance, by Sapir *et al.* 2003 [414] or Kox 2004 [315].

4.3.4.1 Agriculture and land use

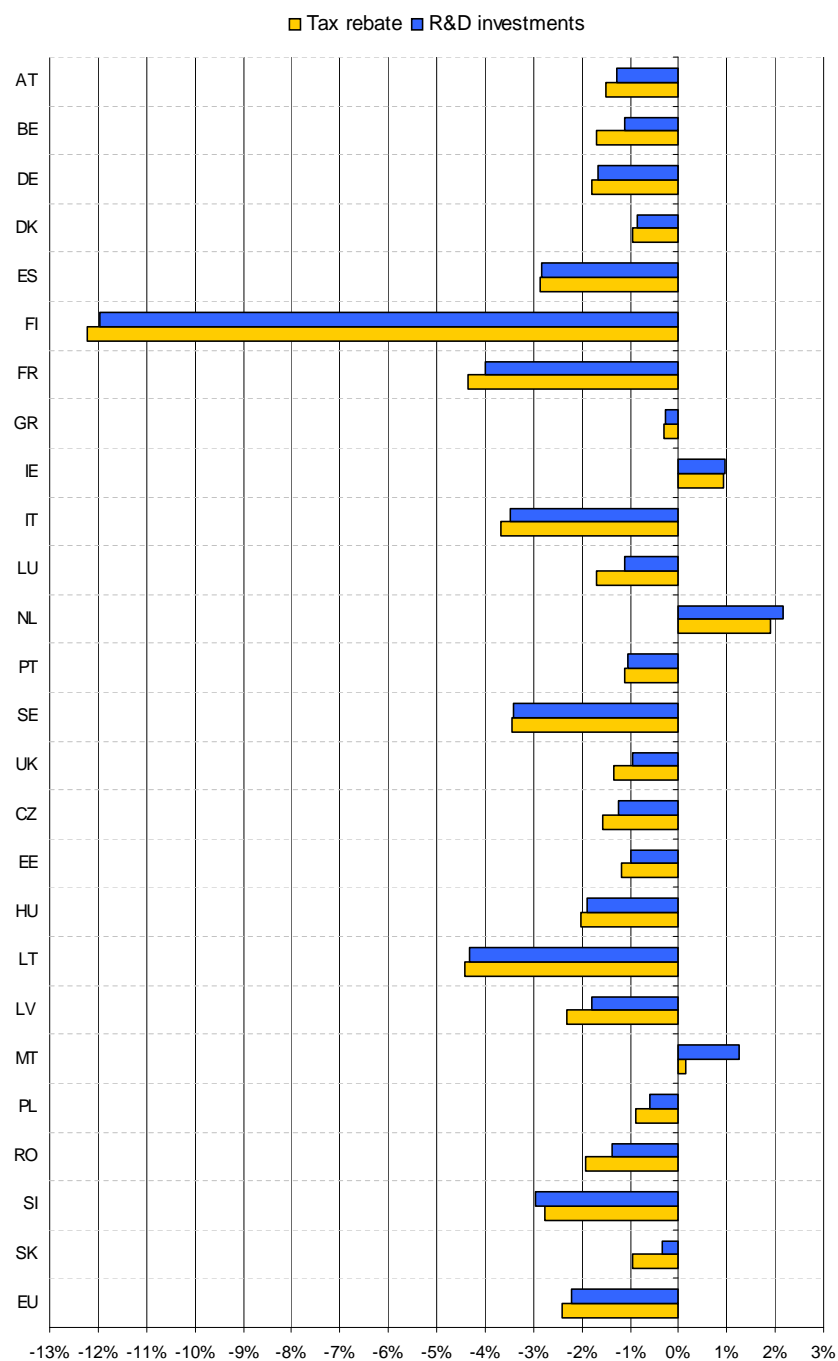
Figure 4.3.3 displays the CAP reform consequences on **total agricultural production** for the both recycling options. The results are presented by country and they are very close according to recycling options. Despite the variation of aggregate demands in NEMESIS, the elasticity of demand for agricultural products is very weak and changes in total demands act only marginally on agriculture. Moreover there is another channel through which the NEMESIS economic changes can influenced agricultural production, that is technological progress, and particularly in the *R&D investments* scenario, but its effects are still moderated. At European level, the fall in total agricultural production passes from 2.4% to 2.2% with the cumulative effect of productivity and demand rising in the *R&D investments* scenario, *i.e.* a change less than 10%. We will go with much detail with regard to the results for agriculture as they have been analysed in a previous section and as the recycling options do not imply important change. The conclusions are relatively similar with **agricultural land price** (see figure 4.3.2) where the results according to both recycling options are very similar. The land price changes come from capitalisation effect, land scarcity and agricultural production needs as presented in the previous section.

Figure 4.3.2: CAP reform agricultural land price results by Member States, with two different recycling options, in 2025



Source: NEMESIS and CAPRI models

Figure 4.3.3: CAP reform agricultural production results by Member States, with two different recycling options, in 2025



Source: NEMESIS and CAPRI models

4.3.4.2 Economy

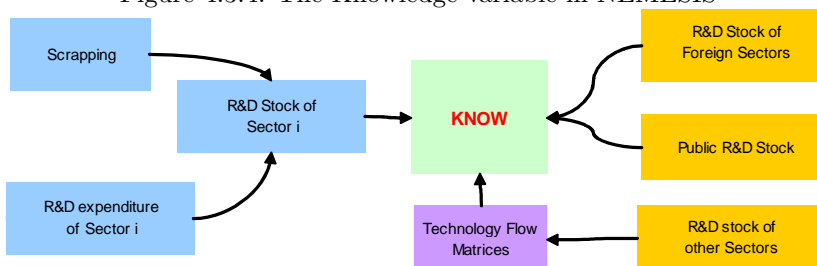
Box 4.3.4.2 : The innovation in NEMESIS (Chevalier *et al.* 2006 [87]) (1/2)

To adapt the model to the new theories of growth and technical change, it is necessary to include several phenomena: the endogenisation of technical change (innovation), spillovers (knowledge transfers) effects, and the economic consequences of innovation. In new growth theory, the knowledge variable and its externalities play a major role in the endogenisation of technical change and in explaining non decreasing returns.

The knowledge variable

The variable that plays a major role in the endogenisation of technical progress in NEMESIS is the variable *KNOW*, for knowledge, that arises out of the R&D stock and which plays a vital role in technical progress. A sector's R&D stock is determined by its R&D expenditures and a constant scrapping rate. It is constituted as a stock of capital, with scrapping being the gradual deletion of knowledge (figure 4.3.4).

Figure 4.3.4: The Knowledge variable in NEMESIS



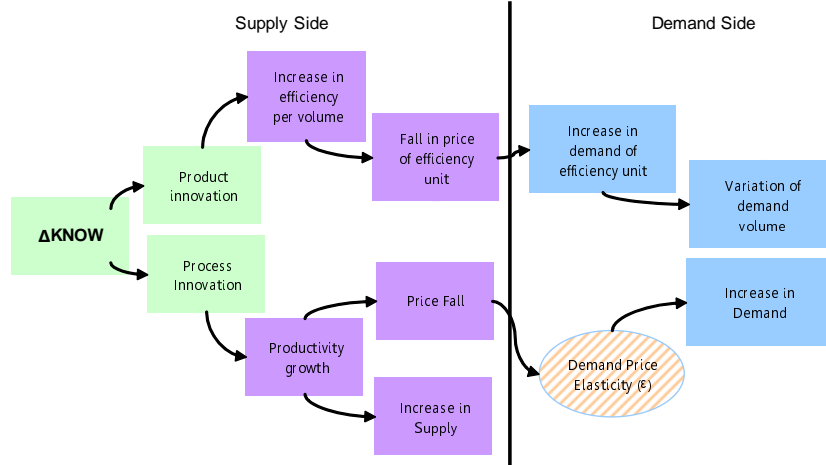
Knowledge is determined both by the sector's R&D stock and also by the knowledge spillovers in all national and foreign sectors. Knowledge spillovers from other sectors are dependent on their stocks of R&D, and are illustrated by technological flow matrices. These matrices, which are differentiated by sector and by country, are constructed according to the methodology developed by Johnson for the OECD (Johnson, 2002 [302]). This involves identifying, for every patent registered at the European Patent Office (EPO), the sectors producing and using the innovation described in the patent. This is then used to determine how much the knowledge accumulated in one sector will benefit other sectors, by calculating the knowledge transfer coefficients, the knowledge, by assumption, being borne by the patents. This involved over 100 sectors, with the results being re-agglomerated in the NEMESIS sector-based nomenclature in the form of technological flow matrices. Knowledge also feeds on R&D stock in foreign sectors and on public sector R&D stock.

From stock of knowledge to innovation and economic performance

Innovations are determined by the variant in the stock of knowledge (figure 4.3.5). Two types of innovation are considered in NEMESIS: process innovations, which increase the global productivity of factors and product innovations, which, in the fixed nomenclature of national accounting that underpins NEMESIS, are shown in quality improvements. These two types of innovation affect economic performance differently. Process innovation increases total factors productivity, thus increasing product supply and reducing unit production cost, and therefore prices. Price reductions lead to increased demand, which is dependent on price elasticity. Growth in demand helps to absorb the extra supply (at a constant usage level) if demand price elasticity is higher than or equal to 1. However, econometric estimates in chronological series reveal an elasticity generally lower than 1 for each sector, and thus for the whole economy. This is based on a representative firm per sector: the innovative firm is not considered to be in competition with other companies in its activity sector. This assumes then that all firms in the sector innovate and reduce their prices. Increased demand then depends on the capacity for absorption represented by elasticity lower than 1. In this case, process innovation reduces the use of factors as supply effects outweigh the effects of demand. Product innovation acts like an increase in efficiency per volume unit and increases demand for units of efficiency (figure 4.3.5). Volume production is only maintained if the increase in demand for the new efficiency is equal to the increased efficiency due to innovation. Generally, product innovation more than compensates for the fall in factor usage due to process innovation. R&D therefore simultaneously leads to an increase in GDP and in the use of factors.

Box 4.3.4.2 : The innovation in NEMESIS (Chevalier *et al.* 2006 [87]) (2/2)

Figure 4.3.5: The Knowledge variable in NEMESIS



The *ex-ante* effects of innovation on GDP depend on the effects of the increase in knowledge on the global productivity of factors and on quality and thus on demand: increased production is in fact linked to increased demand arising respectively from process innovation and quality innovation. Finally, economic performance, measured by increased production due to increased knowledge, can be written as: $\frac{\Delta Y}{Y} = \beta \frac{\Delta KNOW}{KNOW}$.

The calibration of mechanisms

Most econometric studies link increased production to an increase in R&D stock: $\frac{\Delta Y}{Y} = \alpha \frac{\Delta SRD}{SRD}$. Various surveys (see *e.g.* Griliches 1980 [250], Mairesse and Mohnen 1990 [345], Mairesse and Sassenou 1991 [346] or Cameron 1998 [70]) reveal a rather broad range for parameter α of 0.05 to 0.2. The results are independent of the methods chosen. However, where α is estimated using instant cross-section series (inter-companies), it is higher than when estimated chronologically. The effects of innovation on economic performance in NEMESIS has been calibrated as follows:

- Process innovation: the accumulation of knowledge ($KNOW$) generates an increase in total factor productivity (TFP): $\frac{\Delta TFP}{TFP} = \alpha \frac{\Delta KNOW}{KNOW}$.
- Product innovation: the accumulation of knowledge ($KNOW$) leads to an improvement in quality ($QUAL$): $\frac{\Delta QUAL}{QUAL} = \alpha' \frac{\Delta KNOW}{KNOW}$.
- Economic performance: increased production (Y) depends on increased demand due to innovation: $\frac{\Delta Y}{Y} = \varepsilon \frac{\Delta TFP}{TFP} + \varepsilon' \frac{\Delta QUAL}{QUAL}$.

$$\frac{\Delta Y}{Y} = \varepsilon \frac{\Delta TFP}{TFP} + \varepsilon' \frac{\Delta QUAL}{QUAL}$$

$$\frac{\Delta Y}{Y} = (\varepsilon \alpha + \varepsilon' \alpha') \frac{\Delta KNOW}{KNOW} = \beta \frac{\Delta KNOW}{KNOW}$$

This large spectrum of values for α in the empirical studies prompted us in our previous assessment of the Lisbon strategy's 3% RTD objective in 2004 (Brécard *et al.* 2006 [54]), to construct scenarios based on different values for our β parameter. The β value was differentiated by country and production sector, depending on the level of RTD intensity achieved, in order to allow a convergence of rates of return of knowledge across countries and sectors. The parameter β is equal to 0.075 in 2004 and reaches 0.107 in 2030 which is about average in terms of the results of econometric studies for α .

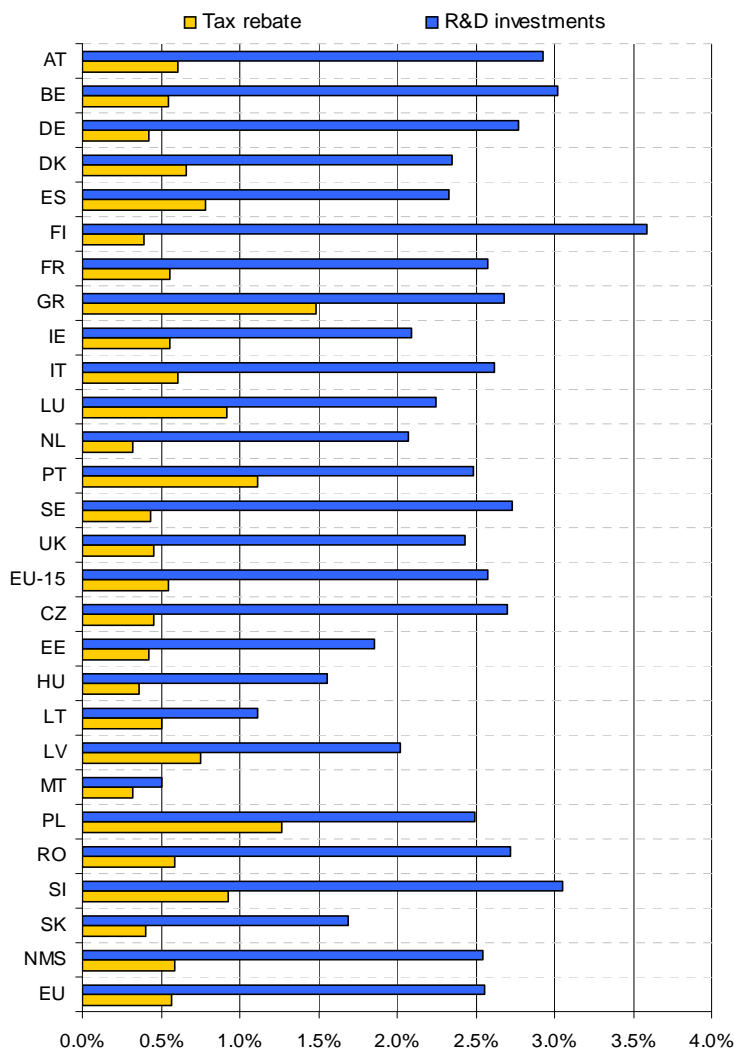
Regarding recycling options, the analysis of the economic results is very interesting inasmuch as there are wider differences between scenarios but also a relatively large impact on *R&D investments* scenario. In both recycling options, the released funds amount to €40.5 billion in 2025 that is to say 0.26% of the European GDP. In *R&D investments*, this money is distributed to each MS according to its share of European GDP. Therefore, an additional R&D intensity of 0.26% is introduced in each MS that leads to a redistribution effect on the contrary to *Tax rebate* where released funds go back to MS according to expected amounts in the *reference scenario*.

Figure 4.3.6 displays the **gross domestic product** changes between both CAP reform scenarios and the *reference scenario* for each MS in 2025. On a European average, the GDP rises by +0.57% and +2.56% in *Tax rebate* and *R&D investments* respectively. The incentives to invest in research and technological development in the *R&D investments* scenario boost the economic performance of European economy compared to *Tax rebate* and *reference scenario*. The investments in research raise the process and quality innovations (see box 4.3.4.2) that: on one hand, increase inputs productivity⁴⁷ and pushes up the competitiveness of European firms and; on another hand, raises the quality of products which stimulates household demand. In addition, a part of the productivity gains are given back to workers through real wage increases in a one third proportion (see Brécard *et al.* 2006 [54]). This results on economic growth are in line with the previous NEMESIS studies on the Lisbon Strategy and particularly on European research policy (EC 2005 [136], Brécard *et al.* 2006 [54], Chevalier *et al.* 2006 [87], Zagamé *et al.* 2009 [477]) but also with other European studies (*e.g.* Gelauff and Lejour 2006 [236]). Looking in more detail, several countries benefit more than others from the R&D investments increase, for instance, Finland has +3.6% of additional GDP compared to the *reference scenario* and +3.2% compared to *Tax rebate*. Finland is already a country with one of the highest R&D intensities in Europe (3.7% in the *reference scenario*) and with a very developed high-technology industry (telecommunication) and then benefits of its profitable position of innovative markets. But, Finland is also a very open economy which then profits from the European GDP surplus, knowledge flows arising from other EU countries, and takes advantage of its competitiveness on new products markets. On the contrary, Greece benefits much less from the switch from *Tax rebate* to *R&D investments*, its GDP rises by +2.7% instead of +1.5%. In addition, to the re-allocation effect which is about -0.35%, Greece, on the contrary to Finland, does not have an economy based on innovations

47. The technological progress in NEMESIS is an unbiased and affected all the inputs even if the effects can differ between inputs, they are defined by parameters and do not change with for instance inputs price or cost.

and therefore the yields of R&D investments and the knowledge spillovers are weaker than in other European countries. The same mechanisms operate in Latvia where the R&D returns are the weakest of EU countries and that has only +0.6% of GDP between *Tax rebate* and *R&D investments* but Latvia is also the country where the re-allocation effects is the strongest with a GDP loss of -0.4%.

Figure 4.3.6: CAP reform GDP results by Member States, with two different recycling options, in 2025



Source: NEMESIS model

Nevertheless, despite diverse R&D returns among EU countries, **all European countries benefit from the EU budget re-allocation**. All GDP are higher in the *Tax rebate* compared to *reference scenario* but the GDP gains are even more important in *R&D investments* than in *Tax rebate*. In great European economies, the GDP gains between both recycling options range between 2.4% in Germany

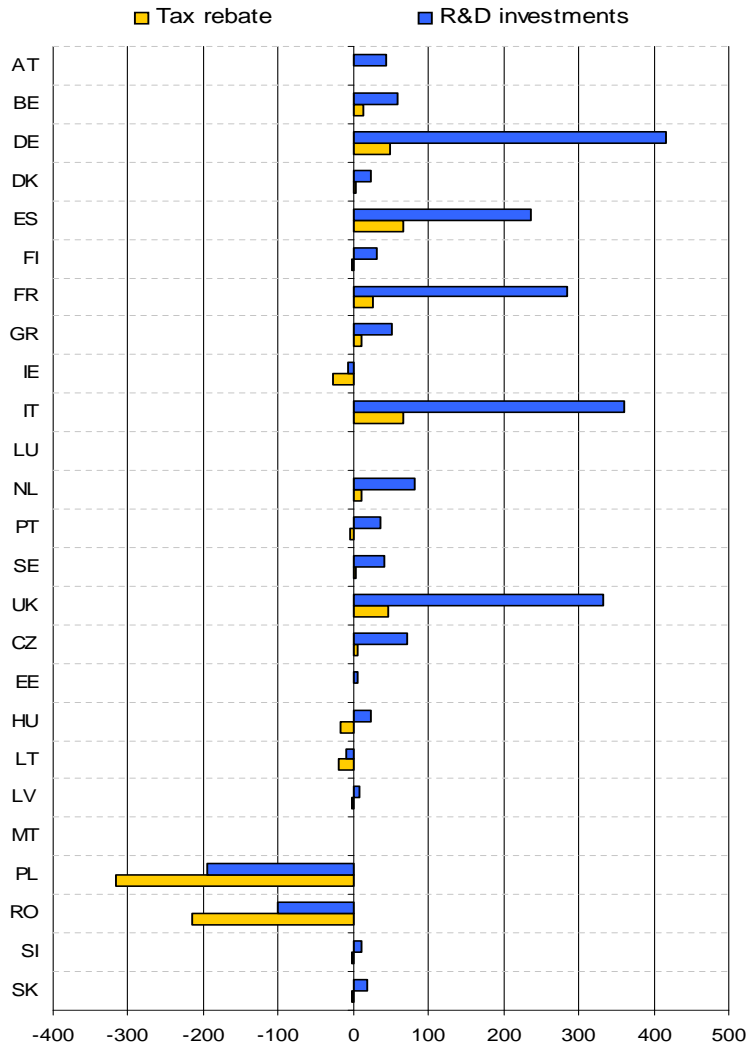
and 1.5% in Spain with around 2% in France, Italy and United Kingdom. The difference between countries have several sources like R&D returns, as seen above. But, there are other explanations related to the MS internal economic situation. For instance, looking at the difference between Germany and Spain and despite difference in R&D intensity (2.5% in Germany and 1.3% in Spain), we could suppose that Germany benefit less in terms of economic performance than Spain insomuch as its labour market is more scarce than in Spain (the unemployment rate in Spain is higher than in Germany⁴⁸ but particularly the Old Age Dependency Ratio - OADR, presented in section 3.2.2, is also larger in Germany than in Spain). However, labour productivity in Germany, implies by R&D investments, allows, even with a high GDP, to reduce the rise of employment needs⁴⁹ and then reduces potential inflationary pressures resulting from the economic activity rise. Finally, **the elasticity of R&D investments with respect to economic performance** is on average in Europe around 0.14 *i.e.* in the range of the studies estimates (α value in box 4.3.4.2, see Cameron 1998 [70] for a survey). Knowing that released funds are progressively invested in R&D between 2013 and 2020 following the phasing-out of the CAP, the full effects of R&D are active in 2025 (a maximum decay of five years is implemented in NEMESIS for public R&D).

The recycling options have also huge consequences on **total employment**. At European level, the loss of -300 000 employment in *Tax rebate* becomes a gain of +1.8 million in the *R&D investments*. In spite of the productivity gains arising from R&D investments and reducing the employment needs, the GDP surplus in *R&D investments*, pushes up employment and then counterbalances the loss in the agriculture sector. At MS level, the gains (in level) are of course more important in the strong European countries like Germany, France, Italy, Spain and United Kingdom that together represent almost +1 million new jobs *i.e.* in terms of percentage, total employment in those countries rises by about +1.2%. Two countries: Poland and Romania still experience a loss of employment in *R&D investments* scenario, with respectively -180 000 and -100 000 (*i.e.* -1.3% for both). These employment falls represent however an increase of +0.8% for Poland and +1.4% for Romania compared to *Tax rebate* scenario.

48. The unemployment is not given in *reference scenario* and in the counter-factual scenarios because the participation rates were exogenous in NEMESIS when we made this study. Therefore, we prefer to present the OADR than unemployment rates which are difficult to calculate all the more that NEMESIS is not a general equilibrium model where, generally, the unemployment is only due to households trade-off between leisure and labour. Nevertheless, there is now a modelling for participation rates in NEMESIS.

49. Indeed, looking at Appendix E, the employment raises about 1% and 0.8% between *R&D investments* and *Tax rebate* in Germany and Spain respectively, while GDP increases about 2.4% and 1.5% respectively.

Figure 4.3.7: CAP reform total employment results by Member States, with two different recycling options, in 2025



Source: NEMESIS model

To summarise, the CAP 1st Pillar abolition and the recycling funds via *Tax rebate* or *R&D investments* have non negligible impact on agricultural production and particularly according to its composition. For instance, dairy production rises in Europe with a strong disparity among MS whereas beef meat production falls heavily. Under the liberalisation effects, the agricultural production decreases which raises household purchasing power and European agriculture competitiveness. In turn, it slightly increases the European GDP. But in addition to the removal of direct supports, the fall of agricultural prices greatly reduces farmers incomes leading to numerous farmers leaving the agricul-

ture sector. Then, we observe a fall of agricultural employment in Europe and especially in Romania and Poland. Nevertheless, compared to *Tax rebate, R&D investments* recycling option allows a rise of European economic activity and thereby cancels out the negative impact of the CAP reform on employment at European level even if the consequences are still negative in Poland and Romania. Hence, we can conclude that according to those results the CAP is not an efficient use of tax money, and by re-allocating CAP 1st Pillar budget to the rest of the economy, economic activity in Europe is stimulated even if other considerations, presented in the following section, could attenuate this statement.

4.3.5 Discussions and concluding remarks

4.3.5.1 General Remarks

Before comparing the results of this study with others one and analysing the potential weak points or omissions, it must be pointed out that the first criticism can concern **the model** themselves. Especially, its representation of the price formation does not include expectations but even more risk aversion of producers. Indeed, Boussard (1996 [46]) introduces risk aversion in the Cobweb model (Ezekiel 1938 [216]) and shows the chaotic nature of agricultural product prices. Furthermore, Boussard *et al.* (2006 [48]) and Boussard *et al.* (2008 [47]) using the ID³ model, an extension of the GTAP⁵⁰ model (Hertel 1997 [269] and Itakura and Hertel 2000 [292]), in which they introduce, among others mechanisms, the risk aversion and expectation errors. They show that benefits from agricultural liberalisation, that is a standard results with all other GTAP based models⁵¹ are much more uncertain with their extended model. The results mainly come from the abolition of market supports that rises price instability⁵² insomuch as agricultural price fluctuations are endogenous to the market. Of course, our study does not include risk aversion and does not take into account price variations. Nevertheless, the liberalisation implemented in this study does not fully abolish the minimum border prices that ensure a minimum price stability. But most of all, our study also aims to assess different European budget allocations and this assessment becomes very difficult with a model such as the one developed by Boussard *et al.* (2006 [48]). Therefore, we continue this section by comparing our results with other studies. But, we keep in mind that the non-inclusion of agricultural price fluctuations can, in a part, modify the conclusion of this study and especially for European agricultural liberalisation. So, we could recommend for a CAP reform, as done by Bureau and Mahé 2008 [63], to “*maintaining public intervention to guarantee a floor price (or safety net)*”. There are finally few quantitative studies with applied economic models in the literature with which we can compare our results either because they

50. www.gtap.agecon.purdue.edu

51. Please note a personal remark on GTAP. The GTAP community is based on a database that allows the modelling of World economy with detailed data for numerous countries. The work achieved by the community is remarkable and very useful for modellers. Nevertheless, the generalisation and “systematic” use of GTAP database by modellers for applied model could be a problem for them at long term. Indeed, the use of an unique source of data by models could lead to a credibility loss even more knowing the diversity of databases and their difference. For instance interested reader could look at the gross value added at current euro price in National Accounts by 60 branches (Eurostat, 2009 [208]) and in the Economic Accounts for agriculture (Eurostat, 2010 [211]) that can differ by 30% as for Lithuania.

52. See *e.g.* for price volatility, the recent “Prices and market risks: farmers faced with volatility” Conference, organised by Centre de coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Conseil Stratégique de l’Agriculture et de l’Agro-industrie Durables (CSAAD), Fondation pour l’Agriculture et la Ruralité dans le Monde (FARM), Institut de la Gestion Publique et du Développement Économique (IGPDE) and Pluriagri. (<http://www.fondation-farm.org/spip.php?article651>)

are too old and did not integrate actual agricultural policy instruments (*e.g.* Burniaux and Walbroeck 1985 [67] or Philippidis and Hubbard 2001 [387]) or because they cover other regions or focus on one of the aspects assessed in this study. Indeed, to our knowledge, no study assesses the problem of EU budget allocation, very few have quantified the Lisbon Strategy or any of its aspects and only some focus on CAP phasing-out and their instruments.

4.3.5.2 CAP instruments

The results of this study underline a slight decrease of agricultural production with the removal of **direct supports** (-1.8% in EU) with production declining slightly more for vegetal products (-2.5%) than for animal products (-1.2%). We also show a quasi-null effect on GDP. However, we found larger impact on land price (-7% without capitalisation and -21% with), on farmers incomes (-14%) and then on agricultural employment (-9%). Gohin (2009 [241]) with a static computable general equilibrium model covering EU-15 and with very detailed agriculture sector and CAP regulation instruments, has also assessed potential economic impacts of a CAP phasing-out after 2013. Furthermore, Gohin (2009) displays some effects of CAP instruments. Compared to our study, Gohin points out that direct supports have an impact slightly larger impact on agricultural production especially for beef meat and soft wheat. Nevertheless, the results are relatively close. In addition, in spite of a decline of farmers income being larger in Gohin (-22%) than in this study, the fall of employment (-2.3%) is much less accentuated. In another study, Jomini *et al.* (2010 [303]) display, with the help of a GTAP model, a moderated influence of direct supports on the agricultural production⁵³ range between +0.5% in NMS and -1.92% in EU-15 for crops and +2% in NMS and -2.5% in EU-15 for livestock. The difference between NMS and EU-15 in Jomini *et al.* (2010) can come from the nature of the analysis. Indeed, they try to assess the actual impact of the CAP and not the potential consequences of a CAP removal beyond 2013. Similarly to our results, but at local level, Sharbacher *et al.* 2007 [411] have analysed the impacts of decoupled payments with the help of the agent-based model AgriPoliS (Agricultural Policy Simulator, Happe *et al.* 2006 [259]) for eleven cases studies in EU. Their research shows that direct payments slow down structural change on agricultural production and they also establish slight effects on production whereas they identify the major expected consequences of direct payments related to land on capitalisation in land prices.

53. In Jomini *et al.* (2010), the results are for added value.

The results for the suppression of **market supports** also have larger consequences in both studies on agricultural production. For Jomini *et al.* (2010 [303]), the vegetal production raises between +2.5% in NMS and +6.2% in the EU-15 and animal production increases by -2.4% in NMS and -4.9% in the EU-15 thanks to market supports. While Gohin suggests larger falls in agricultural production. For instance, beef meat decreases by -17.5% and grain maize by -26%. Furthermore, Gohin also finds a fall of -15% of agricultural income and an -8% loss of agricultural employment. Our results for liberalisation are, at aggregate level, less sensitive than in both studies to market supports with a fall of vegetal production of -1.2% and about -0.3% for animal. Nevertheless, the products are differently impacted with a strong decrease for beef meat (-8.7%) or sugar beet (-14.5%).

Finally, in our study, the **combination** of market supports suppression and removal of direct supports provides a decline of -2.4% of aggregated agricultural production with a loss of -3.6% for vegetal products and -1.4% for animal products. This agricultural production is also characterised by a decline of agricultural prices by -8.8% with -15% for animal products and -4.2% for vegetal. In addition, CAP reform leads to:

- A strong fall of farmers income (-26.3%) under the fall of agricultural production and prices and the removal of direct supports. Those falls act either through farmers direct income loss or through property income loss via fall of land prices (-31% with capitalisation of direct supports and -9.5% without). Then, agricultural employment decreases by about -1.4 million (*i.e.* -16.4%).
- A raise of GDP about 0.5% mainly due to the fall of agricultural products prices that pushes up the competitiveness of European farms. Indeed, the prices decrease are characterised, for a part, by a loss of production but this one is relatively moderated and weakly reported into imports raise. Furthermore, the loss of farmers income coming from direct supports is given back to consumers in a lump sum. Thereby, the global effect on household income is null or very weak. Our gain in GDP then comes from price falls, reducing input costs for firms and raising consumers purchasing power under the hypothesis that producers prices variation are transmitted to consumer prices. However, variations in agricultural prices are not fully reflected in consumer prices (*e.g.* AgraCeas 2003 [3], AgraCeas 2007 [4], EC 2009 [142] or Besson 2008 [34] for France). In NEMESIS, food industries apply a constant mark-up over unit production price in the long term.

The effect on employment of 1st Pillar abolition is about -16% in our study for an income fall of -26% (*i.e.* an agricultural employment elasticity with respect to agricultural income equal to 0.6) that is

relatively high compared to Gohin (2009) for whom the elasticity is 0.33 (-33% of income and -11% of employment). Helming *et al.* (2008 [264]) have estimated this elasticity for each European country and they find a range between 1.2 in Netherlands and 0.04 for Baltic countries. Looking at their results for a scenario of European agriculture liberalisation, agricultural employment falls by more than -30% in Poland, United-Kingdom, Ireland, East Germany and in the centre of France and decreases less in Greece, Portugal and Latvia (less than -10%). In addition, Nowicki *et al.* (2010 [368]) using the estimation of Helming *et al.* (2008) and the LEITAP model (an modified version of the GTAP model⁵⁴) with the CAPRI model, show (in a European agricultural liberalisation scenario where the 1st Pillar is abolished but where the 2nd Pillar is reinforced) a lesser decrease of agricultural employment with less than -2% in Romania, Spain, Italy and south of France and more than -8% in Poland and United Kingdom. Nevertheless, Nowicki *et al.* (2010) specify that “*changes in employment should be seen as lower levels, in the somewhat longer term*”⁵⁵ *the changes in employment in agriculture could be bigger*” because of a weak labour mobility in the LEITAP model. Summarising, our results are a bit stronger than in other studies due to an higher elasticity of agricultural employment with respect to farmers incomes even if there are relatively close to Helming *et al.* (2008 [264]) and Nowicki *et al.* (2010 [368]) to the extent they are comparable. Finally, for agricultural land use, only Nowicki *et al.* (2010) present some results for an abolition of CAP and its impact, compared to our study, are in the same for a land price with a decrease of -30% and higher for agricultural land use that falls by -6% at European level but with a noticeably larger fall of agricultural production .

4.3.5.3 R&D multiplier

Now, to compare our results for **uses of released funds** of CAP 1st Pillar, there are, to our knowledge, very few quantitative studies. We will then focus on R&D investment policy and their assessment with large applied economic models⁵⁶. Gelauff and Lejour (2006 [236]) have assessed the potential impact of five policies related to the Lisbon Strategy (EU 2000 [183]) with the model WorldScan (Lejour *et al.* 2006 [331]) which is a flexible general equilibrium model for the World economy based on GTAP database. Among the five policies analysed by Gelauff and Lejour (2006), one of them consists of assessing the Barcelona objective (EU 2003 [185]) of 3% R&D efforts⁵⁷ in 2010.

54. To our knowledge, there is not available description of the LEITAP model.

55. The time horizon of the Nowicki *et al.* (2010) study is 2020.

56. We excluded the comparison with other studies realised with the help of the NEMESIS model such as EC 2005 [136], Chevallier *et al.* (2006 [87]), Brécard *et al.* (2006 [54]) or Zagamé *et al.* (2009 [477]).

57. R&D effort means the ratio between R&D expenditures at time t and the GDP at time t .

Therefore, they introduce a R&D subsidy to reach 3% on average for EU in 2010 and they give two assessments, one with modest R&D spillovers (a social return of 30%) and another one with higher R&D spillovers (a social return of 90% - using their own estimates). The effort to reach the 3% target in EU corresponds to a rise of +50% of R&D investments in Europe insomuch as according to authors, the R&D intensity was at about 2% when they realised the assessment. So, looking at the European GDP impact in 2025, that rises by +3.2% in the moderated spillovers cases and +10.1% in the upper bound case, it is possible to compute the output elasticity with respect to R&D investments which is about 0.06 for lower bound case and 0.2 for upper bound case. Our study gives an elasticity of about 0.14 *i.e.* between both bounds of Golauff and Lejour (2006)⁵⁸. More recently, the European Commission Directorate General for Economic and Financial Affairs (DG ECFIN) have realised a quantitative assessment of the Lisbon Strategy with the QUEST III model (Ratto *et al.* 2009 [400]), a Dynamic Stochastic General Equilibrium model (DSGE) for EU that serves as an economic policy assessment but also for European economic forecasts⁵⁹ (*e.g.* EC 2010 [149]). Roeger *et al.* (2008 [407]) introduce, in the QUEST III model with endogenous growth (Roeger *et al.* 2009 [408]), a shock of 0.1% of GDP to subsidise R&D investments either by a tax credit on non-liquidated constrained households or by a wage subsidy to the R&D sector. And they bring out a negative or null effect in the short and medium term (20 years⁶⁰) in both cases, the positive impacts arise after 50 years with an elasticity of 0.055 reaching 0.08 after 100 years⁶¹. Therefore, the elasticity of output with respect to R&D investment is lower in Roeger *et al.* (2008) than in our study. In addition to the models themselves which are very different, a possible explanation of the difference in the R&D yields can be explained by human capital. Indeed, as the QUEST III model takes into account three different labour skills, the rise of R&D requires an important availability of high skill labour. This explication is confirmed by another study with the QUEST III model (D'Auria *et al.* 2009 [106]) where, for instance, the yield of R&D investments in Sweden are very weak due to a lack of high skilled workers⁶². And the version of the NEMESIS model

58. Another study (Arpaia *et al.* 2007 [16]) comparing the results of the QUEST III (see after) and the WorldScan for the same scenario (*i.e.* an increase of at least 50% of R&D investments) shows an elasticity about 0.09 for QUEST III and only 0.055 for WorldScan. Nevertheless, the study is not enough detailed on this subject to include it in the comparison.

59. http://ec.europa.eu/economy_finance/publications/european_economy/forecasts_en.htm

60. Roeger *et al.* (2008 [407]) have probably made a mistake in their time unit, because QUEST III is a quarterly model, the unit should be more quarterly than yearly. Nevertheless, we kept the yearly unit as in the paper.

61. We took the raise of R&D investments given by Roeger *et al.* (2008) to calculate the elasticity and not the 0.1% of GDP subsidy. Taking the 0.1% of GDP subsidy and supposing an constant R&D intensity in EU about 1.9%, the elasticity of invested funds with respect to output are about 0.084 and 0.058 for wage subsidy and tax credit respectively after 100 years.

62. In D'Auria *et al.* (2009) the decay to see the complete effects of R&D are much less long (20 years) than in Roeger *et al.* (2008) and seems, even if there is no EU aggregate, more important.

used in this study does not include different skill workers and different labour markets⁶³, thereby the only constraint on the labour market is for the whole of workers. The introduction of a skill-segmented labour market will probably reduce the benefits of R&D investments. Finally, another factor that could presume to an overestimating (or underestimating) of R&D yields is the absence of crowding-out (crowding-in) effects or deadweight loss effect. Indeed, the R&D investments coming from 1st Pillar released funds are supposed to be efficiently affected by MS and we assume that 1 € of subsidies leads to 1 € of R&D expenditure for whatever public or private sector. But, the studies suggests that could crowding-in or crowding-out effects exists (*e.g.* Czarnitzki and Fier 2002 [105], Duguet 2004 [123], Gonzalez and Pazo 2008 [245]).

4.3.5.4 Summary

To summarise our results, the abolition of the CAP 1st Pillar has a moderated impact on agricultural production (-2.4% for EU), despite a non negligible re-combination of the products. Furthermore, it reduces agricultural product prices (-8.8%) notably because of market supports suppression. The fall of internal agricultural prices raises the competitiveness of European agriculture and other sectors using agricultural products thanks to a decrease of input costs. Furthermore, the moderated decline of agricultural production reduces imports needs, the demand being very little affected. The keeping of agricultural activity in Europe combined with the raise of competitiveness and household purchasing power allow a GDP gain of +0.5% in 2025 characterised by an employment fall especially in the agriculture sector (-1.4 million) because of the decrease of farmers incomes (-26%). Finally, the recycling of 1st Pillar funds to R&D subsidies boosts European economic performance (+2.6% of GDP in 2025) and counterbalances the employment loss in agriculture with a creation of +1.8 million jobs showing the importance of taking the European economy towards a knowledge economy.

63. The actual version of NEMESIS includes skill and unskilled workers and the development of the labour market is ongoing.

4.4 Conclusion

The first policy assessment examined in this chapter regards a set of CAP reforms. This assessment is realised with the help of linked models centred on sustainable impact assessment. The linked models regroup three sectoral models: a detailed agricultural model (CAPRI - Britz and Witzke 2008 [57]), a detailed forest management model (EFISCEN - Sallnas 1990 [412] and Schelhaas *et al.* 2007 [416]) and a detailed land use allocation model (Dyna-CLUE - Verburg *et al.* 2006 [463] or Verburg and Overmars 2009 [462]) and a European macro-economic model (NEMESIS - Zagamé *et al.* 2010 [476]). In addition, to a complex exchange of variables between the four models used for this assessment (see figure 4.2.2), the major innovation of this study comes from the link between the detailed agricultural model CAPRI and the NEMESIS model. A procedure, to reach a joint equilibrium on agricultural land use in both models following a shock, has been implemented. By an iterative process of calibration, this procedure allows the NEMESIS model to take advantage of the detailed agriculture sector of the CAPRI model, by modifying its agricultural demand, whereas the CAPRI model in which the total agricultural land is fixed takes advantage of NEMESIS “L-inverse” land supply to introduce a flexibility in its land supply (see figure 4.2.3).

In a second section, the use of the linked models for a set of CAP reform has emphasised the economic and environmental impact (especially land use) of European agricultural policy instruments and two re-allocation options of CAP released funds. The removal of direct supports to farmers shows a small impact on agricultural production. This moderating impact on agricultural production is a classical result of the literature (Bhaskar and Beghin 2009 [37]) insomuch channels of potential coupling of decoupled payments are very small. However, as identified by the studies (Gohin 2006 [240] or Sharbacher *et al.* 2007 [411]) the land-based decoupled payments, are either fully or partially capitalised in land prices. Thereby, the suppression of direct payments to farmers decreases the real agricultural land price by about 21% if direct supports are fully capitalised and 7% without capitalisation. For the abolition of market support, the impact on European agriculture is more important especially for some agricultural products that are still highly protected such as sugar beet (14.5%), beef and veal meat and sheep and goats meat (-9%). The impact of the market supports abolition is also relatively heterogeneous among European countries according to the weight of the most penalised agricultural products on their total agricultural production but also according to quota rents for milk market (Witzke and Tonini 2008 [473], Réquillart *et al.* 2008 [410]).

The analysis of re-allocation of released funds, for a complete liberalisation of European agriculture,

between either *Tax rebate* to households or subsidies to *R&D investments*, shows a significant positive impact on the European economy with the former options. The impact of the *Tax rebate* scenario is relatively moderate. European GDP increases about +0.5%, mainly driven by the fall of agricultural product prices (-8.8% with -4.2% for vegetal products and -15% for animal products), and total European employment loss -300 000 jobs, due to large agricultural employment loss (-1.4 million jobs) mainly coming from Poland and Romania with respectively -470 000 and -245 000 employment loss in the agricultural sector, whereas, when released funds of Common Agricultural Policy (*i.e.* €46 billion) are used to subsidise R&D investments in Europe, GDP gains are expected to be much higher (+2.5%) as well as the impact on total employment (+1.8 million jobs). Even if we have shown that the R&D multiplier is sometimes higher than in the literature due to, for instance, the absence of human capital constraint (Roeger *et al.* 2008 [407]), the re-allocation of Common Agricultural Policies budget, toward Lisbon Strategy objectives or more precisely the new Europe 2020 strategy, allows a better economic performance and seems not impacted too strongly on European agriculture. However, as expressed by alternative studies (Boussard *et al.* 2006 [48] and Boussard *et al.* 2008 [47]), the volatility of agricultural prices and the specificity of the agriculture sector could worsen the impact on agriculture sector. Furthermore, even if the aggregate agricultural production is not too penalised by a liberalisation of European agriculture, some agricultural products could be much more impacted (see table 4.3.3 or Gohin 2009 [241]). Finally, the other economic and social functions of agriculture such as rural development and environment regulation could be affected notably by land abandonment (see figures 4.2.5 and 4.2.6) or the rise of fire risk (Verkerk and Jones 2009 [465]), for instance. Consequently, European funds re-allocation from agriculture to the knowledge economy have important economic benefits in terms of economic growth and employment but a minimum of public intervention in agriculture sector should be achieved (Bureau and Mahé 2008 [63]) as well as some transfers from 1st Pillar (economic support) to 2nd Pillar (other functions of agriculture) to ensure a perennial and qualitative European agriculture⁶⁴ as recommended by Bazin *et al.* (2010 [28]).

64. See *e.g.* Nowicki *et al.* (2009 [368]) an assessment of transfers from CAP 1st Pillar and 2nd Pillar.

Chapter 5

Impact assessment of biodiversity and biofuel policies

5.1 Introduction

Environmental protection has existed in human civilisation, for long time, as an example we could mention the sewer system in ancient Rome or Babylon. With accelerated economic development since the industrial revolution and the accumulation of scientific knowledge, more and more anthropogenic environmental problems are identified. They are very diverse and numerous such as, *inter alia*, Global Warming, soil erosion, waste management, resource depletion or biodiversity. Furthermore, with the enhancement of quality of life, there emerges, in the population, an environmental consciousness and a will for action and consideration of those environmental problems. It has led to the implementation of numerous environmental policies in many countries that cover almost all known environmental issues. At European Union level, following the United Nations Conference on the Human Environment at Stockholm in 1972, European Council established a 1st Environmental Action Programme (EAP) in 1973¹ which has been followed by five other EAP. Those European policies have brought up several legal issues starting from the motor vehicles directive in 1970 (EU 1970 [179]) to building energy performance in 2010 (EU 2010 [191]). By synthesising, we can distinguish two orientations of those environmental policies. Either they warn and treat identified environmental problems (*e.g.* waste management or biodiversity conservation) or they prevent probable environmental impact of new technologies (*e.g.* nanotechnology, genetic modified organisms or biofuels) or new policies (*e.g.* Common Agricultural Policy, as viewed in chapter 4). In this later case, since the EU obligatory of *ex-ante* impact assessment for new policy or changes in existing policy (EC 2002 [154]) and insomuch as environmental impacts are a full part of those *ex-ante* impact assessments, the use of modelling tools has become a regular issue. In this sense, this chapter presents the assessment of two different European environmental policies. The first one assesses the opportunity cost of biodiversity conservation either in forest areas or agricultural areas (warning policy) and the second displays the impact of biofuels development and especially the 10% target in gasoline in 2020 (impact assessment). In order to do this, we obviously use the NEMESIS model and its land use module developed in chapter 2. Thereby, environmental impact is assessed through land use changes.

However, in a first section, we complete our study by the assessment of nutrients input used by agriculture. Indeed, nutrient input for agricultural production has been identified as major source of water pollution in numerous EU regions. Excess of nutrients pollutes groundwater and leads to

1. See *e.g.* Hey (2006 [271]) for a history of European environmental policies.

eutrophication of fresh water. To do this, we constructed a database, updated in 2008, on nutrients (nitrogen and phosphorus) input use in agriculture. Thereafter, we establish a simple modelling for nutrient projections with the help of available information on the NEMESIS model. We project them for the *reference scenario* (see chapter 3) up to 2025. In the second section, after a presentation of the biodiversity conservation policies context, we examine two European policies using the land information of the Natura 2000 network. On one hand, we assess the land use and economic impact as well as the opportunity cost of biodiversity conservation policy by increasing European protected forest areas *i.e.* excluding those areas of available agricultural land. On the other hand, we analyse the consequences of an extensification of European agriculture with the help of a European or national subsidy to farmers lowering the agricultural land price. Finally, the last section studies a European biofuels policy that reaches 10% of total gasoline in 2020. We emphasise the environmental impact on land use and nutrient uses while looking at economic results and especially agriculture ones.

5.2 Nitrogen and phosphorus input in NEMESIS

As it was outlined in the introduction, agriculture has become one major source of pollution of groundwater and eutrophication of fresh water and marine environments, through increasing use of fertilisers and pesticides over the last decades (*e.g.* Smith 2009 [432]). For marine coastal areas, losses of nutrients from fertilisers use, especially nitrogen (*e.g.* Howarth 2009 [274] and Jorgenson 2009 [307]) and phosphorus (*e.g.* Caraco 2009 [76]), were identified by scientists as one major sources of perturbation of marine ecosystems (*e.g.* Wilhelm 2009 [472]). It is consequently particularly important to be able to quantify relatively precisely nitrogen losses from agriculture sector, even if other phenomena, such as nitrogen and phosphorus pollution from sewage and nitrogen depositions from the transport sector, are also important factors of water and coastal areas nutrients contamination (*e.g.* Echols *et al.* 2009 [156]).

This first part of this first section will realise a quantification of nutrient (nitrogen and phosphorus) input uses for EU-27 countries in 2008. Based on this quantification for the year 2008, we will also establish, in the second part, projections for the *reference scenario* on use of nutrients by EU agriculture with the help of the NEMESIS model. Consequently, we will display results on phosphorus and nitrogen for the policy assessment realised in the following section of this chapter.

5.2.1 Use of nutrients in European countries in 2008

For inorganic (or mineral) fertilisers, Eurostat gives detailed annual data by Member State (MS) on the evolution of fertilisers used by category of active substance: nitrogen (N), phosphates (P) and potash², on the basis of a chemical industry estimation. On the contrary, there is no useful information on the use of organic fertilisers for livestock (manure) in European statistics or in other statistical sources like FAO. Two exceptions are the studies by Hansen (2000 [258]) for Eurostat on “*Nitrogen balances in Agriculture*” and the OECD “*Environmental Performance of Agriculture in OECD countries since 1990*” (OECD, 2008 [374]) of which the section focuses on nutrients and especially “*Nitrogen Balances*” (OECD and Eurostat, 2007 [376]).

2. We excluded potash for our study due to too many unavailable data or emission coefficients.

Box 5.2.1 : The Nitrogen Cycle (OECD and Eurostat 2007 [376])^a

Nitrogen is used by living organisms to produce a number of complex organic molecules such as amino acids, proteins and nucleic acids. It is an essential element for plant growth. The largest store of nitrogen is found in the atmosphere where it exists as a gas (mainly N_2). This atmospheric store is about one million times larger than the total nitrogen contained in living organisms. Other major stores of nitrogen include organic matter in soil and the oceans. Within most ecosystems, nitrogen is primarily stored in living and dead organic matter.

Organic matter (humus, plant residues, livestock manure) contains large quantities of plant nutrients, including nitrogen. Conversion processes in the soil (mineralisation and nitrification) break down organic matter to supply the plants with nitrogen. This nitrogen may be dissolved in soil water or bound to soil colloids (colloidal clay and mull particles), and is directly available to the plants. Moreover, atmospheric nitrogen may be fixed naturally in the soil through the action of bacteria. A further source of nitrogen input to the soil is wet (in rainfall) and dry deposition of N compounds from the atmosphere. When plants die, nitrogen is returned to the soil and to a lesser degree to the atmosphere, and the cycle is complete.

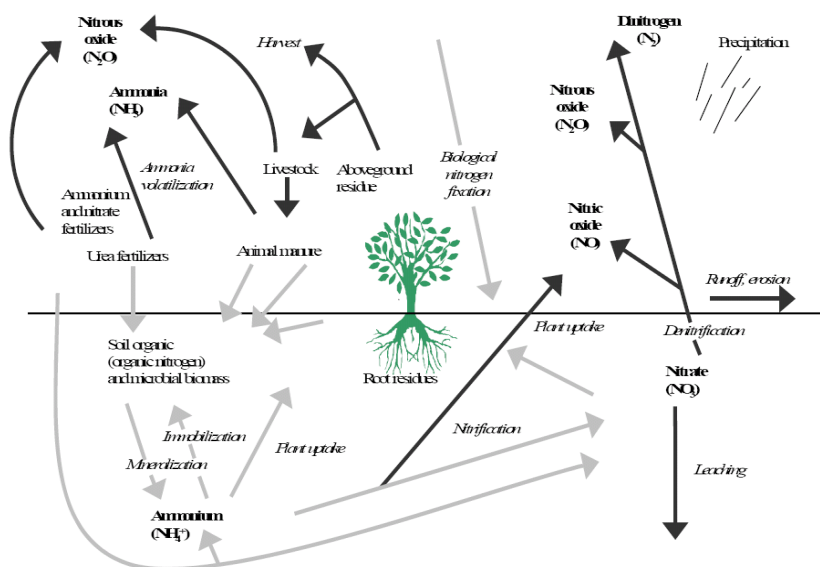
In agriculture this natural nitrogen cycle is interrupted when organic matter is removed in harvested crops and through grazing. Also, certain agricultural practices, such as flooding of paddy fields, lead to loss of soil nitrogen through denitrification. In denitrification, bacteria in anaerobic soils convert nitrate into gaseous nitrogen or nitrous oxide.

Leaching of nitrates from vulnerable soils is also responsible for important losses of soil nitrogen, especially when soils are left bare after harvest, rainfall is heavy and temperatures are low (which reduces the conversion activity of the soil bacteria).

Thus despite its abundance in the atmosphere, nitrogen is often the most limiting nutrient for plant growth. A supplementary input of nitrogen is needed to compensate for these removals and losses and to maintain the balance of nitrogen in the soil.

A supplementary input of nitrogen can be achieved by encouraging natural fixation of nitrogen through the deliberate planting of leguminous plants (the bean family), often in a crop rotation system. But the most common method of supplying supplementary nitrogen is through the spreading of inorganic fertilisers and livestock manure. Not all of this supplementary nitrogen is available to the plants. Some will volatilise from manure, in the form of ammonia (NH_3), during and shortly after spreading, and rainfall will cause run off and leaching of highly soluble nitrate before the plants can absorb it. The volatilisation process can be offset by an increase in the amount of ammonia deposited from the atmosphere. The complex interrelations are illustrated in Figure 5.2.1, below.

Figure 5.2.1: The Nitrogen Cycle



Source: OECD (2001)

For additional detail please refer to OECD and Eurostat (2007 [376]) or OECD (2001 [371]).

^a See Berhe *et al.* (2005 [29]) for a generalised study on nutrients cycle or EEA (1999 [158]) for an analysis of nutrients in European ecosystems.

Hansen (2000 [258]) evaluates notably, for year 1997, the use of organic nitrogen from manure applied to agricultural land in EU-15 countries. He calculated manure input as a function of livestock in each country, by using EU Farm Structure Survey (Eurostat 2010 [215]), “*expert estimates on the quantity of nitrogen that they eject*” and he applied french coefficients for countries without available data such as Greece, Italy and Portugal. Furthermore, OECD and Eurostat (2007 [376]) have developed a methodology to calculate the **nitrogen** (and phosphorus) balance in Agriculture³. It distinguishes the input, *i.e.* the production of nitrogen due to agricultural production, from the output *i.e.* the nitrogen consumption. The input includes:

- fertilisers (inorganic fertilisers from the chemical industry and organic fertilisers excluding livestock manure from sewage sludge, urban compost or industrial waste products),
- livestock manure,
- biological nitrogen fixation (nitrogen fixed in soil from legume crop areas and free living organisms),
- atmospheric deposition of nitrogen compounds
- other inputs (seeds and planting material, ...) .

Whereas outputs distinguish:

- harvested crops (cereals, oil crops, dried pulses and beans, ...)
- and fodder crops and grass (harvested and grazed).

3. The distinction between Gross Nitrogen Balance and Net Nitrogen Balance stems from Gross Nitrogen Balance including “*all residual emissions of environmentally harmful nitrogen compounds from agriculture into the soil, water and the air*” while Net Nitrogen Balance includes “*only emissions into the soil and water, while emissions into the air are excluded; in particular, the net balance deducts the volatilisation of ammonia from agriculture*” (OECD and Eurostat 2007 [376]).

Table 5.2.1: European nitrogen manure emission coefficients (kg/head)

<i>kg/head</i>	BE	DK	DE	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE
Equidae	65.0	44.0	42.5	39.0	25.6	120.0	40.0	61.0	87.2	54.1	34.0	43.4	52.0	42.5
Bov. <1 year	28.0	38.8	26.4	20.0	21.9	21.9	24.0	15.0	33.5	27.6	23.1	26.3	25.0	23.0
Bov. [1-2] years (males)	61.0	57.7	38.3	48.0	43.8	43.8	57.0	43.0	55.8	59.2	40.5	53.0	40.0	49.3
Bovine [1-2] years (females)	56.0	41.5	42.5	49.0	43.8	43.8	57.0	42.0	55.8	88.7	40.5	53.0	37.0	40.0
Bov. >2 years (males)	77.0	52.9	42.5	54.0	51.1	51.1	68.0	63.0	79.7	72.3	57.8	61.0	40.0	49.3
Heifers (>2 years)	77.0	51.4	42.5	62.0	58.4	58.4	63.0	55.0	79.7	88.6	57.8	70.0	40.0	40.0
Dairy cows	97.0	121.6	80.3	70.0	60.2	73.0	85.0	109.0	87.2	123.7	80.8	88.0	100.0	99.5
Other cows (>2 years)	58.0	76.0	98.0	69.0	61.0	67.0	65.0	80.0	68.0	86.0	68.0	61.0	57.0	63.0
Sheep	8.0	17.0	10.0	11.0	6.5	9.0	10.0	12.0	8.3	15.0	22.0	7.0	13.0	13.0
Goats	8.0	10.8	14.0	9.0	8.7	8.0	9.0	13.0	8.3	18.0	11.0	7.0	11.0	11.0
Pigs (<20kg)	2.5	0.4	4.0	3.0	1.2	2.9	10.0	3.0	3.2	–	–	2.0	3.2	2.0
Pigs (>50kg)	24.0	54.4	28.1	21.0	14.8	26.3	25.0	23.0	20.0	21.0	28.1	18.0	26.0	16.2
Pigs (others)	13.0	13.2	10.9	10.0	8.5	8.8	9.0	10.0	9.9	10.4	12.8	9.6	11.0	7.7

<i>kg/head</i>	UK	CZ	HU	PL	SK	NO	BG	EE	CY	LV	LT	MT	RO	SI
Equidae	40.0	60.0	59.0	59.0	60.0	53.0	54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Bov. <1 year	17.3	20.0	24.1	18.0	21.0	28.0	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1
Bov. [1-2] years (males)	40.2	48.8	48.8	48.8	50.0	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8
Bov. [1-2] years (females)	43.4	48.7	48.7	48.7	45.0	48.7	48.7	48.7	48.7	48.7	48.7	48.7	48.7	48.7
Bov. >2 years (males)	62.0	60.0	57.9	57.9	60.0	40.0	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9
Heifers (>2 years)	54.5	59.0	58.5	40.0	55.0	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5
Dairy cows	103.5	99.0	101.0	60.0	90.0	85.0	90.7	90.7	90.7	90.7	90.7	90.7	90.7	90.7
Other cows (>2 years)	66.0	79.0	42.0	55.0	65.0	60.0	67.2	67.2	67.2	67.2	67.2	67.2	67.2	67.2
Sheep	9.0	10.0	9.0	8.0	10.0	14.0	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1
Goats	9.0	10.0	14.0	7.0	10.0	19.0	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8
Pigs (<20kg)	4.4	4.0	3.0	3.0	3.0	0.4	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Pigs (>50kg)	19.5	20.0	23.0	15.0	22.0	22.0	23.4	23.4	23.4	23.4	23.4	23.4	23.4	23.4
Pigs (others)	10.5	11.0	7.0	12.0	15.0	16.0	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1

Source: Hansen (2000 [258]) in black, OECD (2008 [374]) in red and own calculation in blue.

Table 5.2.2: European phosphorus manure emission coefficients (kg/head)

<i>kg/head</i>	BE	DK	DE	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE
Equidae	23.5	8.0	14.1	6.3	12.3	11.3	8.0	9.5	22.4	11.0	10.6	7.8	7.4	8.9
Bov. <1 year	4.9	4.7	5.3	3.3	13.3	2.8	3.0	8.9	4.7	3.6	3.8	3.6	3.6	2.9
Bov. [1-2] years (males)	8.0	7.9	8.8	8.0	23.8	9.3	8.0	8.3	10.4	10.1	8.3	8.3	8.0	8.5
Bov. [1-2] years (females)	8.0	7.6	8.8	7.6	18.1	12.2	8.0	7.8	10.4	8.2	8.3	7.8	8.0	7.6
Bov. >2 years (males)	9.2	8.3	10.6	9.6	28.8	11.8	10.0	24.5	9.7	10.1	13.0	10.0	9.2	9.2
Heifers (>2 years)	13.4	9.4	10.6	9.5	25.0	10.9	10.0	17.4	10.0	10.1	13.0	9.9	7.4	7.6
Dairy cows	13.9	19.0	17.2	15.6	37.4	16.7	13.0	48.2	14.6	17.5	17.0	15.6	17.0	15.9
Other cows (>2 years)	9.2	11.1	13.2	12.1	24.4	17.2	10.0	35.6	9.7	13.9	13.0	12.1	13.6	12.0
Sheep	1.0	3.7	2.6	2.4	3.5	2.5	1.5	3.1	1.0	2.2	3.5	1.9	1.7	1.6
Goats	1.0	2.5	3.5	2.2	4.2	2.1	1.0	3.0	1.0	2.4	1.4	2.2	2.7	8.0
Pigs (<20kg)	0.6	0.4	0.9	0.7	1.6	0.1	0.9	0.7	0.6	1.9		0.6		0.4
Pigs (>50kg)	5.4	5.1	6.2	6.2	13.7	6.6	4.0	16.6	5.7	4.4	7.4	6.2	4.8	7.6
Pigs (others)	5.4	5.1	3.5	6.3	7.6	2.8	2.3	4.4	2.5	2.9	2.2	2.8	2.6	2.8

<i>kg/head</i>	UK	CZ	HU	PL	SK	NO	BG	EE	CY	LV	LT	MT	RO	SI
Equidae	10.1	11.2	13.0	5.0	12.5	8.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
Bov. <1 year	3.8	2.6	30.0	2.0	3.0	3.6	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Bov. [1-2] years (males)	8.8	8.3	30.0	9.4	8.2	7.0	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Bov. [1-2] years (females)	8.2	6.8	30.0	8.8	7.5	7.0	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Bov. >2 years (males)	10.5	11.5	30.0	11.8	10.0	7.0	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8
Heifers (>2 years)	10.0	8.2	30.0	7.0	10.0	7.0	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
Dairy cows	15.9	15.2	30.0	11.0	18.0	13.0	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
Other cows (>2 years)	11.9	11.5	30.0	12.0	12.0	10.0	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9
Sheep	1.7	1.7	2.0	1.8	2.0	1.9	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Goats	2.2	1.9	3.1	1.7	2.0	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pigs (<20kg)	0.7	0.8	0.6	1.0	0.8	0.1	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Pigs (>50kg)	13.9	4.9	5.0	5.0	5.7	5.5	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Pigs (others)	3.4	3.5	2.2	4.0	2.7	0.8	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5

Source: OECD (2008 [374]) in red and own calculation in blue.

Table 5.2.3: European phosphorus and nitrogen emission coefficients for other inputs

		BE	DK	DE	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE
Nitrogen other emission coefficients	Atmospheric deposition (<i>kg/ha of arable land</i>)	45	20	23	5	9	17	10	12	44	16	16	4	2	7
	Biological fixation:														
	- Legume crops areas (<i>kg/ha of legume crops</i>)	137	114	194	222	97	157	66	160	158	222	43	80	75	30
	- Freelifving organism (<i>kg/ha of arable land</i>)	6.7	2.2	8.7	4	4	4	4	4	4	4	5	4	4	5
Phosphorus other emission coefficients	Atmospheric deposition (<i>kg/ha of agricultural land</i>)	0.2	0.1	0.4	0.2	0.34	0.1	0.1	0.3	0.2	1.0	0.34	0.1	0.3	0.2

		UK	CZ	HU	PL	SK	NO	BG	EE	CY	LV	LT	MT	RO	SI
Nitrogen other emission coefficients	Atmospheric deposition (<i>kg/ha of arable land</i>)	17	22	14	17	20	5	16	16	16	16	16	16	16	16
	Biological fixation:														
	- Legume crops areas (<i>kg/ha of legume crops</i>)	95	145	51	108	136	121	121	121	121	121	121	121	121	121
	- Freelifving organism (<i>kg/ha of arable land</i>)	4	5	4	4	5	2.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Phosphorus other emission coefficients	Atmospheric deposition (<i>kg/ha of agricultural land</i>)	0.2	1.0	0.34	0.2	0.2	0.2	0.34	0.34	0.34	0.34	0.34	0.4	0.34	0.34

Source: OECD (2008 [374]) in black and own calculation in blue.

OECD and Eurostat (2007 [376]) also develop the same methodology for the **phosphorus** balance which is similar to the nitrogen balance, but excludes emission factors for volatilisation and biological nitrogen fixation. Our methodology consists of calculating nitrogen and phosphorus inputs for 2008.

- For fertilisers, we use the Eurostat data on “Industry estimate of pesticides use” (Eurostat 2008 [214]) for inorganic fertilisers *i.e.* nitrogen and phosphates⁴. We exclude organic fertilisers coming from sewage sludge, urban compost or industrial waste products insomuch as, according to OECD (2008 [374]), the quantities are very weak and more generally do not exist.
- For livestock manure, we use data on livestock from Eurostat (Eurostat 2008 [209]) and we use the emission coefficients from Hansen (2000 [258]) for available countries in his study (in black in tables 5.2.1 and 5.2.2), except for Greece, Italy and Portugal for which Hansen used french coefficients. We apply OECD (2008 [374]) coefficients for Poland, the Czech Republic, Slovakia, Hungary and Norway as well as for some livestock sub-categories in order to harmonise the data (in red in tables 5.2.1 and 5.2.2). Finally, for the remaining countries, the average of emission coefficients are applied (in blue in tables 5.2.1 and 5.2.2)⁵.
- For biological nitrogen fixation⁶, we calculated emission coefficients from total legume crop areas with OECD (2008) data and we use areas used to produce vegetables and dried pulses from Eurostat (2008 [213]). Furthermore, we calculate emission coefficients from free living organisms with OECD (2008) data and we apply them to NEMESIS arable land in the *reference scenario* (see table 5.2.3).
- For atmospheric deposition of nitrogen or phosphorus compounds, we use emission coefficients from OECD (2008). We apply them to NEMESIS agricultural land use (see table 5.2.3).
- Finally for nitrogen (or phosphorus) input from seeds and planting materials, we use its share on the total of other nitrogen (or phosphorus) input (including biological nitrogen fixation, atmospheric deposition and seeds and planting materials) using OECD (2008). This approximation avoids calculation complication. Indeed, the share of seeds and planting materials is about 5% of other nitrogen input and about 54% of other phosphorus input. While other input represent less than 20% and 3% of total nitrogen and phosphorus inputs respectively (see table 5.2.3).

4. The transformation coefficient for phosphates (PO_4) to phosphorus (P) is, according to the atomic mass, 0.326. Nevertheless OECD (2008 [374]) use 0.44. We did not find explanation of this coefficient thereby we decide to use 0.33 therefore it will underestimate the phosphorus inputs for inorganic fertilisers compared to OECD (2008).

5. We have exclude from livestock the poultry manure which is relatively weakly informed, thereby the manure inputs are a few underestimated.

6. Biological fixation is excluded for phosphorus as in OECD (2007 [376]).

We can then calculate the quantity of nitrogen and phosphorus input used by European farms in 2008, as well as total nitrogen and phosphorus uses in kilogramme per hectare (*kg/ha*) *i.e.* nutrient input intensity. Because quantification of nitrogen and phosphorus requires numerous data on agricultural products and because this information is still not available and differ strongly between Eurostat and OECD (2008), we decided to not calculate nitrogen and phosphorus outputs. Therefore, we are now able to calculate nutrient balance. In addition, as mentioned by Hansen “*as a general rule, the data on inputs are estimated to be more accurate and reliable than the data on outputs [...] the lack of (reliable) data on harvested fodder and grass, mentioned above, also adds an element of uncertainty to the figures*”. Thereby, we only focus on fertilisers (nutrient input) use by agricultural and to avoid too strong approximation and mistakes, we will not calculate nutrients output and balance.

Tables 5.2.4 and 5.2.5 display the **nitrogen** and phosphorus input in tonnes and kg/ha per Member States (MS) in 2008 and for each input source. Both main sources of nitrogen in the EU-27 are manure and chemical fertilisers which represent 18.8 million tonnes in 2008 on a total of 22 million tonnes of nitrogen inputs *i.e.* 86%. Individually, nitrogen from manure accounts for 7.8 million tonnes (*i.e.* 35% of total nitrogen input) and inorganic nitrogen represents 11 million tonnes (*i.e.* 51% of total nitrogen input). Those quantities of nitrogen from manure and chemical are about 102 kg/ha on EU-27 average with inorganic nitrogen density higher than 70 kg/ha in seven EU-15 countries and one in New Member States (NMS). Indeed in Belgium, Germany, France, Ireland, Sweden and United Kingdom, the quantity of inorganic nitrogen ranges between 70 kg/ha to 80 kg/ha. The inorganic nitrogen land intensity is about 90 kg/ha in Slovenia and even reaches 112 kg/ha in Netherlands. The manure nitrogen per hectare is also very high in Belgium (135 kg/ha), Ireland (102 kg/ha) and Malta (188 kg/ha) and reaches a peak of 219 kg/ha in Netherlands. For countries with a relatively weak quantity of nitrogen input per hectare (*i.e.* less than 100 kg/ha) such as Spain (78 kg/ha), Portugal (80 kg/ha), Slovakia (74 kg/ha), Estonia (58 kg/ha), Latvia (76 kg/ha), Lithuania (72 kg/ha) and Roumania (65 kg/ha), it seems, compared with OECD (2008 [374]), that nitrogen input is still slightly too important to equilibrate nitrogen balance. Indeed, for Spain, Portugal and Slovakia, OECD (2008) estimates, for the year 2004, the nitrogen input at about 85 kg/ha, 106 kg/ha and 90 kg/ha respectively and nitrogen output at about 50 kg/ha, 59 kg/ha and 54 kg/ha. But even if it is difficult to compare those numbers and despite lower nitrogen inputs per hectare in our estimation for 2008 than in OECD (2008) for 2004, it is still unlikely than nitrogen balances are null or negative.

Table 5.2.4: Nitrogen and Phosphorus input in EU in 2008 per source (1/2)

Nitrogen	BE	DK	DE	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI
Total (t)	436 366	578 568	3 357 267	478 068	1 853 091	4 125 182	772 170	1 556 430	24 398	813 627	302 573	199 825	253 085
Total (kg/ha)	256.6	178.1	148.4	88.7	77.9	131.7	177.0	107.5	172.5	349.3	132.8	80.0	129.5
Inorganic fertilisers (t)	144 270	205 829	1 779 455	201 549	983 409	2 395 024	312 655	729 420	8 007	261 493	110 512	76 250	161 159
Inorganic fertilisers (kg/ha)	84.8	63.4	78.7	37.4	41.3	76.4	71.7	50.4	56.6	112.3	48.5	30.5	82.4
Livestock manure (t)	230 314	302 218	1 004 336	204 132	594 563	1 228 513	444 928	569 538	12 918	509 256	168 179	110 515	68 869
Livestock manure (kg/ha)	135.4	93.1	44.4	37.9	25.0	39.2	102.0	39.3	91.3	218.6	73.8	44.3	35.2
Atmospheric deposition (t)	48 735	61 127	379 405	22 770	144 534	371 131	10 216	129 552	3 150	19 259	16 569	4 278	3 868
Atmospheric deposition (kg/ha)	28.7	18.8	16.8	4.2	6.1	11.8	2.3	9.0	22.3	8.3	7.3	1.7	2.0
Biological fixation (t):	12 736	8 639	183 168	44 568	117 461	124 612	4 278	122 080	318	22 581	6 964	8 782	8 899
Biological fixation (kg/ha):	7.5	2.7	8.1	8.3	4.9	4.0	1.0	8.4	2.2	9.7	3.1	3.5	4.6
<i>- Legume crops areas (t)</i>	5 480	1 915	39 654	26 351	53 224	37 288	191	78 896	32	17 849	1 875	4 504	1 163
<i>- Legume crops areas (kg/ha)</i>	3.2	0.6	1.8	4.9	2.2	1.2	0.0	5.5	0.2	7.7	0.8	1.8	0.6
<i>- Free living organisms (t)</i>	7 256	6 724	143 514	18 216	64 237	87 325	4 086	43 184	286	4 733	5 090	4 278	7 737
<i>- Free living organisms (kg/ha)</i>	4.3	2.1	6.3	3.4	2.7	2.8	0.9	3.0	2.0	2.0	2.2	1.7	4.0
Seeds and planting material (t)	310	755	10 904	5 048	13 124	5 902	93	5 840	6	1 037	348	0	10 289
Seeds and planting material (kg/ha)	0.2	0.2	0.5	0.9	0.6	0.2	0.0	0.4	0.0	0.4	0.2	0.0	5.3

Phosphorus	BE	DK	DE	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI
Total (t)	66 250	79 069	335 333	73 483	559 147	514 179	92 158	340 025	2 846	90 117	47 343	39 172	27 502
Total (kg/ha)	39.0	24.3	14.8	13.6	23.5	16.4	21.1	23.5	20.1	38.7	20.8	15.7	14.1
Inorganic fertilisers (t)	14 699	9 504	85 475	24 869	171 124	206 271	25 109	113 404	686	12 866	13 996	14 494	13 000
Inorganic fertilisers (kg/ha)	8.6	2.9	3.8	4.6	7.2	6.6	5.8	7.8	4.8	5.5	6.1	5.8	6.7
Livestock manure (t)	50 931	68 102	234 306	47 021	372 862	279 260	66 416	218 699	2 116	74 395	30 724	23 087	13 533
Livestock manure (kg/ha)	29.9	21.0	10.4	8.7	15.7	8.9	15.2	15.1	15.0	31.9	13.5	9.2	6.9
Atmospheric deposition (t)	340	325	9 047	1 078	8 114	3 133	436	4 343	28	2 330	2 279	852	195
Atmospheric deposition (kg/ha)	0.20	0.10	0.40	0.20	0.34	0.10	0.10	0.30	0.20	1.00	1.00	0.34	0.10
Seeds and planting material (t)	279	1 138	6 505	515	7 046	25 515	197	3 581	16	526	345	740	774
Seeds and planting material (kg/ha)	0.2	0.4	0.3	0.1	0.3	0.8	0.0	0.2	0.1	0.2	0.2	0.3	0.4

Source: NEMESIS model

Table 5.2.5: Nitrogen and Phosphorus input in EU in 2008 per source (2/2)

Nitrogen	SE	UK	CZ	HU	PL	SK	NO	EE	LV	LT	MT	RO	SI
Total (t)	325 534	2 089 648	501 719	502 074	1 924 679	175 171	213 595	70 852	139 705	268 965	2 728	811 989	91 098
Total (kg/ha)	130.0	157.6	114.2	87.3	98.7	74.4	59.0	57.8	75.7	72.0	291.5	64.5	151.0
Inorganic fertilisers (t)	190 838	1 048 100	289 063	316 520	1 080 261	91 673	106 107	33 500	83 301	153 797	530	240 880	53 907
Inorganic fertilisers (kg/ha)	76.2	79.0	65.8	55.0	55.4	38.9	29.3	27.3	45.1	41.2	56.6	19.1	89.3
Livestock manure (t)	104 998	907 926	116 391	87362	467 286	42 986	92 725	19 101	28 686	59 510	1 754	366 165	31 417
Livestock manure (kg/ha)	41.9	68.5	26.5	15.2	24.0	18.3	25.6	15.6	15.5	15.9	187.5	29.1	52.1
Atmospheric deposition (t)	15 334	86 130	72 969	69 199	265 781	30 048	8 233	13 346	20 072	37 474	147	134 488	3 906
Atmospheric deposition (kg/ha)	6.1	6.5	16.6	12.0	13.6	12.8	2.3	10.9	10.9	10.0	15.7	10.7	6.5
Biological fixation (t):	11 982	45 821	21 358	25 407	98 328	9 797	5 085	4 454	6 942	16 509	270	63 967	1 696
Biological fixation (kg/ha):	4.8	3.5	4.9	4.4	5.0	4.2	1.4	3.6	3.8	4.4	28.8	5.1	2.8
<i>- Legume crops areas (t)</i>	1 029	25 555	4 774	5 636	35 791	2 285	1 133	760	1 387	6 137	229	26 744	615
<i>- Legume crops areas (kg/ha)</i>	0.4	1.9	1.1	1.0	1.8	1.0	0.3	0.6	0.8	1.6	24.5	2.1	1.0
<i>- Free living organisms (t)</i>	10 953	20 266	16 584	19 771	62 537	7 512	3 952	3 694	5 555	10 372	41	37 223	1 081
<i>- Free living organisms (kg/ha)</i>	4.4	1.5	3.8	3.4	3.2	3.2	1.1	3.0	3.0	2.8	4.3	3.0	1.8
Seeds and planting material (t)	2 382	1 671	1 938	3 586	13 022	667	1 444	452	704	1 675	27	6 489	172
Seeds and planting material (kg/ha)	1.0	0.1	0.4	0.6	0.7	0.3	0.4	0.4	0.4	0.4	2.9	0.5	0.3

Phosphorus	SE	UK	CZ	HU	PL	SK	NO	EE	LV	LT	MT	RO	SI
Total (t)	31 853	255 266	43 088	56 625	258 150	16 068	23 771	8 025	14 899	29 604	575	114 999	12 673
Total (kg/ha)	12.7	19.3	9.8	9.8	13.2	6.8	6.6	6.6	8.1	7.9	61.5	9.1	21.0
Inorganic fertilisers (t)	10 634	75 335	16 151	20 492	136 991	6 886	9 328	2 768	7 101	13 310	45	24 164	5 017
Inorganic fertilisers (kg/ha)	4.2	5.7	3.7	3.6	7.0	2.9	2.6	2.3	3.8	3.6	4.8	1.9	8.3
Livestock manure (t)	19 836	175 974	21 364	32 467	108 477	8 154	12 742	4 476	6 621	13 912	524	82 809	7 271
Livestock manure (kg/ha)	7.9	13.3	4.9	5.6	5.6	3.5	3.5	3.7	3.6	3.7	56.0	6.6	12.0
Atmospheric deposition (t)	751	2 652	4 394	1 962	3 900	471	724	418	630	1 275	3	4 296	206
Atmospheric deposition (kg/ha)	0.30	0.20	1.00	0.34	0.20	0.20	0.20	0.34	0.34	0.34	0.34	0.34	0.34
Seeds and planting material (t)	632	1 305	1 179	1 704	8 781	557	978	363	547	1 107	3	3 730	179
Seeds and planting material (kg/ha)	0.3	0.1	0.3	0.3	0.5	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Source: NEMESIS model

For **phosphorus input**, manure and chemicals remain the most important input source (96% of total phosphorus input) but with a larger contribution for manure than for chemicals where phosphorus from manure represents 2 million tonnes (*i.e.* 63%) and inorganic phosphorus 1 million tonnes (*i.e.* 33%). The Netherlands is still one of the biggest consumers per hectare with 39 kg/ha of which 32 kg/ha comes from manure, followed by Belgium, Cyprus and Denmark with 30 kg/ha, 23 kg/ha and 21 kg/ha respectively. But, it is the Maltese agriculture that uses the most phosphorus per hectare with 56 kg/ha. Furthermore, we observe an huge difference between EU-15 and NMS which are generally less intensive users of phosphorus. Especially, the amount of phosphorus kilogramme per hectare falls further to 7 kg/ha in Bulgaria, Estonia and Slovakia.

To summarise, in the results on nutrients uses by agriculture, we observe a strong heterogeneity among MS, with a higher consumption in EU-15 than in NMS overall for nitrogen or phosphorus. This difference among MS stems from the agricultural products produced in each of them but also from the agricultural practices and environmental policies in each country. In the following section, we present the modelling of nutrients per source for the NEMESIS model and we display their estimated uses in 2025.

5.2.2 Use of nutrients in NEMESIS and results for reference scenario in 2025

For the projections of nutrients used by MS in 2025 for the *reference scenario*, we use several methodologies for each source. Nevertheless, we must stress that our modelling is relatively simple in order to concur with available information in NEMESIS on agriculture production and land use.

5.2.2.1 Inorganic nutrient input

The inorganic nutrients are used for various agricultural production and Hansen (2000 [258]) distinguishes those uses in five types: cereals, other arable, fodder (including maize), fertilised grassland and permanent crops (fruit, vineyard). But in NEMESIS, we only distinguish animal and vegetal productions, thereby we calculate the share used for vegetal production (including cereals, other arable and permanent crops) and for animal production (fodder and fertilised grassland) for each EU-15 using Hansen data. And we apply the average for NMS. We can, now, link the demand for inorganic fertilisers according to both NEMESIS agricultural productions. We choose the following demand functions for each inorganic fertiliser and each use:

$$Inorg_{f,u,i,t} = A_{f,i} \cdot \exp(-\theta \cdot t) \left(\frac{c(Y_{u,i,t})}{P_{f,i,t}} \right)^\gamma Y_{u,i,t} \quad (5.2.1)$$

With $Inorg_{f,i,t}$ the **demand for inorganic fertiliser** f by country i at time t , with u the uses: animal and vegetal and where $f = N, P$ *i.e.* nitrogen or phosphorus. $c(Y_{u,i,t})$ represents the total production cost per unit of production and Y_u the agricultural production is equal to vegetal production for vegetal use ($u = V$) and to animal production for animal use ($u = A$). $P_{f,i,t}$ is the price of fertiliser f which follows the evolution of chemical industry production price whereas $A_{f,i}$ is a scale parameter. Finally, θ is a parameter for trend productivity and γ the price elasticity with respect to total production cost. Those both parameters were calibrated using Ngwa Zang and Le Mouél (2007 [367]) results and are equal to 0.005 and 0.45 respectively.

5.2.2.2 Manure nutrients input

For manure fertilisers, we use the CAPRI model results (Britz and Witzke 2008 [57] - see section 4.2 for a short CAPRI description) on livestock to calculate livestock in 2025 and more precisely its variation. Nevertheless, CAPRI does not have similar livestock nomenclature than the one in tables 5.2.1 and 5.2.2. Thereby, we aggregate the results for cattle only distinguishing dairy cows from other cattle. We also suppose a fixed number of equidae livestock for each MS and we use the aggregate emission coefficients for sheep and goats. For modelling, we apply a very simple relationship between animal production (Y_{ani}) and manure by supposing a **Leontief production function** (Leontief 1936 [333]). Thus, the manure production for nitrogen and phosphorus ($Man_{f,i,t}$) are proportional to animal production ($Man_{f,i,t} = \alpha_{f,i,t}^{Man} \cdot Y_{ani,i,t}$). Nevertheless, we calibrate those relationships in order to match manure nutrient estimates for 2025 realised with CAPRI livestock. In other words, the parameter α_t^{Man} varies with the time in order to reflect the change in livestock volume as well as its structure between 2008 and 2025. Furthermore, with this assumption of Leontief production function for manure nutrient, we suppose that in policy assessment scenarios, the livestock structure in each MS is similar than in the *reference scenario*.

5.2.2.3 Other nutrients input

The modelling of other nutrient inputs is also relatively simple but requires for some of them less assumption. Starting from nitrogen biological fixation, we distinguish two sources: **nitrogen from legume crop** areas and from **free living organisms**. The latter one, as presented in table 5.2.3, is

proportional to arable land (in ha) therefore $N_{i,t}^{liv} = \alpha_i^{liv} \cdot L_{AL,i,t}$. We calculate nitrogen input from free living organisms ($N_{i,t}^{liv}$) with the emission coefficients from table 5.2.3 (α_i^{liv}) that we apply to NEMESIS arable land ($L_{AL,i,t}$). For nitrogen from legume crops areas ($N_{i,t}^{leg}$), we use an similar representation ($N_{i,t}^{leg} = \alpha_i^{leg} \cdot L_{leg,i,t}$) but applying the emission coefficients (α_i^{leg}) from table 5.2.3 to land used for legume crops production ($L_{leg,i,t}$). In this case, the difficulty comes from the representation of the legume crops areas. In order to do this, we still use a simple proportionality relationship ($L_{leg,i,t} = \alpha_{i,t}^{leg} \cdot L_{AL,i,t}$) between legume crops areas and arable land ($L_{AL,i,t}$). As for manure, we use CAPRI results for *reference scenario*, by supposing constant legume crops yields. We apply the evolution of CAPRI legume crop production to quantify the legume crops areas in 2025. Thereby the relationship between arable land and legume crops is fixed between policy assessment scenarios but varies across time in the *reference scenario* ($\alpha_{i,t}^{leg}$), as for manure nutrients. The calculation of nitrogen and phosphorus from **atmospheric deposit** is easy, we use the emission coefficients of table 5.2.3 that we apply to NEMESIS arable land for nitrogen and agricultural land use for phosphorus. Finally, nutrient inputs from **seeds and planting materials** are assumed to be a fixed share of total of other nutrients, as for their calculation in 2008.

5.2.2.4 Nutrients input in 2025 in the *reference scenario*

Table 5.2.6 and 5.2.7 display nitrogen and phosphorus input projections in 2025 in EU for the *reference scenario*. We observe that **nitrogen slightly increases** by +0.2 million tonnes in 2025 for EU⁷ compared to 2008 (*i.e.* +1%) that leads to a rise of +1 kg/ha. The rise of nitrogen inputs is notably strong in Spain with an increase of +0.3 million tonnes (+17%) mainly due to manure nitrogen that rises by about +19% and inorganic fertilisers increasing about +19%. In Spain, livestock grows by about +40% (+43% for cattle and +37% for pigs) between 2008 and 2025 but dairy cows having the highest cattle emission coefficients decrease by about -20%. This reduces the rise of nitrogen manure. Furthermore, as presented in section 3.2, Spanish agricultural production rises about +23% in the reference scenario explaining the increase of inorganic nitrogen. We also see an increase about +10% for Hungary and Latvia for which agricultural production in the *reference scenario* raises by +19% and +17% respectively. At the opposite end of the scale, in Finland, where the agricultural production falls about -15% between 2008 and 2025, nitrogen inputs decreases about -19% *i.e.* -23 kg/ha.

7. EU includes EU-27 except Bulgaria and Cyprus.

Table 5.2.6: Nitrogen and Phosphorus input by Members States in *reference scenario* in 2025 (1/2)

Nitrogen	BE	DK	DE	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI
Total (t)	449 932	613 290	3 318 226	469 437	2 168 962	4 070 910	734 917	1 565 769	24 097	767 141	294 469	195 070	204 061
Total (kg/ha)	274.8	193.0	148.5	87.6	89.8	132.1	173.7	107.9	174.5	337.4	132.4	80.2	106.6
Inorganic fertilisers (t)	155 908	211 477	1 867 950	212 042	1 165 185	2 418 652	296 358	748 503	8 132	271 128	112 963	70 351	134 423
Inorganic fertilisers (kg/ha)	95.2	66.6	83.6	39.6	48.3	78.5	70.0	51.6	58.9	119.3	50.8	28.9	70.2
Livestock manure (t)	232 763	332 729	873 325	184 041	709 386	1 154 150	424 441	557 575	12 473	453 369	157 465	112 115	47 040
Livestock manure (kg/ha)	142.2	104.7	39.1	34.3	29.4	37.5	100.3	38.4	90.3	199.4	70.8	46.1	24.6
Atmospheric deposition (t)	48 324	59 880	381 704	23 075	154 658	368 514	9 888	130 669	3 167	19 154	16 680	4 128	3 791
Atmospheric deposition (kg/ha)	29.5	18.8	17.1	4.3	6.4	12.0	2.3	9.0	22.9	8.4	7.5	1.7	2.0
Biological fixation (t):	12 629	8 463	184 277	45 163	125 689	123 734	4 140	123 132	320	22 458	7 011	8 475	8 722
Biological fixation (kg/ha):	7.7	2.7	8.2	8.4	5.2	4.0	1.0	8.5	2.3	9.9	3.2	3.5	4.6
Seeds and planting material (t)	308	740	10 970	5 116	14 043	5 860	91	5 891	6	1 032	350	0	10 084
Seeds and planting material (kg/ha)	0.2	0.2	0.5	1.0	0.6	0.2	0.0	0.4	0.0	0.5	0.2	0.0	5.3

Phosphorus	BE	DK	DE	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI
Total (t)	69 990	90 007	313 299	70 198	671 990	498 533	87 730	342 324	2 793	82 620	45 205	38 655	21 480
Total (kg/ha)	42.8	28.3	14.0	13.1	27.8	16.2	20.7	23.6	20.2	36.3	20.3	15.9	11.2
Inorganic fertilisers (t)	15 885	9 765	89 726	26 164	202 755	208 306	23 800	116 370	697	13 340	14 306	13 373	10 843
Inorganic fertilisers (kg/ha)	9.7	3.1	4.0	4.9	8.4	6.8	5.6	8.0	5.0	5.9	6.4	5.5	5.7
Livestock manure (t)	53 508	78 812	208 205	42 451	453 841	262 060	63 316	218 011	2 053	66 494	28 338	23 731	9 687
Livestock manure (kg/ha)	32.7	24.8	9.3	7.9	18.8	8.5	15.0	15.0	14.9	29.2	12.7	9.8	5.1
Atmospheric deposition (t)	327	318	8 940	1 072	8 239	3 081	423	4 353	28	2 274	2 224	830	191
Atmospheric deposition (kg/ha)	0.20	0.10	0.40	0.20	0.34	0.10	0.10	0.30	0.20	1.00	1.00	0.34	0.10
Seeds and planting material (t)	269	1 113	6 428	512	7 155	25 086	191	3 589	15	513	336	721	758
Seeds and planting material (kg/ha)	0.2	0.4	0.3	0.1	0.3	0.8	0.0	0.2	0.1	0.2	0.2	0.3	0.4

Source: NEMESIS model

Table 5.2.7: Nitrogen and Phosphorus input by Members States in *reference scenario* in 2025 (2/2)

Nitrogen	SE	UK	CZ	HU	PL	SK	NO	EE	LV	LT	MT	RO	SI
Total (t)	310 991	2 160 047	481 087	551 910	1 905 740	165 210	198 466	80 173	136 991	296 461	2 274	843 090	89 058
Total (kg/ha)	128.8	168.2	111.2	97.3	99.9	73.3	55.7	61.6	69.6	77.4	256.4	69.1	146.8
Inorganic fertilisers (t)	186 284	1 005 559	285 127	363 276	1 125 722	85 061	98 138	38 679	77 087	163 416	537	229 925	55 163
Inorganic fertilisers (kg/ha)	77.1	78.3	65.9	64.0	59.0	37.8	27.5	29.7	39.2	42.7	60.6	18.8	90.9
Livestock manure (t)	95 876	1 026 211	99 162	91 678	399 779	41 817	84 311	21 247	25 769	66 440	1 317	411 838	27 152
Livestock manure (kg/ha)	39.7	79.9	22.9	16.2	21.0	18.6	23.7	16.3	13.1	17.4	148.5	33.8	44.8
Atmospheric deposition (t)	14 887	82 685	73 373	68 328	267 972	28 431	8 932	14 805	24 719	44 844	139	132 114	4 561
Atmospheric deposition (kg/ha)	6.2	6.4	17.0	12.0	14.0	12.6	2.5	11.4	12.6	11.7	15.7	10.8	7.5
Biological fixation (t):	11 632	43 988	21 476	25 087	99 138	9 270	5 517	4 940	8 549	19 756	256	62 838	1 980
Biological fixation (kg/ha):	4.8	3.4	5.0	4.4	5.2	4.1	1.5	3.8	4.3	5.2	28.8	5.1	3.3
Seeds and planting material (t)	2 312	1 604	1 949	3 541	13 129	631	1 567	501	867	2 004	26	6 375	201
Seeds and planting material (kg/ha)	1.0	0.1	0.5	0.6	0.7	0.3	0.4	0.4	0.4	0.5	2.9	0.5	0.3

Phosphorus	SE	UK	CZ	HU	PL	SK	NO	EE	LV	LT	MT	RO	SI
Total (t)	29 974	275 221	40 409	60 018	245 591	15 244	22 058	9 054	13 950	31 881	410	122 416	11 929
Total (kg/ha)	12.4	21.4	9.3	10.6	12.9	6.8	6.2	7.0	7.1	8.3	46.2	10.0	19.7
Inorganic fertilisers (t)	10 381	72 278	15 931	23 519	142 756	6 390	8 627	3 196	6 572	14 142	46	23 065	5 134
Inorganic fertilisers (kg/ha)	4.3	5.6	3.7	4.1	7.5	2.8	2.4	2.5	3.3	3.7	5.2	1.9	8.5
Livestock manure (t)	18 259	19 911	18 990	32 883	90 432	7 870	11 756	5 029	6 124	15 298	358	91 572	6 409
Livestock manure (kg/ha)	7.6	15.5	4.4	5.8	4.7	3.5	3.3	3.9	3.1	4.0	40.3	7.5	10.6
Atmospheric deposition (t)	725	2 568	4 327	1 936	3 815	451	713	444	671	1 306	3	4 163	207
Atmospheric deposition (kg/ha)	0.30	0.20	1.00	0.34	0.20	0.20	0.20	0.34	0.34	0.34	0.34	0.34	0.34
Seeds and planting material (t)	610	1 264	1 161	1 681	8 588	533	963	385	583	1 134	3	3 615	180
Seeds and planting material (kg/ha)	0.3	0.1	0.3	0.3	0.5	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Source: NEMESIS model

The countries like Malta and especially the Netherlands, where nitrogen inputs per hectare are the highest (*i.e.* 349 kg/ha and 292 kg/ha), decrease their nitrogen consumption but not enough. They stay the biggest users in terms of kilogramme per hectare. Indeed, nitrogen input falls by -46 500 tonnes and -450 tonnes in the Netherlands and Malta respectively *i.e.* a decrease of -12 kg/ha and -32 kg/ha respectively.

For **phosphorus inputs**, the evolution between 2008 and 2025 are relatively similar to nitrogen and especially for inorganic phosphorus insomuch as the modelling is identical (see equation 5.2.1). The difference comes from manure for which the emission coefficients are different among livestock components than from other nutrient input of which the proportion of phosphorus is very weak compared to nitrogen. Again we find the strongest increase in Spain with +112 000 additional tonnes in 2025 (+20%) *i.e.* +4 kg/ha and a big fall in Finland with -20%. But the biggest reduction arises for Malta which reduces its phosphorus consumption about -29% *i.e.* -15 kg/ha passing from 61 kg/ha to 46 kg/ha. This Maltese fall is mainly due to phosphorus manure decrease coming from the reduction by 50% of dairy cows and pig livestock.

5.2.3 Concluding remarks

Agriculture has become one major source of pollution of groundwater and eutrophication of fresh water and marine environments through fertiliser usage, it seems relatively important to take into account those environmental problems in policy assessment. To do this, we did not directly quantify the environmental impact because it would be too complex and above all outside the scope of this study. But, we try to model the supply of nutrients in agriculture in each MS which can be viewed as an indicator. Our results seems relatively good and allow, at least, the quantification of nitrogen inputs for 2008 whereas the last available year for official data is 2004 (OECD 2008 [374]). Furthermore, looking at OECD (2008) nutrient input for 2004 in table 5.2.8 and comparing to our estimation for 2008, even if we must take care of the comparability extent, we see that the results are relatively close in terms of kilogramme per hectare. As our modelling for manure nutrients does not include poultry livestock and as for inorganic phosphorus we used a conversion coefficient for phosphates to phosphorus of 0.33, corresponding to atomic mass, whereas OECD (2008) applies a coefficient of 0.44, we certainly underestimate the nutrient input in agriculture.

Table 5.2.8: Comparison between nutrients estimation from NEMESIS model for 2008 and OECD (2008 [374]) for 2004

<i>kg/ha</i>	AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT	SE	UK	EU-15
OECD N inputs (2004)	122.8	351.2	224.9	218.8	84.8	119.5	155.9	70.1	238.4	132.8	272.6	421.0	105.8	117.1	157.5	147.8
NEMESIS N inputs (2008)	132.8	256.6	148.4	178.1	77.9	129.5	131.7	88.7	177.0	107.5	172.5	349.3	80.0	130.0	157.6	131.5
Difference	-9.9	94.6	76.5	40.7	6.9	-9.9	24.2	-18.5	61.4	25.3	100.2	71.7	25.7	-12.9	-0.1	16.3
OECD P inputs (2004)	17.0	48.3	23.4	27.6	27.3	17.3	22.3	11.7	25.4	32.1	35.0	45.4	24.7	13.6	22.1	24.3
NEMESIS P inputs (2008)	20.8	39.0	14.8	24.3	23.5	14.1	16.4	13.6	21.1	23.5	20.1	38.7	15.7	12.7	19.3	19.4
Difference	-3.8	9.4	8.6	3.2	3.7	3.2	5.9	-1.9	4.3	8.6	14.9	6.8	9.0	0.9	2.9	4.9

Source: OECD (2008 [374]) and NEMESIS model.

In addition, our nutrients modelling for policy assessment has important limitations. Firstly, we decided to restrict our analysis to input excluding output. Consequently, we do not provide nutrient balance and we are not able to quantify the surplus affecting the environment. This restriction was unfortunately preferable to avoid too approximate modelling. Indeed, the needs of details data for agriculture crops products and the difference that we found between Eurostat database and OECD (2008 [374]) one for 2004, oblige us to exclude the quantification of nutrients outputs. In addition as mentioned by Hansen (2000 [258]), the emission coefficients for output are generally judged, by experts, much more uncertain than input coefficient. Another important limitation stems from the assumption that policy will have none impact on livestock composition. The livestock structure is supposed to be the same as in the *reference scenario*. But unfortunately, as the emissions coefficients show, there is an important heterogeneity among livestock components that we can not take into account with available information on NEMESIS modelled agricultural products. Finally, EU marine Strategy (EP 2008 [175]) is excluded from our study. However, this directive depends on MS individual measures which were not yet available. However, despite the simplicity of our modelling and the limitations exposed above, the results for 2008 and 2025 seems credible. And we will see in the following section nutrients estimates will give interesting insights despite the extent of the modelling.

5.3 Increasing European Biodiversity: Policy assessment with NEMESIS model

5.3.1 General context

2010, the writing year of this study, was chosen by the United Nation (UN) through the United Nation Environment Programme (UNEP) as the International Year of Biodiversity⁸ (UN, 2007 [445]). For several years, there has been a consensus in the scientific community that biodiversity or biological diversity, in all its dimensions, is globally declining on Earth. For instance, the Millennium Ecosystem Assessment⁹ (MEA) concludes in its “Ecosystems and Human Well-Being: Current State and Trends” Reports (MEA, 2005 [354]) that *“it is well established that losses in biodiversity are occurring globally at all levels, from ecosystems through species, populations, and genes [...] the current documented rate of species extinction is two orders of magnitude higher than the average rate of species extinction from the fossil record, and there is a continuing trend for conversion of naturally occurring, species-rich ecosystems into more intensively managed habitats with reduced biodiversity”* (Agardy *et al.* 2005 [1] and Ricketts *et al.* 2005 [405]). Indeed, MEA has established that biodiversity losses arise at one hundred to one thousand times the normal rate of extinction. For instance they estimate that 20% of known coral reefs have been destroyed and another 20% degraded in the last several decades. Or even 12% of bird species, 23% of mammals, and 25% of conifers are currently threatened with extinction (MEA 2005 [353]). There are several definitions of the biodiversity, the UN convention on biological diversity (UN, 1993 [444]) uses the following definition: *“the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”*. Three levels for biodiversity are generally recognised:

- Genetic diversity, the variety of genetic building-blocks found among individual representatives of a species,
- Species diversity, the variety of living organisms found in a particular place.

8. www.unep.org/iyb

9. The Millennium Ecosystem Assessment (MEA) was initiated in 2001, with the support from United Nations Secretary-General Kofi Annan. Its objectives were “to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being” and “provide a state-of-the-art scientific appraisal of the condition and trends in the world’s ecosystems and the services they provide (such as clean water, food, forest products, flood control, and natural resources) and the options to restore, conserve or enhance the sustainable use of ecosystems”. (www.maweb.org)

- And ecosystem diversity, the variety of species and ecological functions and processes, both their kind and number that occur in different physical settings.

The MEA identifies several anthropogenic indirect drivers of biodiversity losses and change in ecosystems such as land use change, physical modification of rivers or water withdrawal from rivers, invasive alien species, over-exploitation of species and pollution (MEA 2005 [353]). In addition to the international consensus on biodiversity losses, it is also internationally admitted that biodiversity has an anthropocentric value which can be converted, at least theoretically, on economic values. Those economic values of biodiversity appear mainly through two channels¹⁰:

- the environmental and social amenities such as the aesthetic values associated to a landscape (intrinsic value),
- and the services provided by the ecosystems for human activities that include, *inter alia*, production of food, fuel, fibre and medicines, regulation of water, air and climate, maintenance of soil fertility, cycling of nutrients.

The international identification and consensus on the accelerated rate of biodiversity losses as well as the anthropocentric value of biodiversity were also quickly recognised by European Union that ratified the UN convention on biological diversity in 1993. It states: “*In ratifying the Convention, the parties have committed themselves to undertaking national and international measures aimed at its achieving three objectives: the conservation of biological diversity; the sustainable use of its components; and the fair and equitable sharing of benefits arising out of the utilization of genetic resources*” (UN, 1993 [444]). After the ratification, the EU developed a biodiversity strategy (EC 1998 [129]) which was followed by more specific biodiversity action plans in 2001 (EC 2001 [133]). But it also led, during European Council at the Göteborg in 2001, to the objective “*to halt the decline of biodiversity by 2010*” (EU 2001 [178]) and to “*restore habitats and natural systems*” (EC 2001 [131]). The EU internal policy for biodiversity conservation has therefore follows seven axis (EC 2006 [139]):

- safeguarding most important habitats and species,
- integration of biodiversity into the Sustainable Development Strategy (EC 2001 [131]), Lisbon partnership for growth and jobs, and environmental policy,
- integration of biodiversity into agricultural and rural development policy,
- integration into fisheries policy,

10. See e.g. Bielsa *et al.* (2009) for an detail study on economic value of biodiversity or The Economics of Ecosystems and Biodiversity (TEEB) network (www.teebweb.org).

- integration into regional and territorial development policy,
- control of alien species.

Nevertheless, the EU has completed its policy for biodiversity on defining four key policy areas containing ten priority objectives (EC 2006 [139]). The first policy concerns biodiversity in EU and prioritises (1) the safeguard of the EU's most important habitats and species, (2) the conservation and restoration of biodiversity and ecosystem services in the wider EU countryside but also (3) in the wider EU marine environment, (4) the reinforcement of compatibility of regional and territorial development with biodiversity in the EU and (5) the reduction of the impact on EU biodiversity of invasive alien species and alien genotypes. The second key policy focuses on the EU and global biodiversity and has as priority (6) to substantially strengthen effectiveness of international governance for biodiversity and ecosystem services, (7) to substantially strengthen support for biodiversity and ecosystem services in EU external assistance and (8) to substantially reduce the impact of international trade on global biodiversity and ecosystem services. The third key policy aims (9) to support biodiversity adaptation to climate change. Finally, the fourth EU policy for biodiversity emphasises the objective (10) to substantially strengthen the knowledge base for conservation and sustainable use of biodiversity, in the EU and globally. To support and reach the matching of those ten EU priority objectives for biodiversity conservation, the EU has developed several policy instruments that we describe in the following section, focusing mainly on Natura 2000.

5.3.2 European Union policy instruments for biodiversity

The EU instruments for biodiversity policy are numerous and differ by nature, they are intersected such as EU directives or Natura 2000 network or LIFE+ funding¹¹. Table 5.3.1, in a non exhaustive manner, summarises those instruments for seven of the ten EU priority objectives exposed previously through three kind of instruments: legal ones *i.e.* EU laws in which the objectives are included, funds *i.e.* European financing for those objectives and other instruments such as EU research projects, general EU policies, etc.

11. LIFE+ is a European financial instrument for the environment projects. For instance, the LIFE+ 2010 call for proposals accounting for €240 million around three axis: nature and biodiversity, environment policy and governance, and information and communication. The total budget of LIFE+ funding for 2007-2013 is about €2.1 billion.

Table 5.3.1: An overview of European instruments for biodiversity policy

EU priority objectives for biodiversity	Instruments		
	Legal	Funds	Other
(1) Safeguard habitats and species	Birds and Habitats directives (EU 2009 [190] and EU 1992 [181])	LIFE+*	Natura 2000**
(2) EU countryside	Assessment and management of flood risks directive (EU 2007 [188]), Birds and Habitats directives	European Agricultural Fund for Rural Development (EAFRD - CAP 2 nd Pillar), LIFE+	Common Agricultural policy (CAP), cross-compliance, Natura 2000
(3) EU marine environment	Marine Strategy Framework Directive (EU 2008 [189])	LIFE+	Common Fisheries Policy (regulatory measures), Natura 2000
(4) Compatibility of regional and territorial development		European Regional Development Fund and Cohesion Funds	Natura 2000
(5) invasive aliens species genotypes			Streamlining European 2010 Biodiversity Indicators (SEBI 2010 project) ^a , Delivering Alien Invasive Species Inventories for Europe (DAISIE ^b), Assessing Large-scale Risks for biodiversity with tested Methods (ALARM ^c), etc
(9) Climate change		LIFE+	UN Framework Convention on Climate Change, Green Paper (EC 2007 [140])
(10) Knowledge base		LIFE+	Research Framework Programme (FP), The Economics of ecosystems and biodiversity (TEEB)

Source: EC 2008 [141]

*: <http://ec.europa.eu/environment/life/funding/lifeplus.htm>

** : http://ec.europa.eu/environment/nature/natura2000/index_en.htm

^a: <http://biodiversity-chm.eea.europa.eu/information/indicator/F1090245995/>

^b: www.europe-aliens.org

^c: www.alarmproject.net

We will focus our analysis on inland biodiversity, therefore we can divided the EU instruments into:

- Nature protection and/or site protection
- horizontal environmental policies and others policies such as EU Sustainable Development Strategy and Common Agricultural policy.

The both main European policy instruments for nature conservation are the Birds directives (EU 2009 [190])¹² and the Habitats directives (EU 1992 [181]). The Habitats directive establishes a list of “*natural habitat types of community interest whose conservation requires the designation of special areas of conservation*” which includes more than 230 habitats types, regrouped in nine categories: (1) Coastal and halophytic habitats, (2) Coastal, sand, dunes, and inland dunes, (3) Freshwater habitats, (4) Temperate heath and scrub, (5) Sclerophyllous scrub (Matorral), (6) Natural and semi-natural grassland formation, (7) Raised bogs and mires and fens, (8) Rocky habitats and caves and (9) Forests. Furthermore, the Habitats directive also provides a list of “*animal and plant species of community interest whose conservation requires the designation of special areas of conservation*” and that includes about one thousand of species. In the same manner, the Birds directive adds a list of bird species for which MS must “*maintain the population of the species [...] at a level which corresponds in particular to ecological, scientific and cultural requirements*”. Under the Habitats directive, each Members State proposes “*a list of sites indicating which natural habitat types [...] and which species [...] are native to its territory the sites host*” according to some eligibility criteria and the directive list of natural habitats, animal and plant species of community interest. The list of those sites creates “*a coherent European ecological network of special areas of conservation shall be set up under the title Natura 2000*”.

The other main European policy instrument for biodiversity is the CAP 2nd Pillar *i.e.* under the heading of rural development. With the European Agricultural Fund for Rural Development (EAFRD), endowed of €20.3 billion for the financial framework 2007-2013, the EU wants to improve three main axis: (1) the competitiveness of agriculture and forestry, (2) the environment and the countryside and (3) the quality of life and the management of economic activity in rural areas. And under the second axis, EAFRD aims to contribute to sustainable development by encouraging friendly environmental agricultural production practices, by preserving the natural environment and landscape and protecting and improving natural resources. EAFRD objectives put the emphasis on biodiversity, management of NATURA 2000 sites, water and soil protection and climate change mitigation (EU 2005 [186]). In order

12. The first Birds directive dates from 1979 (EU 1979 [180]) but after several amendments, it was re-written in 2009 to be clarify.

to do this, around €580 million of EAFRD resources have been dedicated to Natura 2000 network (EC 2008 [141]). Finally, another important policy instrument for biodiversity related to CAP is the cross-compliance principle which links direct payments to farmers to their respect of environment and other European and national requirements. The cross-compliance principle was introduced in the 2003 CAP reform. The cross-compliance is composed of two axes: good agricultural and environmental conditions and the statutory management requirements related to the protection of environment, public, animal and plant health and animal welfare.

Among all those instruments, we will detail the Natura 2000 network which is the major EU biodiversity policy instrument and which is transverse to EU priority objectives for biodiversity.

5.3.3 The Natura 2000 network

5.3.3.1 Natura 2000 concept

As explained above, the Natura 2000 network is a European Union wide network for nature protection that was established under the **Habitats directive** (EU 1992 [181]) and that includes, by Member States proposition, sites that are of special interest for biodiversity and designed as Special Areas of Conservation (SAC) under the Habitats directive and as Special Protection Areas (SPA) under the **Birds directive** (EU 2009 [190]). Natura 2000 is not only a network including sites for which there is no human activity such as nature reserves, but holds a majority of lands that are privately owned but for which the management must be sustainable. Each MS has liberty in the method to implement the objectives for Natura 2000 sites. Nevertheless, the EU gives some recommendations with regard to the management of Natura 2000 sites. For instance, the European Commission Directorate-General for the Environment has proposed a guidance document for the management of Natura 2000 sites (EC 2001 [132]) and has also established a list of good practice through case studies (EC 2009 [145])¹³. The **financing of Natura 2000** site management is under the responsibility of each MS that generally delegate it to national or regional environmental agencies or even to regional administrations. Nevertheless, the Habitats directive recognises the possibility for EU to co-finance Natura 2000 in exceptional cases. The European Commission (EC 2004 [135]) justifies this possibility of Community co-financing for two main reasons (*i*) the share of biodiversity benefits among all MS whereas the cost is supported by each of them according to its endowment of Habitats and species of interest, (*ii*) the

13. The good practices guidance in managing Natura 2000 is published with the help of a website (<http://ec.europa.eu/environment/nature/natura2000/management/gp/index.html>).

integration of Natura 2000 objectives in several European policies such as regional, agricultural and rural development policies. Thereby, there are several funds that can be used by MS to co-finance the Natura 2000 network. However according to the eligibility to those funds as well as the internal MS organisation, a limited number of MS has access or uses those funds (EC 2004 [135]). According to EC (2004 [135]), the funds used for the Natura 2000 network are:

- European Agricultural Fund for Rural Development (EAFRD) ¹⁴ - 2nd CAP pillar,
- European Rural Development Fund (ERDF) via, *inter alia*, INTERREG - Cohesion fund,
- and LIFE+ ¹⁵.

In 2004, the European Commission has estimated the cost of Natura 2000 network for the EU-25 ¹⁶ (EC 2004 [134]), through the help of a questionnaire sent to MS, at €6.1 billion per year. In 2004, the Natura 2000 network covered around 560 000 km² of terrestrial area and 80 000 km² of marine area *i.e.* 640 000 km² and 17% of total European area. Thereby, the estimated **cost of Natura 2000 network** in 2004, was a little less than 100 €/ha/year for terrestrial areas. Except this estimation by the European Commission, there is, to our knowledge, no assessment of the Natura 2000 network costs.

5.3.3.2 Natura 2000 network in 2009

Table 5.3.2 presents the most recent data on the Natura 2000 networks by MS and by land use types which results of the aggregation of several habitats types. At EU level, the Natura 2000 network covers 19% of the EU terrestrial areas (*i.e.* 800 000 km²) whereas the marine and inland water areas included in the network is about 275 000 km². The Natura 2000 network ¹⁷ is mainly composed by forest areas that regroup 46% of the network *i.e.* 330 000 km² and followed by agricultural land with around 200 000 km² (*i.e.* 28% of EU terrestrial areas) which is composed of 105 000 km² of grassland and 95 000 km² of arable land. Thereafter, the third land use category covered by the Natura 2000 network is “other Natura 2000” with 27% of EU terrestrial areas *i.e.* 190 000 km², including, for instance, coastal sand dunes, sand beaches or heath, scrub, maquis and garrigue.

14. For the financial framework 2007-2103, EAFRD has replaced the European Agricultural Guidance and Guarantee Fund (EAGGF) that was a co-financing source, for the Guidance part, of Nature 2000 network until 2006.

15. LEADER+ were also a co-financing option for Natura 2000 until 2006.

16. This cost excludes the indirect costs, such as the land prices fall for Natura 2000 sites or land price increase for neighbouring areas, the farming or fishing practices restrictions or potential costs for forestry, transport, construction and mining activities.

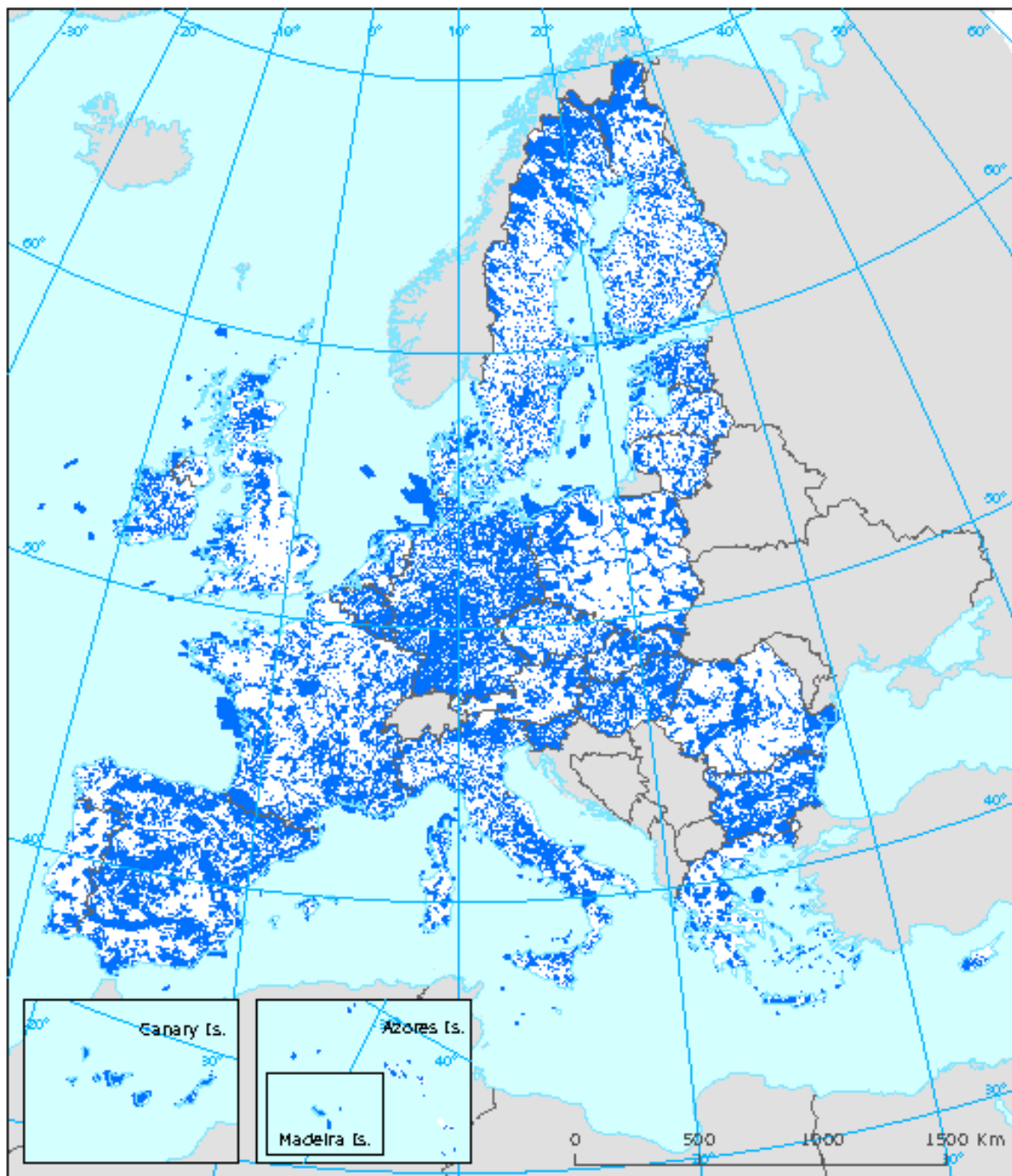
17. The following numbers excludes Austria, Bulgaria, Cyprus and United Kingdom for which there is none detailed data available either from EEA (2009 [162]) or in NEMESIS.

Table 5.3.2: Natura 2000 network in MS in 2009

	Natura 2000 Total terrestrial area (km ²)	% of total area	Natura 2000 Forest (km ²)	% of total forest	Natura 2000 arable land (km ²)	% of total land arable	Natura 2000 grassland (km ²)	% of total grassland	Other Natura 2000 (km ²)	Natura 2000 marine and inland water areas (km ²)
AT	11 533	13.9%	–	–	–	–	–	–	–	0
BE	4 400	14.4%	2 965	48.5%	290	2.7%	685	11.1%	459	599
BG	50 907	45.9%	26 070	–	9 276	–	7 540	–	8 022	2 879
CY	1 255	21.9%	–	–	–	–	–	–	–	61
CZ	18 230	23.3%	9 256	36.2%	5 332	16.1%	2 533	23.5%	1 109	598
DE	60 731	17.0%	32 145	30.9%	6 794	4.1%	14 149	23.1%	7 643	42 566
DK	4 910	11.4%	1 082	28.1%	1 823	6.0%	750	39.2%	1 256	26 104
EE	9 029	20.9%	4 417	21.1%	338	4.1%	685	16.9%	3 589	10 439
ES	156 035	31.0%	60 393	65.0%	19 799	12.3%	20 562	26.6%	55 281	11 587
FI	36 413	12.2%	14 783	7.3%	2 733	14.1%	28	13.8%	18 869	13 926
FR	82 566	15.1%	31 781	21.9%	10 009	4.6%	19 552	20.6%	21 223	62 010
GR	27 882	21.3%	11 997	50.5%	4 151	9.1%	1 897	22.7%	9 836	8 193
HU	24 173	26.5%	10 285	60.2%	3 954	8.0%	4 038	50.0%	5 897	1 696
IE	6 962	10.1%	324	11.0%	36	0.4%	1 294	3.9%	5 309	9 080
IT	64 916	21.8%	25 071	31.7%	3 824	3.5%	14 096	38.3%	21 925	6 956
LT	10 084	15.8%	7 220	38.8%	1 645	7.1%	515	3.6%	705	1 844
LU	526	20.3%	347	38.2%	19	2.6%	113	16.2%	46	12
LV	6 879	10.9%	3 301	12.2%	1 029	8.3%	898	14.6%	1 652	1 002
MT	49	15.5%	0	0.0%	12	13.7%	2	65.7%	33	9
NL	5 106	14.0%	1 726	54.9%	257	2.2%	955	8.3%	2 168	19 170
PL	75 124	24.4%	43 781	47.6%	17 547	11.2%	12 030	31.1%	1 766	14 416
PT	20 620	23.4%	7 858	32.3%	2 901	27.1%	1 470	10.3%	8 390	3 220
RO	29 461	12.6%	19 248	27.6%	2 518	3.0%	4 020	9.3%	3 675	3 356
SE	48 454	11.9%	21 876	8.7%	7 409	33.8%	204	6.5%	18 964	17 504
SI	10 928	54.1%	7 813	68.6%	694	28.9%	1 555	42.8%	867	87
SK	17 531	36.0%	12 216	63.2%	1 798	12.0%	2 379	27.9%	1 138	445
UK	17 295	7.1%	–	–	–	–	–	–	–	16 426
EU-27	801 998	19.1%	–	–	–	–	–	–	–	274 184

Source: EEA (2009 [162]) and own calculation

Figure 5.3.1: Distribution of Natura 2000 sites across EU (EEA, 2009 [162])



See also <http://natura2000.eea.europa.eu>, for details Natura 2000 maps (GIS).

The Natura 2000 network represents 54% of Slovenian terrestrial areas (11 000 km²) of which 7 800 km² is forested area (*i.e.* 69% of the total forest area in Slovenia), 1 600 km² of grassland (*i.e.* 43% of the total grassland), 700 km² of arable land (*i.e.* 29% of the total arable land) and 900 km² of other lands. At the opposite end of the scale, Natura 2000 covers only 10% (7 000 km²) of Irish areas mainly “other Natura 2000” areas with 5 300 km² following by grassland with 1 300 km² (*i.e.* only 4% of Irish grassland). For a country like France, Natura 2000 covers 82 500 km² (15% of its metropolitan land) with forest including 31 800 km², grassland with 19 500 km², arable lands covering 10 000 km² and “other” including 21 000 km².

With the help of those numbers, we will realise an assessment of the EU biodiversity policy, through an increase of the Natura 2000 network, either by an increase of protected forest or by a subsidy to farmers for agricultural land extensification. The following section represents the implementation of those policies and explains assumptions as well as modelling options.

5.3.4 Natura 2000 network extension: assessment with the NEMESIS model

Knowing that biodiversity conservation inside the EU is an objective of European policies, we should assess the **cost of the conservation** action in order to assess the design and legitimise those policies. There are few studies that try to assess the conservation action compared to those that assess the benefits of the conservation (Bruner *et al.* 2008 [61])¹⁸. But, the assessment of costs and benefits are economically essential to identify cost-effective measures of biodiversity policies. The cost assessment includes several types of costs that we can divide into three points: (i) an opportunity cost *i.e.* costs from foregone economic development, (ii) management costs and (iii) transaction costs which are associated with the implementation and control of the policies (TEEB 2008 [440]). For instance at global level, James *et al.* (1999 [296]) and James *et al.* (2001 [297]) estimate the cost of conservation, with the help of current and estimated shortfall spending for protected areas, in developed countries about 12 €/ha/year¹⁹ and about 31 €/ha/year for Europe. Those estimates for developed countries do not include the opportunity costs. But, James *et al.* (2001 [297]) have evaluated the opportunity cost for developing countries at 15 €/ha/year *i.e.* around five times the estimated cost including current and shortfall spending for protected areas in developing countries (3 €/ha/year). In this section, we will try to assess the cost of biodiversity conservation with the help of the land use module developed for the NEMESIS model (see chapter 2). Also we aim to assess the potential economic impact of biodiversity policies for EU, we rely on the Natura 2000 network. Nevertheless, we will make some assumptions on our policy implementation that can be different with the real functioning of the Natura 2000 network. However, the Natura 2000 network, in addition to being the main instrument of EU biodiversity policies, gives us a basis on the extent of existing land use with biodiversity concerned in the EU. It is a starting point in terms of areas concerned by the European biodiversity policy. Our policies consist of expansions of this European network, we will then assess the cost of biodiversity conservation by comparing those expansions with the *reference scenario*. We implement the policies with two different policy options.

On one hand, we suppose **an expansion of the forest in the Natura 2000** network by 10% and 20% respectively (scenario called “forest - 10%” and “forest - 20%”), this spread concerning only

18. See for instance, Constanza *et al.* (1997 [102]), Pimental *et al.* (1997 [390]) or Braat *et al.* (2008 [23]) for an assessment of biodiversity value at global level.

19. James *et al.* (2001 [297]) estimate this cost at 1 090 \$₁₉₉₆/km²/year *i.e.* around 1 500 \$₂₀₀₉/km²/year and supposing an exchange rate of €1 = \$1.25, the cost is the cost about 1 200 €₂₀₀₉/km²/year.

the forest area under the Natura 2000 network in 2009 (see table 5.3.2). Indeed, as confirmed again recently by European Environmental Agency (EEA, 2010 [164]), the European forests “*are important biodiversity repositories with the greatest assemblage of species found in any terrestrial ecosystem*”. In 2009, the European Commission evaluated that 52 % of forest species of European interest (under Habitats Directive) are in “unfavourable conservation status” (EC, 2009 [143]). Furthermore, the Natura 2000 network was identified, despite some malfunctioning, as a good instrument for forest biodiversity conservation (Golob *et al.* 2007 [242]). In order to implement the policies on forest areas, we make the assumption that the new forest areas covered by the Natura 2000 are excluded from forestry activity and then enter in the “Protected Forest” land use category (see section 2.2) which is not exactly in accordance with the practice in the Natura 2000. Practically, this scenario consists of a shift of the land supply asymptote from right to left which includes the overall of new forest areas under Natura 2000 (see section 2.3.1)²⁰.

On another hand, we increase the agricultural Natura 2000 network by 10% and 20% in order to have an **extensification of agriculture**. The extensification of agriculture is not conceived by all scientists as a solution for biodiversity conservation. For instance, Balmford *et al.* (2006 [24]) or Phalan *et al.* (2007 [386]) recommend an increase of agricultural productivity but also a rise of agricultural land intensification, in order to limit the agricultural areas and allow the increase of food production all around the World. While others as such Scherr and McNeely (2001 [418]) and Pretty *et al.* (2006 [396]) laud a reduction of fertilisers and pesticides use and argue that agricultural productivity can increase with farmers environmental-friendly practices²¹. But, this debate concerns more particularly the developing countries where the actual agricultural productivity is relatively weak compared to Europe. At European level, the land intensification with the land abandonment have been identified as the two main trends affecting species and habitats (EEA 2010 [163]). While some authors (see *e.g.* Leroux *et al.* 2008 [334] or Cooper *et al.* 2009 [100]) have shown that there are environmentally friendly farming practices, with a high agricultural productivity level, that enhance biodiversity. Therefore, the expansion of agricultural land under Natura 2000 implemented in this study, supposes environmentally friendly farming practices and especially concerning biodiversity. Those constraints on agricultural

20. Consequently, we do not take into account the impact on forestry activity of the diminishing of commercial forest which could be not negligible. Nevertheless, we remind that the forest resources in EU were assessed, by the EFISCEN model (Schelhaas *et al.* 2007 [416]), to be enough important to support the projected forestry activity in the *reference scenario* and regarding the area concerned by the Natura 2000 forest expansion, it seems possible that impacts on forestry would be small.

21. For a synthesis and a clarification on those problems about the future of the World agriculture, see Charvet (2009 [82]).

practices for farmers lead to an extensification of agricultural productions *i.e.* a decrease of agricultural production per kilometre square of utilised agricultural lands. In addition, the European Environmental Agency shows that “*Natura 2000 [...] is highly relevant to the EU’s goals for maintenance of HNV farming*”²² [...]” (EEA, 2009 [161]), demonstrating the relevance of Natura 2000 network as instrument to represent good farming practices in the EU. To do this, we supposed a financial help to farmers in order to respect fitted Natura 2000 farms practices. And, as we can not implement those practices directly in the NEMESIS model, we replace them by subsidies to land price which were, first of all, national and, secondly, European. We will call those scenarios: “*Agri - 10% - CO*” and “*Agri - 10% - EU*” for a raise of 10% of agricultural lands under Natura 2000 implemented with a subsidy to each EU country (CO) and at European level (EU) respectively. In the same manner, we will call the increase of 20%: “*Agri - 20% - CO*” and “*Agri - 20% - EU*”. An additional assumption was made for those scenarios on agricultural extensification. We have modified agricultural land demand modelling by deleting the partial adjustment, (see equation 2.3.21 in section 2.3.4) *i.e.* behaviour rigidity, and that leads to the following equation:

$$L_{n,i,t}^D = \left(\frac{C(Y_{n,i,t})}{UCT_{n,i,t}} \right)^\theta \quad (5.3.1)$$

With n is the index for grassland (GL) and arable land (AL), t the time index and i the country index. L^D is the land demand, θ is a positive elasticity parameter, $C(Y_n)$ is the cost function of the other production factors, where Y is the animal production ($Y = Y_B$) when $n = GL$ and vegetal production ($Y = Y_A$) when $n = AL$. And UCT is the user cost of land. The rigidity in the farmer demand for land leads to stronger variations of land prices to match the biodiversity objectives. For instance, for the agricultural land expansion under Natura 2000, taking the behaviour rigidity into account leads to a strong fall of land price in the first year compared to the *reference scenario* which seems logical. But in the third year, the land price increases compared to the *reference scenario* to match the policy objectives seem much less logical. Furthermore, we have also deleted the land supply function to avoid non convergence problems. In fact, if we keep the land supply, the increase of land demand, due to subsidies, will raise land prices²³ that will in turn reduce land demand. Therefore,

22. HNV: High Nature Value. High Nature Value farming refers to “*farming types that use and maintain [HNV farmland - farmland characterised by the presence of land cover types which indicate that this farmland is valuable for nature conservation] characteristics of high conservation value*” (EEA, 2009 [161]). Furthermore, an estimate of the extent of HNV farmland in Europe was made by Paracchini *et al.* (2008 [380]) using, *inter alia*, the agricultural lands under Natura 2000.

23. In the NEMESIS model, the land supply is modelled with the land price *i.e.* the inverse function of land supply.

to find an equilibrium, we were obliged to keep the real agricultural price of the *reference scenario* at which we add the subsidy rate. We then assume that the rise of utilised agricultural areas in those scenarios does not imply a rise of real agricultural land price²⁴.

Finally, it is important to specify that the Natura 2000 network does not explicitly take into account the *reference scenario* (see section 3.2). We supposed a constant Natura 2000 network after 2009 in the *reference scenario*. Thereby, the rise of Natura 2000 is based on Natura 2000 network in 2009. An increase of 10% corresponds to 10% raise of the Natura 2000 network in 2009 whatever the starting year of the policy.

24. In a first time, we try to keep the land supply functions endogenous. But, we did not converge to an equilibrium, even with parameter changes for countries with high land price elasticity with respect to land supply, such as Ireland or Malta.

5.3.5 Expansion of Natura 2000 forest

5.3.5.1 Scenario description

The table 5.3.3 presents the expansion of protected forest in the number of square kilometres for both scenarios and for each EU country. The repartition among EU countries of the new protected forests under Natura 2000 is proportional to Natura 2000 network in each country in 2009 (see table 5.3.2). This repartition among MS is probably somewhat fair insomuch as countries the most virtuous in 2009 are also the ones for which the largest efforts are required. Nevertheless, we do not have enough information for a more refined allocation among MS and we could suppose that countries with large Natura 2000 in 2009 are also those where opportunities for biodiversity conservation are the largest.

Thereby, the expansion of Natura 2000 is relatively large in:

- Slovenia with a protected forest increasing to about 1 560 km² in “forest - 20%” *i.e.* 14% of total forest area and 8% of total Slovenian territory,
- Slovakia with 2 440 km² of additional protected forest in “forest - 20%” *i.e.* 13% of total forest area and 5% of total Slovak territory,
- Spain for which protected forest rises to about 12 000 km² *i.e.* 13% of total forest area and 2.4% of total Spanish territory,
- and Hungary with around 2 000 km² *i.e.* 12% of total Hungarian forest area and 2.2% of its total terrestrial area.

We can note that countries where forest covers a large part of the terrestrial area and for which Natura 2000 forest network in 2009 is somewhat extended, also face to an important constraint such as in Czech Republic and Poland. At the opposite end of the scale, the following countries are much less constrained by the expansion of protected forest:

- Sweden where protected forest under Natura 2000 is extended about 4 400 km² in “forest - 20%” scenario *i.e.* 1.7% of its total forest area and a bit more than 1% of its territory,
- Finland with +2 950 km² *i.e.* 1.5% of total forest area and 1% of total terrestrial area,
- Ireland with only 65 km² of additional protected forest in “forest - 20%” scenario *i.e.* 2.2% of its total forest and only 0.1% of its territory,
- and Latvia for which protected forest rises by about 660 km² in “forest - 20%” *i.e.* 2.4% of Latvian forest area and 1% of its territory.

Table 5.3.3: Expansion of forest Natura 2000 networks by 10% and 20%

	Natura 2000 Forest (km ²) in 2009	% of total Forest in 2009	% of total area in 2009	10 % expansion of Natura 2000 Forest (km ²)	20 % expansion of Natura 2000 Forest (km ²)
AT*	9710.3	26.6%	11.7%	971.0	1942.1
BE	2965.5	48.5%	9.7%	296.5	593.1
CZ	9255.9	36.2%	11.8%	925.6	1851.2
DE	32144.7	30.9%	9.0%	3214.5	6428.9
DK	1081.7	28.1%	2.5%	108.2	216.3
EE	4416.6	21.1%	10.2%	441.7	883.3
ES	60392.9	65.0%	12.0%	6039.3	12078.6
FI	14782.8	7.3%	4.9%	1478.3	2956.6
FR	31781.2	21.9%	5.8%	3178.1	6356.2
GR	11996.9	50.5%	9.2%	1199.7	2399.4
HU	10284.8	60.2%	11.3%	1028.5	2057.0
IE	323.8	11.0%	0.5%	32.4	64.8
IT	25070.6	31.7%	8.4%	2507.1	5014.1
LT	7220.1	38.8%	11.3%	722.0	1444.0
LU	347.5	38.2%	13.4%	34.7	69.5
LV	3300.9	12.2%	5.2%	330.1	660.2
MT	—	—	—	—	—
NL	1726.0	54.9%	4.7%	172.6	345.2
PL	43780.6	47.6%	14.2%	4378.1	8756.1
PT	7857.7	32.3%	8.9%	785.8	1571.5
RO	19247.7	27.6%	8.2%	1924.8	3849.5
SE	21876.2	8.7%	5.4%	2187.6	4375.2
SI	7812.6	68.6%	38.7%	781.3	1562.5
SK	12215.5	63.2%	25.1%	1221.6	2443.1
UK*	5134.3	26.6%	2.1%	513.4	1026.9
EU	344726.7	26.6%	8.4%	34472.7	68945.3

*: Based on EU average

In the same manner, France and Ireland where Natura 2000 forest in 2009 covers a weak part of the terrestrial areas (5.8% and 0.5%) are few constrained by the expansion of the network.

5.3.5.2 Results

As exposed in the previous section, the additional forest areas under Natura 2000 were supposed to be excluded from potential land for agricultural production. Practically, we have moved the asymptote

A from land supply (equation 5.3.2²⁵) by including the new forest areas. Thereby A in the *reference scenario* is higher than in the biodiversity policy scenarios.

$$L^s = A - \frac{B}{P_L^\alpha} \quad (5.3.2)$$

Agriculture

Table 5.3.4 displays the results for real agricultural land price and agricultural land utilised for both scenarios: “forest - 10%” and “forest - 20%” in 2025. At European level, the rise of 10% and 20% of the Natura 2000 forest and its classification on protected forest increase the **real agricultural land price** by about +3% and +6.3% respectively. The rise of protected forest about +34 500 km² and +69 000 km² (*i.e.* 2.5% and 5% of EU forest areas and 0.8% and 1.7% of total EU areas) in “forest - 10%” and “forest - 20%” scenarios respectively, increases the constraint on land availability for agricultural production. As this constraint is taken into account in the NEMESIS land supply, the real agricultural land price goes up. This increase of agricultural land price also raises agricultural production costs and consequently slightly reduces European **agricultural production** by -0.2% and -0.3% in “forest - 10%” and “forest - 20%” respectively. Nevertheless, the fall of agricultural production is less important than for **agricultural land** which falls by -11 000 km² and -22 000 km² (*i.e.* -0.6% and -1.2% respectively). Therefore, the agricultural land intensity rises by +0.4% and +0.9% putting more pressure on biodiversity in agricultural areas²⁶. The biodiversity benefits in forest area could then be eclipsed by the rise of agricultural land intensity, identified as the source of biodiversity loss (see *e.g.* EEA 2010 [163]).

At MS level, countries with the strongest constraints like Slovenia, Slovakia, Spain and Hungary are also those facing to the highest rise of real agricultural land price with respectively +8.6% (+18.5%), +7.1% (+15.1%), +5.5% (+11.5%) and +3.9% (+8%) in “forest - 10%” (“forest - 20%”). Countries like Poland and Czech Republic where Natura 2000 forest covers a substantial part of national terrestrial areas, show also a strong raise in real agricultural land price with, respectively, +4.2% and +5.4% in “forest - 10%” and +8.7% and +11.2% in “forest - 20%”. At the opposite end of the scale, we observe weak rise of real agricultural land price, a weak decrease of agricultural land use and agricultural production in France, Ireland and Latvia, countries for which the constrain is weak.

25. Please see section 2.3.2.4 for details on land supply.

26. See also table 5.3.5 on change on nutrients per hectare in those scenarios.

Table 5.3.4: Real land price and Agricultural land use changes by MS for scenarios *Forest - 10%* and *Forest - 20%*, in 2025

% variation w.r.t. reference scenario	Real agricultural land price		Agricultural land utilised		Agricultural production	
	<i>Forest - 10%</i>	<i>Forest - 20%</i>	<i>Forest - 10%</i>	<i>Forest - 20%</i>	<i>Forest - 10%</i>	<i>Forest - 20%</i>
AT	3.2%	6.5%	-0.7%	-1.4%	-0.1%	-0.2%
BE	3.8%	7.8%	-0.9%	-1.7%	-0.2%	-0.4%
CZ	5.4%	11.2%	-1.2%	-2.5%	-0.4%	-0.7%
DE	1.4%	2.9%	-0.3%	-0.5%	0.0%	0.0%
DK	0.8%	1.6%	-0.2%	-0.3%	0.0%	0.0%
EE	2.5%	5.1%	-0.6%	-1.1%	-0.2%	-0.3%
ES	5.5%	11.5%	-1.1%	-2.2%	-0.5%	-1.1%
FI	1.8%	3.6%	-0.4%	-0.7%	-0.1%	-0.2%
FR	0.6%	1.2%	-0.1%	-0.2%	0.0%	0.0%
GR	4.7%	9.8%	-1.0%	-2.0%	-0.4%	-0.8%
HU	3.9%	8.0%	-0.8%	-1.6%	-0.2%	-0.4%
IE	0.2%	0.5%	0.0%	-0.1%	0.0%	0.0%
IT	3.6%	7.3%	-0.7%	-1.5%	-0.2%	-0.4%
LT	4.6%	9.4%	-1.2%	-2.4%	-0.3%	-0.5%
LU	1.7%	3.5%	-0.4%	-0.7%	0.0%	0.0%
LV	2.8%	5.6%	-0.6%	-1.1%	-0.1%	-0.1%
MT	0.3%	0.5%	0.0%	0.1%	0.3%	0.5%
NL	2.0%	4.1%	-0.5%	-0.9%	-0.1%	-0.1%
PL	4.2%	8.7%	-0.9%	-1.8%	-0.2%	-0.5%
PT	2.9%	5.9%	-0.6%	-1.2%	-0.2%	-0.3%
RO	2.5%	5.0%	-0.6%	-1.2%	-0.1%	-0.2%
SE	3.2%	6.6%	-0.7%	-1.4%	-0.1%	-0.3%
SI	8.6%	18.5%	-2.0%	-4.1%	-0.6%	-1.2%
SK	7.1%	15.1%	-1.7%	-3.5%	-0.3%	-0.6%
UK	1.1%	2.1%	-0.2%	-0.5%	0.0%	-0.1%
EU	3.0%	6.3%	-0.6%	-1.2%	-0.2%	-0.3%

Source: NEMESIS model

We also note the positive impact of this policy in Malta, at least in relative terms. In fact, the biodiversity policy is not implemented in Malta (as we do not have forest for Malta in NEMESIS) and so Maltese agriculture slightly benefits of its raise of competitiveness compared to other MS.

The European results for **nutrients** use per hectare (table 5.3.5) show an agricultural intensification in both scenarios. Even if the variations are small due to the extent of the policies, we observe a rise of nitrogen and phosphorus use per hectare of agricultural land with +0.6% for both in “*forest - 10%*” and +1.1% in “*forest - 20%*”. This increase of nutrient use per hectare is characterised by a slightly higher rise of inorganic fertilisers than manure ones due to a favourable substitution to nutrients. The relative price of nutrients compared to land price is decreasing. Therefore, the relative use of inorganic nutrients rises whereas nutrients from manure only depend on animal production evolution. For instance, in “*forest - 20%*” scenario, at EU level, the use of nitrogen manure increases by about +0.9% (*i.e.* +400 g/ha) whereas inorganic nitrogen rises by about +1.6% (*i.e.* +1 kg/ha).

Table 5.3.5: Intensity variations in nutrient use in “*forest - 10%*” and “*forest - 20%*” scenarios, at EU level, in 2025

		% change w.r.t reference scenario	change w.r.t reference scenario in kg/ha
Total nitrogen (kg/ha)	“ <i>forest - 10%</i> ”	0.6%	+0.7 kg/ha
	“ <i>forest - 20%</i> ”	1.1%	+1.4 kg/ha
Total phosphorus (kg/ha)	“ <i>forest - 10%</i> ”	0.5%	+0.1 kg/ha
	“ <i>forest - 20%</i> ”	1.0%	+0.2 kg/ha
Manure nitrogen (kg/ha)	“ <i>forest - 10%</i> ”	0.5%	+0.2 kg/ha
	“ <i>forest - 20%</i> ”	0.9%	+0.4 kg/ha
Manure phosphorus (kg/ha)	“ <i>forest - 10%</i> ”	0.4%	0.0 kg/ha
	“ <i>forest - 20%</i> ”	0.7%	+0.1 kg/ha
Inorganic nitrogen (kg/ha)	“ <i>forest - 10%</i> ”	0.8%	+0.5 kg/ha
	“ <i>forest - 20%</i> ”	1.6%	+1.0 kg/ha
Inorganic phosphorus (kg/ha)	“ <i>forest - 10%</i> ”	0.8%	0.0 kg/ha
	“ <i>forest - 20%</i> ”	1.6%	+0.1 kg/ha

Source: NEMESIS Model

Economic

In economic terms, the scenarios “*forest - 10%*” and “*forest - 20%*” provide very little impact, the extent of the policies and the extent of the agricultural sector in the European economy limit the feedback of those policies. Table 5.3.6 presents, at MS level, the **Gross Domestic Product** (GDP), total employment and agricultural employment changes in “*forest - 10%*” and “*forest - 20%*” scenarios, in 2025. At European level, the GDP decreases by -0.02% and -0.04%, in “*forest - 10%*” and “*forest - 20%*” scenarios respectively, under the joint effect of an agricultural production fall and the raise of agricultural products costs as intermediate consumption. The slight decrease of GDP comes with a fall of European **employment** about -48 000 and -104 000 jobs, in “*forest - 10%*” and “*forest - 20%*” scenarios, *i.e.* -0.02% and -0.05% compared to the *reference scenario*. More than one third of employment losses come from agriculture sector with a decrease of -18 500 and -37 500 jobs while the agricultural added value represents less than 2% of total European one. At MS level, the GDP variations are also relatively weak. Nevertheless, some countries, where the shock is larger, display a stronger GDP decrease. For instance, we note that the Czech Republic with -0.05% and -0.09% in “*forest - 10%*” and “*forest - 20%*” scenarios respectively is one of the hardest hit countries. But, it is also particularly true, in Poland (-0.05% and -0.08%) and Romania (-0.08% and -0.11%) where agriculture share in GDP as well as in total employment, is larger than in other EU countries in 2025 in the *reference scenario*. Poland and Romania account for more than 30% of total European employment losses with a job destruction of -12 000 to -24 000 and -5 200 to -8 200 respectively. And polish job losses in agriculture represent around 36% of total agricultural employment losses *i.e.* -8 800 and -13 800 employments in “*forest - 10%*” and “*forest - 20%*” scenarios respectively.

For the major EU countries like France, Germany, Spain, Italy and United Kingdom, the GDP loss is weak and even slightly inferior to the EU average expect in Spain where the expansion of Natura 2000 forest is large compared to the others. For instance, in Germany, agricultural employment is stable in both scenarios, real agricultural land price increases slightly and agricultural production is nearly stable. Thereby, the loss of employment in Germany (-1 800 and -5 500 in “*forest - 10%*” and “*forest - 20%*” scenarios respectively) mainly comes from the European economic activity degradation.

Table 5.3.6: GDP and total and agricultural employment changes by MS for scenarios “*Forest - 10%*” and “*Forest - 20%*”, in 2025

	GDP*		Total employment**		Agricultural employment***	
	<i>Forest - 10%</i>	<i>Forest - 20%</i>	<i>Forest - 10%</i>	<i>Forest - 20%</i>	<i>Forest - 10%</i>	<i>Forest - 20%</i>
AT	-0.02%	-0.03%	-0.7	-1.5	-155	-314
BE	-0.02%	-0.04%	-0.9	-1.9	-212	-428
CZ	-0.05%	-0.09%	-3.0	-5.7	-618	-1 255
DE	-0.01%	-0.02%	-1.8	-5.5	-50	-98
DK	-0.02%	-0.04%	-0.5	-1.0	27	57
EE	-0.01%	-0.04%	-0.1	-0.2	-21	-43
ES	-0.03%	-0.06%	-5.5	-12.8	-3 858	-7 936
FI	-0.01%	-0.03%	-0.3	-1.0	-141	-276
FR	-0.01%	-0.03%	-3.0	-6.8	297	611
GR	-0.04%	-0.10%	-2.1	-4.7	-1 011	-2 057
HU	-0.03%	-0.06%	-1.5	-3.1	-431	-875
IE	-0.01%	-0.02%	-0.2	-0.4	32	65
IT	-0.01%	-0.03%	-3.5	-7.3	-1 965	-3 988
LT	-0.01%	-0.02%	-0.5	-1.1	-366	-746
LU	-0.02%	-0.04%	0.0	-0.1	0	1
LV	-0.01%	-0.01%	-0.1	-0.1	-22	-44
MT	0.00%	0.00%	0.0	0.0	4	8
NL	-0.01%	-0.03%	-1.0	-2.3	-97	-183
PL	-0.05%	-0.09%	-12.2	-24.0	-6 781	-13 812
PT	-0.03%	-0.06%	-1.6	-3.8	-816	-1642
RO	-0.08%	-0.11%	-5.2	-8.2	-1 377	-2 820
SE	-0.01%	-0.03%	-0.6	-1.3	-120	-240
SI	-0.03%	-0.07%	-0.7	-1.4	-365	-765
SK	-0.02%	-0.05%	-0.7	-1.4	-146	-305
UK	-0.01%	-0.03%	-2.3	-8.6	-177	-350
EU	-0.02%	-0.04%	-48.0	-104.2	-18 369	-37 432

*: % change w.r.t. *reference scenario*.
 **: change w.r.t. *reference scenario* in thousand.
 ***: change w.r.t. *reference scenario*.
 Source: NEMESIS model

5.3.5.3 Remarks

Summary of results

The previous results, whether agricultural or economic, emphasise the negative impact of the expansion of Natura 2000 forest network on agricultural production, but also in the overall economy. We saw that the impact is weak but all the more important according to the extent of the constraint. Thereby, countries with a huge Natura 2000 forest network in 2009 and countries for which Natura 2000 forest network covers substantial areas have the strongest increase in real agricultural land price, fall in agricultural production and then in GDP. Furthermore, we also saw that the increase of protected forest areas can have counterproductive effect, notably an intensification of land use by agriculture because of raise of land production costs.

Opportunity cost of biodiversity conservation policy

To better assess the impact of those biodiversity conservation policies in forest areas, it may be of interest to estimate the cost of the policies regarding their cost per new protected hectare of forest. This allows a comparison of the relative cost of this biodiversity policy in each MS. In order to do this, we divide the GDP loss by the protected forest expansion in each MS which gives us an indicator of the policies gross cost. This gross cost can be viewed as an opportunity cost *i.e.* the cost of foregone economic development. It does not include management costs of new protected forest areas nor the transaction costs, costs related to policy implementation. Furthermore, this gross cost is not a net cost inasmuch as it does not take into account the benefits arising from biodiversity conservation *i.e.* ecosystem services.

Table 5.3.7 shows the **gross cost per hectare** (or marginal gross cost) in all the MS, in 2025. Those gross costs are very disparate among MS, in the “*forest - 10%*” scenario, the range is from a minimum of 72 €₂₀₀₀/ha in Latvia²⁷ to a maximum 10 400 €₂₀₀₀/ha in Ireland and with an European average of 700 €₂₀₀₀/ha. Excluding for the moment the levels of gross costs and focusing on their disparities among MS, we can firstly link those differences on the situation of each MS according to its land supply in 2025 in the *reference scenario*. The countries, where the unused agricultural lands are the smallest, are also those with the highest land price elasticity with respect to land supply ($\varepsilon_{\frac{P_L}{L^*}}$)²⁸.

27. Obviously, we exclude Malta from our comments as the policies are not implemented in it.

28. The elasticity of land price with respect to land supply is not only driven by unused agricultural lands, see section 2.3.2.4. But, the elasticity of land price with respect to land supply is increasing with the land scarcity. Then, the elasticity is generally higher in countries with few unused agricultural lands. See sections 2.3.2.4 and 2.3.3.4 for details.

Table 5.3.7: Cost per hectare of new Natura 2000 forest measured with GDP loss in “Forest - 10%” and “Forest - 20%”, in 2025. Real agricultural land price elasticity with respect to land supply in the *reference scenario*, 2025.

	<i>Forest - 10% (€₂₀₀₀)</i>	<i>Forest - 20% (€₂₀₀₀)</i>		$\varepsilon_{\frac{P_L}{L^*}}$
AT	593	600	AT	0.84
BE	2 498	2 648	BE	3.87
CZ	817	753	CZ	5.80
DE	613	835	DE	1.17
DK	5 102	5 407	DK	4.52
EE	102	123	EE	0.85
ES	533	613	ES	3.80
FI	133	249	FI	0.24
FR	1 084	1 185	FR	0.63
GR	1 060	1 202	GR	3.64
HU	330	342	HU	3.67
IE	10 372	11 068	IE	7.91
IT	909	975	IT	3.49
LT	72	80	LT	6.38
LU	3 024	3 454	LU	0.77
LV	78	87	LV	2.44
MT	0	0	MT	7.05
NL	6 136	6 639	NL	6.46
PL	499	481	PL	2.89
PT	626	760	PT	1.08
RO	497	355	RO	2.45
SE	325	337	SE	0.38
SI	211	209	SI	0.74
SK	134	140	SK	1.82
UK	4 861	7 871	UK	6.08
EU	700	803		

Source: NEMESIS model

In fact, in the *reference scenario* in 2025, the highest land price elasticities can be found in Ireland, the Netherlands, the United Kingdom and the Czech Republic with 7.9, 6.5, 6.1 and 5.8 respectively (see table 5.3.7). While Ireland, United Kingdom and Netherlands are also the countries with the highest gross cost per hectare with respectively 11 000 €₂₀₀₀/ha , 7 900 €₂₀₀₀/ha and 6 600 €₂₀₀₀/ha in

“forest - 20%” scenario. On the contrary, Finland for which the elasticity is the weaker with 0.24, has a gross marginal cost among the lowest with 250 €₂₀₀₀/ha. Nevertheless, the land supply elasticity is not the unique explanation of the differences among MS, the richness of each MS also explains those cost differences given that we measure the gross cost per hectare with the help of the GDP loss. We observe that countries with a weak GDP generally have a lower gross marginal cost. For instance, in France and Slovenia where land price elasticities are very close, the marginal gross costs are very different with 1 200 €/ha in France with a GDP much more higher than in Slovenia where the gross cost per hectare is about 200 €₂₀₀₀/ha/year²⁹.

Discussion

Now, comparing our results with other studies on the cost assessment of biodiversity conservation in forest area³⁰, it seems that the European average 800€₂₀₀₀/ha³¹ is in the upper bound of literature on **biodiversity opportunity costs**. Several studies exist on the opportunity costs of biodiversity conservation in forest areas (see *e.g.* Kramer *et al.* 1995 [318], Chomitz *et al.* 2005 [91] or Grieg-Garn 2006 [249]) but most of them focus on developing countries where the cost is much lower than in developed countries. Kramer *et al.* 1995 [318] evaluate the compensation for local households between 7.9-9.5 €₂₀₀₀/ha/year³² for tropical forest in Madagascar. Chomitz *et al.* 2005 [91] establish an opportunity cost of 17.5 €₂₀₀₀/ha/year for the Brazilian Atlantic forest in the southern part of the state of Bahia. And, Grieg-Garn (2006) provides, in a preparation paper for the Stern Review on the Economics of Climate Change (Stern 2006 [435]), the opportunity costs for several developing countries ranging from 26 €₂₀₀₀/ha/year in Brazil to 98 €₂₀₀₀/ha/year in Papua New Guinea. Studies focusing on developed countries display, generally, much higher opportunity costs (see table 5.3.8) with for instance between 220 and 360 €₂₀₀₀/ha/year for Finnish forest (Horne 2006 [273]). This sample of studies confirm that our estimates of the biodiversity costs, at EU level, is in the upper bound all the more so we do not include opportunity costs for forestry (logging activity), management costs and transaction costs³³.

29. We use the loss in GDP to calculate the gross cost per hectare. Thereby it is an annual cost.

30. See Mullan and Kontoleon (2008 [360]) for a recent survey on study on biodiversity conservation costs.

31. This is the value for “forest - 20%” scenario. We have also simulated a scenario with an expansion of 50% of the forest Natura 2000 network. In this case, the gross marginal cost is about 870 €₂₀₀₀/ha/year *i.e.* we have a slightly increasing marginal cost with the size of the forest expansion. But, we retain 800 €₂₀₀₀/ha/year is the next part of this study.

32. All values are based on Mullan and Kontoleon (2008 [360]) calculation and with an exchange rate 1€₂₀₀₀ = 0.92\$₂₀₀₀.

33. Nevertheless, those two last costs are generally much lower than opportunity cost.

Table 5.3.8: Opportunity cost of biodiversity conservation in developed countries, some studies (Mulland and Kontoleon 2008 [360])

Study	Geographical area	Type of forest	Standardised cost (€ ₂₀₀₀ /ha/year)
Ando <i>et al.</i> (2008 [14])	USA	All habitats	Minimum: 78 € ₂₀₀₀ /ha/year (450 species) Minimum: 665 € ₂₀₀₀ /ha/year (900 species)
Huang and Kronrad (2001 [276])	USA (Southern states)	Loblolly pine	89-77 € ₂₀₀₀ /ha/year
Polasky <i>et al.</i> (2001 [394])	USA (Oregon)	Temperate	<133 € ₂₀₀₀ /ha/year (350 species) 239 € ₂₀₀₀ /ha/year (400 species) 3 690 € ₂₀₀₀ /ha/year (415 species)
Sinden (2004 [429])	Australia (New South Wales)	Native forest	4.8 - 8.1 € ₂₀₀₀ /ha/year
Horne (2006 [273])	Finland	Temperate	220 € ₂₀₀₀ /ha/year (small areas) 360 € ₂₀₀₀ /ha/year (big areas)
Strange <i>et al.</i> (2006 [437])	Denmark	All (not only forest)	324 - 500 € ₂₀₀₀ /ha/year (740 priority species)
Shaick <i>et al.</i> (2007 [424])	Canada	Temperate	2.9 - 23.9 € ₂₀₀₀ /ha/year

Firstly, as we can see with the studies of Ando *et al.* (2008 [14]) and Polasky *et al.* (2001 [394]), the conservation cost is increasing with the number of species *i.e.* the marginal costs of biodiversity is increasing. And as we suppose that the new forests under Natura 2000, in our policy, are totally excluded from economic activity either for agriculture or urban expansion, the level of protection is very high implying high marginal costs. Furthermore, compared to all other studies, we integrate in our gross cost the overall European economy that implies non negligible feedback between EU countries (multiplier effects). For instance, applying the “forest - 20%” scenario only in United Kingdom, the gross cost per hectare decreases from 4 960 to 1 800 €₂₀₀₀/ha/year. Nevertheless, we can not avoid criticism when looking at national gross cost. Indeed, the opportunity costs for some countries seems very high, even if it is generally for countries with a small Natura 2000 expansion which are highly sensitive such as Ireland³⁴. Finally, it is also possible that land price elasticities with respect to land supply are too strong. In fact, we decided in section 2.3.1 to include 100% of the “Commercial Forest” in the available land for agriculture imposing the exclusion of the new Natura 2000 lands from it, in the “forest - 10%” and “forest - 20%” scenarios. Exclude a part of the “Commercial Forest” from the asymptote will reduce the gross cost per hectare insomuch as the overall of new protected land will result in a reduction of land available for agriculture, at least in our study where we do not calculate opportunity cost for forestry. To summarise, we retain the European average gross cost per hectare of 800 €₂₀₀₀/ha/year that can be viewed as the upper bound for biodiversity costs even if it does not include administrative costs, management cost and opportunity costs for forestry.

We now present another implementation of European biodiversity policy to avoid a part of the potential criticisms and to improve our study.

34. Indeed, in Ireland in the “forest - 20%” scenario, the forest Natura 2000 expansion is about 65 km² *i.e.* 0.1% of the Irish terrestrial area.

5.3.6 Expansion of Natura 2000 agricultural land

5.3.6.1 Scenarios implementation

In this section, we present different implementation of biodiversity conservation scenarios to assess the cost of conservation in agricultural areas. Quantitatively, we proceed as in the previous scenarios with an expansion of the Natura 2000 network by 10% and 20% for agricultural lands. The calculation of the additional agricultural lands under Natura 2000 after 2010 is based on Natura 2000 network in 2009. Table 5.3.9 displays the additional Natura 2000 agricultural land in each MS and their importance compared to utilised agricultural areas and national territory³⁵.

In terms of territory, Slovenia is the most constrained MS with a raise of Natura 2000 network about 1.1% and 2.2% of its total area for 10% and 20% scenarios respectively. The Czech Republic, Spain, Hungary, Poland and Slovakia are also among MS where the agricultural Natura 2000 expansion covers the largest areas, with more than 1.6% of their terrestrial lands in the 20% case. On the contrary, Sweden and Finland efforts represent a very small part of their total areas with less than 0.4% for the upper case. At European level, the policies raise the agricultural areas under Natura 2000 either by 20 700 km² or 41 400 km² *i.e.* either 0.5% or 1% of the European terrestrial area. Nevertheless, comparing the Natura 2000 expansions with the utilised agricultural areas in 2009, Sweden now appears much more constrained. The raise of Natura 2000 agricultural land by 20% represents around 6% of Swedish utilised agricultural lands in 2009 and 7.5% in Slovenia, both most restricted countries compared to utilised agricultural lands. At European level, the upper case covers 2.3% of utilised agricultural lands in 2009. Globally, as in the previous scenarios, the most virtuous countries *i.e.* those having the biggest share of agricultural lands under Natura 2000 network, are also those where additional protected land covers the largest share of utilised agricultural land.

We implement the policies with the help of subsidies to farmers for an extensification of the agricultural production. We assume that additional areas under Natura 2000 come as additional utilised agricultural land. Indeed, we have implemented an objective of utilised agricultural areas by MS which is equal to the utilised agricultural land in the *reference scenario* plus the new agricultural areas under the Natura 2000 network. The increase of utilised agricultural land in each MS is presented in table 5.3.9.

35. National objectives will be used for the national subsidies case whereas, with European subsidy case, only European aggregation will be used (see more details later).

Table 5.3.9: Expansion of agricultural land under Natura 2000 networks by 10% and 20%

	Natura 2000 agricultural lands in 2009 (km ²)	% of Utilised agricultural lands in 2009	% of total terrestrial area in 2009	10 % expansion of Natura 2000 agricultural lands (km ²)	20 % expansion of Natura 2000 agricultural lands (km ²)
AT*	3188.3	14.0%	3.8%	318.8	637.7
BE	975.6	5.8%	3.2%	97.6	195.1
CZ	7865.1	17.9%	10.0%	786.5	1573.0
DE	20943.2	9.3%	5.9%	2094.3	4188.6
DK	2572.4	7.9%	5.9%	257.2	514.5
EE	1022.6	8.4%	2.4%	102.3	204.5
ES	40360.8	17.0%	8.0%	4036.1	8072.2
FI	2761.5	14.2%	0.9%	276.1	552.3
FR	29561.4	9.5%	5.4%	2956.1	5912.3
GR	6048.3	11.3%	4.6%	604.8	1209.7
HU	7991.6	13.9%	8.8%	799.2	1598.3
IE	1329.7	3.1%	1.9%	133.0	265.9
IT	17919.9	12.4%	6.0%	1792.0	3584.0
LT	2159.3	5.8%	3.4%	215.9	431.9
LU	132.2	9.4%	5.1%	13.2	26.4
LV	1926.2	10.4%	3.0%	192.6	385.2
MT	14.6	15.7%	4.6%	1.5	2.9
NL	1211.8	5.2%	3.3%	121.2	242.4
PL	29577.6	15.2%	9.6%	2957.8	5915.5
PT	4371.5	17.6%	5.0%	437.1	874.3
RO	6538.5	5.2%	2.8%	653.9	1307.7
SE	7613.2	30.5%	1.9%	761.3	1522.6
SI	2248.5	37.3%	11.1%	224.8	449.7
SK	4177.2	17.8%	8.6%	417.7	835.4
UK*	4781.2	3.6%	2.0%	478.1	956.2
EU	207292.4	11.3%	5.1%	20729.2	41458.5

*: Based on EU average

This policy implementation allows the identification of the cost coming with Natura 2000 expansion thanks to the subsidy to farmers. The subsidy is then the shadow price of the additional constraint. Nevertheless, this implementation excludes the assessment of agricultural land allocation as it is an objective and not an output. A lump sum is deduced from household disposable income to finance the policy *i.e.* the subsidies to farmers. Finally, we implement several scenarios combining a rise of Natura 2000 agricultural lands by 10% and 20% with either national subsidies or European ones (see table 5.3.10). In the case of an unique European subsidy, the objectives are not at national level, as in table 5.3.9. The total European additional agricultural lands under Natura 2000 are allocated among MS according to land demand elasticity with respect to land price³⁶. We implement the European subsidy case in order to avoid an *ad-hoc* allocation among MS as in the national subsidies case, and to homogenise among MS the efforts induced by the policy. Nevertheless, we can also argue that in this case, the areas are not allocated regarding biodiversity potential in each MS. However with the national subsidies, Natura 2000 expansion is proportional to the existing Natura 2000 network that can better reflect the biodiversity potential in each MS.

Table 5.3.10: Policies combination for expansion of Natura 2000 agricultural land

		Expansion of Natura 2000 agricultural lands	
		+10%	+20%
Level of subsidy	National subsidy rates	<i>Agri-10%-CO</i>	<i>Agri-20%-CO</i>
	European subsidy rate	<i>Agri-10%-EU</i>	<i>Agri-10%-EU</i>

5.3.6.2 Results

Subventions and costs

We start the presentation of the results according to subsidy rates *i.e.* the change in the real agricultural land price (see table 5.3.11). The real agricultural land price variation, in the counterfactual scenarios, determines the subsidy rate that matches utilised land by agriculture including policy objective. We observe twenty five different subsidy rates in scenarios with national subsidies and obviously only one rate in the European case.

36. The land is assumed as exogenous as explained in section 5.3.4.

Table 5.3.11: Real agricultural land price variations in “*Agri-10%-CO*”, “*Agri-20%-CO*”, “*Agri-10%-EU*” and “*Agri-20%-EU*” scenarios, at MS level, in 2025.

	<i>Agri-10%-CO</i>	<i>Agri-20%-CO</i>	<i>Agri-10%-EU</i>	<i>Agri-20%-EU</i>
AT	-5.8%	-11.1%	-5.2%	-9.4%
BE	-2.8%	-5.4%	-5.2%	-9.4%
CZ	-7.1%	-13.4%	-5.2%	-9.4%
DE	-4.0%	-7.7%	-5.2%	-9.4%
DK	-3.5%	-6.8%	-5.2%	-9.4%
EE	-3.0%	-5.8%	-5.2%	-9.4%
ES	-7.2%	-13.7%	-5.2%	-9.4%
FI	-5.6%	-10.7%	-5.2%	-9.4%
FR	-3.9%	-7.6%	-5.2%	-9.4%
GR	-4.8%	-9.3%	-5.2%	-9.4%
HU	-6.1%	-11.7%	-5.2%	-9.4%
IE	-1.2%	-2.4%	-5.2%	-9.4%
IT	-5.2%	-10.1%	-5.2%	-9.4%
LT	-2.3%	-4.5%	-5.2%	-9.4%
LU	-3.8%	-7.4%	-5.2%	-9.4%
LV	-4.2%	-8.1%	-5.2%	-9.4%
MT	-6.7%	-12.8%	-5.2%	-9.4%
NL	-2.5%	-4.8%	-5.2%	-9.4%
PL	-6.4%	-12.2%	-5.2%	-9.4%
PT	-6.9%	-13.1%	-5.2%	-9.4%
RO	-2.1%	-4.2%	-5.2%	-9.4%
SE	-11.1%	-20.6%	-5.2%	-9.4%
SI	-12.1%	-22.4%	-5.2%	-9.4%
SK	-6.4%	-12.3%	-5.2%	-9.4%
UK	-6.3%	-12.0%	-5.2%	-9.4%
EU	-5.1%	-9.9%	-5.2%	-9.4%

Source: NEMESIS model

For Natura 2000 expansion with **national subsidies**, we observe a strong relationship between the efforts asked of each MS and the rate of subsidy. In Sweden and Slovenia, where the new agricultural land under Natura 2000 covers the largest areas according to existing land used by agriculture (see table 5.3.9), the subsidy rates reach more than 10% and 20% for an expansion of about 10% and 20% respectively *i.e.* the most important in the EU. Similarly, in the Czech Republic, Spain, Hungary, Poland and Slovakia, where agricultural land expansion is also relatively large, in the 20% expansion case, there is a subsidy rate ranged between 14% and 11.5%. The agriculture extensification policy

with national subsidy rates leads to a European subsidy (see table 5.3.12) about 26 €/ha for 10% case and 50 €/ha for 20% case and then a cost per new area under Natura 2000 around 2 100 €/ha. In the case of an unique **European subsidy** rate, the real agricultural land price decreases by about -5.2% and -9.4% for an expansion of Natura 2000 agricultural land of about 10% and 20% respectively. The average European subsidy is then about 27 €/ha and 48 €/ha respectively. The cost per hectare of new agricultural areas under Natura 2000 is very close between both scenarios with 2 100 €/ha. Obviously, the national objectives are not considered, only the aggregation of national objectives at European level are allocated among MS according to land demand, land supply being exogenous.

Table 5.3.12: European average subsidy per hectare in “Agri-10%-CO”, “Agri-20%-CO”, “Agri-10%-EU” and “Agri-20%-EU” scenarios, in 2025.

€/ha	Agri-10%-CO	Agri-20%-CO	Agri-10%-EU	Agri-20%-EU
EU average subsidy per hectare of utilised agricultural area	26.1	50.2	26.6	48.2
EU average subsidy per hectare of new Natura 2000 area	2 147	2 095	2 111	2 064

Source: NEMESIS model

Comparing scenarios with European subsidy or national ones, we do not observe a significant difference with the average European subsidy rate. Now, comparing, the results for different expansion of Natura 2000 agricultural lands, we obviously observe an increasing cost per hectare of utilised agricultural areas. But, looking at the cost per hectare of new area under Natura 2000, we see very close policy costs for both cases, even if those costs seem to decreasing slightly between 10% and 20% case. To verify if the cost of the policy is really decreasing with the rise of protected the agricultural land, we simulate an expansion of agricultural areas under Natura 2000 from 10% to 100%, with national subsidy. Table 5.3.13 displays the cost per hectare of new Natura 2000 agricultural area (see table 5.3.12). This cost is indeed decreasing with the area passing from 2 147 €/ha for an increase of Natura 2000 agricultural lands of 10% to 1 774 €/ha when we double the agricultural area under Natura 2000. We have an average cost of the policy, *i.e.* the cost per hectare of new lands under Natura 2000, decreasing and therefore a decreasing marginal cost of the policy. And as the land supply is exogenous, it means that the marginal land demand is increasing with the rise of real land price *i.e.* there are increasing scale returns on land. The results come from the agricultural production function introduced in the NEMESIS model.

Table 5.3.13: EU average subsidy per hectare of new Natura 2000 area for an expansion from 10% to 100% with national subsidies

€/ha	EU average subsidy per hectare of new Natura 2000 area
10%	2 147
20%	2 094
30%	2 045
40%	2 000
50%	1 957
60%	1 916
70%	1 878
80%	1 842
90%	1 807
100%	1 774

Source: NEMESIS model

Indeed, Ngwa Zang and Le Mouél (2007 [367]) shows that the scale returns are increasing with the increase of holding size which is approximated with the help of family labour. And, as we will see in the following sections, agricultural employment, for which family labour represents more than two thirds of total agricultural employment, rises less than in the utilised agricultural lands. Thereby, according to agricultural modelling in the NEMESIS model, the rise of holding size leads to decreasing marginal costs of biodiversity conservation policy for agricultural land.

Now we will examine the results for agriculture and the overall economy and we will focus only on the 20% expansion case to simplify presentation of the results.

Agriculture

Table 5.3.14 displays the impact of this biodiversity conservation policies on **agricultural production** as well as on **agricultural product prices** for “*Agri-20%-CO*” and “*Agri-20%-EU*” scenarios. In both scenarios, agricultural production rises by about +0.5% at European level. The fall of land price for farmers also reduces the production costs which are transmitted to agricultural product prices. Those falls of agricultural product prices raises their demand and then increases agricultural production.

Table 5.3.14: Agricultural production and product price changes in “*Agri-20%-CO*” and “*Agri-20%-EU*” scenarios, at MS level, in 2025.

% change w.r.t. reference scenario	Agricultural production		Agricultural products prices	
	Agri-20%-CO	Agri-20%-EU	Agri-20%-CO	Agri-20%-EU
AT	0.5%	0.4%	-2.3%	-2.0%
BE	-0.1%	0.4%	-1.5%	-2.3%
CZ	0.9%	0.6%	-3.2%	-2.3%
DE	0.4%	0.5%	-2.2%	-2.6%
DK	0.3%	0.4%	-1.6%	-2.2%
EE	0.4%	0.7%	-1.1%	-1.7%
ES	1.2%	0.7%	-4.9%	-3.4%
FI	0.8%	0.7%	-2.1%	-1.9%
FR	0.2%	0.3%	-1.7%	-2.1%
GR	0.7%	0.7%	-3.0%	-3.0%
HU	0.6%	0.4%	-3.5%	-2.9%
IE	0.1%	0.5%	-0.5%	-1.4%
IT	0.5%	0.5%	-3.0%	-2.8%
LT	-0.2%	0.4%	-0.7%	-1.3%
LU	0.1%	0.2%	-1.4%	-1.7%
LV	0.1%	0.2%	-2.0%	-2.3%
MT	0.5%	0.1%	-2.5%	-1.9%
NL	-0.1%	0.5%	-1.4%	-2.2%
PL	0.7%	0.5%	-3.3%	-2.6%
PT	0.9%	0.6%	-3.3%	-2.4%
RO	0.0%	0.4%	-0.8%	-1.5%
SE	1.3%	0.4%	-3.3%	-1.7%
SI	1.7%	0.3%	-3.3%	-1.6%
SK	0.4%	0.3%	-1.2%	-1.0%
UK	1.1%	0.8%	-3.2%	-2.5%
EU	0.5%	0.5%	-2.7%	-2.5%

Source: NEMESIS model

In the European average, the fall of -10% of real agricultural land price in “*Agri-20%-EU*” leads to a fall of about -2.5% of agricultural production price which finally increases the agricultural production by about +0.5% due to internal as well as external demand increase. For the “*Agri-20%-CO*” scenario, the largest changes in agricultural product prices or production arise in countries where the changes in real agricultural land price are also the largest. For instance in Slovenia and Hungary, the agricultural production prices decrease by -3.3% and -3.5% and agricultural production raises by +1.7% and +0.6% respectively. On the contrary, countries with low financing, because of a weak expansion

of their Natura 2000 agricultural land, display little change in their production and even a small loss of agricultural production due to a degradation of their competitiveness inside the EU, as in Belgium and the Netherlands. The impact on the agricultural production depends, in addition to the initial change in real agricultural land price, (i) on land cost share in total agricultural production cost, (ii) on internal demand elasticity with respect to agricultural products prices but also (iii) on the opening of the agriculture sector, especially outside the EU. For the “*Agri-20%-EU*” scenario, the variations at European aggregated level are very similar with the national subsidy case. The changes for each MS are very homogeneous insomuch as the subsidy rate is unique and the land demand elasticities are similar among MS. The differences only come from the share of land cost in total agricultural input and external trade.

Those changes in the agricultural production could seem incoherent with the results presented in the section 4.3, where we find that direct supports to farmer have very weak or null effects on agricultural production as generally admitted in the publications (see *e.g.* Bhaskar and Beghin 2009 [37]). But, in this case, the goal of the support (the subsidy) is an expansion of the land used to produce whereas for the CAP, the subsidy does not depend on agricultural production.

Regarding the changes in **land intensity** in the scenario, we observe that the goal of the policies is reached (see table 5.3.15). At European level, land intensity in the agriculture sector decreases by around -1.9% in both scenarios. With the national subsidy case, the land intensity falls to -5.3% in Slovenia, -4.7% in Sweden and -3.2% in Slovakia. Obviously, those decreases of agricultural land intensity come with a fall of the **nutrients used by hectare**. The nitrogen and phosphorus intensities (*i.e.* per hectare) decrease slightly more than fall of the land intensity with around -2.1% on European average. The main reason for the nutrient intensity decrease is the rise of utilised agricultural lands combined with the weak increase of agricultural production. But, there is also a substitution effect that explains the slightly higher decrease of nutrients intensity than land intensity. Indeed, as the land cost for farmers decreases, they substitute other inputs, such as nutrients, to land. This substitution effect is confirmed by the most important fall for nutrient intensity than for land intensity in countries where the subsidies to farmers are the biggest. For instance in Spain in “*Agri-20%-CO*” scenario, where the subsidy rate is about 14%, the land intensity decreases by -2.1% whereas the nitrogen intensity declines by -2.8% *i.e.* a difference of 0.7%. We observe similar results for Slovenia, Sweden and Hungary where the efforts to match the policy objectives are relatively large. We can also see the substitution effect by looking at the fall of inorganic nutrients compared to other ones.

Table 5.3.15: Agricultural land intensity, nitrogen and phosphorus use variations in “*Agri-20%-CO*” and “*Agri-20%-EU*” scenarios, at MS level, in 2025 (% change w.r.t. *reference scenario*).

	Agricultural land intensity		Nitrogen uses (kg/ha)		Phosphorus uses (kg/ha)	
	<i>Agri-20%-CO</i>	<i>Agri-20%-EU</i>	<i>Agri-20%-CO</i>	<i>Agri-20%-EU</i>	<i>Agri-20%-CO</i>	<i>Agri-20%-EU</i>
AT	-2.5%	-2.1%	-2.7%	-2.2%	-2.7%	-2.2%
BE	-1.2%	-1.9%	-1.4%	-2.1%	-1.5%	-2.3%
CZ	-2.6%	-1.8%	-3.0%	-2.1%	-2.9%	-2.0%
DE	-1.5%	-1.8%	-1.8%	-2.1%	-1.7%	-2.1%
DK	-1.3%	-1.9%	-1.5%	-2.1%	-1.5%	-2.1%
EE	-1.1%	-1.9%	-1.1%	-1.8%	-1.3%	-2.1%
ES	-2.1%	-1.4%	-2.8%	-1.9%	-2.3%	-1.6%
FI	-2.0%	-1.8%	-2.4%	-2.1%	-2.5%	-2.2%
FR	-1.7%	-2.1%	-1.9%	-2.4%	-1.9%	-2.4%
GR	-1.5%	-1.5%	-1.8%	-1.9%	-1.9%	-1.9%
HU	-2.2%	-1.7%	-2.8%	-2.3%	-2.7%	-2.2%
IE	-0.5%	-2.1%	-0.6%	-2.4%	-0.6%	-2.4%
IT	-1.9%	-1.8%	-2.2%	-2.1%	-2.3%	-2.1%
LT	-1.3%	-2.3%	-1.2%	-2.1%	-1.3%	-2.4%
LU	-1.8%	-2.2%	-1.8%	-2.3%	-2.0%	-2.6%
LV	-1.8%	-2.0%	-1.9%	-2.1%	-2.1%	-2.4%
MT	-2.7%	-2.1%	-2.6%	-2.1%	-3.0%	-2.4%
NL	-1.1%	-1.9%	-1.3%	-2.2%	-1.2%	-2.0%
PL	-2.4%	-1.8%	-2.8%	-2.1%	-3.2%	-2.4%
PT	-2.6%	-1.9%	-3.1%	-2.2%	-3.1%	-2.2%
RO	-1.1%	-2.2%	-0.9%	-1.9%	-1.1%	-2.2%
SE	-4.7%	-2.1%	-5.3%	-2.4%	-5.3%	-2.3%
SI	-5.3%	-2.3%	-5.9%	-2.6%	-5.9%	-2.5%
SK	-3.2%	-2.4%	-2.7%	-2.1%	-3.2%	-2.5%
UK	-2.1%	-1.6%	-2.7%	-2.1%	-2.5%	-1.9%
EU	-1.9%	-1.8%	-2.2%	-2.1%	-2.1%	-2.1%

Source: NEMESIS model

At European level inorganic nitrogen intensity decreases by -3% in “*Agri-20%-CO*” scenario whereas the manure nitrogen intensity declines by -1.9%. But, in countries like Slovakia or Malta, the substitution effect does not appear. It is concealed by the atmospheric nutrients which are proportional to utilised agricultural lands. In those countries, the share of atmospheric nutrients is larger than in other countries. Consequently, the rise of atmospheric nutrients is not counterbalanced by the weak growth of nutrients linked to production such as manure and inorganic nutrients. Then, in Slovakia the nutrient intensity decreases in the “*Agri-20%-CO*” scenario is -0.5% lower than the fall of land intensity. The raise of atmospheric nitrogen use is about +3.6% whereas the fall of inorganic nitrogen is only about -0.1%. The substitution effect does not compensate the atmospheric nutrients growth.

Economy

We now present the economic results of the “*Agri-20%-CO*” and “*Agri-20%-EU*” scenarios. Table 5.3.16 displays the impact of those scenarios on the **Gross Domestic Product** (GDP) and the total and agricultural employments in 2025. At European level, the implementation of national or European subsidies to raise the agricultural lands under Natura 2000 has a slightly negative impact on GDP which decreases by -0.03% in the national subsidies cases and -0.02% in the European subsidy case. Despite a favourable impact on the agriculture sector, as seen above, the financing of the policy, through a lump sum tax on households disposable income, penalises the other economic sectors through the decrease of household demand. However looking at MS results, we observe much more contrasted results. For instance, the GDP in Spain decreases by -0.2% in the “*Agri-20%-CO*” scenario whereas it raises +0.06% in Slovenia or Luxembourg.

Table 5.3.16: GDP, agricultural and total employment variations in “*Agri-20%-CO*” and “*Agri-20%-EU*” scenarios, at MS level, in 2025 .

	GDP*		Total employment**		Agricultural employment**	
	Agri-20%-CO	Agri-20%-EU	Agri-20%-CO	Agri-20%-EU	Agri-20%-CO	Agri-20%-EU
AT	0.02%	0.02%	1.2	1.1	0.7	0.5
BE	0.01%	0.00%	-0.3	-0.4	-0.1	0.4
CZ	0.05%	0.03%	4.0	2.3	1.5	0.9
DE	-0.04%	-0.05%	-10.4	-13.1	3.0	4.4
DK	0.00%	-0.02%	-0.3	-0.9	0.2	0.4
EE	0.03%	0.04%	0.2	0.2	0.1	0.1
ES	-0.20%	-0.11%	-37.1	-19.8	9.7	5.7
FI	0.05%	0.04%	2.0	1.8	1.0	0.9
FR	0.02%	0.01%	3.9	2.7	1.6	2.5
GR	-0.11%	-0.12%	-3.4	-3.7	2.1	2.2
HU	-0.02%	-0.02%	-0.2	-0.5	1.4	1.0
IE	0.02%	-0.02%	0.3	0.1	0.1	0.6
IT	-0.04%	-0.03%	-6.5	-6.8	5.7	5.0
LT	-0.01%	0.01%	-0.3	0.6	-0.2	0.6
LU	0.06%	0.06%	0.1	0.1	0.0	0.0
LV	0.01%	0.01%	0.0	0.1	0.1	0.1
MT	0.00%	0.00%	0.0	0.0	0.0	0.0
NL	0.00%	-0.01%	-0.5	0.0	-0.4	1.5
PL	-0.09%	-0.06%	10.7	7.5	21.7	15.9
PT	-0.02%	0.01%	3.7	2.6	5.2	2.9
RO	-0.06%	-0.06%	-2.7	4.3	1.1	7.3
SE	0.03%	0.02%	2.3	1.2	1.3	0.4
SI	0.06%	0.02%	1.6	0.3	1.1	0.2
SK	0.03%	0.01%	0.8	0.4	0.2	0.1
UK	0.00%	0.00%	5.3	5.4	5.3	3.8
EU	-0.03%	-0.02%	-25.4	-14.4	62.3	57.4

*: % change w.r.t. reference scenario

**: change w.r.t. reference scenario in thousand

Source: NEMESIS model

The effects of the Natura 2000 network expansion on overall economic activity depends on several factors:

- The **extent of the real land price fall** and those consequences on agriculture sector. Indeed, the more the land price falls, the more agricultural product prices reduce, the more the negative impact on household income is counterbalanced. If the land fall is transmitted for a large part in agricultural product prices, the competitiveness of the country will significantly increase. And

according to the importance of external trade in agricultural sector, the agricultural production rise will more or less. For instance, Slovenia, where the GDP increase is the highest with +0.06%, has a real agricultural land that falls by about -22%, the largest fall. This fall leads to an agricultural product price decrease about -3.3% and an agricultural production rise about +1.7%, also among the highest. On the contrary, Hungarian real agricultural land price falls by about -12% leading to agricultural product price decrease of about -3.5%, the largest among MS. But, agricultural production in Hungary only increases by +0.6% due to a weak share of exports in the added value of agriculture in 2025 in the *reference scenario*.

- The **cost of the policy** and therefore the extent of the lump sum tax compared to household income is also a major factor for economic results. The extent of the lump sum tax depends on the subsidy rates but also on the nominal land price. For instance, there is an important difference in nominal land price between Slovenia, with 5 600€/ha in 2025 in the *reference scenario*, and United Kingdom, with 15 700€/ha. Even if there is also a huge difference in household incomes between the United Kingdom and Slovenia, the difference in nominal land prices amongst MS leads to different economic costs for the same subsidy rate. In Spain, the cost of the subsidy to farmers represents around 0.25% of the real household consumption, the highest among MS, explaining the GDP fall of -0.2%.

Then, globally, the impact on GDP of the policies depends on the combination of (i) the agricultural sector response to the land price fall and (ii) the extent of the lump sum. And comparing the loss of GDP between the cases with national and European subsidies, we observe a slightly smaller fall of GDP with the European subsidy (-0.02%) than with national ones (-0.03%). This difference comes from the re-allocation of the new Natura 2000 agricultural lands. The countries where the efforts are inferior to the EU average, are more penalised with European subsidy than with national ones as for Ireland. Inversely, Spanish GDP loss is weaker in the European subsidy case (-0.1%) than in the national case (-0.2%), this raise of GDP in Spain is the main reason of the slightly better results, at European level, with the European case than with the national one.

In terms of **employment**, the consequences on total employment follow the impact on GDP. At European level, the national subsidy to land extensification creates +62 000 employments in the agricultural sector but destroys -25 000 jobs in overall in the economy. For the European subsidy, job creation in agriculture is slightly weaker with +57 000 jobs and employment loss at macroeconomic level is lower with -14 000 employments. Looking in details, we see that the employment creation in

agriculture is concentrated in Poland and Spain with +22 000 and +10 000 respectively “*Agri-20%-CO*” scenario. Whereas the total employment loss are more dispersed among MS, with for instance, -10 000 in Germany, -37 000 in Spain, +11 000 in Poland and +5 000 in United Kingdom.

5.3.6.3 Remarks

Summary results

To summarise, the implementation, in the NEMESIS model, of biodiversity conservation policies for agricultural land with the help of subsidies to farmers has a positive impact on agriculture sector. The subsidy to farmer through a decrease of agricultural land price reduces production cost and raise competitiveness. Furthermore, it allow an extensification of agricultural production that reduces the pressure of biodiversity in those areas which are confirmed by the fall of nutrient use per hectare. At European aggregated level, a subsidy rate of about 10% per hectare of utilised agricultural areas (UAA) allows a fall of about 2% of agricultural land intensity and nutrients use. Nevertheless, the financing of this policy through a lump sum tax on households, counterbalances, the positive impact on agricultural activity. Despite the increase of agricultural production (+0.5%) and the creation of around 62 000 jobs in agriculture, the weight of the policy cost for households is too important and the overall economic activities fall (between -0.03% and -0.04% for GDP) with a total employment loss between 25 000 and 15 000 jobs according to the scenarios.

Opportunity cost

Now regarding the **gross cost per hectare** of new agricultural land under Natura 2000, we have established a gross cost ranges from 2 150 €/ha (*i.e.* 1 400 €₂₀₀₀/ha/year) for an expansion of 10% to 1 775 €/ha/year (*i.e.* 1 225 €₂₀₀₀/ha/year) a doubling of Natura 2000 network. But, measuring this cost with the GDP loss *i.e.* including the overall economic feedback, we find a cost from 1 030 €₂₀₀₀/ha/year to 740 €₂₀₀₀/ha/year for an expansion of 10% to 100%. We will retain 900 €₂₀₀₀/ha/year in the following of this study which correspond to the gross cost measured with GDP loss in “*Agri-20%-EU*” and which is in the middle range. In this case, the gross cost per hectare includes the opportunity cost, farmers receiving a compensation for the extensification of their production but also management cost because farmers are supposed to respect national Natura 2000 management guidelines, but it excludes administration costs. Comparing those results with other estimates of the biodiversity conservation cost in agriculture areas, the value of 900 €₂₀₀₀/ha/year seems relatively high. Indeed,

Strange *et al.* (2006 [437]) which estimate the cost of biodiversity conservation in Denmark for all types of areas find an opportunity cost reaching 500 €/2000/ha/year for a protection of 740 species³⁷. And in our study, as we extent the Natura 2000 network which is established under the Habitats Directive (1992 [181]) and the Birds Directive (2009 [190]), we cover more than 1 000 species whether animals or plants (Habitats Directive) and all wild bird species naturally occurring in the Union (Birds Directive). Therefore, the Natura 2000 network implies a high level of biodiversity conservation and consequently important costs. Nevertheless, the gross cost per hectare of 900 €/ha/year stays still relatively high compared to other studies.

Comparison with actual EU expenditures

Table 5.3.17 compares the costs per hectare of Utilised Agricultural Areas (UAA) of “*Agri-20%-CO*” and “*Agri-20%-EU*” scenarios in each MS with the planned European expenditures for the protection of the environment in agricultural areas. To calculate the planned expenditures for environmental protection on agricultural areas, we use the Financial Plan - Programming period 2007-2003, for Rural Development in EU (EC 2009 [147]). We take average annual planned expenditures per MS for the Axis 2 - “Improving the environment and the countryside” of the CAP 2nd Pillar³⁸ which correspond for a part to the European Agricultural Fund for Rural Development (EAFRD). And in this Axis 2, we focus on payments for agriculture and for agri-environment. The expenditures for agriculture includes:

1. natural handicap payments to farmers in mountain areas,
2. payments to farmers in areas with handicap, other than mountain areas,
3. Natura 2000 payments and payments linked to Water Directive (EU 2000 [182]),
4. agri-environment payments,
5. animal welfare payments,
6. and non-productive investments³⁹.

37. Strange *et al.* (2006 [437]) use $10 \times 10 \text{ km}^2$ grid cells to cover Denmark and assume that “*all of the species in a single one grid cell are protected adequately if the share of protected areas [in this cell] exceeds 30%*”. Furthermore, their assessment includes opportunity cost, but excludes management and administrative costs.

38. We could also include the 1st Pillar expenditures insomuch as direct supports to farmers are contingent on cross-compliance principle. Nevertheless, it will probably overestimates the payments for agri-environment even if supposing cross-compliance principle constraining. It would multiply, at least, the cost per three.

39. See EC (2006 [138]) for details on those items.

Table 5.3.17: Gross cost per hectare of Utilised Agricultural Areas (UAA) in “*Agri-20%-CO*” and “*Agri-20%-EU*” and Axis 2 of CAP 2nd Pillar financial plan (average cost per hectare of utilised agricultural land in 2008)

€/ha	Gross cost per hectare of UAA, in 2025		Average annual payment per hectare of UAA based on CAP Axis 2 of the 2 nd Pillar	
	Agri-20%-CO	Agri-20%-EU	Total agriculture	Agri-environment
AT	29.8	25.1	249.0	162.0
BE	84.0	145.0	41.5	37.5
CZ	15.8	11.0	73.9	45.2
DE	47.0	56.9	43.1	30.0
DK	89.0	123.4	23.0	22.5
EE	20.6	33.2	47.1	35.2
ES	109.0	74.8	17.1	11.5
FI	40.7	35.7	339.1	147.1
FR	20.8	25.8	29.4	10.9
GR	101.2	102.3	41.1	28.2
HU	31.9	25.6	41.3	40.5
IE	22.1	83.6	116.8	85.9
IT	71.0	66.0	60.1	44.5
LT	2.4	5.0	35.6	20.1
LU	86.8	109.7	232.6	119.5
LV	28.3	32.9	22.2	12.4
MT	630.9	464.9	346.1	145.6
NL	95.0	180.9	20.2	17.5
PL	18.9	14.5	43.9	21.3
PT	68.8	49.3	56.1	21.4
RO	3.0	6.7	21.4	10.0
SE	54.2	24.8	123.7	97.9
SI	62.8	26.4	171.8	89.2
SK	10.3	7.9	80.7	25.2
UK	94.3	73.9	59.2	48.7
EU	50.2	48.2	50.0	31.2

Source: NEMESIS model and own calculation based on EC (2009 [147])

We also calculate expenditures per MS and per UAA for agri-environment by including items 3, 4 and 6. At European level, the gross cost per hectare is around 34 €₂₀₀₀/ha/year⁴⁰, the average annual planned expenditures are about 45 €₂₀₀₀/ha/year for agriculture whereas they are about

40. Now, we use UAA and not only new protected areas as denominator.

28 €₂₀₀₀/ha/year for agri-environment⁴¹. Our estimates of gross cost per hectare of UAA are then in proportion to the actual planned expenditures for agri-environment at European level. But according to the areas concerned by the expansion of Natura 2000 agricultural lands (20% of the existing network), the gross cost seems relatively high and therefore indicates that our estimates represent an upper bound. Nevertheless, those values are comparable with other studies. For instance, Günter *et al.* (2002 [238]) estimate the agri-environmental payments interpreted as willingness to pay for the maintenance of the present agricultural landscape pattern and regional diversity of about 2 200 €/ha/year in 1999 in Switzerland *i.e.* eleven times more than our estimates and for an area eight times bigger (in the case of 100% expansion - see table 5.3.18). Table 5.3.18 displays the evolution of the European average gross cost per hectare of UAA for an expansion of Natura 2000 agricultural lands from 10% to 100% with national subsidies. We see that for a doubling of the Natura 2000 agricultural lands that would represent 20% of total European UAA, we estimate the gross cost per hectare about 130 €₂₀₀₀/ha/year *i.e.* more than four times the annual expenditures planned for the agri-environment supports.

Table 5.3.18: European gross cost per hectare of Utilised Agricultural Areas (UAA) for an expansion from 10% to 100% of Natura 2000 agricultural land with national subsidies, 2025.

Expansion of Natura 2000 agricultural lands in % of actual Natura 2000 agricultural lands	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
European Gross Cost per hectare of UAA (€/ha)	26.1	50.2	72.3	93.0	113.3	131.4	148.0	163.7	178.3	192.2
European Gross Cost per hectare of UAA (€ ₂₀₀₀ /ha)	17.8	34.3	49.4	63.5	77.4	89.8	101.1	111.8	121.9	131.3

Source: NEMESIS model

The extent of this estimated gross cost can be explained by the strong constraints imposed by the Natura 2000 network, as explained above. Indeed, comparing the returns per hectare in the *reference scenario* with those on new agricultural areas under Natura 2000, they are more than four times inferior, with around 1 800 €₂₀₀₀/ha in the *reference scenario* and 400 €₂₀₀₀/ha for the new protected agricultural land. The fall of production per hectare and then the high level of biodiversity conservation is the main explanation of the high values of gross cost per hectare. We can then conclude that gross cost per new land estimated at 900 €/ha/year allows a high level of biodiversity conservation in

41. The values in table 5.3.17 are in current euro. As the gross cost per hectare is calculated in 2025 and the annual payments are an average for 2007-2013. To compare those values, we actualise in €₂₀₀₀, applying the European inflation between 2000 and 2010 for annual payments and between 2000 and 2025 for gross cost.

agricultural areas and can be viewed as the upper bound of the biodiversity conservation cost in EU for agricultural land.

5.3.7 Concluding remarks

The biodiversity policies implemented in this study whether for forestry or agriculture areas have shown an average **European biodiversity conservation cost** about $800 \text{ €}_{2000}/\text{ha}/\text{year}$ for forest and $900 \text{ €}_{2000}/\text{ha}/\text{year}$ for agriculture. Those values were evaluated as upper bound for biodiversity conservation cost even if they do not include administration costs and management costs for the later. The implementation through Natura 2000 implies a high level of protection (more than 1 000 animal or vegetable species) and thereby pushes up the cost. Furthermore, for forest, we suppose a total conversion on “Protected Forest” of all new protected forests. And, according to the modelling of our land supply, it implies an equivalent reduction of available land for agriculture. This assumption is strong and reinforce the cost of biodiversity conservation in forest areas. Nevertheless, despite the high value of our estimate of biodiversity conservation cost, cost-effective policies would be still relevant according the evaluation of the biodiversity conservation benefits in other studies. For instance in a recent study, Bielsa *et al.* (2009 [39]) recommend a value of metropolitan french forest ecosystem of $970 \text{ €}/\text{ha}/\text{year}$ for economic valuation of french administration and a value of $600 \text{ €}/\text{ha}/\text{year}$ for grassland with extensive use. Although the last value is inferior to our cost estimates, Bielsa *et al.* (2009 [39]) specify “*les estimations proposées sont des estimations a minima, qui peuvent donc sans conteste remplacer dès maintenant la valeur nulle utilisée pour la biodiversité dans le calcul socioéconomique*”⁴². We could also present other studies on biodiversity benefits in EU that would confirm the cost-effective of biodiversity conservation even with our high estimates. For instance, ERM (1996 [177]) evaluates the benefit of United Kingdom forest biodiversity with the help of household willingness-to-pay that ranges from 840 to $1\,700 \text{ €}_{2000}/\text{ha}/\text{year}$. Or even Zandersen *et al.* (2005 [478]) value the recreation value of forest in Denmark of about $2\,200 \text{ €}_{2000}/\text{ha}/\text{year}$.

In addition, the implementation of the policies has displayed different consequences on the agricultural sector. In the forest case, the agriculture sector is penalised by the rise of real land price which reduces its competitiveness. Furthermore, the increase of real agricultural land price tends to raise the use of nutrients per hectare diminishing the positive impact of biodiversity. The fall in agriculture leads to a contraction of EU GDP and an employment loss. However with the agricultural area case, the fall of real agricultural land price reduces the production cost of agricultural products in the EU and raises the competitiveness outside EU. Consequently, European agricultural production rises as

42. “The estimates are a minima estimates, which can undoubtedly replace the null value for biodiversity used in economic valuation”

well as agricultural employment. Nevertheless, the cost of policy supported by household impacts negatively the rest of the economy and finally counterbalances the positive impact on the agriculture sector leading to a fall of GDP and total employment.

5.4 Assessment of European biofuels policy

5.4.1 Introduction

5.4.1.1 Biofuels definition

Biofuels can be either liquid or gaseous and even solid and are transportation fuels derived from biological sources. We will only focus on liquid biofuels, the more usual. We distinguish two types of liquid biofuels: ethanol (or bio-ethanol) and biodiesel which are two different industries. **Ethanol** can be produced from cereals (*e.g.* maize, wheat), sugar crops (*e.g.* sugar cane or sugar beet) and any other feedstocks that contain a high starch and sugar content starches, by the fermentation of carbohydrates (see box 5.4.1.1 for details on bio-ethanol production). Ethanol can be used in its pure form as motor fuel or as a blending component of gasoline after conversion into Ethyl-Tertiary-Butyl-Ether (ETBE - IEA 2004 [283]). Low level ethanol blends, such as E10 (10 percent ethanol and 90 percent gasoline) can be used in conventional vehicles, while high level blends, such as E85 (85 percent ethanol and 15 percent gasoline) can only be used in specially motorised vehicles, such as flexible fuel vehicles. In 2007, Brazil production of bio-ethanol, mainly from sugar cane, represented around 90% of Worldwide bio-ethanol production (Fischer *et al.* 2010 [225]). **Biodiesel** is made by transesterification, a chemical process that reacts a feedstock oil or fat with methanol and a potassium hydroxide catalyst. The process produces Fatty Acid Methyl Esters (FAME - the chemical name for biodiesel). The feedstock can be vegetable oil, such as that derived from oilseed crops (*e.g.* soy, sunflower, rapeseed, soya), used frying oil (*e.g.* yellow grease from restaurants) or animal fat (beef tallow, poultry fat, pork lard). The biodiesel production process yields as co-products crushed bean “cake”, an animal feed, and glycerin. Glycerin is a valuable chemical used for making many types of cosmetics, medicines and foods (IEA 2004 [283]). Biodiesel is used either in blends with diesel, and can be used in any diesel engine for low level blends, or in its pure form and used in special engines since 1994. In 2006, European Union biodiesel production was the highest with 75% of Worldwide production (Fischer *et al.* 2010 [225]).

We also distinguish the biofuel 1st-generation and the 2nd-generation technologies. The biofuel **1st-generation technology** using food crops such as cereals, sugar crops and oil seeds to produce biofuel. It is now well-established especially in Brazil (sugar cane), USA (maize) and EU (oilseeds). Indeed, farm technology does not require important adaptation to produce energy crops and conversion technologies from crops to bio-ethanol or biodiesel are not expected to change significantly only through efficiency improvement. Biofuel 1st-generation technology also generates large quantities of by-products

and residues. Some by-products as glycerin have many valuable use in other industries as chemical products whereas other by-products such as rapeseed cake, soybean meal or Distillers Dried Grains (DDG) are valuable livestock feed. Finally residues such as straw and husks can be returned to the field or used for co-firing (Fischer *et al.* 2010 [225]). The biofuel **2nd-generation technology** produced biofuels from non-food feedstocks such as residues or by-products of agriculture and forestry. Nevertheless, the present biofuel 2nd-generation technology is not still advanced enough for economic viability. Nevertheless, there is a technical breakthrough in technological routes that will probably significantly reduce the production costs and boost investments (Sims *et al.* 2010 [428]). Therefore, significant public and private R&D investments are presently being committed. For instance, in 2007, US Department of Energy Biomass Program financed six large-scale ethanol demonstration plants for \$385 million and Canada invested \$500 million in private companies developing large-scale facilities for producing both ethanol and biodiesel from cellulose (IEA 2008 [282]). But experts estimate that biofuel 2nd-generation technology could have a significant lead in the overall biofuels market but not before 2020 (Sims *et al.* 2010 [428]).

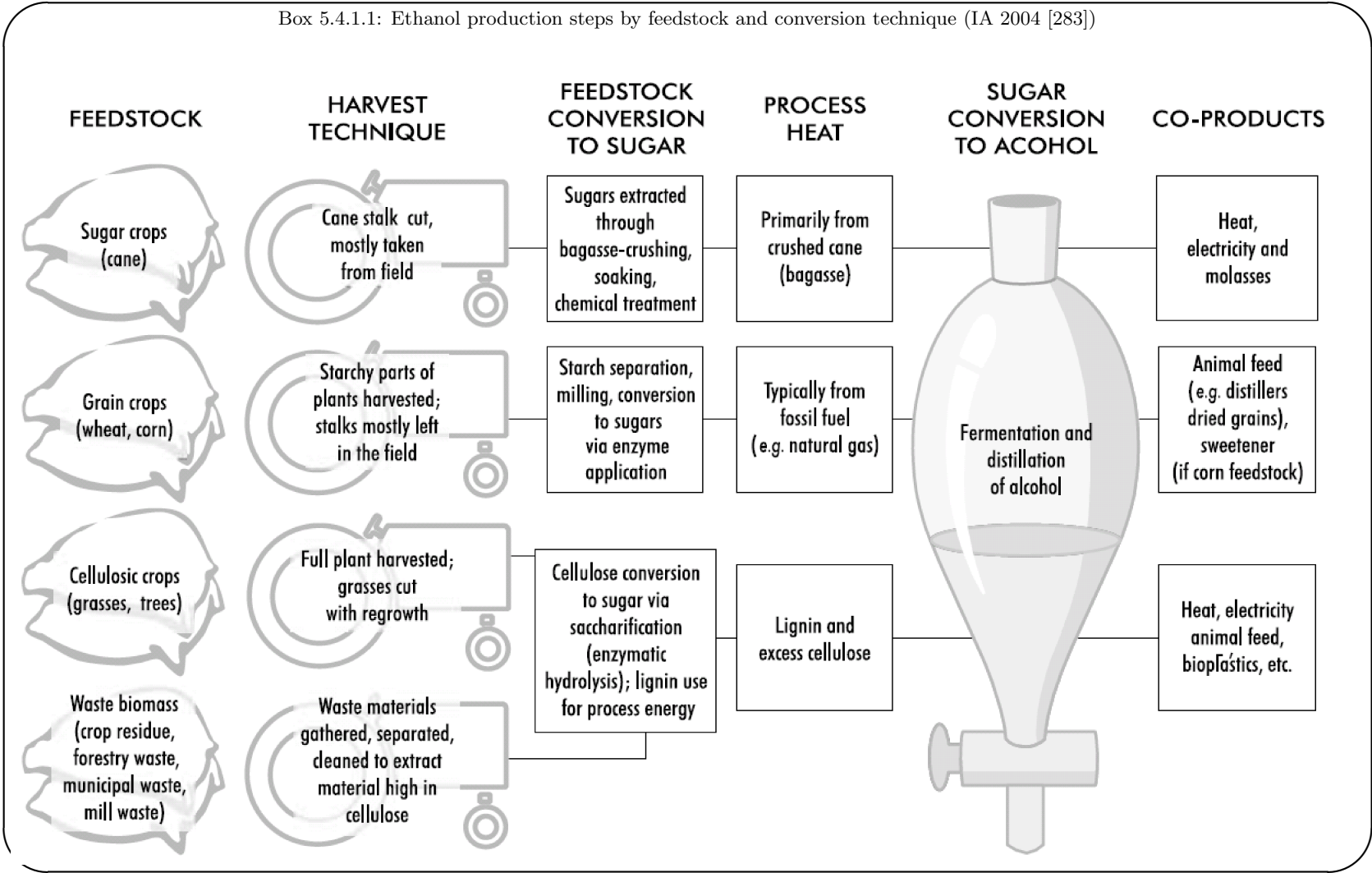
5.4.1.2 Biofuels development motivations

From an historical point of view, biofuels have emerged about three decades ago as a potential substitute to oil in transports fuels. Even if biofuels have a long history, Henry Ford's Model T were designed to support ethanol (Kovarik 1998 [317]) while the first diesel engines invented by Rudolf Diesel and presented at Paris Exposition in 1900, was powered by peanut oil (Pahl 2008 [378]). The real development of biofuel production arose in the seventies with the 1973 and 1979 oil crisis. Before the oil crisis, biofuels were too expensive compared fossil fuels to make significant development in transport, so there were only marginal uses. In 1975, the Brazilian government launched the "Programa Nacional do Álcool"⁴³ that promoted ethanol production from sugar cane in substitution to tradition fossil fuels. In USA, biofuel and especially ethanol development also started in the seventies, but the amended Clean Air Act (US Congress 1990 [449]) and the amended Energy Policy Act (US Congress 1998 [450]) have been the first substantial policies to support biofuel development in transport. Whereas in Europe, several European countries have implemented national policies to encourage the biofuel development in the nineties mainly through tax exemption⁴⁴.

43. The National Alcohol Program

44. See van Thuijl and Deurwaarder (2006 [458]) for a detail review on past national biofuel policies in European countries. And see Sorda *et al.* (2010 [434]) for an overview of biofuel support policies around the World.

Box 5.4.1.1: Ethanol production steps by feedstock and conversion technique (IA 2004 [283])



At European Union level, a first objective of 18 Million Tonne of Oil Equivalent (Mtoe) of liquid biofuels in 2010 was mentioned in White Paper “Energy for the future: Renewable sources of energy” (EC 1997 [128]) but the Green Paper “Towards a European strategy for the security of energy supply” (EC 2000 [130]) was the start for a more comprehensive European policy. Thereafter in all those regions, the policies were generally reinforced by increasing the biofuel development objectives. Through those dates and policies titles, we guess the three motivations of political support to biofuels development in transport.

- Firstly, biofuel promoting is usually justified by **security of energy supply**. Most of developed countries and a huge part of developing countries are large net importers of fuels for transport which is essential for their economic development. And with both oil crisis⁴⁵ common consciousness on the necessity to find credible substitutes to fossil fuel emerged in all those countries. Thereby, biofuels, for which technologies were known, appeared as potential substitute all the more so as they can be blended with traditional fossil fuels. The promotion of biofuel produced in the national territory reduces oil dependency of importer countries and secures energy supply but also a reduction of energy monetary charges.
- Secondly, biofuel production requires feedstocks which are produced by agriculture. Consequently, biofuel development for transport raises the demand for agricultural products and provides **new outlets and incomes to farmers** who are generally strongly dependent on agricultural policy support in developed countries. The rise of biofuels use is therefore seen as an opportunity for farmers as well as for states that could reduce farmers supports or at least reduce their lobbying pressure.
- And finally, a more recent motivation for promoting biofuels arises with consciousness on **Global Warming**. Indeed, as fossil fuels and their related GreenHouses Gases (GHG) emissions were identified as the main sources of Global Warming, the cleaner aspect of biofuels in terms of GHG emissions strengthens their interest as substitutes to fossil fuels in transport.

5.4.1.3 Biofuels controversies

Nevertheless, biofuel development is also facing serious criticism for two main reasons *(i)* biofuel crops are in **competition with food crops** and *(ii)* their potential negative environmental impact

45. We could also include the 2008 oil price peak.

via land use or net GHG accounting or even agricultural production practises⁴⁶. Firstly, as biofuel production requires a large amount of feedstock, the potential land substitution between land used for biofuel crops and land used for food production implies a likely strong impact on agricultural markets. In 2007, Jean Ziegler, United Nation special reporter on the right to food and great detractor of biofuels development all around the world, called for a five year moratorium on biofuels, adding “*it is a crime against humanity to convert agricultural productive soil into soil which produces food stuff that will be burned into biofuel*” (UN news 2007 [448]). Through this riotously affirmation, Ziegler emphasises that the competition between different uses of crops can act dramatically on accessibility on food for the poor. Indeed, if the additional demand for crops arising from biofuels demand is not fully compensated by a supply rise, crop prices will increase food cost which will penalise the poor. This effect is therefore accentuated by a high oil price. In this case, the biofuel production is more profitable for transport use and with high crop prices, it is also more profitable for farmers to sell biofuel crops instead of food crops. Therefore, the fear of numerous experts on food security is an lining up of crops prices on oil prices. For instance, Mitchell (2008 [357]) for the World Bank estimates that up to 75% of 2007-2008 food price increase could be explained by bioenergy expansion. Lipsky (2008 [337]) for the International Monetary Fund (IMF) attributes about 70% of corn prices rise and 40% of soybean prices increase to biofuels increasing demand. Recently several empirical studies have quantified the link between oil prices and crops prices. For instance, Ciaian and Kancs (2010 [97]), starting from a theoretical model studying the interdependencies between fuel price and agricultural prices, show an increasing interdependency between them over time. They find for the period 2004-2008 a cointegration between nine agricultural commodities prices and crude oil price that emphasises the impact of biofuels on agricultural prices. Equally, Chang and Su (2010 [81]) establish, with the help of a bivariate EGARCH model, a price spillover effects from crude oil futures to corn and soybean futures only during high crude oil price periods. In a context of high oil price, biofuels become credible substitutes for gasoline and their large development leads to strong competition with food crops for which the consequences on low-income population could be very severe. Consequently, biofuel support policies have generally revised downwards their medium long term objectives.

Secondly, large scale production of biofuels comes with increasing **environmental problems**. On one hand, the arguments in favour of biofuels for reducing GHG emissions are reconsidered regarding

46. Those criticisms only concern the biofuel 1st generation technology, the biofuel 2nd generation technology are not directly in competition with food crops and the environmental impact of its development seems much less questionable.

the net GHG emission accounting of biofuels. The production process of biofuels requires a huge amount of energy. IEA (2004 [283]) estimates, with the help of a survey, the GHG reduction from biofuels (only considering production process - well-to-wheels) between 20% and 50% for ethanol from grain, between 35% and 55% for ethanol from sugar beet and 40% and 65% for biodiesel from rapeseed. But, biofuel 1st-generation technology leads to indirect effect on land use change *i.e.* when biofuel crops grow on land previously used for food crop production and when those food crops grow in new land which were not in use⁴⁷. Furthermore, land use change and intensive cultivation associated with biofuel development can also lead to environmental problems such as water use or biodiversity. In 2008, the International Water Management Institute (IWMI 2008 [294]) estimates that there is enough water to produce food and biofuels, but in regions where water is already scarce, biofuel crop production will reinforce the water existing problems. And for biodiversity concern, in a study on assessment of European Union biofuel policy, Hellmann and Verburg (2010 [263]) show a direct effect of relatively small land use change whereas they lead to a much more substantial indirect effect which could impact biodiversity. Overall criticisms do not brake biofuel development but some of biofuel support policies objectives have been revised downwards or at least revised to include a sustainable aspect in biofuel development. In the EU, the first directive of biofuel (EP 2003 [173]) in 2003 defines an objective of 5.75% of biofuel in total gasoline in 2010 in EU and mentioned the Green Paper “Towards a European strategy for the security of energy supply” (EC 2000 [130]) objective of 20% of biofuel in total gasoline in 2020. In 2009, the European Parliament has approved a new directive (EP 2009 [176]) that fixes a minimum share of biofuel in total gasoline of 10% in 2020 with a minimum of 35% GHG emissions reduction to be achieved by biofuel all long its cycle and 50% in 2017 for existing installation and 60% for new ones. Furthermore, the 2009 directive includes sustainability criteria for indirect land use changes such as no biofuel crop production in land with high biodiversity values (*e.g.* primary forest or other wooded land) or with high carbon stock (*e.g.* wetlands or continuously forested areas). Each MS should create an economic operator that will validate the sustainable criteria with the help of a mass balance verification method that will be provided by the European Commission at latest in 2012.

In this context, it appears very interesting to quantify such policies in order to assess its economic as well as environmental impact, obviously even if it will not possible to answer to all questions. To do this,

47. The analysis of land use change on GHG emissions from biofuels is very complex, and the results vary strongly between studies according to modelling options as well as scenarios options. For instance, in a large survey European Commission Directorate-General for Energy (EC 2010 [153]) ranges the net biofuel GHG emissions (*i.e.* include emissions from production process plus emissions from land use change minus emission from avoided fossil fuel consumption) from 232 grams of CO₂ equivalent per megajoule to -69.

we aspire to the assessment of the European target of 10% of biofuel in total gasoline in 2020 with the NEMESIS model and the land use module. Even if the modelling tool can appear not detailed enough for this policy assessment and requires strong assumptions, we will see that even with a restricted tool, it is possible to display interesting results. The next section presents the scenario assessed by making the modelling assumption explicit along with the related restrictions, by displaying biofuel evolution in the *reference scenario* and by indicating political objectives and their extent compared to the *reference scenario*.

5.4.2 Scenario “10%-2020”

5.4.2.1 General assumptions

In this study, we assess the economic and environmental impact of EU 2009 directive (EP 2009 [176]) for biofuels aiming to reach 10% biofuels share in total gasoline in 2020 at European level. We will call this scenario “10%-2020”. In order to do this, we realise a normative exercise without knowing if actual policies instruments at European level are sufficient to reach the targets. We made this assumption for simplification insomuch as the biofuel policy instruments are implemented at national level and they are very disparate among MS (see *e.g.* Wiesenthal *et al.* 2009 [471]). Furthermore, we do not calculate a subsidy rate even with an uniform instrument to reach the 10% target. It supposes that there are no additional costs for the economy to support biofuel development *i.e.* either the financing of the policy which increases the national debt without feedback on the overall economy or we assume an oil price that makes biofuels competitive even if this situation is different from the *reference scenario*⁴⁸.

In addition, we assume the following technical coefficients (see table 5.4.1) for biofuel modelling. We also suppose several assumptions related to those coefficients:

- A rise in crop yields of about 2.5% per year for wheat, 1.5% for sunflower and rapeseeds, 0.5% for maize and soya and none for sugar beet.
- Technological progress of 0.5% per year from 2008 to 2025 for yields of feedstock conversion into bio-ethanol and biodiesel (column 7 of table 5.4.1).
- A fixed share for each crop in bio-ethanol and biodiesel production.
- A production of bio-ethanol production co-product: Dried Distillers Grains (DDG) about 1 *kg/l* of bio-ethanol from wheat and 0.77 *kg/l* of bio-ethanol from maize (OECD-FAO 2009 [375]), a price of DDG of 120€/t in 2000 (Eurostat 2010 [203]). The DDG are then used by agriculture as cattle food at the same price as other cattle food.
- We exclude the biodiesel production co-products such as glycerin and other bio-ethanol production co-products from our analysis.
- We do not include none biofuel 2nd-generation technology in 2020.

48. The biofuels production costs are estimated about 900 €/toe for biodiesel and 1 170 €/toe for bio-ethanol (EUBIA 2009 [194]) whereas it supposes an oil price higher than \$130 per barrel (supposing an exchange rate about \$1 = €1.25) to reach an equivalent production cost than for biodiesel.

Table 5.4.1: Technical coefficients for biofuel modelling in NEMESIS

	Feedstock	Price in 2000 (€/t)	Price in 2008 (€/t)	Yields in 2005 (t/ha)	Share in bio- ethanol/diesel	Biofuels production (t/kl)	Conversion factors ^(d)	Conversion factors ^(d)
Bio-ethanol	Wheat	118 ⁽¹⁾	117 ⁽¹⁾	5.11 ⁽²⁾	15% ^(a)	2.71 ^(c)	792l/t	1 389l/toe
	Maize	118 ⁽¹⁾	114 ⁽¹⁾	7.07 ⁽²⁾	15% ^(a)	2.48 ^(c)		
	Sugar beet	39 ⁽¹⁾	35 ⁽¹⁾	60.44 ⁽²⁾	70% ^(a)	10.1 ^(c)		
Biodiesel	Rapeseed	260 ⁽¹⁾	230 ⁽¹⁾	2.67 ⁽²⁾	74% ^(b)	2.69 ^(c)	800l/t	823l/toe
	Soya	190 ⁽¹⁾	200 ⁽¹⁾	1.66 ⁽²⁾	18% ^(b)			
	Sunflower	180 ⁽¹⁾	250 ⁽¹⁾	2.48 ⁽²⁾	8% ^(b)			

⁽¹⁾: Average European prices, Eurostat (2010 [203]).⁽²⁾: Average European yields, Eurostat (2010 [210]).^(a): Eurobserv'ER (2010 [195] - www.energies-renouvelables.org). Coefficients for France with 70% from sugar beet and 30% from cereals. Own calculation for split between wheat and maize.^(b): EC (2010 [153]).^(c): OECD-FAO (2009 [375]) from AGLINK-COSIMO model (OECD 2007 [373]) with an assumption of 0.45 tonne of oil for 1 tonne of oilseed for biodiesel.^(d): Bioenergy Feedstock Information Network (BFIN 2009 [35] - bioenergy.ornl.gov).NB: *t*: tonne, *l*: liters, *kl*: 1000 liters, *ha*: hectare and *toe*: tonne of oil equivalent.

All those assumptions and technical coefficients allow the calculation of the addressed demand from the refined oil sector to agriculture for biofuel production. The refined oil sector reduces, *ceteris paribus*, its production of gasoline from fossil fuels in equivalent amount of biofuel increase. Whereas, we assume the endogenous exports and imports from the agriculture sector to fulfil its new demand coming from the refined oil sector, in other words, we keep the existing imports and exports functions of the NEMESIS model without additional assumptions. Finally, the scenario is not implemented for Luxembourg and Malta due to problems of data availability.

5.4.2.2 Biofuels in the *reference scenario*

The NEMESIS model includes an energy/environment module⁴⁹ that calculates the energy consumption for each production sector and for households in physical unit for 8 energy products: fossil energies (coal, oil and gas) and renewable energies (wood, biofuel, biogas and electricity power generation: wind and solar⁵⁰). Those energy sources are modelled with nested CES production functions that link total energy consumption in monetary unit with energy consumption by products in physical units. For the *reference scenario*, the projections of energy consumption by products are based on the PRIMES model (E³Mlab 2008 [126]) projections realised for European Commission Directorate-General for Energy and Transport in 2007 (EC 2007 [152])⁵¹. Table 5.4.2 presents the consumptions and the share of biofuels in each MS in five year steps⁵². At European level, the total consumption of biofuels more than doubles in 10 years with 12 100 ktoe in 2010, 19 300 ktoe in 2015 and 26 140 ktoe in 2020 *i.e.* 3.5% in 2010, 5.2% in 2015 and 6.5% in 2020 of total European gasoline consumption. Five countries cover more than 70% of the total European biofuel consumption in transports in 2020 with 2 960 ktoe in United Kingdom, 3 150 ktoe in Italy, 3 440 ktoe in France, 3 800 ktoe in Spain and 5 170 ktoe in Germany. We find the biggest share of biofuels in total gasoline in 2020 in the *reference scenario* in the Czech republic with 9.4%, Slovakia with 9.3%, Poland with 8.8% and Denmark with 8.1% whereas, except Malta, Romania with 2.2% and Greece with 4.1% have the smallest shares in 2020.

49. We will not detail the NEMESIS energy/environment module insomuch as we impose a target for biofuels that will substitute equivalent gasoline consumption from fossil fuels without additional cost, see Zagamé *et al.* (2010 [476]) for more details on energy module.

50. Hydraulic and nuclear power generation are exogenous.

51. The NEMESIS energy consumptions by product could differ slightly from PRIMES projections due to different assumptions such as economic growth or oil price.

52. The split between bio-ethanol and biodiesel is an *ex-post* calculation (with PRIMES projections) from total biofuel consumption in NEMESIS.

Table 5.4.2: Biofuel consumption and share in gasoline in *reference scenario*

	Biofuel share			Bio-ethanol consumption (ktoe)			Biodiesel consumption (ktoe)		
	2010	2015	2020	2010	2015	2020	2010	2015	2020
AT	3.3%	4.8%	6.5%	102	161	232	154	233	338
BE	1.6%	3.3%	4.8%	49	110	176	127	285	452
CZ	5.8%	7.5%	9.4%	93	135	189	228	342	504
DE	4.6%	5.6%	6.2%	642	1 164	1 949	2 715	3 228	3 223
DK	3.4%	5.2%	8.1%	55	94	132	83	141	205
EE	4.4%	5.5%	6.4%	11	17	23	27	41	56
ES	4.9%	7.7%	8.4%	555	806	868	1 142	2 250	2 932
FI	1.7%	3.7%	4.8%	27	75	123	53	106	124
FR	3.3%	4.7%	5.7%	461	698	915	1 233	1 912	2 523
GR	2.1%	3.2%	4.1%	93	180	280	104	163	193
HU	4.4%	5.6%	7.4%	47	67	96	118	170	262
IE	2.0%	3.4%	4.8%	46	91	146	65	129	204
IT	3.6%	5.0%	7.0%	414	579	859	1 060	1 541	2 293
LT	0.7%	2.2%	5.1%	3	12	32	9	33	90
LU	2.5%	5.3%	7.3%	15	32	48	39	93	146
LV	3.4%	4.6%	6.8%	10	15	24	33	55	91
MT	0.0%	1.1%	1.6%	0	1	2	0	1	1
NL	2.3%	4.8%	7.0%	67	149	228	188	443	718
PL	3.5%	5.9%	8.8%	91	177	303	271	559	971
PT	2.4%	4.0%	5.4%	39	68	103	102	187	287
RO	1.2%	1.9%	2.2%	29	62	96	38	87	134
SE	4.0%	5.8%	7.0%	241	331	395	63	146	227
SI	1.7%	3.4%	4.6%	8	17	26	22	51	77
SK	3.0%	6.0%	9.3%	12	25	40	28	64	110
UK	2.6%	4.6%	6.8%	766	1 249	1 662	296	712	1 296
EU	3.5%	5.2%	6.5%	4 048	6 492	9 131	8 027	12 795	17 272

Source: NEMESIS model

By using the technical coefficient of table 5.4.1, we can estimate the biofuel crop production in EU in 2020 as follows:

- 4.4 Mt of wheat,

- 2.2 Mt of maize,
- 58 Mt of sugar beet,
- 32 Mt of rapeseed,
- 4.7 Mt of sunflower,
- and 4.9 Mt of soya.

Those 122 Mt of biofuel crops represent around 16.5 billion liters (bl) of biodiesel and 8.7 bl of bio-ethanol. And our estimates, assume no import from the Rest of the World, the agricultural land used for biofuel production about 165 000 km² *i.e.* around 9% of the European Utilised Agricultural Area (UAA). Furthermore, we observe that the 2010 target of 5.75% (biofuels directives 2003 - EP 2003 [173]) of biofuel in total gasoline is not reached in the *reference scenario*.

5.4.2.3 Biofuels targets in the “10%-2020” scenario

The biofuel projections for the “10%- 2020” scenario and its distribution among MS (see table 5.4.3) is based on PRIMES (E³Mlab 2008 [126]) simulation as for *reference scenario* but realised for the EU Framework Programme 6 (FP6) Integrated Project SENSOR⁵³ (Le Mouél 2007 [328]). Table 5.4.3 shows the extent of biofuel shares in the “10%-2020” scenario and the additional consumption of biofuels compared with the *reference scenario*. Obviously, we tend to a European biofuels share of 10% in 2020 that represents a rise of 11 000 ktoe (+42%) compared with the *reference scenario i.e.* a biofuel consumption about 40 600 ktoe in transports in 2020. Germany makes the strongest efforts in biofuel development in absolute value as well as in percentage with +4 400 ktoe in 2020 (*i.e.* +85%). On the contrary, Slovakia for which the biofuels development in the *reference scenario* (150 ktoe) is already above its “10%-2020” target, does not need to raise its biofuels consumption. After this presentation of the assumptions, the biofuels development in the reference scenario and the biofuel targets in the “10%-2020” scenario, we now will present and explain the agricultural, land use and economic results.

53. www.zalf.de/home_ip-sensor/index.html

Table 5.4.3: Biofuel consumption and share in gasoline in “10%-2020” scenario

	2010		2015		2020	
	Biofuel share	Additional consumption w.r.t. <i>reference scenario</i>	Biofuel share	Additional consumption w.r.t. <i>reference scenario</i>	Biofuel share	Additional consumption w.r.t. <i>reference scenario</i>
AT	4.3%	65	6.5%	114	9.4%	196
BE	2.5%	87	5.4%	221	8.5%	411
CZ	6.5%	4	8.8%	11	12.2%	54
DE	8.1%	2 284	10.4%	3 294	12.2%	4 395
DK	4.3%	28	7.1%	62	11.2%	84
EE	5.8%	6	7.9%	13	10.2%	23
ES	6.1%	231	10.5%	521	12.6%	927
FI	2.2%	21	5.1%	56	7.1%	93
FR	4.9%	707	7.2%	1 136	9.2%	1 717
GR	3.1%	85	5.0%	159	6.8%	239
HU	5.2%	12	6.8%	21	9.8%	57
IE	2.7%	39	5.1%	93	7.8%	184
IT	4.8%	409	6.6%	585	9.8%	954
LT	1.0%	4	3.3%	18	9.2%	61
LU ^a	2.5%	0	5.3%	0	7.3%	0
LV	4.5%	10	6.1%	16	9.5%	26
MT ^a	0.0%	0	1.1%	0	1.6%	0
NL	2.8%	44	6.3%	137	9.9%	289
PL	4.0%	33	7.0%	49	11.4%	142
PT	2.9%	21	4.9%	44	7.3%	92
RO	1.5%	19	2.7%	51	3.4%	100
SE	5.1%	70	7.7%	120	9.8%	186
SI	2.4%	11	5.1%	29	7.6%	56
SK ^b	3.1%	0	6.4%	0	10.4%	0
UK	3.2%	219	5.9%	439	9.2%	775
EU	5.0%	4 410	7.6%	7 190	10.1%	11 059

Source: NEMESIS model

^a: Policy does not implement for this country.^b: Biofuel consumption already too high in the *reference scenario*

NB: Biofuels share in total gasoline can change between *reference scenario* and “10%-2020” scenario even without additional biofuels consumption due to change in total gasoline consumption like in Slovakia.

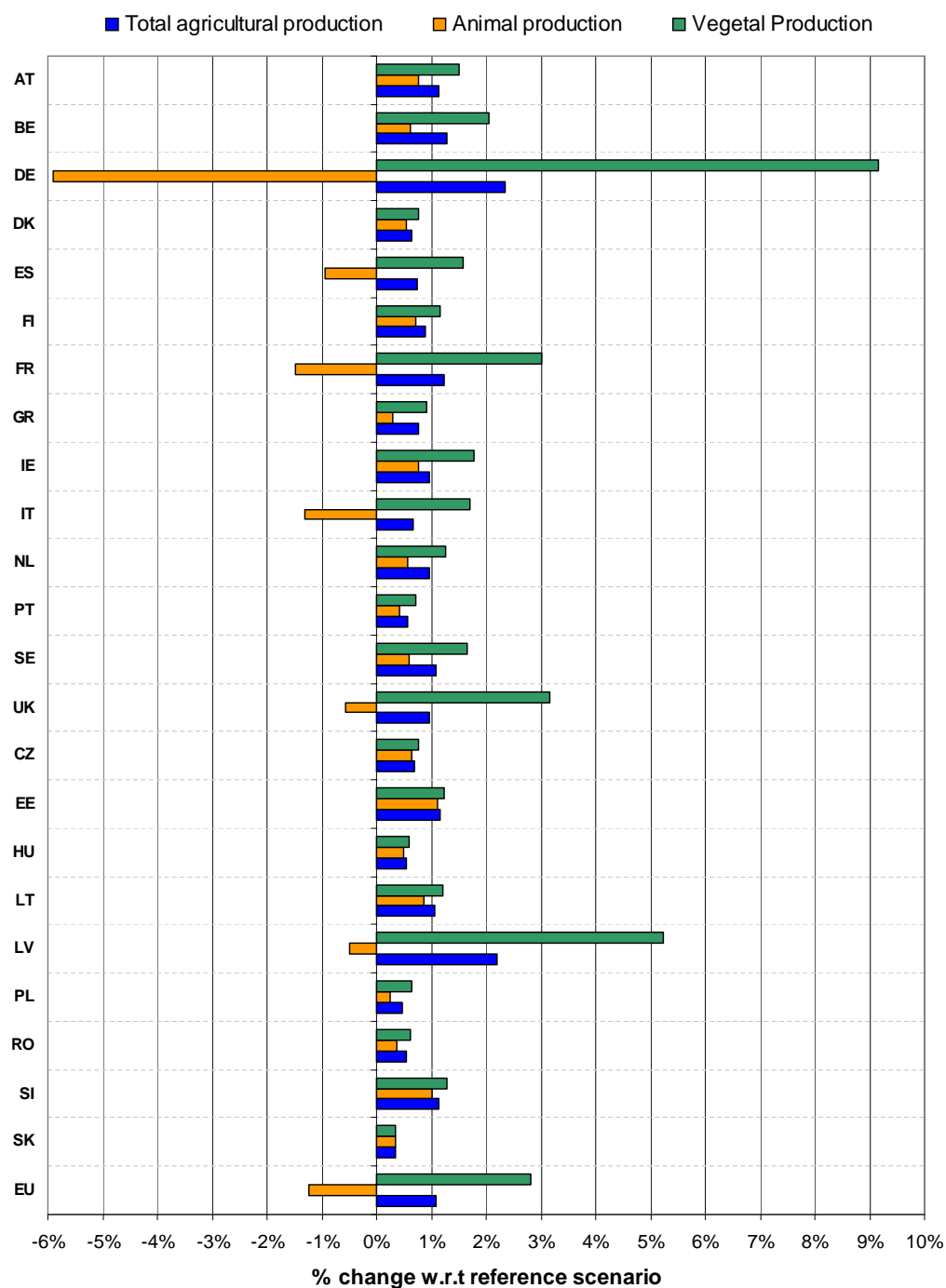
5.4.3 Results

We will present the “10%-2020” scenario results starting with the agriculture sector, going on to land use and environment and finishing with brief economic results. Obviously, we do not present the results for Malta, Luxembourg and Norway, the scenario is not implemented for them.

5.4.3.1 Agriculture

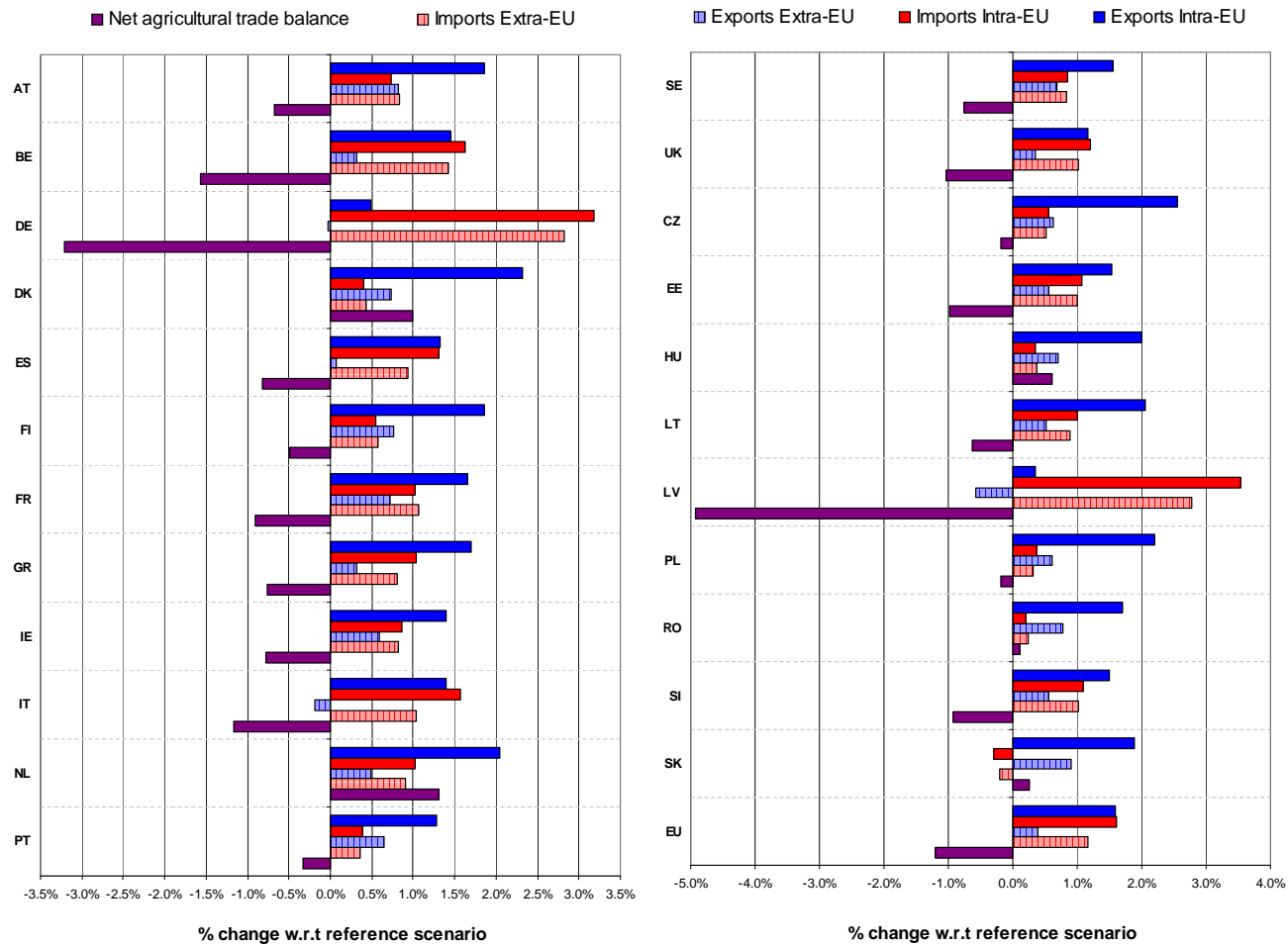
Figure 5.4.1 shows the percentage change of total **agricultural, vegetal and animal production** in 2020 in “10%-2020” compared to the *reference scenario*. We observe, at European level, a rise of agricultural production of about +1.1% in 2020 characterised by a relatively strong increase of vegetal production (+2.8%) and a weaker fall of animal production (-1.2%). Indeed, the strong rise of demand for biofuels crops from the refined oil sector increases the production of vegetal products to match this demand. This rise of vegetal production is realised in part at the expense of animal production. Farmers trade off between both productions leading to a substitution in favour of vegetal products that benefit from biofuels outlets. Nevertheless, the substitution is not totally neutral, the European total agricultural production rises (+1.1% compared with the *reference scenario*). This substitution between both agricultural production mainly comes from changes in German agriculture, where total agricultural production rises by +2.4%, with +9.2% for vegetal production and -5.9% for animal production. The extent of agricultural production changes in Germany, resulting from the “10%-2020” scenario efforts to reach the biofuels share target, represents more than 40% of the European vegetal production rise and more than 65% of the European animal production fall. Effectively, expect in other large EU countries like France, Spain, Italy and United Kingdom where there is also a substitution between agricultural production in favour of vegetal products but to a smaller extent than for Germany, overall in other countries, expect in Latvia, animal production grows to a smaller extent than for vegetal, yet it grows compared to the *reference scenario*, for instance +1% in Slovenia, +0.6% in Belgium and Netherlands or +0.2% in Poland. We can also see that in Slovakia, where there are no additional biofuels in “10%-2020” scenario, agricultural production benefits from the EU increasing demand for biofuel crops with a rise of +0.4% of vegetal production. Slovakia also benefits from the re-allocation among MS of animal production with also an increase of +0.4%.

Figure 5.4.1: Agricultural production changes in MS in “10%-2020” scenario in 2020, % change w.r.t. reference scenario



Source: NEMESIS model

Figure 5.4.2: Changes in agricultural trades in MS in “10%-2020” scenario in 2020, % change w.r.t. to *reference scenario*



Source: NEMESIS model

These changes and re-allocations among MS can also be observed looking at the **agricultural trades in the EU** (see figure 5.4.2). Looking at German intra-EU imports and exports, we observe a strong rise of German intra-EU imports compared to the *reference scenario* with +3.2% whereas the intra-EU exports only rise about +0.5%, much less than total increase of intra-EU agricultural exchanges (+1.6%). It leads to a fall of net intra-EU balance for Germany of about -4% (*i.e.* around -245 million €₂₀₀₀ in 2020). It is the largest fall among MS with Latvia for which the net intra-EU balance loss is -4.3%. Italy also loses in terms of intra-EU trade with a fall of -1.7% of its intra-EU net agricultural balance (*i.e.* -33 million €₂₀₀₀). This fall of intra-EU net agricultural trade balance in Germany or Italy benefits to other MS and especially to the Netherlands. The Dutch intra-EU imports of agricultural products rise by 1% whereas the intra-EU exports increase about 2%, raising the Dutch intra-EU net agricultural balance by 2.8%. And it represents more than half of the German loss (*i.e.* +140 million €₂₀₀₀). The “10%-2020” scenario also advantages agricultural trade in France (the intra-EU net agricultural balance rising by +3.1% *i.e.* around 20% of the German loss), Spain (+1.3% for the net agricultural balance *i.e.* 25% of German loss), Denmark (+7.2% for the net agricultural balance *i.e.* 7% of German loss) and Romania (+3.1% for the net agricultural balance *i.e.* 5% of German loss). Figure 5.4.1 also displays the **extra-EU agricultural trades**. Globally, EU raises its agricultural extra-EU imports about +1.2% and increases its agricultural extra-EU exports only by +0.4%. The EU net agricultural balance then decreases by about -1.2% (*i.e.* 1.6 billion €₂₀₀₀). The biofuels development in EU leads to an importation of additional agricultural products to fulfil the biofuel crops needs but also to satisfy the demand for animal products for which a part of the European production have been substituted to biofuel crops. Once more, the biggest fall of agricultural trade balance occurs in Germany for which extra-EU exports are unchanged whereas extra-EU imports rise by +2.8%. Thereby, German extra-EU net agricultural balance deterioration represents more than one third of European net agricultural balance loss. But, on the contrary to intra-EU agricultural trades, all MS lose competitiveness *vis-à-vis* rest of the World, except in Slovakia which does not need to produce biofuel crops for its own consumption and where its extra-EU net agricultural balance is increasing slightly. Other important rises of extra-EU trade deficits arise in France, Spain, Italy and United Kingdom with around 10% of the European fall for each of them.

In terms of employment, the rise of total European agricultural production benefits to **agricultural employment** with a job creation of 96 000 (see table 5.4.4) in 2020 compared to the *reference scenario*. Agricultural employment raises in all MS but only three countries create two thirds of those agricultural

employment with +19 200 jobs in Germany, +22 200 in Romania and +22 500 in Poland.

Table 5.4.4: Agricultural employment changes in MS in “10%-2020” scenario in 2020, % change w.r.t. to *reference scenario*

	AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	NL	PT
Employment change in %	1.4%	2.0%	3.6%	1.6%	0.9%	1.3%	1.5%	0.7%	1.2%	0.7%	1.3%	0.7%
Employment change in thousand	1.9	1.4	19.2	1.2	6.9	1.0	10.0	2.9	1.3	7.4	2.9	3.5
	SE	UK	CZ	EE	HU	LT	LV	PL	RO	SI	SK	EU
Employment change in %	1.3%	1.3%	1.3%	1.5%	1.1%	0.8%	2.0%	1.0%	1.1%	1.2%	1.3%	1.2%
Employment change in thousand	1.2	3.9	1.3	0.2	1.8	1.2	0.7	22.5	22.2	0.8	0.7	95.7

Source: NEMESIS model

Thereby, biofuel development in EU, in the context of the “10%-2020” scenario, leads to an agricultural re-allocation between production as well as between MS. The strong rise in demand for biofuel crops tends to favour vegetal production at the expense of animal production, European animal production falls by -1.2% and the vegetal production rises by about +2.8%. Globally, it leads to a European production rises of +1.1%. We also see that the substitution between animal and vegetal productions does not appear in all MS and two thirds of the animal production decrease comes from Germany which is the most impacted EU country. This re-allocation among MS benefits mainly to the Netherlands for which the intra-EU net agricultural trade balance rises by 140 million €₂₀₀₀ *i.e.* around 60% of the German intra-EU loss. Nevertheless, in all European countries, except in Slovakia, the imports from the Rest of the World grow faster than the exports, reducing European net agricultural balance *vis-à-vis* Rest of the World. Despite this rise of imports and the substitution between agricultural productions, a part of demand for biofuel crops is achieved in EU by creating nearly 100 000 jobs in agriculture (*i.e.* +1.2% compared to the *reference scenario*).

5.4.3.2 Environment

Land use

An important factor influencing the re-allocation of agricultural production among MS and the Rest

of the World, is the change of real agricultural land price which is driven by land use changes. Bio-fuel crop production requires substantial arable land and tends to raise European agricultural land use. Table 5.4.5 displays the agricultural land use change in EU in the “10%-2020” scenario compared to the *reference scenario*. At EU level, the substitution between animal and vegetal productions is also observable between grassland and arable land. The EU arable land increases about +40 800 km² whereas the grassland used by agriculture decreases about -6 300 km². Thereby, the European Utilised Agricultural Area (UAA) sprawls by +34 500 km² (*i.e.* +1.9%) under the development of biofuel crop production. By calculating the additional land for biofuel crop production using the technical coefficients of table 5.4.2, we estimate the land requirement for biofuel crop production about +62 700 km² in EU compared to *reference scenario*. Thereby, the EU arable land increase represents two thirds of the land requirement estimates for biofuel crop production. This difference comes for a large part from the European rise of imports from the Rest of the World but another part can be attributed to a substitution effect due to real agricultural land price rise in some European countries (see table 5.4.5)⁵⁴. Indeed, the rise of biofuel crop demand followed by arable lands, pushes up the land price especially in countries where the additional demand for biofuel is heavy. In both countries for which biofuels rise in the “10%-2020” scenario is the largest, the real agricultural land also rises significantly. German real agricultural land price goes up by +11.3% and Latvian one increases by +8.8% compared to the *reference scenario*. We also observe a non negligible rise of real agricultural land price in Spain with +3.5%, Italy with +4.6% and United Kingdom with +4.4% where the need of biofuel crops is relatively high to match their biofuel target in 2020. In addition, we see that in Belgium, the real agricultural land price also increases significantly with +3.3%. But, for Belgium, this rise is more due to agricultural land scarcity than large rise of biofuels crop demand. Indeed, arable land in Belgium only rises by +176 km² (*i.e.* +1.2%). In terms of areas, more than half of arable land rise comes from Germany with +21 000 km² and more than 40% of grassland fall also stems from Germany. France is second major important contributor of EU arable land rise with +9 300 km² (*i.e.* 23% of total EU raise) as well as EU grassland abandonment with -900 km² (*i.e.* 14% of EU fall).

54. Furthermore, the increase of imports from Rest of the World can also be explained by the raise of real agricultural land price at least in countries where variations are substantial.

Table 5.4.5: Land use and real agricultural land price changes in MS in “10%-2020” scenario in 2020, km² change w.r.t. to *reference scenario*

km ²	Land use			Real agricultural
	UAA	Arable land	Grassland	land price ^(a)
AT	112	118	-6	0.4%
BE	134	176	-42	3.3%
DE	18 283	20 970	-2 686	11.3%
DK	60	63	-3	0.9%
ES	2 174	2 935	-761	3.5%
FI	158	158	0	0.2%
FR	8 418	9 300	-882	1.8%
GR	211	237	-26	1.4%
IE	75	143	-68	1.5%
IT	1 850	2 409	-560	4.6%
NL	56	90	-34	1.6%
PT	49	50	-1	0.2%
SE	324	324	-1	0.5%
UK	880	1 834	-953	4.4%
CZ	66	79	-13	0.9%
EE	51	44	7	0.3%
HU	89	98	-9	0.6%
LT	88	104	-16	1.4%
LV	688	800	-112	8.8%
PL	574	645	-71	0.9%
RO	192	232	-41	0.4%
SI	23	18	5	0.3%
SK	7	9	-3	0.1%
EU	34 562	40 835	-6 273	3.5%

^(a): % change w.r.t. reference scenario

Source: NEMESIS model

Thereby, the substitution between animal and vegetal productions, observed with agricultural results, appears equally with the land use results through a substitution between grassland (-6 300 km² for EU) and arable land (+40 800 km²). Nevertheless, the substitution is not complete and total agricultural land use in Europe increases by +34 500 km² mainly in Germany with +18 300 km² and in France, in a small extent, with +8 400 km². The sprawling of utilised agricultural areas in Europe

pushes up real agricultural land price up with +3.5% in European average and with a peak in Germany of +11.3%. The real agricultural land price variations imply substitution effects between agricultural production factors and explained, in part, the fall of net agricultural balance in Europe *vis-à-vis* Rest of the World. Therefore, we have estimates of around two thirds of the land use requirement for biofuel crops production are implemented in Europe whereas one third is realised with the help of imports from the Rest of the World. Now with the help of the land use results, we will look at the “10%-2020” scenario the consequences of nutrient use on the environment.

Nutrients

Table 5.4.6 presents the nutrients use changes in the “10%-2020” scenario compared to the *reference scenario*. As there is a strong substitution between animal and vegetal production that does not exist in the biodiversity policy assessment of the previous section 5.3, we have slightly modified the modelling of inorganic and nitrogen and phosphorus manure. Indeed, as explained in section 5.2, we model the inorganic nutrients as an input demand function (see equation 5.2.1) and manure nutrients as a co-product of animal production. Thereby, in the case of substitution at the expense of animal production, manure nutrients will declined and this fall will not be compensated by inorganic nutrients use even if the agricultural needs could be the same or higher for agricultural production. Consequently, instead of modelling only the inorganic nutrients as a production factor, we suppose that farmers determine their demand for total “tangible” nutrients (including manure and inorganic and, obviously, excluding atmospheric deposition and biological fixation). Thereafter, according to the availability of manure nutrients, farmers buy inorganic nutrients as the balance between total “tangible” nutrients and available manure nutrients. Furthermore, to avoid changes in the *reference scenario* and to focus on “10%-2020” scenario, we calibrated inorganic nutrients to reproduce *reference scenario* projections. Thereby, equation 5.4.1 (previously equation 5.2.1 in section 5.2) now defines total “tangible” nutrients including manure and inorganic nutrients and inorganic nutrients (equation 5.4.2) are defined as follows:

$$\tan_{f,u,i,t} = B_{f,i,t} \cdot \exp(-\theta \cdot t) \left(\frac{c(Y_{u,i,t})}{P_{f,i,t}} \right)^\gamma Y_{u,i,t} \quad (5.4.1)$$

$$Inorg_{f,i,t} = \sum_u \tan_{f,u,i,t} - Man_{f,i,t} \quad (5.4.2)$$

With $\tan_{f,i,t}$ the demand for total tangible nutrients f in country i at time t , with u the uses: animal

and vegetal and where $f = N, P$ *i.e.* nitrogen or phosphorus. $c(Y_{u,i,t})$ represents the total production cost per unit of production and Y_u the agricultural production is equal to vegetal production for vegetal use ($u = V$) and to animal production for animal use ($u = A$). $P_{f,i,t}$ is the price of nutrients f whereas $B_{f,i,t}$ is a calibrated parameter to reproduce *reference scenario* outputs. Finally, θ is a parameter for trend productivity and γ the price elasticity with respect to total production cost. Finally, $Man_{f,i,t}$ and $Inorg_{f,i,t}$ are respectively manure and inorganic demands for nutrients f in country i at time t .

Table 5.4.6: Changes in European nutrients use intensity in “10%-2020” scenario in 2020, w.r.t. to *reference scenario*

		Nitrogen intensity			Phosphorus intensity		
		Total	Inorganic	Manure	Total	Inorganic	Manure
First modelling option	%	-0.4%	0.4%	-2.6%	-1.7%	0.2%	-2.8%
	kg/ha	-0.5	0.3	-1.1	-0.3	0.0	-0.3
Second modelling option	%	0.6%	2.4%	-2.6%	0.3%	6.1%	-2.8%
	kg/ha	0.7	1.4	-1.1	0.1	0.4	-0.3

Source: NEMESIS model

Table 5.4.6 then presents the European results for **nutrient input intensity** with both modelling approaches. We remark that even if the results display opposite signs, the extent of the change in total nitrogen and phosphorus is relatively weak. The European total nitrogen input per hectare decreases by -0.5 kg/ha with the first modelling approach and increases by +0.7 kg/ha with the second one. However, European total phosphorus use per hectare decreases about -0.3 kg/ha and rises by +0.1 kg/ha with the first and second modelling approaches respectively. Obviously, the difference between both models comes from the inorganic nutrients that increase from +0.3 kg/ha with first modelling to +1.4 kg/ha with the second for nitrogen and from 0 kg/ha to +0.4 kg/ha for phosphorus respectively. Thereby, assuming that farmers choose their nutrients demands for total “tangible” nutrients and not only inorganic ones, farmers increase their demand for inorganic nutrients in order to counterbalance the loss of manure nutrients leading to a relatively stable quantity of nutrients input per hectare between *reference scenario* and “10%-2020” scenario. Despite this relative uncertainty on inorganic nutrients according to both modelling approaches, we observe a fall of manure nutrients due to decrease of animal production, -1.1 kg/ha for nitrogen and -0.3 kg/ha for phosphorus. We can nevertheless conclude a small impact on total nutrients inputs of biofuels development whatever the modelling approach. At country level, we do not observe large difference between MS, except in Germany where obviously we

observe the strongest EU change in nutrient input per hectare. The total German nitrogen input per hectare decreases with both modelling approaches, -6.1 kg/ha with modelling with farmers decision on inorganic nitrogen only and -2.7 kg/ha with modelling of total “tangible” nitrogen. In the Netherlands where nutrients input per hectare is the highest among MS and that benefits from the European re-allocation of agricultural production, the nitrogen intensity rises slightly in percentage terms with +0.3% and +0.5% according to modelling approach. But in terms of kilogramme per hectare, the Netherlands, where the animal production raises by 0.6%, has, with the first modelling approach, one of the highest European increase of nitrogen intensity with +1.1 kg/ha. In the case of the second modelling, nutrient intensity increases closely to EU average with +1.8 kg/ha insomuch as there is substitution between animal and vegetal production in the Netherlands. To summarise, expect in Germany where biofuel development is very important, the changes on nutrient intensity with biofuel development, in the context of “10%-2020” scenario, do not display a higher harmful environmental impact than in *reference scenario*.

5.4.3.3 Economy

We now briefly present and comment on some economic results. Nevertheless, the extent of the economic results should be considered carefully regarding our assumptions for biofuels development insomuch as we do not suppose a cost for biofuel supports. Therefore, we overestimate the economic impact.

Table 5.4.7 displays the variations of **sectoral added value and employment** in 2020 in the “10%-2020” scenario compared to the *reference scenario*⁵⁵. We observe that all sectors, expect agriculture, are slightly penalised by the development of biofuels in EU. Firstly, the substitution of fossil fuels by biofuels reduces activity in Energy sectors (-0.55%) and especially in Oil & Gas Extraction but as this sector is very marginal in EU, the impact is moderated. Secondly, the raise of real agricultural land price slightly increases the production costs of new buildings and therefore slightly decreases the activity in Construction sector.

55. Sectors of table 5.4.7 are an aggregation of NEMESIS sector (see Appendix A for NEMESIS sectoral production nomenclature). Energy includes: Coal and Coke, Oil & Gas Extraction, Gas Distribution, Refined Oil, and Electricity. Intermediate Industry regroup: Ferr. & non Ferrous Metals, Non Metallic Min. Products, Chemicals, Metal Products, Agr. & Indus. Machines, Paper & Printing Products, Rubber & Plastic and Other Manufactures. Equipment goods aggregate: Office Machines, Electrical Goods and Transport Equipment. Consumptions Goods regroup: Food, Drink & Tobacco and Tex., Cloth & Footwear. Transports include: Inland Transports and Sea & Air Transport. And finally Services aggregate: Water Supply, Distribution, Lodging & Catering, Other Transports, Communication, Bank, Finance & Insurance, Other Market Services and Non Market Services.

Table 5.4.7: Sectoral added value and employment changes in EU in “10%-2020” scenario in 2020, w.r.t. *reference scenario*

	Added value	Employment	
	%	%	thousands
Agriculture	1.10%	1.18%	95.7
Energy	-0.55%	-0.79%	-20.6
Intermediate Industry	-0.06%	-0.13%	-30.0
Equipment Goods	-0.02%	-0.14%	-14.0
Consumption Goods	-0.03%	-0.06%	-4.6
Construction	-0.10%	-0.13%	-18.0
Transports	-0.04%	-0.07%	-5.2
Services	-0.03%	-0.05%	-76.4
Total	-0.03%	-0.03%	-73.1

Source: NEMESIS model

Finally, the impact on those sectors (Energy and Construction) is transmitted to other sectors which are also penalised. The same mechanisms explain the changes in European sectoral employment where, except in agriculture (+95 700 jobs), the overall sectors destroy employment with -170 000 jobs leading to a total employment destruction of -73 000 in EU. To summarise, biofuel development impacts negatively on the European economy especially Energy sector due to fall of fossil fuel consumption and the Construction sector through the rise of real agricultural land price. However, this decrease of European economic activity is, for a part, counterbalanced by the rise of added value of agriculture and leads to a very weak negative effect on total European added value (-0.03%) as well as on European employment (-73 000 jobs *i.e.* -0.03%).

At country level (see table 5.4.8), we observe the strongest **GDP** falls in Denmark with -0.91% coming with -12 400 **employment** loss. Denmark is still one of the last (with United Kingdom in a smaller extent) with a non negligible activity of oil extraction, thereby the fall of fossil fuels consumption in European transport tends to penalise Danish economy much more than the other European economies. For other countries, biofuel development impacts are relatively weak on GDP. For instance, in Germany having the strongest efforts in reaching its biofuels share in transports in 2020, the GDP decreases slightly (-0.09%).

Table 5.4.8: GDP and total employment changes at MS level in “10%-2020” scenario in 2020, w.r.t. *reference scenario*

	GDP*	Employment**
AT	0.00%	0.7
BE	0.06%	-0.2
DE	-0.09%	-6.1
DK	-0.91%	-12.4
ES	0.02%	-21.9
FI	0.00%	0.7
FR	0.12%	-4.5
GR	-0.01%	2.1
IE	-0.03%	1.0
IT	0.00%	-4.7
NL	0.04%	1.5
PT	0.04%	3.1
SE	0.06%	-0.3
UK	-0.10%	-14.4
CZ	0.02%	-4.6
EE	0.00%	0.5
HU	-0.08%	-2.9
LT	-0.01%	1.1
LV	-0.36%	1.8
PL	-0.02%	4.7
RO	-0.14%	-0.5
SI	-0.04%	0.6
SK	-0.08%	-18.2
EU	-0.03%	-73.1

*: % change w.r.t. reference scenario

** : change w.r.t. reference scenario in thousand

Source: NEMESIS model

The important rise of agricultural production counterbalances the inflationary effect of real agricultural land price increase that limits the fall of German GDP as well as its total employment (only

-6 100 jobs destroyed in 2020 compared to *reference scenario*). France also benefits from agriculture production rise coming from internal as external biofuel crops demand. On contrary to German, French real agricultural land prices does not increase to much leading to a slight GDP raise (+0.12%). Nevertheless, the change in sectoral composition of the french economy leads to a slight job destruction, with -4 500 employments. Globally, the results do not show huge economic impact of biofuel development among MS, except in Denmark where, on the contrary to other MS, oil extraction is still an important economic activity, the changes in GDP or employment are very weak with an European GDP decreasing by -0.03% and European total employment about -73 000.

5.4.4 Concluding Remarks

5.4.4.1 Results Summary

Firstly we will summarise the modelling results for the “10%-2020” scenario where we implement the European target of 10% of biofuels in transports in 2020 *i.e.* a biofuel consumption passing from 26 000 ktoe to 37 500 ktoe in 2020. The scenario is also characterised by a strong effort in Germany that must increase its biofuels consumption in transports by from 5 200 ktoe to 9 600 ktoe. We have shown that the rise of biofuel crops demand implies a substitution between animal and vegetal productions at the expense of animal products. The European fall of animal products mainly comes from Germany (65% of European animal production decrease) and does not appear in all European countries. Thereby, we observe a re-allocation of EU agricultural production inside the EU which has penalised Germany most of all but also Italy and the United Kingdom however it benefits the Netherlands and France. However, the rise in biofuel crops demand leads a degradation of the net agricultural trade balance in each MS, with around one third of biofuel crops needs, to reach the 10% target, coming from the rest of the World. In environmental terms, we also observed a substitution between arable land and grassland with a strong increase of arable land (+4.1 million ha) partially compensated by a reduction of grassland (-0.6 million ha) leading to a raise of utilised agricultural areas of nearly +3.5 million ha in 2020. Looking at nutrients input intensity, we have shown a weak impact at a European level characterised by a fall of manure nutrients due to animal production reduction and a raise of inorganic nutrients about +0.3kg/ha to +1.4kg/ha for nitrogen and no change to +0.4kg/ha for phosphorus according to the modelling approach *i.e.* if farmers integrate in their behaviour the fall of manure inputs or if they compensate it by additional inorganic nutrients. We concluded on a small harmful impact on environment of nutrients use due to biofuel crop production rise. Finally, we have examined economic results that do not exhibit significant impact of biofuel policy except in Denmark which is a crude oil producer and which is penalised by the fall of fossil fuel demand for EU.

5.4.4.2 Discussions

The studies on biofuel development impact on agricultural markets and the environment are very substantial and we allow the comparison of our results with other studies. We will use some of

them using modelling tools⁵⁶ and focusing on the EU. There are numerous studies with different modelling approaches focusing on either economics, agricultural and environmental impact of biofuel development in EU or on one or several of those aspects. An interesting survey realised by Fonseca *et al.* (2010 [231]) resumes three comparable modelling exercises⁵⁷ with three different agricultural sector models: the AGLINK-COSIMO model (OECD 2007 [373]), the European SIMulation Model (ESIM - Banse *et al.* 2005 [25]) and CAPRI model (Britz and Witzke 2008 [57]). According to agricultural markets, these models, which are much more detailed for agriculture than NEMESIS, give large details of the biofuel development impact on biofuel crops production. Without going into further details, we compare some keys findings. Firstly, the biofuel development in AGLINK-COSIMO model displays larger imports of biofuel crops than in our study with around 50% for wheat and coarse grains and 75% for oilseed. Nevertheless, the results observed with the ESIM model are closer to our results with a contribution of imports of about 20%-30% to provide additional biofuel crops. Therefore, with an estimation of a third of biofuel crop imports in our results, it seems relatively robust compared to other models⁵⁸. But, it appears that the substitution between animal and vegetal products does not appear in the other modelling. AGLINK-COSIMO and ESIM models find hardly impact of biofuel policy on animal products. AGLINK-COSIMO shows a slight substitution between animal products with a fall of ruminants animal productions (beef and veal) and a raise of non-ruminant animal productions (pork, poultry and eggs). However, with the CAPRI model, animal production (livestock) decreases slightly in the EU but with a very large variation among MS reaching up to -6% in some EU regions. Therefore, the substitution effects between animal and vegetal production observed with the NEMESIS model seems relatively strong compared to other models results. Nevertheless, considering the CAPRI results showing non negligible animal production decrease in some EU regions, we must keep in mind that the animal fall in NEMESIS does not occur in all MS. Furthermore, more than two thirds of animal production falls in EU come from Germany. It is unlikely that the scenario implemented with those three models demands a such strong biofuel development in Germany as in our scenario. Unfortunately, there is no detailed information on biofuels repartition among MS. But other studies focusing on biofuel development impact at Global level have already found negative impact of biofuels

56. See Kretschmer and Peterson (2010 [320]) for a survey on bio-energy in Computable General Equilibrium Models (CGEM) and Witzke *et al.* (2008 [474]) for a survey on bio-energy in agricultural sectors models.

57. The scenarios implemented in this study correspond to a raise of European biofuels consumption about 11 000 ktoe as in our scenario.

58. We can not calculate the imports contribution to additional biofuel crops demand with the CAPRI model inasmuch as all results are expressed in percentage and Fonseca *et al.* (2010 [231]) do not report enough detailed on baseline level.

development on livestock. For instance, Birur *et al.* (2008 [42]) displays, with the help the GTAP-E model (Burniaux and Truong 2002 [66]) including Agro-ecological Zones (AEZs - Lee *et al.* 2009 [330]), that for an increase of about 7 000 ktoe of biofuel in EU, the livestock production decreases by about -0.5%. Therefore, despite a strong impact in Germany, it seems likely that the biofuels crop development leads to a fall of animal production.

Looking at environmental results, Fonseca *et al.* (2010) shows a substitution between arable land and grassland at EU level. The model AGLINK-COSIMO expects an increase of +1.4 million ha associated with a fall of -1.1 million ha of grassland whereas the CAPRI model, for which total agricultural area is fixed, also displays a raise of arable land and a fall of fallows and pasture⁵⁹. Furthermore, ESIM estimates an increase of total agricultural land of about +0.7 million ha. Despite the similarity in terms of agricultural lands substitution, those results display smaller land use change than in our study for which we find a rise of total utilised agricultural areas about +3.5 million ha with an increase of arable land about +4.1 million ha and a decrease of grassland about +0.6 million ha. Several aspects can explain our “overestimates” of agricultural land use changes.

- Firstly, we assumed none biofuel 2nd-generation technology in 2020 while Fonseca *et al.* (2010) suppose a share in total biofuel of 20%. Yet, land use requirement to produce biofuel crops from 2nd-generation technology is much smaller than with the 1st-generation technology.
 - In addition, the three models used in Fonseca *et al.* (2010) are agricultural sector models with a detailed representation of agricultural products. Thereby, it is likely that observed substitution between animal and vegetal production occurs also between vegetal products but those intra-products substitution are not take into account which could explain a more large land use impact of biofuel development with the NEMESIS model.
 - Finally, the weaker technical progress implemented in the “10%-2020” scenario compared to Fonseca *et al.* (2010), could also explain the stronger agricultural land use change in our study.
- Finally, Britz and Hertel (2009 [55]), assessing the impact of the EU biofuel Directive (EP 2009 [176]) with the help of a combination of GTAP-E model including AEZs and the CAPRI model, shows an slight increase of nitrogen use in EU with +0.14% characterised by a fall of manure nitrogen (-0.5%) and a raise of inorganic fertilisers (+1.4%). Britz and Hertel (2009 [55]) also give a range between +3 kg/ha to -1 kg/ha in EU regions. Those results tend to validate our results with the second modelling

⁵⁹. CAPRI provides the following results: “Cereals and oilseeds areas are higher by 0.05% and 10.5%, respectively, at the expense of fodder activities and fallow land (0.2% and 5.6% lower, respectively)” (Fonseca *et al.* 2010) but we can not estimate the effect in hectare.

approach (farmers choosing total “tangible” nutrients instead of only inorganic ones) on nutrients input changes with the biofuel crop development. Indeed, we have also established a small change in total nutrients use per hectare but with a rise of inorganic nutrients and a decrease of manure nutrients.

To summarise, the implementation of 10% biofuel target in 2020 with the NEMESIS model, has shown substitution effects between vegetal and animal production as well as between arable land and grassland. Various studies generally find similar results for land use but to a smaller extent due to biofuel 2nd-generation technology development which is not included in our study and due to probable substitution between vegetal products. But, other studies do not provide consensus on the animal production decrease. Studies with detailed agricultural production give a smaller animal production decrease than less detailed models because the first ones establish substitutions between animal products. Finally, biofuel development does not imply additional harmful environmental impacts due to nutrients uses, even if the demand for inorganic nutrients will probably increase to counterbalance the diminishing of manure nutrients.

5.5 Conclusion

This chapter has emphasised the usefulness of modelling exercises in policy assessments. Especially, despite the relative simplicity of its modelling, the use of the land use module established in chapter 2 in the frame of the *reference scenario*, presented in chapter 3, has allowed the assessment of diverse European environmental policies.

To add an interesting environmental indicator, we have made, in a first section, a database for nutrient use in the European Union quantifying nutrient (nitrogen and phosphorus) input intensity for 2008. We have also developed a modelling approach to project nutrient input for agricultural production and we have presented the results for the *reference scenario* up to 2025. Indeed, nutrients in agricultural production have become one major source of pollution of groundwater and eutrophication of fresh water and marine environments, from the increasing use of fertilisers and pesticides over the last decades. For marine coastal areas, losses of nutrients from fertilisers use, especially nitrogen and phosphorus are identified by scientists as one major sources of perturbation of marine ecosystems. It is consequently particularly important to look at this environmental indicator for the assessment European policies that can act on nutrient uses in Europe.

Thereafter, we have assessed two European biodiversity policies using the data of the Natura 2000 network. The first policy consists of increasing the European protected forest areas and excluding them from potential agricultural land. This assessment has led to two main conclusions. On one hand, we have established an opportunity cost of biodiversity conservation for EU forest of about 800 €₂₀₀₀/ha/year, identified as an upper bound. On the other hand, we have shown possible counterproductive effects of forests biodiversity conservation due to land intensification of agricultural production and thereby a rise of nutrient input intensity in agriculture. For the second biodiversity policy, we have raised the agricultural areas under Natura 2000 network with the help of either a national subsidy or a European one. The results show a small difference, at European level, between the two implementations. We have also found an upper bound for opportunity cost of biodiversity conservation in agricultural areas with 900 €₂₀₀₀/ha/year. And we have shown that even if our estimates of opportunity costs in forest and agricultural areas are relatively high compared to other studies, the economic viability of such biodiversity conservation policies are still relevant.

Finally, in last section, we have assessed the European 10% biofuel target in transports in 2020 with the help of PRIMES projections for the quantification of biofuels consumption in physical units by member states up to 2020 and with the NEMESIS model and its land use module. We have observed

farmer trade off between agricultural products in favour vegetal products and at the expense of animal products, results which do not have consensus in the relevant studies. On the contrary, the substitution between arable land grassland, found in this study, seems to be a common results in other studies. In addition, we do not find significant impact of biofuels crops development on nutrient input intensity even with a second modelling approach counterbalancing the fall of manure nutrients by an increase of inorganic ones. And finally, we have estimated the contribution of European agriculture to biofuel crops need of about two thirds, a few more than in other studies.

Thereby, we have established some interesting results for those European environmental policies with the NEMESIS model combined with the land use module and the nutrient modelling. It may also be interesting to implement other European policy assessments with this modelling framework such as a taxing of inorganic or tangible nutrients use in order to reduce their impact on the environment. However, comparing the results with other studies, it appears that additional refinements on the model could improve the results. For instance, it could be interesting for environmental policies involving the agricultural sector to detail agricultural products in NEMESIS and then improve the modelling of the agriculture sector. It could also be useful to quantify the greenhouse gas emissions from Land Use, Land Use Change and Forestry (LULUCF) even if would require additional land use categories and conversion matrices. Furthermore, it could be innovative to include “alternative” environmental indicators such those provided by the European Environmental Agency such as High Natural Value farms. All those developments and others could allow the improvement of policy assessment and could form a part of future research.

Chapter 6

General Conclusion

6.1 Main conclusions and discussions

Impact assessment, as we have expressed several times in this dissertation, is since only recently an obligatory for the European Commission for all new policy or changes in existing policy. Particularly, with the rise of environmental consciousness and the identification of numerous environmental risks, environmental impact assessment has taken a substantial role at European level. But, those environmental impact assessments should also be regarded through economic consequences considering the importance of economic impact for policy makers. In this context, the number of requests by the European Commission for *ex-ante* impact assessments has considerably progressed and the need of quantitative tools, that are well qualified for those assessments with their complexity or their function of clustering knowledge, have experienced an increasing interest from policy makers. Among all environmental problems, a large number are connected with land use and land use change such as Global Warming through biomass or carbon sink, water pollution or biodiversity.

The aim of this study was then to take into account, at least partially, those needs for economic and environmental assessments of European policies by integrating land use change in the large applied economic model NEMESIS. We also wanted to test this modelling of land use by applying it to several European policies assessments either in its original form or with more or less important modifications. We also always made a critical review of our results by confronting them with publications. By summarising the overall work of this dissertation, we can formulate the following main conclusions.

Firstly from a methodological point of view, we have started this study by establishing the situation of available land for agricultural production in European Union countries with the help of a harmonised land use database and the construction of the asymptote for total agricultural land which supposes the non reconversion of built-up areas, protected forest and unsuitable land into agricultural land but assuming the conversion possibility of all commercial forest into agricultural land. Thereby, with this methodology, we have estimated the available land for agriculture production about 1.3 million of square kilometres for European Union in 2000. At country level, the disparity of unused land is very large ranging from more than 80% of potential land available for agriculture in Sweden and Finland to less than 15% in Netherlands, Denmark, United Kingdom, Malta and Ireland. Nevertheless, the inclusion of the overall commercial forest as available land probably implies a large estimate of those areas. But lacking available information, this assumption seems the more credible and at least does not underestimate the available lands that would be more problematic for the impact assessments.

Thereafter, regarding advantages and disadvantages of several functional forms generally used in

the applied economic model for the modelling of the land supply, the advantages of the “L-inverse” land supply has been demonstrated. Notably, land price elasticity with respect to land supply with the “L-inverse” function is increasing with land scarcity. Moreover, the parametrisation of the “L-inverse” function has been identified as more simple when the data are scarce inasmuch as one parameter can be calibrated and the second estimated. Furthermore, with the estimates of the “L-inverse” land supply curve, we have determined land supply elasticity with respect to land price. For the year 2000, those elasticities vary from 4.6% in Finland to 0.1% in Malta or United Kingdom *i.e.* a agricultural land supply strongly elastic with respect to price in Finland and weakly elastic in United Kingdom and Malta. The agricultural land supply elasticity with respect to land price was also estimated of about 1.1% in Germany, 1.4% in France and 0.36% in Spain. By aggregating national results, the European land supply elasticity with respect to land price is about 0.5% in 2000.

The implementation of the agricultural land supply and demand in the NEMESIS model for the so-called *reference scenario* (a scenario mainly based on extrapolation approach but also using experts knowledge as for agriculture production projections), has allowed the projection of land use change up to 2025. In the *reference scenario*, we expect a decline of agricultural land, reaching a land abandonment of about 29 000 km² in the European Union characterised by a strong decline of grassland of about 42 000 km² and a slight raise of arable land about 13 000 km². In addition, urban land use is strongly increasing with more than 16 000 additional square kilometres (*i.e.* +10%) in the *reference scenario* compared to 2005. Those results on urban sprawling in European Union from 2005 to 2025, were achieved with the help of the modelling of commercial and industrial buildings and housing land use that transforms the stock of buildings in each countries (expressed in constant monetary unit) in square kilometres of land occupied by both kinds of buildings. The stock of industrial and commercial buildings results from the investments addressed from firms to the construction sector and the stock of housing stems from households gross fixed capital formation that has been modelled with an error correction model and has been estimated using panel data. Thereby, with the economic development expected in the *reference scenario*, firms invest in buildings for the development of their activities whereas household invests in housing which leads to urban sprawling of about +16 000 square kilometres between 2005 and 2025 in the European Union. Urban expansion is a common results in the studies on land use change, except in rupture scenarios, and the extent of urban sprawling in the *reference scenario* is in the range of other publications. However, despite the fact that the majority of studies also expects agricultural land abandonment in European Union in the following decades and also pro-

jects a strong decline of grassland, the trend agricultural yields for arable land in our scenarios have been identified as lower than those expected in other studies. We reach the projected agricultural yields for arable land only by raising R&D investments, but without additional innovation, the trend productivity is not enough.

The first policy assessment released in this dissertation regards a set of Common Agricultural Policy reforms. From a methodological point of view, this assessment is achieved with the help of linked models centred on sustainable impact assessment. In addition to a complex exchange of variables between the four models used for this assessment, the major methodological innovation of this study comes from the link implemented between the detailed agricultural model CAPRI and the NEMESIS model. A procedure to reach a joint equilibrium on agricultural land use in both models, following an external shock, has been implemented. By an iterative process of calibration, this procedure allows NEMESIS to model and to take advantage of the detailed agriculture sector of CAPRI model, by modifying its agricultural demand. Whereas the CAPRI model in which the total agricultural land is fixed takes advantage of NEMESIS “L-inverse” land supply to introduce a flexibility in its land supply.

In terms of results, the use of the linked models for a set of Common Agricultural Policy reform displays a small impact on agricultural production for the removal of direct supports to farmers that is a common result in other studies. Furthermore, as identified in the publications, direct supports to farmers are capitalised in land prices. Thereby, their suppression decreases the real agricultural land price by about 21% if direct supports are fully capitalised and 7% without capitalisation. For the abolition of market supports, the impact on European agriculture is stronger especially for some agricultural products which are still highly protected such as sugar beet (14.5%), beef and veal meat and sheep and goats meat (-9%). The impact of the market supports abolition is also relatively heterogeneous among European countries according to the weight of the most penalised agricultural products on their total agricultural production but also according to quota rents for the dairy market.

The analysis of re-allocation of released funds, for a complete liberalisation of European agriculture, between either *Tax rebate* to households or subsidies to *R&D investments*, shows significant positive impact on European economy with the former options. While the impact of the *Tax rebate* scenario is relatively moderating on European GDP (+0.5%) and employment (-300 000 jobs) but with -1.4 million jobs in agriculture. When released funds of Common Agricultural Policy (*i.e.* €46 billion) are used to subsidise R&D investments in Europe, GDP gains are expected to be much more higher (+2.5%) as well as impact on total employment (+1.8 million jobs). Even if we have shown that the

R&D multiplier is sometimes higher than in other studies due to, for instance, the absence of human capital constraint, the re-allocation of Common Agricultural Policies budget, toward Lisbon Strategy objectives or more precisely the new Europe 2020 strategy, allows a better economic performance and does not seem to impact too strongly on European agriculture production. Nevertheless, the European agriculture is few impacted thanks to the rise of agricultural labour productivity (around +14%) indeed the employment losses in agriculture are very large (-1.4 million jobs) especially in Poland and Romania representing almost half of the agricultural employment losses. Thereby, there is a re-allocation of jobs from agriculture towards the rest of the economy and especially when Common Agricultural Policy funds are re-allocated to R&D activities. In addition, as expressed in alternative studies, the volatility of agricultural prices and the specificity of the agriculture sector could worsen the impact on the agriculture sector. Furthermore, even if the aggregate agricultural production is not too penalised by a liberalisation of European agriculture, some agricultural products could be much more impacted. Finally, the other economic and social functions of agriculture such as rural development and environment regulation could be affected notably with for instance agricultural employment losses, land abandonment or fire risk. Consequently, European funds re-allocation from agriculture to the knowledge economy have important economic benefits in terms of economic growth and employment but a minimum of public intervention in agriculture sector should be achieved as well as some transfers from 1st Pillar (economic support) to 2nd Pillar (other functions of agriculture) to ensure a perennial and qualitative European agriculture.

The second application of the land use module was achieved for European environmental policies assessment. But firstly, we have calculated the nutrients use in agriculture for the year 2008 and with the help of a modelling of each nutrients source for nitrogen and phosphorus, we have projected them up to 2025 for the *reference scenario*. The calculation of nutrients input in agriculture in 2008 have shown a use of 22 millions tonnes of nitrogen and 3.1 million tonnes of phosphorus that represent 118 kg/ha and 17 kg/ha respectively. The main source of nutrients input is inorganic with 11 million tonnes for nitrogen and 2 million tonnes for phosphorus followed by manure with respectively 7.8 and 1 million tonnes. The results have also established huge difference among Members States with for extreme cases, 350 kg/ha in Netherlands and 58 kg/ha in Estonia. With the modelling of nutrients and its application to the reference scenario, we expect a slightly rise of nutrients about +0.2 millions tonnes in European Union with for instance an important increase of nutrients input in Spain with +0.3 million tonnes of nitrogen *i.e.* +12 kg/ha. On the contrary, countries like the Netherlands decrease

their use of nitrogen by -13 kg/ha between 2008 and 2025 but stay the most intensive users of nutrients in European Union.

Thereafter, the biodiversity conservation policies implemented either in forest or agricultural areas have shown an average European biodiversity conservation cost of about 800€₂₀₀₀/ha/year for forest and 900€₂₀₀₀/ha/year for agriculture. Those values were evaluated as upper bound for biodiversity conservation cost even if they do not include administration costs and management costs for the later one. The high level of protection imposed in the assessment, the full conversion on “Protected Forest” of all new protected forests and the modelling of our land supply implying an equivalent reduction of available land for agriculture, have reinforced the cost of biodiversity conservation in forest areas. The strong fall of agricultural intensification in new protected agricultural areas, four times lower than in the *reference scenario*, explains our high estimate of biodiversity conservation cost in agriculture. Furthermore, the biodiversity conservation policy in forest area with a reduction of potential available land for agriculture could lead to counterproductive effects in agriculture by increasing agricultural intensification and nutrient use.

Finally, the last application of the land use module for the assessment of the biofuel target of 10% in total gasoline in 2020 have displayed a strong substitution between vegetal production and animal production, benefiting from biofuel crops rise. This substitution also appears for agricultural land use with a large rise of arable land about 41 000 km² and a decrease about 6 000 km² of grassland leading to an increase of agricultural land about 35 000 km². Those results are generally expected in other studies but the extent of the agricultural land use change is generally lower. This difference, among other elements, emphasises some limits of the assessment and especially the lack of detailed agricultural products in the NEMESIS model, reducing the potential substitution among agricultural products that would attenuate the extent of agricultural land use change.

6.2 Future researches

The work achieved and the limits identified in this thesis open several worthwhile extensions. Firstly, we could assess other European policies such as policy on nutrient restriction through a tax on nutrients use or subvention to farmers. Furthermore, with additional time and resource, it could be interesting to support and improve the linked models developed in chapter 4 which could be used for diverse assessments of European policy such as those presented chapter 5 that could bring out

numerous impact whether economics or environmental.

Furthermore, as we have seen, it will be very useful for numerous policy assessments to extent the number of agricultural products in the NEMESIS model, even if we did it partially with the link with the CAPRI model. Indeed, agricultural products are not impacted in the same manner, for instance each crop production does not require the same quantity of land or does not use the same quantity of nutrients which could change the aggregated results on agricultural land use change. Thereby, an improvement of the NEMESIS agriculture sector going into more detail on agricultural products could significantly improve some policy assessments but it also requires substantial additional details that are not always easily available such as data on input per agricultural product. Consequently, it would require important work on data collection and surveys.

In addition, an impact assessment of European policies in the Rest of the World, could be very interesting. Especially, the assessment of European policies impacting agriculture in Africa or in low income countries could be useful for policy makers. In order to do this, assessment tools such as NEMESIS should include a modelling of those regions and more generally worldwide coverage which will be done in the next months with the help of the WIOD¹ European project constructing economic and environmental World databases. Furthermore, the assessment of European policies such as Common Agricultural Policy reform could be coupled with other objectives such as biodiversity targets or objectives on renewable energy from agriculture or forestry in order to establish the best policy mix according to some key criteria or indicators regarding, for instance, economic performance, rural development, nutrients uses, agricultural land use intensity, net greenhouse gas emissions, etc.

The arrival, on October first 2010, of a new detailed database on European land use in Eurostat called “Land cover and land use, soil, landscape” (LUCAS) will allow an updating and a harmonisation of national land use data but also at NUTS2 level. Indeed, this new database is complete for the year 2009 and for twenty three of the EU-27 countries at NUTS2 level and it distinguishes six main land use categories and thirteen land use sub-categories at least at national level. This database opens new perspective for impact assessments insomuch as it refers to six categories of land use with heavy environmental impact. Nevertheless, there is still no time series and there is no price.

1. World Input-Output Database (WIOD) is a project funded by the European Commission, Research Directorate General as part of the 7th Framework Programme, Theme 8: Socio-Economic Sciences and Humanities - Grant Agreement no: 225 281. www.wiod.org

“Of course it must be understood that it is a model. We ask a question to a model and the model plays back another question. This is a question we did not think of before, but it is extremely helpful in the discussion process. And this, in effect, draws us closer to the answer of the original question.” Paul Zagamé.

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Chapter 7

Appendix

7.1 Appendix A: Nomenclatures and Abbreviations

7.1.1 Nomenclatures

Table 7.1.1: European countries nomenclature

AT	Austria	IT	Italy
BE	Belgium	LT	Lithuania
BG	Bulgaria	LU	Luxembourg
CY	Cyprus	LV	Latvia
CZ	Czech Republic	MT	Malta
DE	Germany	NL	Netherlands
DK	Denmark	PL	Poland
EE	Estonia	PT	Portugal
ES	Spain	RO	Roumania
FI	Finland	SE	Sweden
FR	France	SI	Slovenia
GR	Greece	SK	Slovakia
HU	Hungary	UK	United-Kingdom
IE	Ireland	NO	Norway

Table 7.1.2: NEMESIS sectoral nomenclature

01	Agriculture	16	Food, Drink & Tobacco
02	Coal and Coke	17	Tex., Cloth & Footw.
03	Oil & Gas Extraction	18	Paper & Printing Products
04	Gas Distribution	19	Rubber & Plastic
05	Refined Oil	20	Other Manufactures
06	Electricity	21	Construction
07	Water Supply	22	Distribution
08	Ferr. & non Ferrous Metals	23	Lodging & Catering
09	Non Metallic Min. Products	24	Inland Transports
10	Chemicals	25	Sea & Air Transport
11	Metal Products	26	Other Transports
12	Agr. & Indus. Machines	27	Communication
13	Office Machines	28	Bank, Finance & Insurance
14	Electrical Goods	29	Other Market Services
15	Transport Equipment	30	Non Market Services

7.1.2 Abbreviations

- AEZ: Agro-Ecological Zone (Lee *et al.* 2009 [330])
- CAP: Common Agricultural Policy
- CAPRI model: Common Agricultural Policy Regionalised Impact Modelling System (Britz and Witzke 2008 [57])
- CES: Constant Elasticity of Substitution (Arrow *et al.* 1961 [18])
- CET: Constant Elasticity of Transformation (Powell and Gruen 1968 [395], Shumway and Powell 1984 [427])
- CGEM: Computable General Equilibrium Model
- CLC2000: Corine Land Cover 2000
- CO₂: Carbon dioxide
- DDG: Dried distillers grains
- DSGE: Dynamic Stochastic General Equilibrium Model
- E³MLAB: Energy - Economics - Environment Modelling Laboratory, Research and Policy Analysis (www.e3mlab.ntua.gr)
- EAFRD: European Agricultural Fund for Rural Development

- EAGF: European Agricultural Guarantee Fund
- EAGGF: European Agricultural Guidance and Guarantee Fund
- EAP: Environmental Action Programme
- EC: European Commission (www.ec.europa.eu)
- EEA: European Environmental Agency (www.eea.europa.eu)
- EFISCEN model: European Forest Information SCENnario Model (Schelhaas *et al.* 2007 [416])
- EP: European Parliament (www.europarl.europa.eu)
- ERDF: European Rural Development Fund
- EU: European Union
- EU-15: European Union including: Belgium, Denmark, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden and United Kingdom
- EU-25: European Union including: Belgium, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Slovenia, Slovakia, Finland, Sweden and United Kingdom
- EU-27: European Union including: Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden and United Kingdom
- EUBIA: EUropean Biomass Industry Association (www.eubia.org)
- FTP: File Transfer Protocol
- FAO: Food and Agriculture Organization of the United Nations (www.fao.org)
- I&C: Industrial and Commercial
- IEA: International Energy Agency (www.iea.org)
- IIASA: International Institute for Applied Systems Analysis (www.iiasa.ac.at)
- IMF: International Monetary Fund (www.imf.org)
- IPCC: Intergovernmental Panel on Climate Change (www.ipcc.ch)
- IPS: Im, Pesaran and Shim (2003 [285])
- IWMI: International Water Management Institute (www.iwmi.cgiar.org)
- GDP: Gross Domestic Product
- Gg: Giga gram

- GIS: Geographical Information System
- GJ: Giga Joule
- GTAP: Global Trade Analysis Project (www.gtap.agecon.purdue.edu)
- HNV: High Nature Value
- LULUCF: Land Use, Land Use Change and Forestry
- MNF: Most Favoured Nation
- MS: Member States
- MW: Maddala and Wu (1999 [344])
- NEMESIS: New Econometric Model of Evaluation by Sectoral Interdependency and Supply (Zagamé *et al.* 2010 [476] - www.erasme-team.eu)
- NMS: New Member States (including: Bulgaria, Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Romania, Slovenia and Slovakia. For NEMESIS results the NMS refer to the same countries except Bulgaria and Cyprus).
- NTUA: National Technical University of Athens (www.ntua.gr)
- NUTS: Nomenclature d'Unités Territoriales Statistiques (see: http://ec.europa.eu/eurostat/ramon/nuts/introduction_regions_en.html)
- MEA: Millennium Ecosystem Assessment (www.maweb.org)
- OADR: Old Age Dependency Ratio (ratio between persons aged 65 years and over compared with persons 15-64 years old)
- OECD: Organization for Economic Co-operation and Development (www.oecd.org)
- PLUREL: Peri-urban Land Use RELationships (www.plurel.net)
- PRELUDE: PRospective Environmental analysis of Land Use Development in Europe (scenarios.www.eea.europa.eu/reports/fo1077184 - EEA 2007 [157])
- R&D: Research and Development
- RTD: Research and Technological Development
- SAPS: Single Area Payment Scheme
- SENSOR: Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions (www.sensor-ip.eu)
- SPS: Single Payment Scheme
- SRES: Special Report on Emissions Scenarios (IPCC SRES 2001 [289])
- TEEB: The Economics of Ecosystems and Biodiversity (www.teebweb.org)

- toe: tonne of oil equivalent
- UAA: Utilised Agricultural Areas
- UN: United Nations (www.un.org)
- UNEP: United Nation Environment Programme (www.unep.org)
- WTO: World Trade Organization (www.wto.org)
- w.r.t.: with respect to

7.2 Appendix B: Presentation of the NEMESIS model

7.2.1 Introduction to NEMESIS

The NEMESIS model (New Econometric Model of Evaluation by Sectoral Interdependency and Supply)¹, has been partially funded under the fifth and sixth RTD Framework Programs of European Commission General Directorate of Research². It is a system of economic models for every European country (EU27 less Bulgaria and Cyprus, plus Norway), devoted to study issues that link economic development, competitiveness, employment and public accounts to economic policies, and notably all structural policies involving long term effects: RTD, environment and energy regulation, general fiscal reform, etc. The essential purpose of the model is to provide a framework for making forecasts, or “Business As Usual” (BAU) scenarios, up to 25 to 30 years, and to assess for the implementation of all extra policies not already involved in the BAU. NEMESIS uses as main data source EUROSTAT, and specific databases for external trade (OECD, CHELEM, New CRONOS), technology (OECD and EPO) and land use (CORINE 2000). NEMESIS is recursive dynamic, with annual steps, and includes more than 160.000 equations. The main mechanisms of the model are based on the behaviour of representative agents: Enterprises, Households, Government and rest of the world. These mechanisms are based on econometrics works. The main originality of the model, when compared to others used for similar policies, lies in the belief that the medium and long term of macroeconomics path is the result of strong interdependencies between sectoral activities that are very heterogeneous from a dynamic point of view, with leading activities grounded on Research and Development, and from environment and sustainable development. These interdependencies are exchanges of goods and services on markets but also of external effects, as positive technological spillovers. Another originality of NEMESIS is that it is a “Framework model” with different possibilities on the several mechanisms involved in the functioning (see figure 7.2.1 for basic functioning of the model and figure 7.2.2 for the different available modules). Although econometrics, the model cannot be classified as a neo-keynesian model, in the new version that built-in the new theories of growth; it escapes also to the classification of general equilibrium model, as it incorporates original mechanisms that do not refer to the strict orthodoxy of

1. This presentation of the NEMESIS model is based on Zagamé *et al.* (2010 [476]) but the NEMESIS model version used for this dissertation differs from the one presented in Zagamé *et al.* (2010). Thereby, the present NEMESIS presentation is slightly different from Zagamé *et al.* (2010) even if a complete rewriting could not be done. It must be noted that Zagamé *et al.* (2010) is a draft paper.

2. The core teams of the NEMESIS model are: ERASME (France - www.erasme-team.eu) as coordinator, CCIP (France - www.ccip.fr), Federal Planning Bureau (Belgium - www.plan.be) and National Technical University of Athens (Greece - www.ntua.gr).

the mainstream neo-classical approach, on which was based the general equilibrium approach.

We now present the main mechanisms, outputs and uses of NEMESIS.

7.2.2 Main NEMESIS' mechanisms

On the supply side, NEMESIS distinguishes 32 production sectors, including Agriculture, Forestry, Fisheries, Transportation (4), Energy (6), Intermediate Goods (5) Capital goods (5), Final Consumption Goods (3), Private (5) and Public Services. Each sector is modelled with a representative firm that takes its production decisions given its addressed demand and input prices. Firms behaviour includes very innovative features grounded on new growth theories, principally endogenous R&D decisions that allow firms improving their process productivity and product quality. Production in sectors is in this way represented with CES production functions (with the exception of Agriculture which uses a transcendental logarithmic functions, and Forestry and Fisheries where technology is represented with Leontief functions) with 5 production factors : capital, unskilled labour, skilled labour³, energy and intermediate consumption, where endogenous innovations of firms can modify the efficiency of the different inputs and the quality of output. The production function was estimated by the dual approach and estimates and calibration of links between R&D expenditures, innovations and economic performance were picked up from the abundant literature on the subject. Interdependencies between sectors and countries are finally caught up by a collection of convert matrices describing the exchanges of intermediary goods, of capital goods and of knowledge in terms of technological spillovers, and the description of substitutions between consumption goods by a very detailed consumption module enhance these interdependencies.

On the demand side, representative households' aggregate consumption is dependent on current income. Total earnings are a function of regional disposable income, a measure of wealth for the households, interest rates and inflation. Variables covering child and old-age dependency rates are also included in an attempt to capture any change in consumption patterns caused by an ageing population. The unemployment is used, in the short-term equation (only), as a proxy for the degree of uncertainty in the economy. Consistent with the other behavioural equations, the disaggregated consumption module is based on the assumption that there exists a long-run equilibrium but rigidities are present which prevent immediate adjustment to that long-term solution. Altogether, the total households aggregated

3. The distinction between unskilled and skilled labours was not included in the NEMESIS model version used in this dissertation.

Figure 7.2.1: Basic functioning of the model

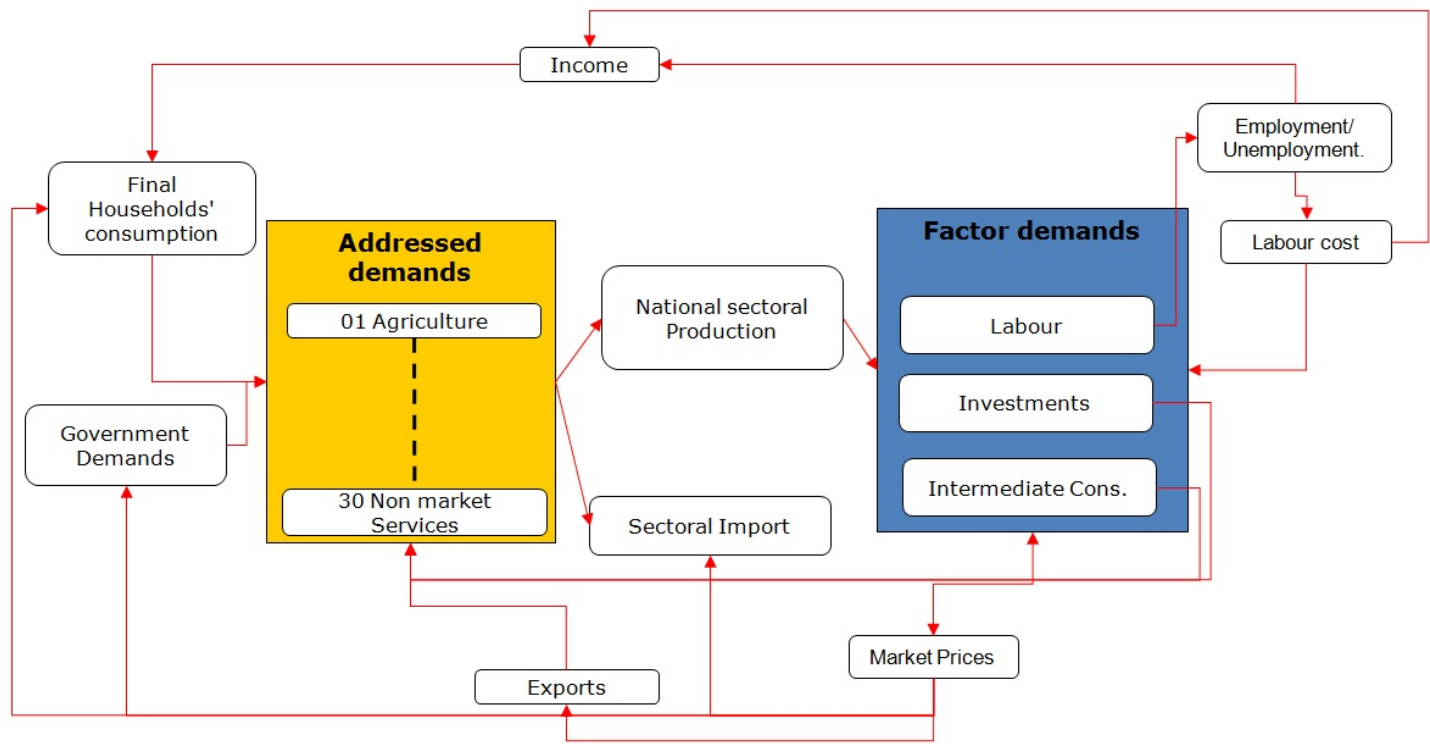
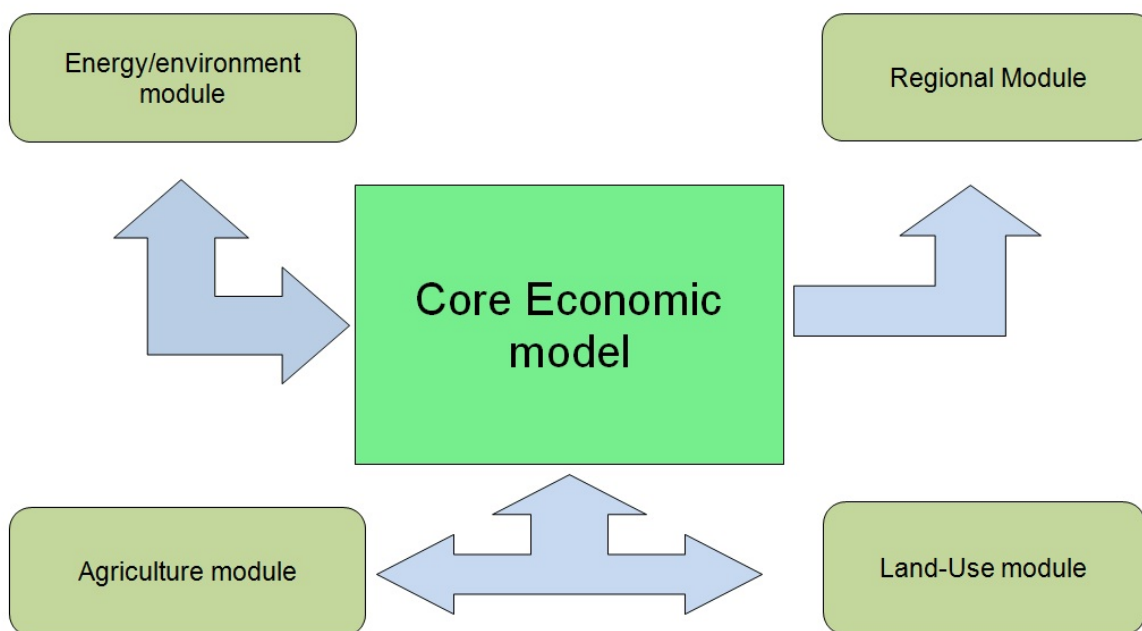


Figure 7.2.2: NEMESIS modularity



consumption is indirectly affected by 27 different consumption sub-functions through their impact on relative prices and total income, to which demographic changes are added. Government public final consumption and its repartition between Education, Health, Defence and Other Expenditures, are also influenced by demographic changes.

For external trade, it is treated in NEMESIS as if it takes place through two channels: intra-EU, and trade with the Rest of the World (extra-EU). Data availability was an important factor in this choice – it allowed an emphasis to be put on intra-EU trade flows, which are a large portion of the total trade in the EU. The intra-EU and extra-EU export equations can be separated into two components, income and prices. The income effect is captured by a variable representing economic activity in the rest of the EU for intra-EU trade, and a variable representing economic activity in the rest of the world for extra-EU trade. Prices are split into two sources of impacts in each of the two equations (intra-EU and extra-EU trade). For intra-EU trade, they are the price of exports for the exporting country and the price of exports in other EU countries. For extra-EU trade, prices impacts come through the price of exports for the exporting country, and a Rest of the World price variable. The stock of innovations in a country (which, in NEMESIS, is taken relative to the total innovation stock in Europe in a particular sector) is also included in the export equations in order to capture the role of innovations in trade

performance and structural competitiveness. For imports, equations are identical for both Indra-EU and extra-EU trade. The income effect is captured through domestic sales by domestic producers. The stock of innovations is again included to account for the effects of innovations on trade performance.

The wage equations, which determine in NEMESIS the dynamics of prices and incomes, are based on a theory of wage-setting decisions made by utility maximising unions. The unions calculate utility from higher levels of employment and from higher real wages (relative to wages outside the sector) in the sector, subject to the labour demand constraint imposed by firms' profit maximisation. The implication of this form of wage equation is that conditions, such as productivity shocks, changes in unemployment rate, or changes in real wage outside the sector, are important for determining wage and real wages in a given sector.

7.2.3 Main NEMESIS' inputs and outputs

With its original characteristics and great detail level results, NEMESIS can be used for many purposes such as short and medium term economic and industrial "forecasts" for business, government and local authorities; analysing Business As Usual (BAU) scenarios and economy long term structural change, energy supply and demand, environment and more generally sustainable development; revealing the long term challenges of Europe and identifying issues of central importance for all European, national, regional scale structural policies; assessing for most of Lisbon agenda related policies and especially knowledge (RTD and human capital) policies; emphasising the RTD aspect of structural policies that allows new assessments (founded on endogenous technical change) for policies, and new policy design based on knowledge: education, skill and human capital and RTD.

NEMESIS has notably been used to study BAU scenarios for European Union and reveal the implication for European growth, competitiveness and sustainable development of the Barcelona 3% GDP RTD objective, of the 7th Research Framework Program of European Commission, National RTD action plans of European countries, European policies on greenhouses gases emissions reduction, increasing oil price, European action plan for renewable energies, etc. NEMESIS is currently used to assess for European action plan for environmental and energy technologies, European financial perspective and Lisbon agenda, with in deep development on the modelling of RTD, human capital and labour market and European regions.

7.2.4 Production

The production in NEMESIS is defined at thirty sectors level with the help of five factors of production: intermediate consumptions (excluding energy), high skill labour, low skill labour, stock of capital and energy consumption. Sectoral production functions are represented by a four level nested Constant Elasticity of Substitution (CES) function (Arrow *et al.* 1961 [18]). The CES framework is the same for each sector *i.e.* same factor bundle, but with sectoral parameters (elasticity of substitution, scale parameter, etc).

7.2.4.1 Nested CES function in NEMESIS

Framework

The NEMESIS model considers five factors (if we except intermediate energy demand which is considered as a fixed part of the production) K, L_u, L_s, E and M represents respectively Capital, low skill labour, high skill labour, intermediate consumptions (excluding energy) and energy. The production function is a nested four-level CES function (see figure 7.5.3). At a first level, we consider a bundle between Capital, Energy and Labours (noted $KE L_s L_u$) on one hand and materials demands (M) on another hand. The second level the $KE L_s L_u$ bundle is split between “Capital-Energy-High skill” bundle ($KE L_s$) and Low skill (L_u). Thereafter, “Capital-Energy-High skill” is split between “Capital-Energy” (KE) on one side and High skill (L_s) in another side. Finally the last level distinguish Capital from Energy.

Thereby, production in the NEMESIS NEMESIS is defined by the following equations:

$$Y_t = A \cdot \left[\delta_1 \cdot (KE L_s L_u)_t^{-1/\lambda_1} + (1 - \delta_1) \cdot M_t^{-1/\lambda_1} \right]^{-\lambda_1} \quad (7.2.1)$$

$$(KE L_s L_u)_t = \left[\delta_2 \cdot (KE L_s)_t^{-1/\lambda_2} + (1 - \delta_2) (L_u)_t^{-1/\lambda_2} \right]^{-\lambda_2} \quad (7.2.2)$$

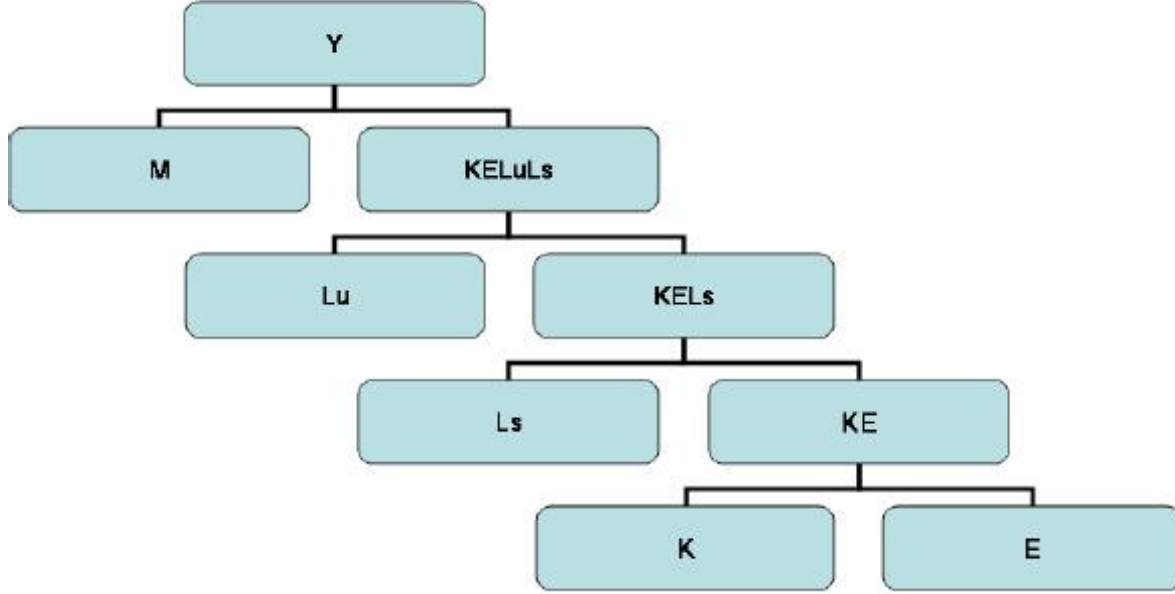
$$(KE L_s)_t = \left[\delta_3 (KE)_t^{-1/\lambda_3} + (1 - \delta_3) \cdot (L_s)_t^{-1/\lambda_3} \right]^{-\lambda_3} \quad (7.2.3)$$

$$(KE)_t = \left[\delta_4 K_t^{-1/\lambda_4} + (1 - \delta_4) \cdot E_t^{-1/\lambda_4} \right]^{-\lambda_4} \quad (7.2.4)$$

Where, Y_t is the sectoral output at time t , δ are a distribution parameter (with $0 < \delta < 1$), λ are

substitution parameters and A is the Hicks neutral technological (see section 7.2.9) ⁴.

Figure 7.2.3: Nested Constant Elasticity of Substitution structure in NEMESIS



The elasticity of substitution (σ) is defined as $\sigma = \lambda/(1+\lambda)$ (with $0 < \sigma < 1$). With this framework, we distinguish four different elasticity of substitution between each level *i.e.* σ_4 between K and E , σ_3 between KE and L_s , σ_2 between KEL_s and L_u and σ_1 between KEL_uL_s and M . A small value for this elasticity means that input are gross complements, on the contrary, a high value means that input are gross substitute. Elasticity between two factors of different bundle is given by the Morishima partial elasticity of substitution (Morishima 1967 [358]).

$$MES_{K,M} = \frac{P_K \cdot C_{KM}}{C_M} - \frac{P_K \cdot C_{KK}}{C_K} \quad (7.2.5)$$

7.2.4.2 Factor Demand

The input demand functions are derivated from the traditional program of cost minimisation under technology constraint as follows:

$$\text{Min } P_{KEL_sL_u} \cdot KEL_sL_u + P_M \cdot M$$

4. Please refer to Brécart *et al.* (2006 [54]) and Chevallier *et al.* (2006 [87]) for a description of technological change in the NEMESIS model or see boxes 4.3.4.2 and 4.3.4.2 in section 4.3.

$$\text{Min } P_{KEL_s} \cdot KEL_s + P_{L_u} \cdot L_u$$

$$\text{Min } P_{KE} \cdot KE + P_{L_s} \cdot L_s$$

$$\text{Min } P_K \cdot K + P_E \cdot E$$

Where P_j is the input price, with $j = K, E, L_s, L_u, M$, P_h is the composite input price, with $h = KE, KEL_s, KEL_s L_u$. Solving the minimisation program leads to the following input demand:

$$K = \frac{Y}{A} \left[\frac{P_Y \cdot \delta_1}{P_{KEL_s L_u}} \right]^{\sigma_1} \cdot \left[\frac{P_{KEL_s L_u} \cdot \delta_2}{P_{KEL_s}} \right]^{\sigma_2} \left[\frac{P_{KEL_s} \cdot \delta_3}{P_{KE}} \right]^{\sigma_3} \cdot \left[\frac{P_{KE} \cdot \delta_4}{P_K} \right]^{\sigma_4} \quad (7.2.6)$$

$$E = \frac{Y}{A} \left[\frac{P_Y \cdot \delta_1}{P_{KEL_s L_u}} \right]^{\sigma_1} \cdot \left[\frac{P_{KEL_s L_u} \cdot \delta_2}{P_{KEL_s}} \right]^{\sigma_2} \left[\frac{P_{KEL_s} \cdot \delta_3}{P_{KE}} \right]^{\sigma_3} \cdot \left[\frac{P_{KE} \cdot (1 - \delta_4)}{P_E} \right]^{\sigma_4} \quad (7.2.7)$$

$$L_s = \frac{Y}{A} \left[\frac{P_Y \cdot \delta_1}{P_{KEL_s L_u}} \right]^{\sigma_1} \cdot \left[\frac{P_{KEL_s L_u} \cdot \delta_2}{P_{KEL_s}} \right]^{\sigma_2} \cdot \left[\frac{P_{KEL_s} \cdot (1 - \delta_3)}{P_{L_s}} \right]^{\sigma_3} \quad (7.2.8)$$

$$L_u = \frac{Y}{A} \left[\frac{P_Y \cdot \delta_1}{P_{KEL_s L_u}} \right]^{\sigma_1} \cdot \left[\frac{P_{KEL_s L_u} \cdot (1 - \delta_2)}{P_{L_u}} \right]^{\sigma_2} \quad (7.2.9)$$

$$M = \frac{Y}{A} \left[\frac{P_Y \cdot (1 - \delta_1)}{P_M} \right]^{\sigma_1} \quad (7.2.10)$$

Demands functions are classical. They depend positively of production goal Y , negatively of relative input price even more if elasticity of substitution is important.

7.2.4.3 Estimation

Estimation method

We estimate input demand equation with the Full Information Maximum likelihood (FIML) method. FIML is the asymptotically efficient estimator for linear and nonlinear simultaneous models, under the assumption that the disturbances are multivariate normal. When this assumption fails, FIML may still be asymptotically efficient (see White 1982 [470] and Gouriéroux *et al.* 1984 [247]). NEMESIS

database includes input prices P_M , P_L , P_K and P_E and input in volume: M , L , K and E . Labour did not previously distinguish between skills in order to split the labour between both skills we use EU KLEMS database (2009 [193]) using only two skill levels: skilled including high skill and unskilled including low and medium skill labours Furthermore, we calibrate the distribution parameters with the help of the input cost share in total production cost such as: $(1 - \delta_1) = \frac{P_M M}{P_M M + P_{KEL_s L_u} \cdot K E L_s L_u}$. To avoid endogeneity problem we use lag value $[-1]$ for input and price in the calibration. In order to estimate the technical parameter A , we use an exogenous form that takes a determinist linear trend, *i.e.* $A = A_0 e^{a \cdot t}$ where A_0 is a scale parameter which will be calibrated and a is the technological change growth rate.

Estimated model

Because input does not adjust immediately to their long term optimal level, we need to take into account a adjustment delay. Consequently, we transform input demands as follow:

$$\log(M_{i,t}) = \rho_{i,M} \cdot \left[\log(Y_{i,t}) - \log(\sum_c d_c A_{0,i,c}) - (a_i \cdot t) + \sigma_{1,i} \log \left(\frac{P_{Y,t,i} \cdot (1 - \delta_{1,i,t})}{P_{M,t,i}} \right) \right] + (1 - \rho_{i,M}) \cdot \log(M_{i,t-1})$$

Where $i = 1, \dots, 30$ is the sectoral index, $c = 1, \dots, 15$ the country index, ρ represents time adjustment and $\frac{1-\rho}{\rho}$ the time for 50% of adjustment realised. We use pooled panel data, assuming that substitution elasticities are common for all countries but different between sectors. Furthermore, we also included fixed effects by countries in order to measure country specificities.

Result

Table 7.2.1 reports the four estimates of substitution elasticities.⁵ All sectoral elasticities range from 0 to 1, this implies that factors and bundle factor at same level are gross complements (for a elasticity higher than 1, we talk about gross substitutes). Results differs between sectors but some trends are well identified. Indeed, first and fourth levels present lower elasticities than middle one *i.e.* both labours (skilled and unskilled) are more easier substitute than other inputs.

5. For some sectors, a convergence was reached only with some constrains on parameters. Parameters constrained take the value n.a for their p-value

Table 7.2.1: Estimates of substitution elasticities

Sector	SIG1		SIG2		SIG3		SIG4	
1	0.692455	[.000]	0.793899	[.000]	0.84252	[.000]	0.813126	[.000]
2	0.050069	[.513]	0.434565	[.000]	0.434551	[.000]	0.072775	[.429]
3	0.308964	[.000]	0.584819	[.000]	0.64407	[.000]	0.256518	[.070]
4	0.060211	[.001]	0.05	n.a	0.05	n.a	0.077311	[.115]
5	0.074106	[.029]	0.627363	[.000]	0.626998	[.000]	0.170111	[.025]
6	0.05	n.a	0.177385	[.000]	0.149378	[.000]	0.104694	[.043]
7	0.384673	[.000]	0.509548	[.000]	0.545406	[.000]	0.114117	[.431]
8	0.682193	[.000]	0.639294	[.000]	0.644741	[.000]	0.760485	[.000]
9	0.05	n.a	0.169432	[.191]	0.216708	[.057]	0.317051	[.000]
10	0.925683	[.000]	0.915284	[.000]	0.923443	[.000]	0.861707	[.000]
11	0.54085	[.000]	0.466572	[.000]	0.499406	[.000]	0.609094	[.000]
12	0.337751	[.000]	0.447455	[.000]	0.47238	[.000]	0.152205	[.165]
13	0.276548	[.008]	0.501215	[.000]	0.557258	[.000]	0.180407	[.261]
14	0.536791	[.000]	0.556943	[.000]	0.595794	[.000]	0.62227	[.000]
15	0.477587	[.000]	0.672752	[.000]	0.683737	[.000]	0.05	n.a
16	0.862152	[.000]	0.687902	[.000]	0.722905	[.000]	0.05	n.a
17	0.252355	[.044]	0.30554	[.016]	0.307552	[.012]	0.182452	[.262]
18	0.24865	[.007]	0.507384	[.000]	0.516847	[.000]	0.156699	[.268]
19	0.489485	[.000]	0.653612	[.000]	0.707617	[.000]	0.093419	[.593]
20	0.390049	[.000]	0.446227	[.000]	0.43863	[.000]	0.474684	[.000]
21	0.175964	[.000]	0.457277	[.000]	0.493408	[.000]	0.325784	[.000]
22	0.587854	[.000]	0.716392	[.000]	0.76145	[.000]	0.574633	[.000]
23	0.325756	[.000]	0.478265	[.000]	0.413883	[.000]	0.05	n.a
24	0.149046	[.203]	0.514028	[.000]	0.605445	[.000]	0.05	n.a
25	0.383857	[.000]	0.585168	[.000]	0.641768	[.000]	0.05	n.a
26	0.747517	[.000]	0.769426	[.000]	0.778898	[.000]	0.867615	[.000]
27	0.257889	[.000]	0.187498	[.021]	0.240256	[.000]	0.145398	[.004]
28	0.28261	[.001]	0.269396	[.000]	0.271585	[.000]	0.05	n.a
29	0.332583	[.000]	0.316949	[.000]	0.319932	[.000]	0.289396	[.000]
Moyenne	0.37702234		0.49798586		0.52091607		0.29386038	
Ecart Type	0.24403127		0.20458182		0.21310156		0.2753642	

Simulation

In order to illustrate the extent of substitution between input according to sector, we apply price shocks which are 10% permanent rises of each input factor (see table 7.2.2 to Y). Furthermore, to see adjustment delay, we present the results in the short term (one year), medium term (3 years) and long term (25 years). The results could be interpreted as direct elasticity between inputs: a positive value meaning substitution between inputs and a negative one meaning complementarity.

Table 7.2.2: Price shocks results for sectors 1 to 5

		SR					MR					LR					P P
		D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	
1	P Mat	-1.536	3.176	1.725	0.162	0.180	-2.480	3.859	3.109	0.462	0.515	-2.686	3.867	3.609	2.354	2.629	5.541
	P LS	0.247	-5.658	0.279	0.026	0.029	0.401	-6.811	0.500	0.075	0.084	0.435	-6.825	0.580	0.380	0.424	0.661
	P HS	0.023	0.047	-3.583	0.003	0.003	0.037	0.057	-6.321	0.008	0.009	0.040	0.057	-7.282	0.040	0.045	0.061
	P E	0.263	0.544	0.340	-0.305	0.033	0.427	0.659	0.609	-0.868	0.094	0.463	0.661	0.705	-4.306	0.476	0.704
	P Inv	1.048	2.176	1.354	0.117	-0.243	1.706	2.642	2.436	0.335	-0.690	1.851	2.648	2.827	1.669	-3.371	2.826
2	P Mat	-0.078	0.165	0.141	0.015	0.015	-0.159	0.279	0.241	0.042	0.043	-0.221	0.326	0.287	0.197	0.232	4.946
	P LS	0.023	-2.057	0.642	0.067	0.069	0.046	-3.444	1.099	0.189	0.197	0.064	-4.014	1.310	0.898	1.061	1.372
	P HS	0.017	0.548	-1.927	0.049	0.050	0.033	0.926	-3.268	0.138	0.144	0.047	1.083	-3.878	0.653	0.771	0.995
	P E	0.037	1.224	1.042	-0.114	-0.074	0.075	2.072	1.786	-0.323	-0.213	0.104	2.426	2.130	-1.518	-1.133	2.239
	P Inv	0.006	0.211	0.180	-0.013	-0.057	0.013	0.356	0.307	-0.036	-0.162	0.018	0.415	0.365	-0.168	-0.847	0.381
3	P Mat	-1.083	0.626	0.509	0.731	0.066	-1.645	1.088	0.951	1.047	0.188	-1.950	1.352	1.284	1.212	1.018	3.458
	P LS	0.102	-3.014	0.203	0.292	0.026	0.155	-5.170	0.379	0.417	0.075	0.184	-6.378	0.512	0.483	0.406	0.575
	P HS	0.062	0.151	-2.790	0.201	0.018	0.094	0.262	-5.135	0.287	0.052	0.112	0.326	-6.858	0.332	0.279	0.348
	P E	0.754	1.848	1.709	-1.281	0.037	1.151	3.228	3.208	-1.826	0.105	1.367	4.023	4.347	-2.110	0.567	4.318
	P Inv	0.211	0.516	0.478	0.112	-0.143	0.321	0.897	0.893	0.161	-0.409	0.380	1.110	1.199	0.185	-2.138	1.187
4	P Mat																
	P LS																
	P HS																
	P E																
	P Inv																
5	P Mat	-0.037	0.180	0.144	0.152	0.043	-0.095	0.342	0.271	0.266	0.116	-0.261	0.431	0.338	0.314	0.409	5.955
	P LS	0.001	-0.244	0.002	0.002	0.000	0.003	-0.462	0.003	0.003	0.001	0.008	-0.582	0.004	0.004	0.005	0.113
	P HS	0.002	0.004	-0.193	0.003	0.001	0.006	0.008	-0.363	0.006	0.003	0.016	0.010	-0.454	0.007	0.009	0.223
	P E	0.032	0.060	0.048	-0.169	0.043	0.083	0.113	0.090	-0.295	0.116	0.228	0.143	0.112	-0.347	0.411	3.309
	P Inv	0.004	0.007	0.006	0.018	-0.085	0.010	0.013	0.010	0.032	-0.231	0.027	0.017	0.013	0.037	-0.805	0.385

Table 7.2.3: Price shocks results for sectors 6 to 10

		SR					MR					LR					P P
		D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	
6	P Mat	-0.046	0.136	0.135	0.088	0.025	-0.121	0.299	0.293	0.201	0.070	-0.351	0.493	0.481	0.369	0.377	5.498
	P LS	0.006	-1.794	0.239	0.156	0.043	0.016	-3.890	0.519	0.356	0.124	0.045	-6.341	0.851	0.653	0.667	0.540
	P HS	0.004	0.143	-1.878	0.093	0.026	0.009	0.313	-4.024	0.211	0.074	0.027	0.517	-6.499	0.386	0.395	0.320
	P E	0.032	1.278	1.269	-0.333	0.008	0.083	2.822	2.770	-0.755	0.022	0.243	4.701	4.572	-1.381	0.117	2.921
	P Inv	0.007	0.296	0.294	0.006	-0.099	0.019	0.650	0.638	0.013	-0.284	0.055	1.070	1.041	0.024	-1.474	0.662
7	P Mat	-0.043	0.173	0.144	0.117	0.005	-0.106	0.301	0.255	0.148	0.016	-0.236	0.389	0.336	0.174	0.088	5.627
	P LS	0.004	-0.990	0.060	0.049	0.002	0.009	-1.717	0.107	0.062	0.007	0.020	-2.211	0.141	0.073	0.037	0.337
	P HS	0.005	0.100	-0.679	0.054	0.003	0.012	0.174	-1.199	0.068	0.007	0.027	0.225	-1.577	0.080	0.041	0.465
	P E	0.034	0.669	0.443	-0.229	0.009	0.082	1.168	0.787	-0.291	0.026	0.183	1.511	1.038	-0.343	0.147	3.193
	P Inv	0.004	0.077	0.051	0.022	-0.019	0.009	0.134	0.090	0.028	-0.055	0.021	0.172	0.118	0.033	-0.298	0.356
8	P Mat	-1.379	1.578	1.333	0.665	0.102	-1.649	2.050	1.864	1.271	0.292	-1.662	2.085	1.923	1.577	1.489	5.236
	P LS	0.157	-3.550	0.220	0.110	0.017	0.188	-4.577	0.306	0.209	0.048	0.190	-4.652	0.316	0.260	0.245	0.502
	P HS	0.124	0.204	-3.258	0.098	0.015	0.148	0.265	-4.512	0.187	0.043	0.150	0.270	-4.652	0.231	0.218	0.395
	P E	0.974	1.607	1.537	-0.770	-0.062	1.168	2.089	2.149	-1.462	-0.178	1.178	2.124	2.217	-1.808	-0.901	3.141
	P Inv	0.193	0.319	0.305	-0.083	-0.069	0.231	0.414	0.426	-0.158	-0.198	0.233	0.421	0.439	-0.195	-0.979	0.617
9	P Mat	-2.951	2.027	1.793	0.599	0.226	-3.294	3.106	2.843	1.443	0.629	-3.269	3.265	3.030	2.774	2.582	4.539
	P LS	0.407	-3.693	0.244	0.082	0.031	0.455	-5.573	0.386	0.197	0.086	0.451	-5.846	0.411	0.376	0.351	0.692
	P HS	0.196	0.133	-3.426	0.040	0.015	0.219	0.202	-5.351	0.097	0.042	0.217	0.213	-5.689	0.185	0.172	0.333
	P E	1.353	0.917	0.827	-1.028	0.150	1.514	1.400	1.308	-2.447	0.417	1.502	1.472	1.393	-4.622	1.708	2.311
	P Inv	1.111	0.753	0.680	0.327	-0.416	1.244	1.150	1.074	0.786	-1.150	1.234	1.209	1.145	1.507	-4.538	1.897
10	P Mat	-0.046	0.092	0.071	0.088	0.023	-0.112	0.197	0.157	0.160	0.062	-0.233	0.298	0.250	0.196	0.225	5.145
	P LS	0.002	-0.566	0.019	0.023	0.006	0.005	-1.210	0.041	0.042	0.016	0.011	-1.823	0.065	0.051	0.058	0.221
	P HS	0.004	0.038	-0.546	0.049	0.013	0.009	0.081	-1.199	0.088	0.034	0.018	0.123	-1.900	0.108	0.124	0.350
	P E	0.031	0.324	0.338	-0.398	0.170	0.075	0.697	0.746	-0.722	0.465	0.156	1.055	1.189	-0.884	1.700	3.066
	P Inv	0.012	0.126	0.132	0.259	-0.206	0.029	0.272	0.291	0.470	-0.562	0.060	0.410	0.462	0.576	-2.007	1.176

Table 7.2.4: Price shocks results for sectors 11 to 15

		SR					MR					LR					P P
		D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	
11	P Mat	-2.433	4.831	3.382	0.880	0.261	-3.509	5.278	4.986	2.177	0.746	-3.666	5.304	5.232	4.653	3.804	5.657
	P LS	1.245	-6.191	1.197	0.314	0.093	1.811	-6.730	1.757	0.774	0.266	1.894	-6.762	1.842	1.641	1.345	2.044
	P HS	0.310	0.423	-5.290	0.082	0.024	0.450	0.462	-7.645	0.201	0.069	0.470	0.464	-7.997	0.425	0.349	0.507
	P E	0.105	0.143	0.105	-1.386	0.005	0.152	0.156	0.154	-3.374	0.014	0.159	0.157	0.161	-6.991	0.069	0.171
	P Inv	0.829	1.133	0.831	0.128	-0.381	1.204	1.236	1.219	0.316	-1.083	1.259	1.242	1.277	0.667	-5.224	1.359
12	P Mat	-1.414	1.720	1.393	0.379	0.233	-1.918	3.038	2.591	0.952	0.647	-1.943	3.460	3.085	2.140	2.580	5.923
	P LS	0.185	-2.313	0.078	0.021	0.013	0.252	-4.024	0.144	0.053	0.036	0.255	-4.562	0.171	0.119	0.143	0.492
	P HS	0.152	0.079	-2.014	0.022	0.014	0.207	0.138	-3.693	0.055	0.038	0.210	0.157	-4.371	0.123	0.149	0.404
	P E	0.369	0.191	0.195	-0.609	0.059	0.502	0.335	0.361	-1.518	0.162	0.509	0.381	0.429	-3.359	0.643	0.981
	P Inv	0.767	0.397	0.406	0.197	-0.312	1.044	0.698	0.752	0.495	-0.862	1.059	0.794	0.894	1.108	-3.324	2.047
13	P Mat	-0.971	0.553	0.490	0.305	0.078	-1.623	1.202	1.067	0.607	0.225	-1.889	1.864	1.664	0.835	1.183	4.420
	P LS	0.096	-1.496	0.091	0.057	0.015	0.160	-3.214	0.198	0.113	0.042	0.187	-4.921	0.309	0.155	0.220	0.511
	P HS	0.087	0.094	-1.406	0.057	0.015	0.146	0.204	-3.027	0.113	0.042	0.170	0.315	-4.668	0.155	0.219	0.466
	P E	0.606	0.652	0.631	-0.378	-0.020	1.019	1.419	1.376	-0.750	-0.056	1.188	2.201	2.148	-1.028	-0.293	3.277
	P Inv	0.229	0.247	0.239	-0.030	-0.086	0.385	0.536	0.520	-0.059	-0.245	0.448	0.828	0.808	-0.081	-1.249	1.226
14	P Mat	-0.643	0.412	0.379	0.274	0.082	-1.028	0.952	0.870	0.606	0.232	-1.123	1.649	1.478	0.947	1.141	5.586
	P LS	0.090	-1.176	0.113	0.082	0.024	0.144	-2.691	0.260	0.181	0.070	0.158	-4.600	0.440	0.283	0.340	0.573
	P HS	0.075	0.103	-1.218	0.082	0.024	0.121	0.238	-2.763	0.180	0.069	0.132	0.411	-4.635	0.281	0.339	0.480
	P E	0.396	0.539	0.589	-0.401	-0.026	0.635	1.246	1.351	-0.882	-0.075	0.694	2.161	2.299	-1.373	-0.366	2.539
	P Inv	0.115	0.157	0.171	-0.027	-0.101	0.184	0.362	0.392	-0.059	-0.288	0.201	0.625	0.665	-0.091	-1.373	0.730
15	P Mat	-1.261	2.535	1.800	0.920	0.182	-1.625	3.626	3.057	1.916	0.519	-1.663	3.786	3.447	2.684	2.557	6.645
	P LS	0.185	-3.586	0.140	0.072	0.014	0.239	-5.064	0.236	0.148	0.040	0.245	-5.278	0.265	0.207	0.198	0.453
	P HS	0.120	0.127	-2.783	0.057	0.011	0.155	0.181	-4.652	0.118	0.032	0.159	0.188	-5.219	0.165	0.157	0.293
	P E	0.330	0.349	0.305	-1.384	0.036	0.426	0.497	0.516	-2.848	0.101	0.436	0.518	0.581	-3.952	0.494	0.807
	P Inv	0.679	0.718	0.628	0.367	-0.240	0.878	1.023	1.062	0.763	-0.679	0.898	1.067	1.195	1.065	-3.212	1.665

Table 7.2.5: Price shocks results for sectors 16 to 20

		SR					MR					LR					P P
		D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	
16	P Mat	-1.125	1.629	1.414	0.345	0.147	-1.633	2.670	2.403	0.873	0.421	-1.702	2.922	2.687	2.040	2.155	6.049
	P LS	0.261	-3.168	0.412	0.101	0.043	0.380	-5.116	0.698	0.255	0.123	0.396	-5.579	0.780	0.593	0.627	0.845
	P HS	0.073	0.133	-3.094	0.029	0.013	0.106	0.217	-5.175	0.074	0.036	0.111	0.237	-5.762	0.172	0.182	0.236
	P E	0.718	1.305	1.176	-0.409	-0.150	1.046	2.137	1.995	-1.029	-0.428	1.091	2.339	2.232	-2.374	-2.151	2.339
	P Inv	0.124	0.227	0.204	-0.062	-0.052	0.181	0.370	0.345	-0.156	-0.147	0.189	0.404	0.386	-0.362	-0.728	0.403
17	P Mat	-1.261	5.080	3.938	1.784	0.411	-2.340	5.642	5.114	3.112	1.150	-2.746	5.510	5.032	3.427	4.817	6.262
	P LS	0.371	-5.671	0.286	0.131	0.030	0.692	-6.262	0.370	0.227	0.085	0.815	-6.124	0.364	0.250	0.349	1.013
	P HS	0.105	0.104	-4.851	0.050	0.012	0.196	0.115	-6.219	0.087	0.032	0.231	0.113	-6.126	0.096	0.134	0.287
	P E	0.696	0.691	0.726	-1.668	-0.353	1.302	0.765	0.938	-2.874	-0.979	1.533	0.748	0.923	-3.155	-3.967	1.907
	P Inv	0.126	0.125	0.131	-0.277	-0.102	0.235	0.138	0.169	-0.480	-0.283	0.277	0.135	0.167	-0.529	-1.145	0.344
18	P Mat	-0.602	0.498	0.399	0.345	0.084	-0.976	1.043	0.860	0.693	0.236	-1.057	1.453	1.263	0.907	1.032	5.234
	P LS	0.037	-1.079	0.031	0.027	0.007	0.060	-2.241	0.066	0.053	0.018	0.065	-3.102	0.097	0.070	0.079	0.273
	P HS	0.041	0.043	-0.867	0.030	0.007	0.067	0.089	-1.858	0.060	0.021	0.073	0.124	-2.711	0.078	0.089	0.304
	P E	0.438	0.450	0.365	-0.403	0.015	0.712	0.943	0.787	-0.808	0.042	0.772	1.313	1.155	-1.054	0.182	3.258
	P Inv	0.117	0.121	0.098	0.016	-0.110	0.190	0.252	0.211	0.032	-0.307	0.206	0.351	0.309	0.041	-1.310	0.861
19	P Mat	-0.715	1.172	0.874	0.391	0.101	-0.995	1.407	1.236	0.675	0.281	-1.022	1.412	1.274	0.763	1.135	5.388
	P LS	0.103	-3.800	0.333	0.149	0.039	0.143	-4.537	0.470	0.258	0.107	0.147	-4.554	0.485	0.291	0.432	0.616
	P HS	0.073	0.318	-2.994	0.110	0.028	0.102	0.381	-4.201	0.189	0.079	0.105	0.383	-4.328	0.213	0.317	0.439
	P E	0.461	1.999	1.532	-0.594	-0.039	0.643	2.400	2.170	-1.022	-0.107	0.661	2.410	2.237	-1.153	-0.429	2.785
	P Inv	0.114	0.496	0.381	-0.038	-0.126	0.159	0.594	0.538	-0.066	-0.348	0.164	0.597	0.554	-0.075	-1.376	0.685
20	P Mat	-1.025	2.365	1.537	0.540	0.152	-1.683	2.859	2.437	1.172	0.434	-1.841	2.865	2.611	1.739	2.145	5.747
	P LS	0.329	-4.284	0.618	0.218	0.062	0.543	-5.143	0.978	0.472	0.175	0.595	-5.154	1.047	0.699	0.862	1.266
	P HS	0.128	0.369	-3.410	0.103	0.029	0.211	0.445	-5.331	0.222	0.083	0.231	0.446	-5.695	0.329	0.406	0.491
	P E	0.512	1.477	1.164	-0.740	-0.160	0.845	1.784	1.845	-1.595	-0.455	0.925	1.788	1.976	-2.350	-2.212	1.974
	P Inv	0.098	0.283	0.223	-0.111	-0.081	0.162	0.341	0.353	-0.239	-0.230	0.177	0.342	0.378	-0.354	-1.099	0.376

Table 7.2.6: Price shocks results for sectors 21 to 25

		SR					MR					LR					P P
		D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	
21	P Mat	-0.918	2.190	1.497	1.031	0.236	-1.395	2.434	2.040	1.486	0.630	-1.472	2.432	2.083	1.538	1.968	5.746
	P LS	0.109	-3.907	0.167	0.115	0.026	0.167	-4.327	0.227	0.166	0.071	0.176	-4.324	0.232	0.172	0.219	0.469
	P HS	0.059	0.130	-2.728	0.059	0.014	0.089	0.145	-3.688	0.085	0.036	0.094	0.145	-3.763	0.088	0.113	0.251
	P E	0.405	0.902	0.594	-1.624	0.113	0.618	1.002	0.808	-2.327	0.302	0.652	1.001	0.825	-2.407	0.940	1.744
	P Inv	0.388	0.864	0.569	0.473	-0.380	0.591	0.959	0.774	0.681	-1.010	0.624	0.959	0.790	0.704	-3.082	1.669
22	P Mat	-0.643	0.287	0.222	0.209	0.043	-0.733	0.630	0.511	0.438	0.121	-0.729	0.961	0.866	0.611	0.614	5.046
	P LS	0.070	-1.308	0.095	0.090	0.018	0.080	-2.849	0.220	0.188	0.052	0.079	-4.303	0.372	0.262	0.264	0.501
	P HS	0.045	0.080	-1.129	0.064	0.013	0.052	0.175	-2.576	0.135	0.037	0.051	0.266	-4.319	0.188	0.189	0.323
	P E	0.354	0.619	0.532	-0.493	0.052	0.403	1.363	1.226	-1.031	0.147	0.401	2.082	2.082	-1.434	0.745	2.554
	P Inv	0.207	0.364	0.313	0.149	-0.122	0.236	0.800	0.720	0.312	-0.348	0.235	1.220	1.221	0.435	-1.708	1.491
23	P Mat	-0.849	2.269	1.483	0.488	0.274	-1.838	2.769	2.404	1.139	0.742	-2.713	2.751	2.577	1.985	2.477	4.592
	P LS	0.196	-4.867	0.537	0.177	0.100	0.427	-5.892	0.868	0.413	0.269	0.634	-5.855	0.930	0.718	0.894	1.166
	P HS	0.061	0.255	-3.786	0.062	0.035	0.133	0.311	-6.038	0.146	0.095	0.198	0.309	-6.452	0.253	0.315	0.362
	P E	0.188	0.783	0.581	-0.915	0.051	0.409	0.954	0.939	-2.118	0.137	0.606	0.948	1.006	-3.647	0.455	1.114
	P Inv	0.428	1.795	1.329	0.206	-0.451	0.935	2.189	2.153	0.481	-1.212	1.390	2.176	2.308	0.838	-3.927	2.562
24	P Mat	-0.949	0.850	0.873	0.217	0.129	-1.448	1.439	1.356	0.539	0.355	-1.532	1.606	1.445	1.163	1.368	4.435
	P LS	0.088	-2.523	0.178	0.044	0.026	0.135	-4.225	0.276	0.110	0.072	0.143	-4.698	0.293	0.236	0.278	0.481
	P HS	0.044	0.087	-2.328	0.018	0.010	0.068	0.147	-3.585	0.043	0.029	0.072	0.164	-3.813	0.093	0.110	0.241
	P E	0.757	1.483	1.201	-0.247	-0.104	1.161	2.518	1.867	-0.611	-0.285	1.229	2.811	1.989	-1.311	-1.087	4.194
	P Inv	0.102	0.201	0.162	-0.024	-0.058	0.157	0.339	0.252	-0.060	-0.159	0.166	0.378	0.268	-0.129	-0.602	0.559
25	P Mat	-0.301	0.311	0.211	0.110	0.036	-0.564	0.599	0.451	0.273	0.101	-0.697	0.757	0.662	0.606	0.520	4.732
	P LS	0.030	-2.003	0.126	0.065	0.021	0.056	-3.815	0.269	0.163	0.060	0.070	-4.794	0.395	0.361	0.310	0.489
	P HS	0.015	0.092	-1.673	0.040	0.013	0.028	0.178	-3.536	0.100	0.037	0.035	0.225	-5.149	0.221	0.190	0.243
	P E	0.240	1.478	1.228	-0.193	-0.038	0.451	2.860	2.639	-0.480	-0.109	0.558	3.626	3.899	-1.060	-0.555	3.979
	P Inv	0.030	0.188	0.157	-0.015	-0.030	0.057	0.362	0.334	-0.038	-0.084	0.070	0.457	0.491	-0.085	-0.422	0.495

Table 7.2.7: Price shocks results for sectors 26 to 30

		SR					MR					LR					P P
		D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	D M	D LS	D HS	D E	D K	
26	P Mat	-1.070	0.995	0.787	0.276	0.107	-1.579	1.777	1.503	0.649	0.306	-1.638	2.046	1.842	1.160	1.553	5.146
	P LS	0.119	-2.627	0.162	0.057	0.022	0.175	-4.627	0.309	0.134	0.063	0.182	-5.299	0.378	0.239	0.319	0.498
	P HS	0.047	0.082	-2.384	0.027	0.010	0.070	0.146	-4.490	0.062	0.029	0.073	0.168	-5.465	0.111	0.149	0.199
	P E	0.813	1.402	1.290	-0.310	-0.094	1.205	2.509	2.470	-0.726	-0.269	1.250	2.889	3.030	-1.290	-1.346	3.453
	P Inv	0.142	0.246	0.227	-0.043	-0.043	0.211	0.438	0.432	-0.102	-0.124	0.219	0.504	0.529	-0.182	-0.610	0.598
27	P Mat	-1.108	2.787	2.270	0.134	0.156	-2.475	3.183	3.048	0.384	0.444	-3.967	3.197	3.116	1.965	2.218	4.126
	P LS	0.350	-5.295	1.009	0.060	0.070	0.789	-6.013	1.351	0.171	0.198	1.277	-6.038	1.381	0.874	0.985	1.735
	P HS	0.133	0.470	-4.991	0.024	0.027	0.300	0.535	-6.619	0.067	0.078	0.485	0.538	-6.759	0.342	0.386	0.658
	P E	0.062	0.218	0.184	-0.352	0.017	0.140	0.249	0.246	-1.001	0.048	0.226	0.250	0.251	-4.984	0.239	0.306
	P Inv	0.587	2.078	1.745	0.138	-0.266	1.324	2.372	2.341	0.393	-0.756	2.146	2.382	2.393	1.971	-3.616	2.921
28	P Mat	-0.632	0.202	0.180	0.645	0.065	-0.927	0.535	0.479	0.930	0.187	-0.982	1.616	1.466	0.980	0.959	5.746
	P LS	0.036	-0.247	0.003	0.009	0.001	0.052	-0.652	0.007	0.013	0.003	0.055	-1.947	0.020	0.014	0.013	0.221
	P HS	0.057	0.005	-0.276	0.036	0.004	0.084	0.012	-0.731	0.051	0.010	0.090	0.036	-2.207	0.054	0.053	0.358
	P E	0.484	0.039	0.084	-0.660	-0.004	0.713	0.104	0.223	-0.948	-0.013	0.755	0.314	0.681	-0.999	-0.064	3.052
	P Inv	0.090	0.007	0.016	-0.009	-0.064	0.132	0.019	0.041	-0.013	-0.182	0.140	0.057	0.125	-0.014	-0.909	0.559
29	P Mat	-0.374	0.710	0.678	0.075	0.066	-0.828	1.219	1.167	0.206	0.187	-1.267	1.340	1.286	0.732	0.937	4.519
	P LS	0.010	-1.425	0.019	0.002	0.002	0.022	-2.427	0.032	0.006	0.005	0.033	-2.664	0.035	0.020	0.026	0.133
	P HS	0.014	0.028	-1.363	0.003	0.003	0.031	0.048	-2.330	0.008	0.008	0.048	0.053	-2.563	0.029	0.038	0.192
	P E	0.309	0.618	0.599	-0.070	-0.036	0.686	1.060	1.031	-0.192	-0.103	1.054	1.166	1.136	-0.679	-0.514	4.293
	P Inv	0.058	0.116	0.113	-0.008	-0.032	0.129	0.199	0.194	-0.022	-0.091	0.198	0.219	0.213	-0.078	-0.446	0.797
30	P Mat	-0.514	0.425	0.403	0.658	0.176	-1.115	0.972	0.918	0.955	0.466	-1.680	1.629	1.535	1.002	1.381	4.197
	P LS	0.026	-0.908	0.024	0.040	0.011	0.056	-2.056	0.056	0.058	0.028	0.085	-3.412	0.093	0.061	0.083	0.273
	P HS	0.031	0.031	-0.863	0.049	0.013	0.068	0.071	-1.952	0.071	0.034	0.102	0.118	-3.230	0.074	0.102	0.327
	P E	0.298	0.297	0.286	-0.940	0.101	0.649	0.678	0.652	-1.360	0.268	0.981	1.135	1.089	-1.425	0.794	3.174
	P Inv	0.182	0.181	0.175	0.231	-0.292	0.396	0.414	0.398	0.335	-0.771	0.598	0.692	0.663	0.351	-2.246	1.927

7.2.5 Households final consumption

The consumption behaviour is divided in two stages. The first is the aggregate consumption that splits households incomes in consumption and global saving. At the second stage, the aggregate consumption is allocated in 27 consumption functions.

7.2.5.1 Aggregate consumption

At the beginning of the aggregate consumption equation, there is a model inspired by Davidson *et al.* (1978 [107]) but that links consumption to income and wealth with the help of an error correction model (Engle and Granger 1987 [171]). The econometrics estimate at first the long term relationship, then the dynamics. In the first version of the model, the wealth was represented by a permanent income function that was computed as a mean of the lagged revenues⁶. Later, the cumulative investment in dwelling was used as a proxy for the housing stock of households, and was added to the wealth effect. Other significant variables on the link between wealth on different support and consumption are interest rates and inflationary pressures. The unemployment rate is used as a proxy for the degree of uncertainty in the economy. Thereby, aggregate consumption is modelled as follows:

Co-Integrating Long term equation

$$\begin{aligned}
 \ln\left(\frac{CONS\text{NAT}N\text{Q}_c}{POP_c}\right) &= lrscnn0_c \\
 &+ lrscnn1 \cdot \ln\left(\frac{\frac{INCGDISP_c}{PCONS\text{NAT}TOT_c}}{POP_c}\right) \\
 &+ lrscnn2 \cdot \ln\left(\frac{POP\text{RET}_c}{POP_c}\right) \\
 &+ lrscnn3 \cdot \ln\left(\frac{POP\text{CHI}_c}{POP_c}\right) \\
 &+ lrscnn4 \cdot \ln(R\text{RLR}_c) \\
 &+ lrscnn5 \cdot DUM97
 \end{aligned} \tag{7.2.11}$$

6. The long run elasticity of consumption in relation to incomes has been set to one to ensure that the life-cycle theory is fulfilled

Dynamic equation

$$\begin{aligned}
 \Delta \ln \left(\frac{CONS\text{NAT}N\text{Q}_c}{POP_c} \right) &= crscnn0_c \\
 &+ crscnn1 \cdot \Delta \ln \left(\frac{\frac{INCGDISP_c}{PCONS\text{NATTOT}_c}}{POP_c} \right) \\
 &+ crscnn2 \cdot \Delta \ln \left(\frac{POP\text{RET}_c}{POP_c} \right) \\
 &+ crscnn3 \cdot \Delta \ln \left(\frac{POP\text{CHI}_c}{POP_c} \right) \\
 &+ crscnn4 \cdot \Delta \ln(RRLR_c) \\
 &+ crscnn5 \cdot \Delta \ln \left(\frac{PCONS\text{NATTOT}_c}{PCONS\text{NATTOT}_c^{-1}} \right) \\
 &+ crscnn6 \cdot \Delta \ln \left(\frac{CONS\text{NAT}N\text{Q}_c^{-1}}{POP_c^{-1}} \right) \\
 &+ crscnn7 \cdot ERR^{-1} \\
 &+ crscnn8 \cdot DUM97
 \end{aligned} \tag{7.2.12}$$

with:

- POP_c , Population
- $INCGDISP_c$, Gross Disposable Income
- $PCONS\text{NATTOT}_c$, Consumers Price
- $POP\text{RET}_c$ Retired Population
- $POP\text{CHI}_c$ Child Population
- $RRLR_c$ Interest Rate
- ERR , the Error Term
- $DUM97$, a dummy variable

Parameters Restrictions:

Long term parameters

$$lrscnn4 < 0$$

Short term term parameters

$$crscnn1 > 0$$

$$crscnn4 < 0$$

$$crscnn5 < 0$$

$$0 < crscnn6 < 1$$

$$0 > crscnn7 > -1$$

Researches on the aggregate consumption are always going on, and they are now focusing, for the NEMESIS model, on two directions:

- at first, the building of a genuine wealth variable in a forward looking module that would be isolated from the rest of the model
- aggregate consumption function could be the result of two type of behaviours; that of “liquidity constrained” households which is founded on the current revenue ; that of “neoclassical households” which can borrow or lend liquidity without restrictions and which is grounded on wealth, discounted sum of future revenues.

7.2.5.2 Allocation of aggregate Consumption

We will present in this section the theoretical and empirical grounds of the system that will allow to disaggregate the macroeconomic consumption determined above. The basic presentation thereof are from Bracke and Meyermans (1997 [50]). The only difference with respect to their work as far as the econometric is concerned, is that now panel estimation is applied instead of individual OLS regressions. The econometric allocation system is derived from the theory of rational consumer and restrictions imposed by it are implemented in a flexible way thanks to a Dutch Central Bureau of Statistics (CBS - Keller and van Driel 1985 [310]) version of the system *i.e.* a hybrid of the Almost Ideal Demand (AID - Deaton and Muellbauer 1980 [109]) and Rotterdam systems (Theil 1967 [441])⁷. The total aggregate consumption is therefore divided into 27 components as a function of relative prices and total income (to which are added demographic changes). Furthermore, this allocation module assumes group separability, meaning that the consumer faces a decision problem in several stages. In particular, the representative consumer decides, in a first stage, how much he will spend on “durable and complementary non-durable goods” on the one hand (see figure 7.2.4) and on “other

7. See *e.g.* Barten (1993 [27]) for a comparison between different functional form of consumer allocation models

non-durable goods” on the other hand (see figure 7.2.5). In a second stage, he decides how to spend the money allocated in the first stage within the group *i.e.* how much of the amount dedicated to the durable goods will be allocated to clothing, household utilities and transportation. Transportation includes public transportation, equipment (such as cars) and energy, divided into petrol, heavy fuel and oil. A further decision stage takes place in the non-durable goods group. It consists of the choice between ”necessities” (including food, beverages, tobacco, education, rent, health, electricity and other expenditure items) and ”luxuries” (including communication, tourism and domestic services).

Based on the CBS parametrisation, the long-run equilibrium relationship is:

$$w_{c,i} \ln \left(\frac{CONS_{c,i}}{INCRDISP_c} \right) = c_{c,i} + b_i \ln(INCRDISP_c) + \sum_{j=1}^{27} s_{i,j} \cdot \ln(PCONS_{c,j}) \quad (7.2.13)$$

$$+ g_{1,i} \ln(DEMP_c) + g_{2,i} \ln(DEMW_c) + \vartheta_{c,i}$$

and the short-run one is:

$$w_{c,i} \Delta \ln \left(\frac{CONS_{c,i}}{INCRDISP_c} \right) = b_i^s \Delta \ln(INCRDISP_c) + \sum_{j=1}^{27} s_{i,j}^s \cdot \Delta \ln(PCONS_{c,j}) + \sum_{j=1}^{26} f_{i,j}^s \Delta \ln(POP_{c,i}) \quad (7.2.14)$$

$$+ h_{1,i}^s \Delta \ln(DEMP_c) + h_{2,i}^s \Delta \ln(DEMW_c) + u_{c,i}$$

where : $i, j = 1$ to 27 consumption categories, $c = 1$ to 26 countries, $CONS$ is the consumption of commodity, $INCRDISP$ is the real personal disposable income, $PCONS$ is the commodity price, $DEMW$ is the share of people of working age in total population and $DEMP$ is the share of old age people in total population.

Figure 7.2.4: Allocation of durable goods

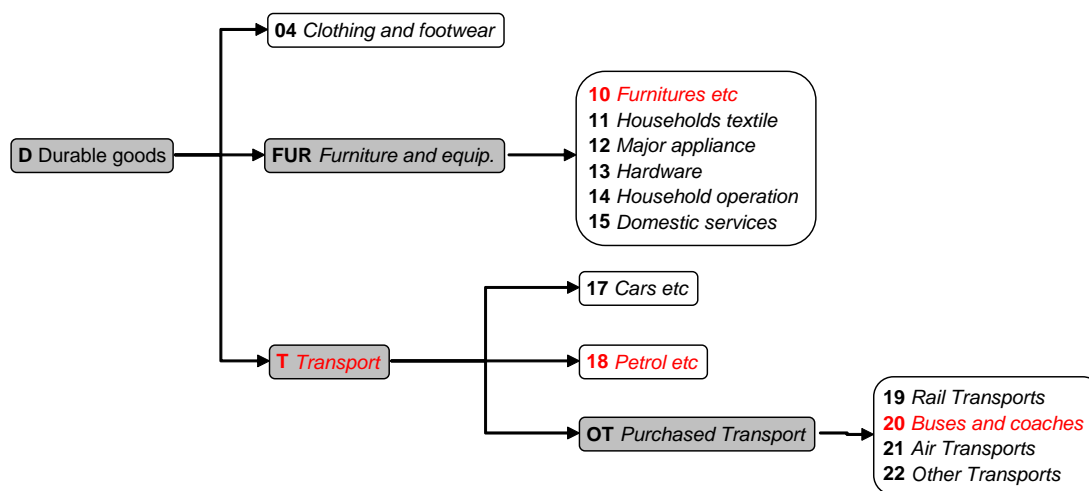
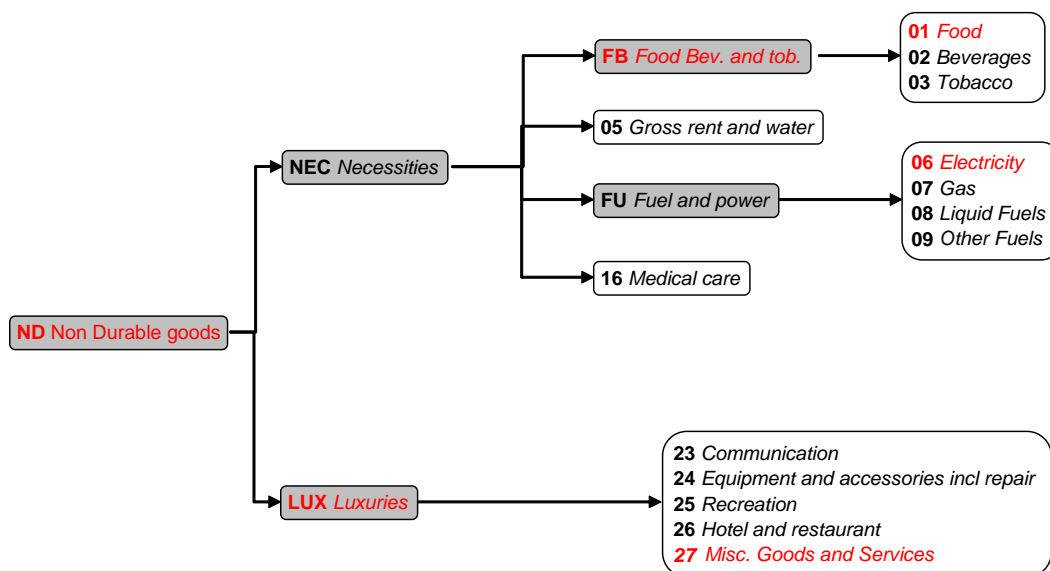


Figure 7.2.5: Allocation of non durable goods



More specifically, under groups separability, the equations that follow were estimated. They show the interactions within a group of commodities and between groups of commodities.

Within a group I , the long-run equilibrium relationship is:

$$w_{c,i} \ln \left(\frac{CONS_{c,i}}{Q_c^I} \right) = c_{c,i}^I + b_i^I \ln(Q_c^I) + \sum_{j=1}^{27} s_{i,j}^I \cdot \ln(PCONS_{c,j}) + g_{1,i}^I \ln(DEMP_c) \quad (7.2.15)$$

$$+ g_{2,i}^I \ln(DEMW_c) + \vartheta_{c,i}^I$$

for $i \in I$ and where

- the scale effect of group I is defined by $\ln(Q_c^I) = \sum_{i \in I} w_{c,i}^I \ln(CONS_{c,i})$
- b_i^I : the income coefficient of commodity i in group I
- $s_{i,j}^I$: the compensated price effect of commodity j on I , both elements of I
- $w_{c,i}^I$: the budget share of commodity i in group I ,

and the short-run one is:

$$w_{c,i}^I \Delta \ln \left(\frac{CONS_{c,i}}{Q_c^I} \right) = b_i^{s,I} \Delta \ln(Q_c^I) + \sum_{j=1}^{27} s_{i,j}^{s,I} \cdot \Delta \ln(PCONS_{c,j}) + \sum_{j=1}^{26} f_{i,j}^{s,I} (\vartheta_{c,i}^I)^{-1} \quad (7.2.16)$$

$$+ h_{1,i}^{s,I} \Delta \ln(DEMP_c) + h_{2,i}^{s,I} \Delta \ln(DEMW_c) + u_{c,i}$$

for $i \in I$

Between groups of commodities, the long-run equilibrium relationship is:

$$w^I \ln \left(\frac{Q_c^I}{INCRDISP_c} \right) = c_c^I + b^I \ln(INCRDISP_c) + \sum_{J=1}^k s_J^I \cdot \ln(PCONS_{c,J}) \quad (7.2.17)$$

$$+ g_1^I \ln(DEMP_c) + g_2^I \ln(DEMW_c) + \vartheta_c^I$$

for $I = 1, \dots, k$ groups and where

- $\ln(Q_c^I) = \sum_{i \in I} w_{c,i}^I \ln(CONS_{c,i})$
- $\ln(PCR_c^I) = \sum_{i \in I} w_{c,i}^I \ln(PCONS_{c,i})$
- w^I : the budget share of group I

and the short-run one is:

$$\begin{aligned}
 w^I \Delta \ln \left(\frac{Q_c^I}{INCRDISP_c} \right) &= b^{s,I} \Delta \ln(Q_c) + \sum_{J=1}^k s_J^{s,I} \cdot \Delta \ln(PCONS_{c,J}) + \sum_{J=1}^{k-1} f_J^{s,I} (\vartheta_c^I) \\
 &+ h_1^{s,I} \Delta \ln(DEMP_c) + h_2^{s,I} \Delta \ln(DEMW_c) + u_{c,I}
 \end{aligned} \quad (7.2.18)$$

for $I = 1, \dots, k$ groups.

From those intra-group and inter-group interactions, the overall interactions, which are defined as the interactions between commodities of different groups, may be computed. For the long-run overall coefficients:

$$\begin{aligned}
 m_i &= m^I \cdot m_i^I \quad \forall i, I \\
 s_{i,j} &= s_{i,j}^I \cdot w^I \cdot \delta_{i,j} + m_i^I \cdot S^{I,J} \cdot m_j^J \quad \forall i, I, j, J
 \end{aligned}$$

with $\delta_{i,j} = 1$ only if $I, j \in I$ and $= 0$ elsewhere and where

- m_i^I : the marginal propensity to spend on commodity i in group I
- m^I : the marginal propensity to spend on group I
- m_i : the overall marginal propensity to spend on commodity i (in the case of the CBS parametrisation, the marginal propensity to consume is defined as $m_i = b_i + w_i$)
- $s_{i,j}^I$: the compensated price effect of commodity j on i in group I (non zero only if $i, j \in I$)
- $S^{I,J}$: the compensated price effect of group J on group I
- $s_{i,j}$: the overall compensated price effect of j on i
- w^I : the budget share of group I .

Mutatis mutandis, those equations may also be applied to compute the short-run overall coefficients.

Restrictions

- Summability : $\sum_{i=1}^n c_{c,i} = 0$, $\sum_{i=1}^n b_i = 0$, $\sum_{i=1}^n s_{i,j} = 0$, $\sum_{i=1}^n b_i^s = 0$, $\sum_{i=1}^n s_{i,j}^s = 0$
- Homogeneity : $\sum_{j=1}^n s_{i,j} = 0$, $\sum_{j=1}^n s_{i,j}^s = 0$
- Symmetry: $s_{i,j} = s_{j,i}$, $s_{i,j}^s = s_{j,i}^s, \forall i, j$
- Negativity : $s_{ii} < 0$, $s_{ii}^s < 0$

The consumption per category is then allocated to consumption by product using consumption transition matrix (*mcons*) with fixed coefficient.

$$ADDCONSQ_{c,s} = \sum_{co=1}^{27} (mcons_{c,co,s} \cdot CONS_{c,co}) \quad (7.2.19)$$

This transition matrix is also used for calculating consumption price per category using sectoral production and import prices prices to which VAT taxes and Excises duties are added:

$$PCONS_{c,co} = \frac{\sum_{s=01}^{30} (mcons_{c,co,s} \cdot CONS_{c,co} \cdot PADDDEM_{c,s}) + VATCP_{c,co} + EXCIPAH_{c,co}}{CONS_{c,co} + VATCP_{c,co}^{1995} + EXCIPAH_{c,co}^{1995}} \quad (7.2.20)$$

7.2.6 External trade

7.2.6.1 General remarks

External trade is of a crucial importance in applied models such as NEMESIS. Indeed, one of the most important transmission effects between the different countries in the model goes through trade in goods and services. This matter of fact is reinforced by the strong European integration that as led to an increasing degree of openness, resulting in an increasing share of external trade ratio to the final demand. External trade is modelled in the models through a three sets of equations:

1. Intra-European trade in volume
2. Extra-European trade in volume
3. Exports and imports prices equations

If it were possible to separate intra and extra European trade in volume, this is not yet possible for prices, that is the reason why no distinction is made between intra and non prices modelling, except the fact that Rest of the World trade prices includes trade barriers such as import duties, that are not present into intra European trade.

7.2.6.2 Intra-European trade

The basic assumption regarding intra-European trade is that it take place into a “trade pool” *i.e.* into the same distribution network. In other words, tall European countries export into a pool and import from it. One of the major drawback of this kind of modelling is that as exports and imports are both econometrically estimated, nothing insure that at the global European level, total exports

and total imports are equals⁸. As underlined by Satchi (2004 [415]), it is not yet possible to estimate trade equations without bilateral data, that follows straightforwardly this constraint. However, this “adding up” problem was solved by modifying the exports equations in order to insure the equilibrium between the sums of exports and the sums of imports *per* sector, it implicitly signifies that imports equations are better modelled than exports ones.

Numerous attempt had be made for integrating in external trade equations (particularly in exports equation) the so called non price competitiveness, one convincing attempt was made using quality index build up with using made on importers by Crozet and Erkel-Rousse (2004 [103]). In our framework however, such quality indexes are not available for the 27 modelled countries, and hence we had to estimate this effect through the Knowledge variable. Of course, taking knowledge as a proxy variable for quality covers, as noted by Crozet and Erkel-Rousse (2004), not exactly the same content as quality indexes, and may focus on a particular dimension of quality, technological differentiation. Moreover, empirical testing shows that bilateral trade flows are more suitable for estimating such quality effects, as this allows for changes in the direction of this trade (see *e.g.* Hallak 2006 [257]), that one of the reason why the possibility for implementing bilateral trade flows in NEMESIS is currently studied. A great part of international trade theory nowadays concerns the so-called Home Market effect (see *e.g.* Corsetti *et al.* 2007 [101] or Crozet and Trionfetti 2008 [104]) explaining that big countries have an advantage for specialising their production to increasing return to scale sectors, and on the contrary, small countries are more focused on constant return to scale production. However, this effect refers largely to world trade, and the European integration tends to largely reduce this effect. Finally, the borders effect was not taking into account in our modelling framework the “trade pool” hypothesis does not allow for bilateral trade. Moreover, one can argue that the European market integration tends to reduce this effect (see *e.g.* Chen 2004 [86]).

Imports equations

The three main effects integrated in the trade equations are income and prices effects and non prices effects. For imports equations, these effects are taken into account with the following variables

- The income effect for a country is taken into account through a demand variable, represented by the demands addressed to the sector

8. The modelling of bilateral trade flows insure this “adding up” constraint, we are currently studying the possibility to model bilateral trade flows, at least for goods, as bilateral trade flows of services data are too weak for the moment.

- The price effect is represented by the ratio of the import price to the domestic price.
- the non price effect is taken into account through national knowledge stock to European knowledge stock ratio

$$\begin{aligned}
 \ln(IMPEUQ_{c,s}) &= limpeu0_{c,s} \\
 &+ limpeu1_s \cdot \ln(ADDDEM_{c,s}) \\
 &+ limpeu2_s \cdot \ln\left(\frac{PIMP_{c,s}}{PPROD_{c,s}}\right) \\
 &+ limpeu3_s \cdot \ln\left(\frac{KNOW_{c,s}}{KNOW_{eu,s}}\right)
 \end{aligned} \tag{7.2.21}$$

with :

- $ADDDEM_{c,s}$ Total domestic Demand by products
- $PIMP_{c,s}$ The Price of Imports
- $PPROD_{c,s}$ The production Price
- $KNOW_{c,s}$ the national knowledge Stock
- $KNOW_{eu,s}$ the European knowledge Stock

Parameters Restrictions:

$$limpeu1_s > 0$$

$$limpeu2_s < 0$$

$$limpeu3_s < 0$$

Exports Equations

For exports equations, the incomes and prices effects are taken into account with the following variables

- The income effect for a country j is taken into account through a demand variable, resulting from the demands of partners countries, weighted past trade intensities (in a matrix form, for year 2000)
- The price effect is represented by the ratio of the export price to a European price index, which is a weighted variable of other EU countries export prices.

$$\begin{aligned}
 \ln(EXPEUQc, s) &= lexpeu0_{c,s} \\
 &+ lexpeu1_s \cdot \ln(INDACTEU_{c,s}) \\
 &+ lexpeu2_s \cdot \ln\left(\frac{PEXP_{c,s}}{PINDICEXPEU_{c,s}}\right) \\
 &+ lexpeu3_s \cdot \ln\left(\frac{KNOW_{c,s}}{KNOW_{eu,s}}\right)
 \end{aligned} \tag{7.2.22}$$

- $INDACTEU_{c,s}$, indicator of activity
- $PEXP_{c,s}$, the Export Price
- $PINDICEXPEU_{c,s}$, Indicator of competing Prices
- $KNOW_{c,s}$ the national knowledge Stock
- $KNOW_{eu,s}$ the Global European knowledge Stock

Parameters Restrictions:

$$\begin{aligned}
 lexpeu1_s &> 0 \\
 lexpeu2_s &< 0 \\
 lexpeu3_s &> 0
 \end{aligned}$$

7.2.6.3 Extra European Trade

Extra European trade *vis-à-vis* of the rest of world (divided into ten exogenous areas), follows broadly the same formalisation than intra European Trade and includes therefore the same effects as described above.

Imports equations

The three main effects integrated in the trade equations are income and prices effects and non prices effects. For imports equations, these effects are taken into account with the following variables

- The income effect for a country is taken into account through a demand variable, represented by the demands addressed to the sector
- The price effect is represented by the ratio of the import price to the domestic price.
- the non price effect is taken into account through national R&D stock to the extra European zone R&D stock ratio

$$\begin{aligned}
 \ln(IMPROW_{c,s}) &= \limprow0_{c,s} \\
 &+ \limprow1_s \cdot \ln(ADDDEM_{c,s}) \\
 &+ \limprow2_s \cdot \ln\left(\frac{PIMPROW_{c,s}}{PPROD_{c,s}}\right) \\
 &+ \limprow3_s \cdot \ln\left(\frac{KNOW_{c,s}}{KNOW_{z,s}}\right)
 \end{aligned} \tag{7.2.23}$$

with :

- $ADDDEM_{c,s}$ Total domestic Demand by products
- $PIMPROW_{c,s}$ The Price of Imports for extra European imports
- $PPROD_{c,s}$ The production Price
- $KNOW_{c,s}$ the national knowledge Stock
- $KNOW_{z,s}$ the extra European zone knowledge Stock

Parameters Restrictions:

$$\limprow1_s > 0$$

$$\limprow2_s < 0$$

$$\limprow3_s < 0$$

Exports Equations

For exports equations, the incomes and prices effects are taken into account with the following variables

- The income effect for a country j is taken into account through a demand variable, resulting from the demands of partners countries, weighted past trade intensities (in a matrix form, for year 2000)
- The price effect is represented by the ratio of the export price to a non European price index, which is a weighted variable of other extra European zone export prices.

$$\begin{aligned}
 \ln(EXPROW_{c,s}) &= \lexprow0_{c,s} \\
 &+ \lexprow1_s \cdot \ln(INDACTROW_{c,s}) \\
 &+ \lexprow2_s \cdot \ln\left(\frac{PEXPROW_{c,s}}{PINDICEXPROW_{c,s}}\right) \\
 &+ \lexprow3_s \cdot \ln\left(\frac{KNOW_{c,s}}{KNOW_{z,s}}\right)
 \end{aligned} \tag{7.2.24}$$

- $INDACTROW_{c,s}$, indicator of activity
- $PEXPROW_{c,s}$, the Export Price

- $PINDICEXPROW_{c,s}$, Indicator of competing Prices
- $KNOW_{c,s}$ the national knowledge Stock
- $KNOW_{z,s}$ the extra European zone knowledge Stock

Parameters Restrictions:

$$lexprow1_s > 0$$

$$lexprow2_s < 0$$

$$lexprow3_s > 0$$

7.2.6.4 Imports and Exports prices

Exports and imports prices play a large role in determining trade volumes. the basic feature of trade prices in NEMESIS assume that European countries operate in oligopolistic markets, following this assumption, importers and exporters sets mark-ups on their prices taking others partners prices into account. As noted above, the lack of data regarding import and exports prices differentiated per trade partners, make that the distinction between Intra-European and Rest of the World distinction was not possible, however, in order to take into account for possible trade barriers between the EU and the rest of the world, we sets two different prices, the sole difference between the two prices lay precisely in the existing trade barriers (import duties...) that multiplies the global import and exports prices. Other partners prices are weighted in the same manner than for volume equations, exchange rates are directly taken into account in the European (making a clear distinction between intra and extra Euro zone) and ROW price index .

The majority of trade prices are treated in the same manner (with the notable exception of crude oil and gas, that are treated exogenously)

Export prices

$$\begin{aligned}
 \ln(PEXP_{c,s}) &= lpexp0_{c,s} \\
 &+ lpexp1_s \cdot \ln(PINDICEXPEU_{c,s}) \\
 &+ lpexp2_s \cdot \ln(PINDICEXPRW_{c,s}) \\
 &+ lpexp3_s \cdot \ln(PPROD_{c,s})
 \end{aligned}
 \tag{7.2.25}$$

- $PINDICEXPEU_{c,s}$, Price Index for competing Exports in Europe

- $PINDICEXPRW_{c,s}$, Price Index for competing Exports in the Rest of the World
- $PPROD_{c,s}$, Production Price

Parameters Restrictions:

$$lpexp1_s + lpexp2_s + lpexp3_s = 1$$

Import prices

$$\begin{aligned} \ln(PIMP_{c,s}) &= lpimp0_{c,s} \\ &+ lpimp1_s \cdot \ln(PINDICIMPEU_{c,s}) \\ &+ lpimp2_s \cdot \ln(PINDICIMPRW_{c,s}) \\ &+ lpimp3_s \cdot \ln(PPROD_{c,s}) \end{aligned} \tag{7.2.26}$$

- $PINDICIMPEU_{c,s}$, Price Index for competing Imports in Europe
- $PINDICIMPRW_{c,s}$, Price Index for competing Imports in the Rest of the World
- $PPROD$, Production Price

Parameters Restrictions:

$$lpimp1_s + lpimp2_s + lpimp3_s = 1$$

7.2.7 Wage setting

In section we will present the specification, the estimation and the implementation the NEMESIS labour market. Indeed, including labour skills in the model has implied to reformulate and to extend the labour market of NEMESIS. It allowed to look at the latest theoretical developments and to proceed to an econometric analysis at a disaggregated level. This section is organised as follows, we first analyse the theoretical issues and the consensus that has emerged in the last years, and then in a second part we will define the formalisation that will be implemented in the model. The third part is dedicated to the presentation of the data used in the econometric estimation that will be presented in the fourth part. Finally, we will present the functional form implemented in the NEMESIS model.

7.2.7.1 Theoretical overview

The formulation of wage process suffers from a lack of consensus arisen from a long and stormy history. Main empirical and theoretical controversy opposes proponents of the Philips curve (Philips 1958 [389]) to those of the WS-PS model (Layard *et al.* 1991 [326] and Cahuc and Zylberberg 1999 [69]). Philips curve is an empirical relation that highlights the negative relation between nominal wage and unemployment. It could be well represented by :

$$\Delta w = c + \Delta p^e - bU \quad (7.2.27)$$

All variables are expressed in logarithm except U which is express in level. Δw is the variation of nominal wage ($w - w_{-1}$), Δp^e is the expected inflation (it is equal to Δp if expectations are perfect) and is U the unemployment rate. Whereas Philips curve estimates well wage formation over the course of a business cycle, it suffers from a lack of theoretical foundation.

At the opposite, the WS-PS models are theoretical based but present some unrealistic assumptions about their key concepts. Almost all these models⁹ are founded on assumption that real wage fluctuates around a reservation wage which represents the income opportunity of employees outside the firm. Main models explain wage reservation by unemployment benefit, labour productivity, positive trend or lagged real wage. Recent literature (Chagny *et al.* 2002 [80] and Reynes 2006 [402]) rejects the theoretical underpinning of the first three explanations and retains the latter, leading to a Philips curve specification. Almost all theoretical models based of bargain model or efficiency wage can be represented as:

$$\tilde{w} = w - p = \tilde{w}^r + Z - bU \quad (7.2.28)$$

Where \tilde{w} is the real wage, \tilde{w}^r is the reservation wage and Z embodied all other variables that can explain wage formation (almost institutional variables). As highlight by Manning (1993 [349]), Blanchard and Katz (1999 [43]), if we consider reservation wage as the lagged real wage ($\tilde{w}^r = \tilde{w}_{-1} = w_{-1} - p_{-1}$), equation can be transformed into a Philips curve.

$$\Delta w = \Delta p + Z - bU \quad (7.2.29)$$

9. For instance efficiency wage model, matching model, competitive wage competition, etc.

In assuming that the reservation wage is the lagged wage, the Philips curve theoretical underpinnings are as valid as those of the WS setting. Chagny *et al.* (2002 [80]) and Reynes (2006 [402]) go farther in narrowing the empirical difference between the two approaches. Their models allows “*a clear distinction between medium run of equilibrium rate of unemployment (ERU) and the long run ERU*” which key differences between Philips curve and WS-PS models. Assuming that medium run wage formation is directed by :

$$\Delta w = Z + a\Delta p_{cons} - b_1 U - b_2(U - U_{-1}) + d\Delta\pi - f\Delta t_{cs} \quad (7.2.30)$$

In this specification, wage formations may be indexed on consumer price p_{cons} , hysteresis or not b_2 , depend of labour productivity π , employer’s social contribution t_{cs} and influenced by a pool of institutional variables Z .

The long run ERU is:

$$U_{ELR} = (Z - (1 - d)\Delta\pi - (1 - a)\Delta p^0)/b_1 \quad (7.2.31)$$

Where Δp^0 is the inflation target of the monetary authorities. U_{ELR} differs from the medium run (assume that $b_2 = 0$) by:

$$U_{EMR} = U_{ELR} + (w - w^d)/b_1 T \quad (7.2.32)$$

Where T is the number of quarter during which authorities are implicitly assumed to correct the unemployment gap.

7.2.7.2 The model

We extend the model developed by Chagny *et al.* (2002 [80]) and Reynes (2006 [402]) in order to estimates the wage formation. We transform equation 7.2.30 to take into account NEMESIS specificities. Since NEMESIS model is sectoral and integrates two kinds of labour (high skill and low skill). The equation retains is as following:

$$\Delta w_{i,l,c,t} = Z_{i,l,c} + a_{c,l}(L)\Delta p_{c,l,t} - b_{1,c,l}(L)U_{l,c,t} - b_{2,c,l}(L)(U_{l,c,t} - UT_{l,c,t}) \quad (7.2.33)$$

$$+d_{c,l}(L)\Delta\pi_{i,l,c,t} + \epsilon_{i,l,c,t}$$

Where

- $t = 1; \dots; 11$ is a time index ranging from $t = 1992$ to 2005 .
- c is a country index, $c = 1, \dots, 19$
- l corresponds to the labour qualification
- i is a sector index, $i = 2, \dots, 29$
- $Z_{i,l,c}$ represents institutional variables.

UT correspond to the long term unemployment rate. Due to lack of data, we limit our sample to nineteen countries (instead of 27) and twenty eight sectors (instead of 30). Institutional variables $Z_{i,l,c}$ are treated as country-sector fixed effect.

Box 7.2.7.2: Long run equilibrium rate of unemployment U_{ELR}

Recall the relevant wage setting equation:

$$\Delta w = Z + a\Delta p_{cons} - b_1 U - b_2(U - U_{-1}) + d\Delta\pi - f\Delta t_{cs} \quad (7.2.34)$$

Consider Δp^0 is the constraint inflation target of the monetary authorities. In the long run $\Delta t_{cs} = 0$, $U - U_{-1} = 0$ it follows:

$$\Delta w = Z + a\Delta p^0 - b_1 U + d\Delta\pi$$

The unemployment rate consistent with the target inflation rate and growth rate of labour productivity is:

$$\Delta w - \Delta p^0 = \Delta\pi = Z + (a - 1)\Delta p^0 - b_1 U + d\Delta\pi$$

We note the long run equilibrium rate of unemployment $U = U_{ELR}$.

$$U_{ELR} = (Z - (1 - d)\Delta\pi - (1 - a)\Delta p^0)/b_1 \quad (7.2.35)$$

7.2.7.3 Data

Wage

Unfortunately, there is no data available for $w_{i,l,c}$ (or $\Delta w_{i,l,c}$), which make the distinction between different kinds of labour. By definition, the variation of wage equal variation of labour compensation and variation of employer's social contribution rate, *i.e.* $\Delta w_{i,l,c} = \Delta Comp_{i,l,c} + \Delta t_{cs,i,l,c}$ with $Comp_{i,l,c}$ the

labour compensation. Under hypothesis that $\Delta t_{cs,i,l,c} = 0$, wage variation equal labour compensation variation, which is available in the EU KLEMS database (2009 [193]). $Comp_{i,l,c}$ is built as follows:

$$Comp_{HS} = \frac{COMP * \frac{LABHS}{100}}{HEMPE * \frac{HHS}{100}}$$

Where $HEMPE$ is the total hours worked by employees (in million), $COMP$ the compensation of employees (in million euros), $LABHS$ the high-skilled labour compensation (share in total labour compensation) and HHS the hours worked by high-skilled persons engaged (share in total hours). $Comp_{HS}$ is thus the hours labour compensation for high skill workers. Same method is used for the low skill compensation.

Unemployment

$U_{l,c}$ is the unemployment rate, obviously unemployment rate is not defined by sector. Data come from Eurostat (2009 [207]), we use set called “Unemployment rates by sex, age groups and highest level of education attained (%)”. We retain as “age groups”, the 15-64 years old. We convert the International Standard Classification of Education (ISCE) into low and high skill classification.

Price

$pc_{l,c}$ comes from the OECD database (2009 [370]) “Consumer price indexes” for all countries except for Slovenia. Since database was not available for Slovenia, we used Eurostat (2009 [205]) prices (with lower time coverage).

Labour productivity

$\pi_{i,l,c}$ is the “seeming” labour productivity. It is calculated as usual way, *i.e.* national GDP divided by number of hours worked ($\pi_{Hs} = \frac{GOQI}{HEMPE * \frac{HHS}{100}}$ for unskilled labour and $\pi_{Ls} = \frac{GOQI}{HEMPE * (1 - \frac{HHS}{100})}$ for skilled labour). $GOQI$ is also taken from the EU KLEMS database (2009 [193]).

7.2.7.4 Results

In order to highlight the difference between macro-economic and the sectoral view, we implement two set of regression. First set is made at the macro-economic level, while second set is made with sectoral specifications. To deal with error auto-correlation we use an first order auto-regressive model AR(1).

Macro

The estimated equation at macro-economic level is based on equation 7.2.33:

$$\Delta w_{l,c,t} = Z_{l,c} + a_{c,l}\Delta pc_{l,c,t} - b_{1,c,l}U - b_{2,c,l}(U_{l,c,t} - UT_{l,c,t}) + d_{c,l}\Delta\pi_{l,c,t} + \epsilon_{l,c,t} \quad (7.2.36)$$

With the macro-economic estimate, we proceed to two estimates either supposing the absence of hysteresis phenomena ($b_2 = 0$) or assuming its existence. Figure 7.2.6 displays the results for estimates with hysteresis which are relatively very disparate among MS. The R^2 are generally good, mainly ranges between 0.5 and 0.9. Looking at coefficients signs, numerous of them are goods i.e. $a_{c,l} > 0, b_{i,c,l} > 0$

Firstly, we presume the non existence of hysteresis phenomena, in that case, we constraint $b_2 = 0$. Results of macro-economic estimates without hysteresis hypothesis are given in figure 7.2.6. In a second step, we test hysteresis phenomena existence, the results are given in figure 7.2.7. Results of first estimation present expected signs for coefficient for twenty on thirty eight estimates (sample including 19 countries with two labour markets leading to 38 estimates). Six countries (Germany, France, Ireland, Netherlands, Hungary and Slovenia) provide expected sign for both markets. In some case, parameter values exceed the unity, it arises only for high skill market (except in Hungary). Price and unemployment seem to play a more important role for high skill wage, at the opposite productivity has a stronger effect on low skill wage. Figure 7.2.7 presents estimates for the model with hysteresis. Most of the results are in the opposite sign than expected one, thereby, we reject this modelling.

Figure 7.2.6: Estimates results with macro-economic model without hysteresis

PriceUnempProductivityR-Sqr							PriceUnempProductivityR-Sqr						
AT	LS	coef	0.0477	-0.0714	0.7007	0.6918	PT	LS	coef	0.1107	-0.6166	0.9314	0.5563
		ppvalue	0.8762	0.8837	0.0000				ppvalue	0.8175	0.1616	0.0285	
	HS	coef	-0.6613	-2.9676	0.5912	0.3979		HS	coef	0.2184	0.2398	0.4271	0.7999
		ppvalue	0.4824	0.0581	0.0788				ppvalue	0.5428	0.6083	0.0000	
BE	LS	coef	-0.0487	-0.4167	0.2245	0.2968	SP	LS	coef	1.8980	-0.0632	-0.2876	0.6502
		ppvalue	0.9393	0.1710	0.2851				ppvalue	0.0000	0.4920	0.3349	
	HS	coef	1.4574	0.3724	0.2214	0.3258		HS	coef	1.3353	0.0350	0.5003	0.7616
		ppvalue	0.0216	0.5560	0.2628				ppvalue	0.0000	0.6190	0.0074	
DK	LS	coef	0.0510	-0.1117	0.3014	0.2678	SW	LS	coef	2.6433	0.3912	1.0081	0.4107
		ppvalue	0.9175	0.2287	0.0453				ppvalue	0.0000	0.0093	0.0017	
	HS	coef	-1.6667	-0.5135	0.4720	0.5555		HS	coef	-1.1596	-2.3396	0.1713	0.3084
		ppvalue	0.0675	0.4608	0.0262				ppvalue	0.2694	0.0455	0.2443	
GE	LS	coef	0.8148	-0.7152	0.4638	0.8952	UK	LS	coef	1.0158	-0.9912	0.7682	0.7078
		ppvalue	0.0000	0.0000	0.0167				ppvalue	0.0354	0.0000	0.0005	
	HS	coef	1.3731	-1.0122	0.1458	0.7359		HS	coef	-1.1548	1.2985	-0.3765	0.2130
		ppvalue	0.0000	0.1991	0.1796				ppvalue	0.4818	0.2907	0.1881	
FI	LS	coef	0.3766	0.0214	-0.1985	0.1980	CZ	LS	coef	-0.0631	-1.0785	0.7738	0.9142
		ppvalue	0.3669	0.8742	0.6332				ppvalue	0.6524	0.0031	0.0000	
	HS	coef	0.5096	-0.1268	0.4920	0.4785		HS	coef	-0.0594	-0.5032	0.8702	0.6717
		ppvalue	0.1423	0.6218	0.0012				ppvalue	0.8301	0.8492	0.0238	
FR	LS	coef	0.1579	-0.6356	0.3497	0.6603	HU	LS	coef	1.5851	-3.5976	0.6434	0.5709
		ppvalue	0.8315	0.0000	0.2098				ppvalue	0.0035	0.0249	0.3900	
	HS	coef	0.1383	-0.1872	0.0310	0.0241		HS	coef	0.2288	-1.8078	0.8476	0.9117
		ppvalue	0.9219	0.8340	0.9203				ppvalue	0.1638	0.1331	0.0000	
GR	LS	coef	0.9144	0.5793	0.5839	0.6431	PL	LS	coef	1.9406	0.5375	0.0777	0.9723
		ppvalue	0.0001	0.4053	0.0058				ppvalue	0.0000	0.0994	0.8260	
	HS	coef	0.5381	-3.1910	0.6023	0.7079		HS	coef	2.3618	1.3036	-0.5984	0.9146
		ppvalue	0.0430	0.0079	0.0005				ppvalue	0.0000	0.0442	0.0410	
IR	LS	coef	0.2439	-0.1753	0.1803	0.7306	SN	LS	coef	0.6915	-0.9806	-0.5731	0.7700
		ppvalue	0.2383	0.0001	0.0268				ppvalue	0.0000	0.0062	0.0012	
	HS	coef	0.4315	-0.0172	0.5348	0.7195		HS	coef	1.1691	-1.7181	0.2509	0.9538
		ppvalue	0.4664	0.9749	0.0000				ppvalue	0.0000	0.1525	0.0000	
IT	LS	coef	0.9901	-0.2314	0.0057	0.5103	SK	LS	coef	0.2240	0.4844	0.8950	0.9019
		ppvalue	0.0001	0.3106	0.9828				ppvalue	0.0636	0.0005	0.0000	
	HS	coef	1.0167	-0.5824	-0.1487	0.2161		HS	coef	1.0592	-2.3690	-0.4007	0.6665
		ppvalue	0.2583	0.4203	0.7663				ppvalue	0.0001	0.1105	0.1337	
NL	LS	coef	0.3749	-0.6084	0.0023	0.8267							
		ppvalue	0.5684	0.0000	0.9943								
	HS	coef	0.7217	-1.5991	0.1242	0.7716							
		ppvalue	0.2133	0.0017	0.0380								

Figure 7.2.7: Estimates results with macro-economic model with hysteresis

			Price	Unemp	hysteresis	Productivity	R-Sqr				Price	Unemp	hysteresis	Productivity	R-Sqr
AT	LS	coef	-0.4624	2.7210	-5.2604	0.3926	0.9120	PT	LS	coef	0.8739	1.2093	-3.8869	0.8413	0.7705
		ppvalue	0.0006	0.0000	0.4170	0.0000				ppvalue	0.0179	0.0471	0.8131	0.0093	
	HS	coef	-1.1275	-3.6893	3.5209	0.3267	0.5434		HS	coef	0.1882	0.3385	-0.1755	0.4299	0.8005
		ppvalue	0.1281	0.0547	0.4170	0.1674				ppvalue	0.6254	0.5900	0.8131	0.0000	
BE	LS	coef	0.0479	-0.2162	-0.3487	0.1823	0.1135	SP	LS	coef	0.6790	0.0710	-0.2255	0.2888	0.4286
		ppvalue	0.9469	0.6835	0.0462	0.4457				ppvalue	0.0271	0.1282	0.1765	0.2355	
	HS	coef	1.0120	-0.6671	2.7429	0.3124	0.5472		HS	coef	0.6980	-0.0492	0.2862	0.2443	0.6800
		ppvalue	0.0224	0.4201	0.0462	0.0283				ppvalue	0.0055	0.4289	0.1765	0.1000	
DK	LS	coef	-0.5242	-0.1926	-0.4855	0.4044	0.3615	SW	LS	coef	2.4608	0.4159	-0.3036	0.9579	0.4475
		ppvalue	0.3978	0.1072	0.0020	0.0161				ppvalue	0.0000	0.0039	0.1192	0.0021	
	HS	coef	-1.1985	-2.1776	2.5093	0.2551	0.6898		HS	coef	-0.1250	-1.4346	0.5531	0.1349	0.4315
		ppvalue	0.0945	0.0000	0.0020	0.0912				ppvalue	0.9154	0.2338	0.1192	0.2609	
GE	LS	coef	0.2927	-0.8863	0.5567	0.3831	0.8729	UK	LS	coef	1.1061	-1.0319	1.2789	0.6972	0.7231
		ppvalue	0.1660	0.0000	0.0831	0.0154				ppvalue	0.1375	0.0000	0.1897	0.0056	
	HS	coef	1.1690	-0.0820	-1.5900	0.0767	0.6416		HS	coef	-1.3732	1.4573	-0.5499	-0.3509	0.5439
		ppvalue	0.0079	0.5832	0.0831	0.4857				ppvalue	0.7229	0.2817	0.1897	0.7653	
FI	LS	coef	0.6529	-0.1547	0.4104	-0.0463	0.5087	CZ	LS	coef	-0.0718	-1.0733	0.0268	0.7761	0.9141
		ppvalue	0.0429	0.1830	0.0220	0.8865				ppvalue	0.7538	0.0047	0.1224	0.0000	
	HS	coef	0.4702	-0.7266	-0.8556	0.7411	0.6499		HS	coef	-0.5777	4.0425	-1.3438	1.2693	0.7358
		ppvalue	0.0527	0.0150	0.0220	0.0000				ppvalue	0.1335	0.2873	0.1224	0.0025	
FR	LS	coef	0.0879	-0.2914	-1.2354	0.0394	0.7743	HU	LS	coef	2.4819	-6.9728	3.4944	0.3472	0.7070
		ppvalue	0.8742	0.0806	0.6680	0.8679				ppvalue	0.0005	0.0033	0.8825	0.5838	
	HS	coef	-0.0923	-0.1443	-0.2412	0.0894	0.0368		HS	coef	0.2051	-1.8097	-0.0592	0.8446	0.9117
		ppvalue	0.9469	0.8628	0.6680	0.7969				ppvalue	0.3657	0.1310	0.8825	0.0000	
GR	LS	coef	1.0740	1.0818	-0.8222	0.5902	0.6479	PL	LS	coef	1.5862	0.1679	0.2880	0.3522	0.9743
		ppvalue	0.0196	0.4466	0.0089	0.0053				ppvalue	0.0024	0.7593	0.4190	0.4581	
	HS	coef	-0.4609	-7.8735	7.0931	0.5405	0.7472		HS	coef	2.8378	1.5823	0.7061	-0.8087	0.9203
		ppvalue	0.2833	0.0001	0.0089	0.0001				ppvalue	0.0001	0.0257	0.4190	0.0314	
IR	LS	coef	0.3284	-0.1352	-0.1097	0.0708	0.5817	SN	LS	coef	1.0693	-3.1589	4.4658	-0.5313	0.8617
		ppvalue	0.1634	0.0288	0.0000	0.6043				ppvalue	0.0000	0.0029	0.2944	0.0001	
	HS	coef	1.0688	-0.0314	3.5710	0.5663	0.8908		HS	coef	1.3243	-4.2582	5.0984	0.2362	0.9585
		ppvalue	0.0020	0.0955	0.0000	0.0000				ppvalue	0.0000	0.0982	0.2944	0.0000	
IT	LS	coef	1.0936	-0.2445	0.1490	-0.0814	0.4660	SK	LS	coef	0.1470	0.6390	0.3313	0.8759	0.9405
		ppvalue	0.0106	0.4459	0.7543	0.7895				ppvalue	0.1256	0.0000	0.0000	0.0000	
	HS	coef	1.7823	-0.4850	-0.9335	-0.2785	0.3009		HS	coef	1.4008	-7.7192	2.3163	-0.9576	0.8752
		ppvalue	0.2435	0.7036	0.7543	0.6372				ppvalue	0.0000	0.0000	0.0000	0.0000	
NL	LS	coef	-0.1956	-0.7532	-0.4514	-0.0351	0.9135								
		ppvalue	0.6874	0.0000	0.0000	0.8708									
	HS	coef	0.5252	-1.0259	1.0860	0.1203	0.8767								
		ppvalue	0.2040	0.0429	0.0000	0.0000									

Sectoral results

The estimated equation at sectoral level is also based on equation 7.2.33, but including sectoral parameters for labour compensation and productivity.

$$\Delta w_{i,l,c,t} = Z_{i,l,c} + a_{c,l} \Delta pc_{l,c,t} - b_{1,c,l} U_{l,c,t} - b_{2,c,l} (U_{l,c,t} - UT_{l,c,t}) + d_{c,l} \Delta \pi_{i,l,c,t} + \epsilon_{i,l,c,t} \quad (7.2.37)$$

Results for the sectoral model are given in figure 7.2.8 for the case without hysteresis phenomena ($b_2 = 0$) and in figure 7.2.9 with hysteresis. First set of results (figure 7.2.8) presents expected coefficient sign for twenty parameters on thirty eight. Eight equations, for which we find non expected value, are the same than in first regression (high skill: Austria and Poland, low skill: Belgium and Slovakia and both: Finland and Sweden). Figure 7.2.9 presents estimates for the model with hysteresis but as most of the results are not conform with expected sign, we decide to the sectoral model with hysteresis.

Figure 7.2.8: Estimates results with sectoral model without hysteresis

PriceUnempProductivityR-Sqr								PriceUnempProductivityR-Sqr						
AT	LS	coef	-0.5200	-1.0821	0.1101	0.3492	PT	LS	coef	0.0577	0.5775	0.2132	0.1970	
		ppvalue	0.0633	0.0047	0.0000				ppvalue	0.8255	0.0047	0.0000		
	HS	coef	-1.3575	-1.8635	0.0287	0.2216		HS	coef	0.2829	-0.3934	0.0811	0.1192	
		ppvalue	0.0000	0.0001	0.0005				ppvalue	0.3805	0.3169	0.0027		
BE	LS	coef	-0.4113	-0.4164	0.0783	0.0869	SP	LS	coef	1.2654	-0.0226	0.3024	0.2878	
		ppvalue	0.4308	0.0227	0.0145				ppvalue	0.0000	0.6506	0.0000		
	HS	coef	0.0771	0.0463	0.0618	0.0729		HS	coef	1.8802	-0.0575	0.1358	0.2393	
		ppvalue	0.8715	0.9273	0.0534				ppvalue	0.0000	0.4682	0.0000		
DK	LS	coef	-0.1954	-0.1675	0.1085	0.1731	SW	LS	coef	0.4726	0.0328	0.0877	0.1114	
		ppvalue	0.5630	0.0080	0.0000				ppvalue	0.0384	0.6505	0.0333		
	HS	coef	0.4469	-0.2810	0.0735	0.1035		HS	coef	-0.5553	-0.8137	0.1597	0.2545	
		ppvalue	0.5034	0.4264	0.0010				ppvalue	0.1097	0.0420	0.0000		
GE	LS	coef	0.9118	-0.9645	0.0374	0.2696	UK	LS	coef	1.0776	-0.6548	0.5388	0.3883	
		ppvalue	0.0002	0.0000	0.2070				ppvalue	0.1099	0.0083	0.0000		
	HS	coef	1.5567	-0.8940	0.1062	0.2560		HS	coef	4.5039	-2.4107	0.3537	0.2513	
		ppvalue	0.0000	0.0835	0.0005				ppvalue	0.0000	0.0007	0.0000		
FI	LS	coef	1.1393	0.3521	0.1558	0.4154	CZ	LS	coef	0.2528	-0.6263	0.0923	0.3570	
		ppvalue	0.0056	0.0094	0.0000				ppvalue	0.0032	0.0128	0.0002		
	HS	coef	1.0049	0.7706	0.2049	0.3827		HS	coef	0.6694	-3.2168	0.0204	0.3247	
		ppvalue	0.0202	0.0112	0.0000				ppvalue	0.0000	0.0000	0.4919		
FR	LS	coef	0.2512	-0.5685	0.3433	0.2831	HU	LS	coef	-0.8741	2.9175	0.7397	0.5137	
		ppvalue	0.7113	0.0049	0.0000				ppvalue	0.0100	0.0055	0.0000		
	HS	coef	-0.7576	0.6074	0.1391	0.1476		HS	coef	1.2787	-37.0817	0.4853	0.6830	
		ppvalue	0.4022	0.2310	0.0024				ppvalue	0.0000	0.0000	0.0000		
GR	LS	coef	0.7796	-0.5481	0.1442	0.1989	PL	LS	coef	1.4466	-0.3764	0.4871	0.4149	
		ppvalue	0.0003	0.4290	0.0000				ppvalue	0.0000	0.2810	0.0000		
	HS	coef	0.9360	-0.7548	0.1257	0.2093		HS	coef	1.3613	0.1363	0.2170	0.3495	
		ppvalue	0.0000	0.4534	0.0000				ppvalue	0.0000	0.8491	0.0032		
IR	LS	coef	0.1313	-0.0053	0.1867	0.1857	SN	LS	coef	0.4546	-1.8042	0.0648	0.2119	
		ppvalue	0.7885	0.9662	0.0000				ppvalue	0.0476	0.0004	0.1165		
	HS	coef	-0.4600	-0.3871	0.1359	0.1409		HS	coef	0.5469	-2.4502	0.3659	0.5804	
		ppvalue	0.4104	0.3448	0.0003				ppvalue	0.2653	0.1544	0.0000		
IT	LS	coef	0.9797	-0.2303	0.2298	0.3824	SK	LS	coef	-0.0257	0.0824	0.0784	0.2122	
		ppvalue	0.0000	0.0273	0.0000				ppvalue	0.8808	0.6728	0.0015		
	HS	coef	0.8596	-0.1996	0.2282	0.6127		HS	coef	1.2434	-1.5130	0.0998	0.3468	
		ppvalue	0.0000	0.2422	0.0000				ppvalue	0.0000	0.0172	0.0000		
NL	LS	coef	-0.7003	-0.8834	0.1650	0.2283								
		ppvalue	0.0437	0.0000	0.0054									
	HS	coef	1.2018	-0.0849	0.3176	0.4512								
		ppvalue	0.0007	0.7598	0.0000									

Figure 7.2.9: Estimates results with sectoral model without hysteresis

PriceUnemphysteresisProductivityR-Sqr									PriceUnemphysteresisProductivityR-Sqr							
AT	LS	coef	-0.2565	2.2952	-2.0970	0.1087	0.4080	PT	LS	coef	0.6892	1.4581	-1.1335	0.2146	0.2644	
		ppvalue	0.3622	0.0227	0.0010	0.0000	ppvalue			0.2643	0.0000	0.0001	0.0000			
	HS	coef	-1.6372	-2.4262	0.4904	0.0306	0.2672		HS	coef	-0.2086	-1.1159	0.6733	0.1095	0.1307	
		ppvalue	0.0000	0.0149	0.5593	0.0003	ppvalue			0.8371	0.5034	0.6600	0.0007			
BE	LS	coef	-1.2926	-0.6538	0.1167	0.0298	0.1349	SP	LS	coef	0.1097	-0.0373	0.0551	0.3433	0.2913	
		ppvalue	0.0360	0.0014	0.5249	0.3281	ppvalue			0.7861	0.5311	0.6917	0.0000			
	HS	coef	-0.5708	-1.3201	1.6973	0.0262	0.1332		HS	coef	0.3739	-0.0590	0.0468	0.1467	0.2016	
		ppvalue	0.3070	0.0636	0.0016	0.3896	ppvalue			0.4429	0.5706	0.8227	0.0000			
DK	LS	coef	0.3799	0.1713	0.5229	0.0946	0.2432	SW	LS	coef	0.5032	0.0928	-0.1553	0.0984	0.1222	
		ppvalue	0.3658	0.3377	0.0016	0.0000	ppvalue			0.0300	0.2447	0.0825	0.0172			
	HS	coef	-0.7539	-1.6231	1.4622	0.0278	0.1739		HS	coef	0.1443	-0.3354	0.3620	0.1608	0.2866	
		ppvalue	0.2374	0.0002	0.0000	0.2584	ppvalue			0.7166	0.4243	0.0017	0.0000			
GE	LS	coef	-0.2210	-1.4635	0.5783	0.0398	0.1648	UK	LS	coef	0.0589	-0.8987	-0.9104	0.4611	0.4251	
		ppvalue	0.7714	0.0071	0.2271	0.2352	ppvalue			0.9673	0.1486	0.3616	0.0000			
	HS	coef	0.3844	-1.3269	0.0815	0.1090	0.1634		HS	coef	-4.5977	1.9532	1.8325	0.3871	0.4174	
		ppvalue	0.6537	0.1591	0.9164	0.0023	ppvalue			0.0925	0.3402	0.1573	0.0000			
FI	LS	coef	1.2956	0.3093	0.1697	0.1557	0.4183	CZ	LS	coef	0.7376	-0.1540	-0.7594	0.0538	0.4071	
		ppvalue	0.0029	0.0280	0.2759	0.0000	ppvalue			0.0000	0.5526	0.0000	0.0413			
	HS	coef	1.1853	1.0952	0.4815	0.2038	0.3864		HS	coef	0.7952	-4.3230	0.5324	0.0159	0.3320	
		ppvalue	0.0093	0.0070	0.2325	0.0000	ppvalue			0.0000	0.0000	0.1303	0.5927			
FR	LS	coef	0.1295	-0.4721	-0.2961	0.3635	0.3241	HU	LS	coef	-0.7600	2.4435	0.4679	0.7374	0.5142	
		ppvalue	0.8788	0.1658	0.4660	0.0000	ppvalue			0.0623	0.0821	0.6119	0.0000			
	HS	coef	2.5046	3.2327	-4.7328	0.1614	0.3165		HS	coef	0.9489	-37.0884	-0.8311	0.4754	0.6844	
		ppvalue	0.0269	0.0000	0.0000	0.0003	ppvalue			0.0524	0.0000	0.4488	0.0000			
GR	LS	coef	0.1777	-0.9786	0.0977	0.1150	0.1375	PL	LS	coef	1.3407	-0.4893	0.1336	0.4921	0.4153	
		ppvalue	0.7258	0.4211	0.9048	0.0001	ppvalue			0.0035	0.3026	0.7256	0.0000			
	HS	coef	0.5251	-0.6858	-1.0864	0.1012	0.1499		HS	coef	1.3598	0.1375	-0.0054	0.2172	0.3495	
		ppvalue	0.3530	0.7464	0.3975	0.0004	ppvalue			0.0001	0.8501	0.9923	0.0041			
IR	LS	coef	0.4770	0.1682	0.0396	0.1639	0.1728	SN	LS	coef	-0.2707	1.2314	-2.9437	0.0660	0.2253	
		ppvalue	0.3894	0.3801	0.8824	0.0000	ppvalue			0.5280	0.4435	0.0469	0.1050			
	HS	coef	-0.2310	-0.6063	-0.9234	0.1341	0.1410		HS	coef	0.2066	4.4386	-6.7014	0.3506	0.5964	
		ppvalue	0.7201	0.4192	0.1683	0.0015	ppvalue			0.6711	0.1158	0.0032	0.0000			
IT	LS	coef	1.1680	-0.3385	0.2518	0.1350	0.3878	SK	LS	coef	-0.1635	0.1565	0.1913	0.0794	0.2160	
		ppvalue	0.0000	0.0773	0.3888	0.0130	ppvalue			0.4666	0.4551	0.3443	0.0012			
	HS	coef	1.2112	-0.4341	0.1256	0.1587	0.6052		HS	coef	1.3898	-0.2223	-0.7918	0.0988	0.3504	
		ppvalue	0.0000	0.1489	0.7479	0.0075	ppvalue			0.0000	0.8720	0.2913	0.0000			
NL	LS	coef	-0.1213	-0.7336	0.3645	0.1893	0.2612									
		ppvalue	0.7575	0.0000	0.0030	0.0012										
	HS	coef	1.0216	-0.6281	-0.6814	0.2982	0.4928									
		ppvalue	0.0031	0.0352	0.0001	0.0000										

Summary

Table 7.2.8 presents aggregated results for models 7.2.36 and 7.2.37 without hysteresis hypothesis. Price seems to play a more important role for high skill wage. Unemployment has a same effect for both kinds of labour and productivity has a stronger effect on low skill wage. Comparing results with macro-economic and sectoral models, parameters are higher for price and unemployment with the sectoral model but lower for productivity.

Table 7.2.8: Summary of results

		Model 7.2.36 with $b_2 = 0$			Model 7.2.37 with $b_2 = 0$		
		Price	Unemployment	Productivity	Price	Unemployment	Productivity
LS	parameter	0.42 (-0.32)	-0.46 (0.33)	0.41 (0.19)	0.76 (0.46)	-0.58 (0.52)	0.24 (0.17)
HS	parameter	0.69 (0.43)	-1.34 (1.09)	0.29 (0.37)	1.05 (0.54)	-0.52 (0.50)	0.15 (0.08)

Standard errors in brackets

7.2.8 Taxation and subsidies

7.2.8.1 Institutional sectors accounts

The main data source was the Eurostat Annual sector accounts (2009 [206]), completed if necessary by national sources (mainly for Luxembourg, Denmark and Norway). The data availability for some countries (Ireland, Luxembourg, Hungary, Malta, Slovenia and Romania) were too weak to construct agents account for them, but main taxes and subsidies were integrated. All data and the sequence of accounts follows the European accounting framework ESA95¹⁰. The different institutional sectors distinguish General Government (GG), Households and Non-Profit Institutions Serving Households (HNPIISH), Financial Corporations (FC), Non-Financial Corporations (NFC), all of which are of course linked to the sectoral nomenclature of the model. The split of households and NPISH's was not possible for most countries, so it had been decided not to separate them for the moment, this will be done as soon as data will be available. This huge database has been checked (aggregations, paid/received...) completely and corrected if errors were encountered. Agents accounts are implemented from the production account up to the Acquisition of non financial assets account (*i.e.* up to the b9 Net lending (+) /net borrowing (-)).

10. ESA: European System of Accounts

7.2.8.2 Public finances

The main taxes and subsidies considered are:

Taxes on production and imports (D.2)

- Taxes on products (D.21)
 - value added type taxes (D.211)
 - Taxes and duties on imports excluding VAT (D.212)
 - Taxes on products, except VAT and import taxes (D.214)
 - Excises duties and consumption taxes (D.214a)
 - Mineral oil
 - Alcoholic beverage
 - Tobacco
 - Electricity
 - Non alcoholic beverages
 - ...
 - Other taxes on products (D214-D214a)
- Other taxes on production (D.29)

Subsidies (D.3)

- Subsidies on products (D.31)
- Other subsidies on production (D.39)

Current taxes on income, wealth, etc. (D.5)

- Taxes on income (D.51)
- Other current taxes (D.59)

Social Contributions (D.61)

- Actual social contributions (D.611)

- Employer’s actual social contributions (D.6111)
- Employees social contributions (D.6112)
- Social contributions by self and non-employed persons (D.6113)
- Imputed social contributions (D.612)

Capital Transfers (D.9)

- Capital Taxes (D.91)
- Investment Grants (D.92)

7.2.8.3 Focus on most important taxation system

We will focus here on the main important taxation part of the model. The main difficulties in sectoral applied modelling is to apply the right taxation rate and/or subsidy to the right sector. For a part of the taxation system, some information are available in the EUROSTAT databases, while for others some assumptions had been made.

Value added type taxes (D.211)

The VAT is probably the most difficult tax to be implemented in a model such as NEMESIS. Firstly, if we consider the databases needed the available information on VAT particularities is often too detailed for modelling as on one side the sectoral disaggregation of the model allow a strict differentiation of the different VAT rates applicable to the different products and services, but on the other side, calculating VAT rates applicable to one sector based on actual rates is fastidious and need numerous assumptions concerning the sharing of each rate in the same sector, taking into account existing exemptions and therefore complicate more the linking of the sectoral taxation system up to the macro-economic one. Secondly, considering the formalisation in itself, the traditional framework in applied modelling for integrating VAT, is to calculate implicit tax rates for each sector, with the drawback that for analysing the consequences of the modification of one VAT rate, the implicit rate has to be recalculated *ex-ante* with all errors that it may imply. In the NEMESIS model the implicit VAT rate is fully modelled flowing from the actual VAT rates up to the product/sector implicit rate. The implicit rate is thus the result of linear combination of the different rates (0 rate, super reduced rate, reduced rate 1, reduced rate 2, normal rate and the parking rate) and of the different shares of each products in the consumption. The main information sources for building the data needed are furnished by the European Commission

Directorate-General for Taxation and Customs Union. For calculating final consumption VAT rates as precisely as possible, the most disaggregated data of the COICOP nomenclature were used. Starting from this the VAT bloc is composed of three components:

1. The actual VAT rates series for the period 1980-2007, for all European countries.
2. The share for each COICOP three digit category of the different rates applied
3. Finally coefficients allowing to flow from the COICOP three digit nomenclature to the NEMESIS one

Hence, our final implicit VAT rate is the linear combination of these three databases (the example shown below is for the NEMESIS Medical Care category):

$$\begin{aligned}
 TVAIMP^{medcar} &= shpmed_c \cdot \sum_T \alpha_{T,c}^{pmed} \cdot T \\
 &+ shecons_c \cdot \sum_T \alpha_{T,c}^{econ} \cdot T \\
 &+ shhosp_c \cdot \sum_T \alpha_{T,c}^{hosp} \cdot T
 \end{aligned} \tag{7.2.38}$$

With:

- $shpmed$, $shecons$ and $shhosp$, respectively the share of the COICOP three digit “medical products and apparel”, “external consultation” and “hospital services” categories in the Medical care category of NEMESIS
- $T = T0, TSR, TR1, TR2, TN, TP$, the different existing rates, 0 rate, super reduced rate, reduced rate(s) (sometimes two rates), normal rate and the parking rate.
- $\alpha_{T,c}^{pmed}$, the share of the $pmed$ category to which we apply the rate T in country c .

Taxes on products, except VAT and import taxes (D.214)

These taxes were split into two broad taxes, Excises duties and consumption taxes (D214a) on one part, and other taxes on products (D214-D214a) on the other part. The distinction between the different excises duties and their allocation between the sectors were made possible using DG taxation and custom Union information (2008 [127]). The same database was used for allocating the rest of Taxes on products, except VAT and import taxes. Hence, aside the three main Excises duties (alcoholic beverages, tobacco and mineral oil), some countries have other excises duties (electricity, non alcoholic beverage...), all of which had been incorporated in the model.

Social contributions

Employers social contribution (D6111) are split into sectors using the sectoral data on D11 wage and salaries and D1 Compensation of employees that are available on Eurostat, employees social contribution (D6112) as well as imputed social contribution (D612) are split between sectors depending on relative compensation of employees as no other data were available, while Social contributions by self and non-employed persons (D6113) are calculated only at the macroeconomic level, the figures 7.2.10 and 7.2.11 sums up the functioning of the social contribution bloc. Then, each type of social contribution is allocated to institutional sectors account (Gov: general government, FC: financial corporations, NFC, Non Financial corporations, H&NPISH: Households and non profit institutions serving households) through fixed shares.

Figure 7.2.10: Social Contribution paid

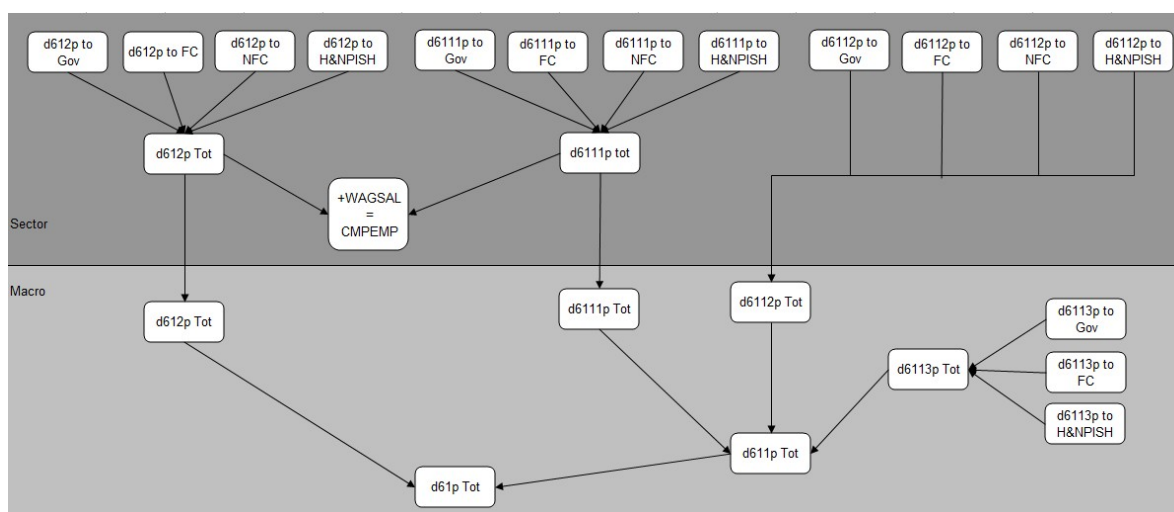
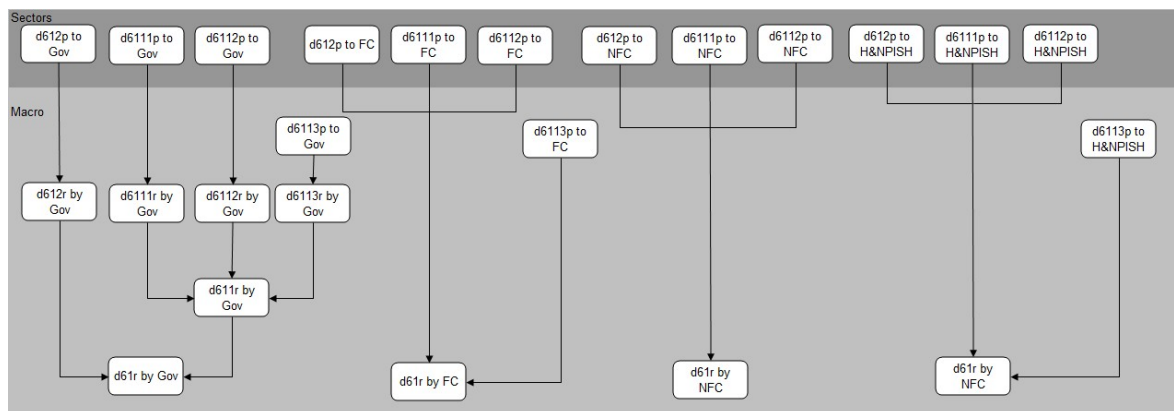


Figure 7.2.11: Social Contribution received



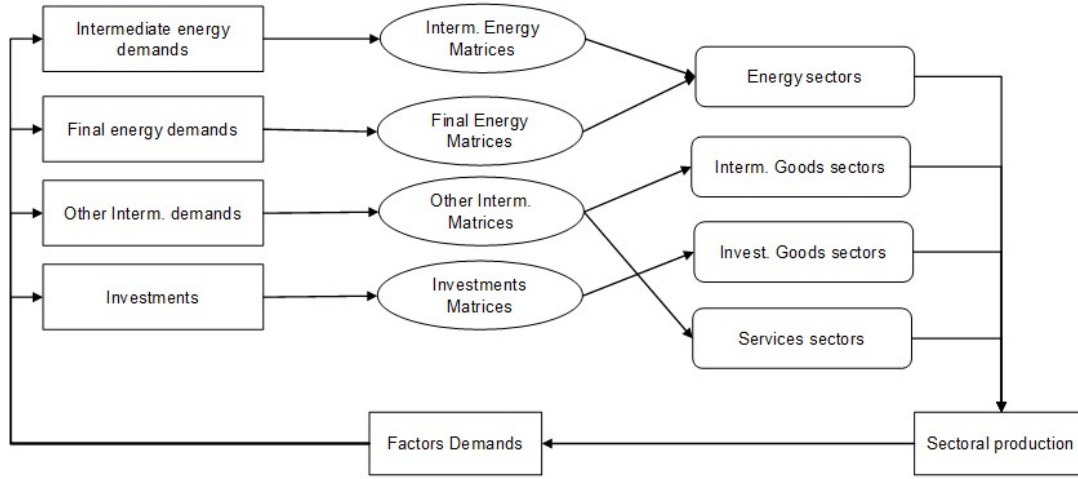
7.2.9 Sectoral Interdependencies

In sectoral detailed models, macroeconomic dynamics is driven by sectoral ones, the mix between 32 production sectors will describe the strength and weaknesses of each European economy modelled, and hence will describe their respective macroeconomic results in terms of economic growth, employment, etc. Therefore, interlinks between sectors are an important part of the model scheme as they will reflect the different sectoral tendencies either in short/medium term or long term.

7.2.9.1 Demand flows to products

Each sector, in order to produce a certain quantity of its product (supposed to be homogeneous), needs production factors: the five factors described in NEMESIS are employments (high and low skills), intermediate energy demands, final energy demands, materials demands and investments. A sixth factor could be added, even if it is not directly treated as a pure production factor, this is the Research and Development (R&D) expenditures. In the NEMESIS model, sectoral interdependencies are handled through energy demands (intermediate and final), materials demands, investment demands, and through R&D rent and knowledge spillovers (that will be explained separately). Each of those factor demands is addressed to other sectors and even the demanding sector (reflecting the intra-branch consumption). These interactions are presented in figure 7.2.12 below.

Figure 7.2.12: Sectoral interdependencies in NEMESIS



These interactions between the sectors are threatened in two ways in the NEMESIS model depending on the simulations runs term. In the short/medium term, one can consider that substitutions between products are rather weak, as input substitution often requires changes in the production process (employees formation, capital structure,...) thus matrix are considered to be fixed and the demands are formulated as:

$$DEM_{C,i}^j = \beta_{c,i}^j \cdot FACTD_{C,i} \quad (7.2.39)$$

With this formulation a sector can not shift from a product to an other. If the sector producing product j improves its productivity (that is produces the same product but with a lower price), every sectors i using the product j will face a lower investment price, *ceteris paribus*. By using fixed matrix, it will only lead for sector i to a smaller global investment price, but it can not choose to buy more of the j 's good instead of other ones. Consequently, we can easily see that sector j does not have gain to make TFP in order to lower its price. Theoretically, if the i 's sector lowers its price, this must lead to improve its market share. The fixed matrix are therefore not compatible with the developments proposed. Consequently, in order to keep the global theoretical coherency of the model, we have to endogenise these coefficients. We choose to endogenise the share of each product j in the total factor demand of sector i as a cost minimisation on a CES function. Firms determine their global factor demand using its production function, then minimises the cost of provisioning this global

demand from a CES function with a elasticity of substitution (ϵ_i). The substitution elasticity ought to be sufficiently slack to not to conduct to too sharp fluctuations for technical coefficients. In order to lowers as more as possible quick shifting between the different sources of supply, we add in this derived shares adjustment delays. The modelling chosen for each type of firms matrix (Intermediate Consumption, final Energy demand and Investment) is the following:

$$COEF_{C,i}^j = \lambda_i \cdot coefmat_{C,i}^j \cdot \left(\frac{PD_{C,i}}{PV_C^j} \right)^{\epsilon_i} + (1 - \lambda_i) \cdot coefmat_{C,i}^j \quad (7.2.40)$$

with

- λ_i the adjustment delay,
- $PD_{C,i}$ the global factor demand price of sector i
- PV_C^j the sale price of the product j and
- ϵ_i the price elasticity.

Using this formulation, if the sector j decrease its price (other sectors unchanged) the share of demand of the sector i asked to sector j will increase depending on the price elasticity and the adjustment delay. The price elasticities can not be estimated and was selected from other studies between 0.05 and 0.1. Furthermore, the delays taken between 4 years and 10 years according to sectors. Of course, endogeneising all these coefficients increases dramatically the number of equations of the model (around 60 000 equation added). Some remarks must be here formulated:

1. The adoption of an optimisation procedure for the choice of these coefficients, grounded on a re-aggregation function of a CES. type, allows to easily explicit the products components of investment, intermediate consumption and energy sectoral demands and is moreover fully coherent with the framework we choose for closing- up the NEMESIS supply side. Nevertheless, coefficients so calculated are not those determined by national accounts statisticians.
2. But in the baseline projections, coefficients evolution must be exogeneised, the endogenous determination of thousands of coefficients complicate the model resolution.

This formalisation of matrix had been tested using several economic and environmental policies and is operational.

7.2.9.2 Technological progress interactions

Endogenous technical change in NEMESIS needs to take into account technological interactions between sectors. Technological change needs three kind of interactions: knowledge spillover, rent spillover and technology flows.

Knowledge spillovers

Knowledge spillovers represent the case where a sector could benefit from R&D activities of another sector without pay monetary compensation. An example of knowledge spillovers is when one invention might lead to a new ideas for different inventor. In NEMESIS model knowledge spillover relies positively R&D expenditure of a sector to the knowledge stock of another. We distinguish national and international knowledge spillover.

$$Know_{s,c,t} = f(RD_{s,c,t'}, SKN_{s,c,t''}, SKI_{s,c,t''}, RD/Y) \quad (7.2.41)$$

- s : sector, c : country and t : time
- $Know$ is the Knowledge stock of sector
- RD is the R&D expenditure of sector
- SKN is the national Knowledge spillovers
- SKI is the international Knowledge spillovers

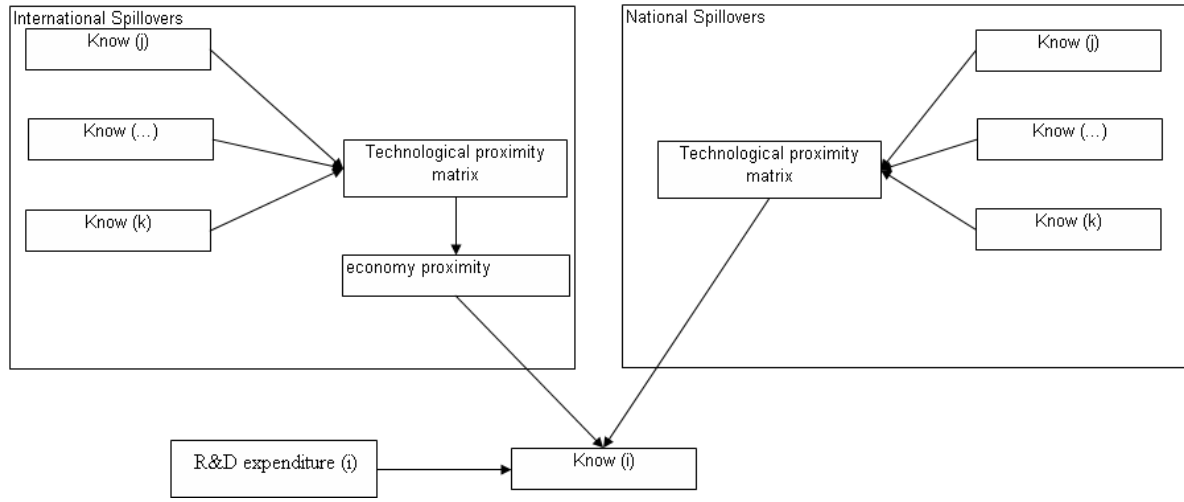
Measure of knowledge spillover follow the seminal work of Jaffe (1986 [295]) and Verspagen (1997 [467]) which develop methods to take into account non-incorporated or disembodied R&D spillovers. This concept of technological link is called technological proximity because it is derived from the relative position of sector in a technological space. Concretely technological proximity matrix assume that main IPC code into which a patent is classified provides a good proxy of producing sector of the knowledge, and the listed supplementary IPC codes given an indication for technology spillovers to other industrial sectors. The more two sectors are close to each other, the higher is the effect of R&D expenditure.

For national knowledge spillover we assume:

$$SKN_{i,c,t} = \sum_{j \neq i} \theta_{ij} \cdot RD_{j,c,t'}$$

For international knowledge spillover we assume :

Figure 7.2.13: Knowledge spillovers



$$SKI_{i,c,t} = \sum_d \sum_{j \neq i} \beta_{cd} \theta_{ij} \cdot R\&D_{j,d,t'}.$$

where θ_{ij} is the technology proximity between sector i and j and β_{cd} is the economy distance between c and d .

Rent Spillovers

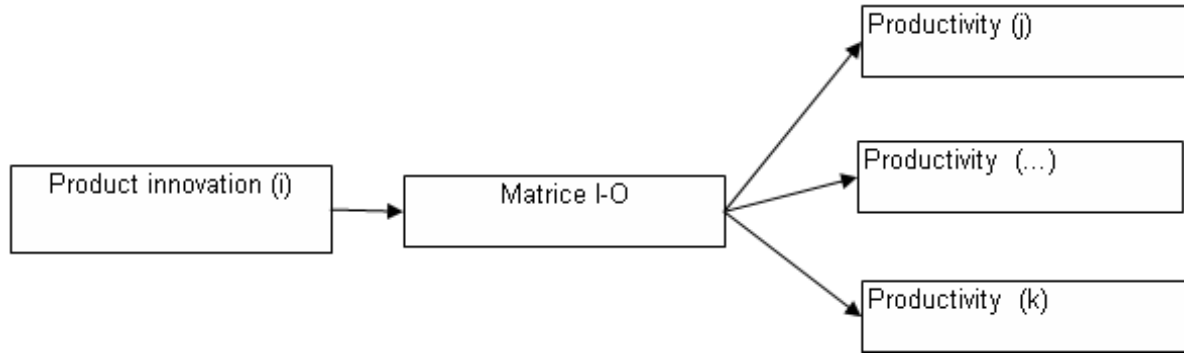
Second kind of technological interaction is rent spillovers. Rent spillovers refer to the case where R&D intensive input are purchased from other industries at less than their fully adjusted price. This failure to embody correctly a higher quality into output price is the consequence of imperfectly monopolistic pricing arising from competitive pressure on innovating industry. For Griliches (1992 [251]), rent spillover is a problem of measuring capital equipment, materials and their price correctly and not a case of pure knowledge spillovers. If innovation are sold at prices that entirely reflect quality improvement *i.e.* on hedonic price index, problem does not arise. In the NEMESIS model, we assume that prices do not reflect totally quality improvement. Importance of rent spillovers relatively to the adjustment of price will depend on the degree of competition. Low degree induces more importance on rent spillovers effect than on price adjustment. In NEMESIS, rent spillover originate exclusively from economic transaction. We assume that rent spillover diffuse proportionally to the level of intermediate input flows between sectors. This level is simply measured by Input-Output matrices. It results that factor productivity is not only affected by its own R&D but also by productivity improvement in another

sector to the extent of its purchase.

$$RentS_{i,t} = \sum_{j \neq i} \delta_{ij} Innov_{j,c,t'}$$

Where δ_{ij} is the I-O matrix coefficient and *Innov* is product innovation of sector *j*.

Figure 7.2.14: Rent spillovers



Technology flows

NEMESIS model allows some innovation produced in one sector and implemented in another. Innovation which improves productivity could be made in own sector or purchase to another through patent transaction. To link sector innovation in user-producer principle, we use the so-called “Yale matrices”. This matrix is constructed on the basis of data from the Canadian patent Office. This last (exclusively in the world) assigns principal user and producing sectors to each patent. We use matrices made by Johnson (2002 [302]) and extent it to other country.

7.2.10 NEMESIS agricultural module

7.2.10.1 Introduction ¹¹

In order to estimate the production structure one can examine the production function or the related cost function. The work in duality has established that, under rather weak regularity conditions, there is an unique correspondence between production and cost functions and information about underlying technology is contained in both functions (Shephard 1970 [425], Mac Fadden 1978 [343]). The cost function is expressed in terms of factor prices and output level; the production function is in terms of

11. This presentation of the NEMESIS agricultural module comes from Ngwa Zang and Le Mouél (2007 [367]).

factor inputs. The main statistical issue it is safer to treat the factor prices and level of output, or the use of inputs, as exogenous to the firm. If the firm is a cost minimiser, its input choice is necessarily endogenous and direct estimation of the production function will yield inconsistent results (Mundlak et Hoch 1965 [363], Mundlak 1996 [362]). Since we treat output and factor prices as given, the cost function is used in this analysis. This approach has two additional advantages. First, it yields direct estimates of the various Allen-Uzawa elasticities of substitution. Second, according to duality theory (Shephard's Lemma), the derivative of the cost function with respect to a factor price leads to input demand.

There are several approaches used in empirical analyses of cost functions. The most common is the static equilibrium approach which assumes that firms minimise their total production cost by fully optimising with respect to all inputs (Mundlak 1968 [361]). Each observation is interpreted as a long run, cost minimising position. At the other extreme are disequilibrium models in which the firm encounters costs of adjusting all its inputs (*e.g.* Nadiri and Rosen 1969 [365], Luh and Stefanou 1991 [341], Luh and Stefanou 1993 [342], Fernandez-Cornejo *et al.* 1992 [224]), or some specific “quasi-fixed” inputs. The third approach is to specify a variable cost function in which some inputs are treated as “quasi-fixed” (Binswanger 1974 [41], Brown and Christensen 1981 [59], Guyomard and Vermersch 1989 [254], Karagiannis *et al.* 1996 [309], Fousekis and Pantzios 1999 [233]). The theoretical development is found under the heading of restricted profit functions. The level of variable cost is expressed as a function of the price of variable inputs, the level of output, and the quantity of quasi-fixed factor. The most advantage of this approach is that, these models are more flexible inasmuch as they do not impose a particular structure on the evolution of fixed factors. But for the same reason, they yield no information about dynamic substitution possibilities or the time path of fixed inputs. The objective of this study using the third approach with some additional specificity is to analyse empirically the agricultural production structure of some European countries at aggregate level. Particular attention is focused on the dynamic pattern of substitution among the factor inputs (variable and quasi-fixed) and the imposition of the regularity conditions. We address this issue by estimating an restricted aggregate transcendental logarithmic cost function for the agriculture of European countries, using annual panel data.

7.2.10.2 Theoretical Model

The restricted cost function

We can define restricted (variable) cost function (CR) in the following way:

$$CR(p_x, u, Y) = \underset{x}{Min} \left[p'_x x; x \in X(Y, u) \right]$$

Under the strict positivity of vector price p_x of inputs, the hypothesis (i) ensures existence of $CR(p_x, u, Y)$. Furthermore, $CR(p_x, u, Y)$ is negative, positive when y is different from zero, non-decreasing, homogeneous and linearly positive, concave and continuous in price (Mac Fadden 1978 [343]). In the same way, it is possible to show that the hypothesis (ii) implies $CR(p_x, u, Y)$ non-decreasing in Y and non-increasing in u (Guyomard and Vermersch 1988 [254]). Under the hypothesis of convexity (iii), the knowledge of restricted cost function $CR(p_x, u, Y)$ is sufficient to describe, in an exhaustive way, the short run Hicksian technology used. At last, the results of the duality show that:

$$\begin{aligned} X^*(u, Y) &= \left[x \geq 0; p'_x x \geq CR(p_x, u, Y), \text{ for all strictly positive } p_x \right] \\ &= X(u, Y) \end{aligned} \quad (7.2.42)$$

In addition, if one supposes that restricted cost function $CR(p_x, u, Y)$ is twice differentiable with respect to input prices, the following properties can be deducted:

- Shephard's lemma relates $(, ,) \times CR$ p y u and the cost minimising input demand functions through its partial derivatives:

$$\frac{\partial CR}{\partial p_{x_i}} = x_i(p_x, u, Y) \quad (7.2.43)$$

- the following Hessian matrix is symmetric, negative semi-definite, and of rank $N-1$:

$$\Omega_{p_x p_x} = \left[\frac{\partial^2 CR}{\partial p_{x_i} \partial p_{x_j}} \right] \quad i, j = 1, \dots, N$$

Finally, under the hypothesis of differentiability of $CR(p_x, u, Y)$ with respect to the quasi-fixed inputs and to the output, it is convenient to define the total Hessian matrix:

$$\Omega = \begin{bmatrix} \Omega_{p_x p_x} & \Omega_{p_x u} & \Omega_{p_x Y} \\ \Omega_{u p_x} & \Omega_{uu} & \Omega_{uY} \\ \Omega_{Y p_x} & \Omega_{Y u} & \Omega_{YY} \end{bmatrix}$$

The properties of production possibilities set and twice differentiability of $CR(p_x, u, Y)$ with respect to variable inputs prices imply that the matrix $\Omega_{p_x p_x}$ is negative semi-definite. Furthermore, if the restricted cost function is twice differentiable with respect to quasi-fixed factors and with respect to output, the function $CR(p_x, u, Y)$ is locally strictly convex with respect to u and y (Jorgenson and Lau 1974 [306]) and the sub-matrix $\begin{pmatrix} \Omega_{uu} & \Omega_{uY} \\ \Omega_{Yu} & \Omega_{YY} \end{pmatrix}$ is the positive definite.

The corresponding (total) short run cost function of 7.2.42 is:

$$CR^{CT}(\cdot) = CR(\cdot) + \sum_u p_u \times u$$

Where p_u is the service price of the quasi-fixed input u . The optimal long run Hicksian level of the quasi-fixed input is defined by $u^h(p_x, p_u, Y)$. This optimal quantity of quasi-fixed input is defined implicitly by the envelope condition (Samuelson 1953 [413]): $-\frac{\partial CR(\cdot)}{\partial u} = p_u$ provided that the restricted cost function is decreasing and convex in u .

Deriving long run cost function characteristics from the restricted cost function

The restricted cost function, corresponding to the program of minimisation of the cost of a subset of inputs subject to the choice of remaining inputs, provides a functional characterisation of the technology at short run Hicksian equilibrium. In the long run Hicksian equilibrium, the total cost function may be written as:

$$\begin{aligned} CT(p_x, p_u, Y) &= \underset{x, u}{Min} \left[p'_x \times X + p'_u \times u, Y = f(X, u) \right] \\ &= \underset{u}{Min} \left[CR(p_x, p_u, Y) + p'_u \times u, Y = f(x, u) \right] \\ &= CR[p_x, u^h(p_x, p_u, Y)] + p'_u \times u^h(\cdot) \end{aligned} \tag{7.2.44}$$

The total cost is obtained in two stages. In the first, one minimises the restricted cost function conditional upon the level of the quasi fixed input u . And one minimises the total cost with respect to u , while fixing the variable inputs to their short run Hicksian levels $x_i(p_x, u, Y)$, coming from Shephard's lemma $\frac{\partial CR}{\partial p_{x_i}} = x_i(p_x, u, Y)$. A sufficient condition to use this two stages decision rule is that the restricted cost function $CR(p_x, u, Y)$ is strictly convex in u (in a domain which includes the observed and optimal long run Hicksian levels of the inputs u), *i.e.* the matrix Ω_{uu} is positive definite

in this domain.

In addition, the restricted cost function Hessian matrix is symmetric, negative semi-definite. So, it is sufficient to add to previous properties of the restricted cost function the assumption of strict convexity of $CR(.)$ in u , if we want to infer the long run Hicksian characteristics of the technology from the only knowledge of the restricted cost function.

7.2.10.3 Econometric model

It follows from the duality principles that the cost function can be used to characterise equivalent structure of the production process. This theory considers the proposition that if the cost function (equation 7.2.42) does exist, it exists an input-regular production possibility set such that equation 7.2.42 is the minimum cost function. We begin by defining the following implicit production function:

$$Y = F(K_1, K_2, K_3, K_4, T, LNS, N, LS, EG, S, CI, t)$$

With, Y representing the agricultural production. K_1, K_2, K_3 and K_4 are the quasi-fixed factors representing the stocks of machines, buildings, other equipments and livestock respectively. T and LNS are fixed factors representing land and family labour. LS, EG, CI, S, N and E are the variable factors representing hired labour, energy, other intermediate consumptions, seeds, cattle-food and fertiliser respectively. And t represents a time trend.

The output Y is an aggregation of animal (Y_B) and vegetal (Y_A) productions. In this perspective, the agricultural production structure consists in two outputs and twelve inputs.

In short-run, farmers try to maximise their profit with respect to outlets, technology, fixed inputs and capital. While taking in to account the profit function, the restricted (or variable) cost function may be expressed by the following expression:

$$CR(.) = CR(p_i, K_1, K_2, K_3, K_4, LNS, Y_A, Y_B, S_{i,t-1}, t)$$

With p_i , the variable input prices vector and $i = S, N, E, LS, EG, CI$.

Knowing the regularity conditions of the production function, the function $CR(p_x, u, Y)$ may be interpreted as the dual of production function (Diewert 1974 [119]).

This restricted cost function represents a significant departure from earlier empirical studies in this area, which was based on static equilibrium models and dynamic models with *ad hoc* adjustment

mechanism. First, we use four quasi-fixed factors (machines K_1 , buildings K_2 , other equipments K_3 and livestock K_4). Second, we establish a relationship between demand factors for period t with the past period cost-share ($S_{i,t-1}$) of this factor. This is observed by the introduction of the past cost-share variable in the restricted cost function.

Separability and adjustment cost

The use of aggregate input index requires the assumption that the cost function is separable in these aggregates (Denny and Fuss 1977 [113]). Separability implies that marginal rates of substitution between pairs of factors in the separated group are independent of the levels of factors outside that group. An alternative definition is that Allen-Uzawa Partial Elasticities of substitution (Allen 1938 [8] and Uzawa 1962 [452]) between a factor in the separable group and some factor outside the group be equal for all factors in the group (Berndt and Christensen 1973 [30]). We will use this notion of separability for two reasons (*i*) to simplify the calculation and especially to describe the real substitution possibilities between sets of input, (*ii*) because for some inputs, the available data do not allows splitting them between the two outputs. First, we suppose separability between vegetal production (Y_A) and animal production (Y_B). Afterwards, we suppose separability between variable inputs. Some are specific to each production and the others ones are common to both productions.

1. First block is constituted of hired labour (LS), energy (EG) and intermediate consumptions (CI) is common to both outputs.
2. The second block is constituted of fertiliser (E) and seeds (S) and is specific to vegetal production.
3. Block 3 includes cattle-food (N) variable is specific to animal production.
4. The fourth Block is composed by machines (K_1), buildings (K_2) and others equipment (K_3).
5. And, Block 5 includes livestock (K_4).

The substitutions are possible inside blocks 1 and 2 and between blocks. For quasi-fixed factors, we suppose substitutions possibilities inside block 4 and between blocks 4 and 5.

In order to take into account the inertia degree of restricted cost function, we privileged a dynamic functional form. Indeed, instead of supposing that all inputs fit instantaneously with their level of full employment equilibrium, we distinguished variable inputs from quasi-fixed inputs ones. In short run, the adjustment of variable factors is conditioned by the level of quasi-fixed inputs. And these quasi-fixed factors converge to their levels of full employment equilibrium during one period at the

speed of convergence. In this framework the short-run exogenous variables are, of course, endogenous in long-run analysis. Formally we consider the following specification:

$$CR = F \left[G \left[(K_1, K_2, K_3, LS, EG, E, S, Y_A), (K_1, K_2, K_3, K_4, LS, EG, N, Y_B) \right], H \left(p_i, K_i, \bar{S}_i, \bar{S}_{K_i}, Y_w \right) \right]$$

With, $i = N, E, S, LS, EG$; $l = 1, 2, 3, 4$ and $w = A, B$. $G(\cdot)$ is an aggregate function of both productions Y_A with common factors K_1, K_2, K_3, LS, EG and its specific variable factors E and S and Y_B with same common factors and its specific factors N and K_4 . This aggregate function is derived from farmer optimal behaviour. $G(\cdot)$ is therefore the equilibrium value of the restricted cost function in long-run. $H(p_i, K_i, \bar{S}_i, \bar{S}_{K_i}, Y_w) = \prod_i p_i^{\bar{S}_{i(-1)}} \times \prod_l K_l^{\bar{S}_{l(-2)}} \times \prod_w Y_w^{\bar{S}_{w(-1)}}$ is the equilibrium value of the restricted cost function achieved with past factors demand given the prices prevailing at t . $G(\cdot)$ and $H(\cdot)$ are quadratic (translog) in all their arguments. Then $\log(CR) = F[G, H]$ can only be linear in G and H (Denny and Fuss 1977 [113]). This can be writing as: $\log(CR) = [G(\cdot)]^\lambda \times [H(\cdot)]^{1-\lambda}$.

When $\lambda = 0$ then $\log(CR) = H(\cdot)$. This means that adjustment costs are very higher and farmer do not modify the relative factors demand shares at the period t . And When $\lambda = 1$ then $\log(CR) = G(\cdot)$. In that case the adjustment costs are null, and then there is no problem: the farmer will always be in long-run equilibrium.

Notice that we constrained the quadratic form of the function (H) to the linear one. This allows us to delete the second order coefficients of this function. Indeed, $G(\cdot)$ and $H(\cdot)$ functions have the same second order coefficients and we must keep only one set of these parameters.

Model specification

As announced before, we are going to adopt a cost function under the assumption that it represents an exact measure of farmer costs. Without loss of generality, this cost function must verify curvature conditions (Christensen *et al.* 1973 [95], Lau 1978 [325]). It must be homogeneous of degree one with respect to price, upon the levels of production (Y_A) and (Y_B), the levels of the quasi-fixed factors: machines (K_1), buildings (K_2), other equipments (K_3) and livestock (K_4); the levels of the fixed factors: family labour (LNS), land (T) and the trend (t). It implies the following parameters restrictions:

$$\sum_i \alpha_i = 1, \sum_i \alpha_{ij} = \sum_i \alpha_{ji} = \sum_i \alpha_{iY} = 0$$

In long-run, we can check that the restricted cost function verifies the necessary and sufficient condition of constant returns to scale. It implies the verification of the following relations (Brown and Christensen 1981 [59]):

$$\begin{aligned}\sum_w \alpha_{Y_w} + \sum_u \alpha_u + \alpha_T + \alpha_{LNS} &= 1 \\ \sum_u \alpha_{uY_A} &= \sum_u \alpha_{uY_B} = 0\end{aligned}$$

Thereby, the restricted cost function for variable factors conditionally to quasi-fixed factors may be then written as follows (equation 7.2.45):

$$\begin{aligned}\ln \frac{CR(p_i, u, Y)}{p_{ci} \times LNS} &= \alpha_0 + \lambda \times \left[\sum_u \alpha_u \cdot \ln \frac{u_{-1}}{LNS} + \alpha_T \cdot \ln \frac{T_{-1}}{LNS} + \alpha_{Y_A} \cdot \ln \frac{Y_A}{LNS} + \alpha_{Y_B} \cdot \ln \frac{Y_B}{LNS} \right. \\ &+ \sum_i \alpha_i \cdot \ln \frac{p_i}{p_{CI}} + \left(\sum_u \alpha_{uY_A} \cdot \ln \frac{u_{-1}}{LNS} \right) \cdot \ln \frac{Y_A}{LNS} + \left(\sum_u \alpha_{tu} \cdot \ln \frac{u_{-1}}{LNS} \right) \cdot t \\ &+ \alpha_{TY_A} \cdot \ln \frac{Y_A}{LNS} \cdot \ln \frac{T}{LNS} + \left(\sum_u \alpha_{uY_B} \cdot \ln \frac{u_{-1}}{LNS} \right) \cdot \ln \frac{Y_B}{LNS} + \left(\sum_i \alpha_{ti} \cdot \ln \frac{p_i}{p_{CI}} \right) \cdot t \\ &+ \frac{1}{2} \cdot \sum_{i=E, S} \sum_{j=i} \alpha_{ij} \cdot \ln \frac{p_i}{p_{CI}} \cdot \ln \frac{p_j}{p_{CI}} + \alpha_t \cdot \ln t + \frac{1}{2} \cdot \alpha_{tt} \cdot (\ln t)^2 \\ &+ \frac{1}{2} \cdot \alpha_{NN} \cdot (\ln N)^2 + \frac{1}{2} \cdot \sum_{i=LS, EG, CI} \sum_{j=i} \alpha_{ij} \cdot \ln \frac{p_i}{p_{CI}} \cdot \ln \frac{p_j}{p_{CI}} \\ &+ \left(\sum_i \gamma_{ui} \cdot \ln \frac{p_i}{p_{CI}} \right) \cdot \sum_u \ln \frac{u_{-1}}{LNS} + \frac{1}{2} \cdot \sum_{u=K_1, K_2, K_3, K_4, Th=u} \sum \alpha_{uh} \cdot \ln \frac{u_{-1}}{LNS} \cdot \ln \frac{h_{-1}}{LNS} \\ &+ \frac{1}{2} \cdot \sum_{i=Nj=LS, EG, CI} \sum \alpha_{ij} \cdot \ln \frac{p_i}{p_{CI}} \cdot \ln \frac{p_j}{p_{CI}} + \alpha_{TY_B} \cdot \ln \frac{Y_B}{LNS} \cdot \ln \frac{T_{-1}}{LNS} \\ &+ \frac{1}{2} \cdot \sum_{i=E, S} \sum_{j=LS, EG, CI} \alpha_{ij} \cdot \ln \frac{p_i}{p_{CI}} \cdot \ln \frac{p_j}{p_{CI}} + \left(\sum_{w=A, B} \alpha_{tY_w} \cdot \ln \frac{Y_w}{LNS} \right) \cdot t \\ &+ \left(\sum_i \alpha_{iT} \cdot \ln \frac{p_i}{p_{CI}} \right) \cdot \ln \frac{T_{-1}}{LNS} \Big] \\ &+ (1 - \lambda) \cdot \left[\left(\sum_i \ln \frac{p_i}{p_{CI}} \right) \cdot S_{i(-1)} - \left(\sum_u \ln \frac{u_{-1}}{LNS} \cdot S_{u(-2)} + \sum_w \ln \frac{Y_w}{LNS} \cdot S_{Y_w(-1)} \right) \right] \\ &+ \alpha_{LNS} \cdot \ln LNS\end{aligned} \quad (7.2.45)$$

Where $i = E, S, N, LS, EG$ when not specified, $u = K_1, K_2, K_3, K_4$ when not specified and the index (-1) or (-2) represents the variable at time $t - 1$ or $t - 2$. Note that long run returns to scale are controlled by parameter α_{LNS} . They are respectively increasing, constant or decreasing if at normalised point α_{LNS} is significantly positive, null or negative.

Differentiating equation 7.2.45 with respect to variable input prices: seeds, cattle-food, fertiliser, hired labour, energy, and intermediate consumptions, respectively noted upon to the levels of quasi-fixed factor: machines, buildings, other equipments and livestock; the levels of fixed factor: family labour and land; the levels of the agricultural production, livestock production, and the trend respectively noted; and using Shephard's Lemma, one gets the cost-shares equations under the following form:

$$\begin{aligned} \frac{\partial \ln CR}{\partial \ln p_i} = \frac{\partial CR}{\partial p_i} \cdot \frac{p_i}{CR} = \frac{p_i \cdot x_i}{CR} = S_i = & \lambda \left[\alpha_i + (\forall i = N, LS, EG) \alpha_{iY_B} \cdot \ln \frac{Y_B}{LNS} \right. \\ & + (\forall i = E, S, LS, EG) \alpha_{iY_A} \cdot \ln \frac{Y_A}{LNS} + \alpha_{it} \cdot \ln t \\ & \left. + \sum_j \alpha_{ij} \cdot \ln \frac{p_j}{p_{CI}} + \sum_u \alpha_{iu} \cdot \ln \frac{u_{-1}}{LNS} \right] \\ & (1 - \lambda) \cdot S_{i(-1)} \end{aligned} \quad (7.2.46)$$

Applying the envelope condition to equation 7.2.45 yields the cost-shares factors of quasi-fixed inputs. The systemic form of these cost-shares may be writing as follows:

$$\begin{aligned} S_U = & \lambda \left[\alpha_u + \sum_i \alpha_{iu} \cdot \ln \frac{p_i}{p_{CI}} + \sum_h \alpha_{uh} \cdot \ln \frac{h}{LNS} + \alpha_{uT} \cdot \ln \frac{T}{LNS} + \sum_w \alpha_{Y_w u} \cdot \ln \frac{Y_w}{LNS} \right] \\ & + (1 - \lambda) \cdot S_{u(-1)} \end{aligned} \quad (7.2.47)$$

Notice that for quasi-fixed factor, their cost-shares depend on their level instead of their service price. This allows us therefore, with the restricted cost function, to calculate the Shadow price of the quasi-fixed inputs and to compare them with their service price. More precisely, the value of quasi-fixed inputs represents the reduction of the cost led by a growth of a supplementary quasi-fixed input unit.

7.2.10.4 Results

According to the number of parameters to be estimated, we choose to use panel estimation that supposes completely identical functions for all countries (model pooled). In this case, the elasticity are identical for all countries. Nevertheless, to take into account specific country characteristics, individual effects under the form of specific constants have been introduced for each country of the panel. According to the information that we have, we will suppose that an identical relation exists between the countries but that an individual constant effect also exists which is not controllable due to a lack of information. We adopt a model therefore with fixed effects. For estimate the model, we used Seemingly Unrelated Regression (SUR) method. The data come from Economic Accounts for Agriculture from Eurostat (Eurostat 2007 [211]) and cover nine European countries: Denmark, Greece, Spain, France, Netherlands, Portugal, Finland, Sweden and United Kingdom and they start from 1980, in best case, to 2003.

Regarding at historical data for Agricultural Utilised Area (AUA) and family labour, taken as a proxy for number of holdings, it appears a very strong concentration of holdings that result in an increase of the size of holdings *i.e.* an increase of the number of hectares (T) by farms (LNS). Furthermore, we observe an exponential reduction of holdings number (LNS). This structural effect hides the relations existing, on the one hand, between the variable cost and AUA and, on another hand, between the variable cost and family labour. In order to control this structural effect, we chose to normalise the variable cost by the family labour taking into account the relation that exists between the family labour and the land such as: $LNS = f(T)$. It allows us the calculation of the variable cost elasticity with respect to land in terms of variable cost elasticity with respect to the average size of the exploitations rather than with respect to land directly.

Estimates

We analyse here the total variable cost or short-run cost. We start by verifying if the regularity conditions are satisfied at the approximation point. The parameters estimates for the final form of the model are shown in table 7.2.9 together with their t-statistic. More of half of the coefficients estimates are significant (5% or 1% per cent significance level is use throughout the paper) according to the asymptotic t-statistic. It appears that for each point, the concavity of the restricted cost function in input prices is verified at the approximation point. Indeed, the cost function satisfies the regularity conditions which are: (i) non decreasing and concave with respect to variables factors prices: seeds

($\alpha_{SS} < 0$), cattle-food ($\alpha_{NN} < 0$), fertiliser ($\alpha_{EE} < 0$), hired labour ($\alpha_{LSLS} < 0$), energy ($\alpha_{EGEG} < 0$) and (ii) convex with respect to the fixed-factors: machines ($\alpha_{K_1K_1} > 0$), buildings ($\alpha_{K_2K_2} > 0$), other equipments ($\alpha_{K_3K_3} > 0$) and livestock ($\alpha_{K_4K_4} > 0$). On the other hand, one sees that the value of the inertia factor λ is 0.41. This seems to suggest that the adjustment delay of the variable cost function in agricultural sector is one year and half. In other words, in the short term, 50% of the factors adjustment is achieved after one year and half. It also appears that the magnitude of the elasticity of cost with respect to average size of the holding (α_{AZE}) when the structural effect is taken to account is 0.837. This value is particularly high, and indicates that the implementation of changes in the available technology, which can not be observed directly, were strongly affected by investment in land in agriculture. The neutral technical change (α_t) is 0.0135 which may seem low.

Table 7.2.9: Estimates results

Parameter	Value	t-statistic	Parameter	Value	t-statistic	Parameter	Value	t-statistic	Parameter	Value	t-statistic
α_{AZE}	0.831	3.936	$\alpha_{K_1 K_4}$	0.0001	2.125	$\alpha_{N K_2}$	0.0013	-0.024	$\alpha_{Y_B N}$	0.0082	0.724
λ	0.413	23.647	$\alpha_{K_1 Y_B}$	-0.0114	-2.839	$\alpha_{N K_3}$	-0.0161	-2.428	$\alpha_{Y_B EG}$	-0.0137	-1.894
α_{LSLS}	-0.0071	-0.382	$\alpha_{K_2 K_2}$	0.0002	5.077	$\alpha_{N K_4}$	-0.0058	-2.814	$\alpha_{Y_B LS}$	0.0110	0.876
α_{EE}	-0.0001	-17.148	$\alpha_{K_2 K_3}$	0.0002	6.110	α_{EK_1}	0.0010	-0.032	$\alpha_{Y_A E}$	0.0018	0.224
α_{SS}	-0.0051	-2.094	$\alpha_{K_2 T}$	0.0021	2.010	α_{EK_2}	-0.0147	-1.399	$\alpha_{Y_A S}$	-0.0045	-1.930
α_{EGEG}	-0.0004	-2.580	$\alpha_{K_2 Y_A}$	-0.0030	-0.305	α_{EK_3}	0.0035	-0.277	$\alpha_{Y_A LS}$	0.0094	0.990
α_{NN}	-0.0049	-0.879	$\alpha_{K_2 K_4}$	0.0000	4.578	α_{SK_1}	0.0125	3.588	$\alpha_{Y_A EG}$	-0.0090	-1.399
α_{LSEG}	-0.0017	-0.194	$\alpha_{K_2 Y_B}$	-0.0033	-0.411	α_{SK_2}	-0.0012	-0.232	$\alpha_{t K_1}$	0.0007	0.445
α_{LSE}	0.0007	-0.210	$\alpha_{K_3 K_3}$	0.0001	7.980	α_{SK_3}	-0.0082	-3.745	$\alpha_{t K_2}$	-0.0019	-3.063
α_{LSS}	0.0060	0.693	$\alpha_{K_3 T}$	0.0018	4.891	α_{LSK_1}	0.0107	2.366	$\alpha_{t K_3}$	-0.0017	-3.226
α_{LSN}	0.0059	0.131	$\alpha_{K_3 Y_A}$	-0.0026	-0.106	α_{LSK_2}	0.0001	0.086	$\alpha_{t K_4}$	-0.0008	-0.490
α_{EGE}	0.0002	-5.060	$\alpha_{K_3 K_4}$	0.0000	8.863	α_{LSK_3}	0.0002	-0.198	$\alpha_{t T}$	-0.0253	-0.773
α_{EGS}	0.0015	-1.104	$\alpha_{K_3 Y_B}$	-0.0029	-0.389	α_{LSK_4}	-0.0020	-2.191	$\alpha_{t E}$	-0.0018	-5.920
α_{EGN}	0.0014	-0.784	$\alpha_{K_4 K_4}$	0.0000	11.370	α_{EGK_1}	-0.0048	-0.740	$\alpha_{t S}$	-0.0001	-1.336
α_{ES}	-0.0006	-4.190	$\alpha_{K_4 Y_B}$	-0.0007	-1.375	α_{EGK_2}	0.0214	4.551	$\alpha_{t N}$	-0.083	-7.716
α_{SN}	-0.0050	-0.742	$\alpha_{K_4 T}$	0.0005	10.298	α_{EGK_3}	0.0018	1.851	$\alpha_{t LS}$	0.0020	2.283
α_{EN}	-0.0006	-4.418	α_{TT}	0.0242	4.142	α_{EGK_4}	0.0020	1.860	$\alpha_{t EG}$	0.0005	0.453
$\alpha_{K_1 K_1}$	0.0022	1.329	α_{TY_A}	-0.0343	-3.696	α_{TE}	0.0087	0.513	$\alpha_{t Y_A}$	-0.0008	-2.810
$\alpha_{K_1 K_2}$	0.0006	1.340	α_{TY_B}	-0.0380	-2.664	α_{TS}	-0.0049	-0.242	$\alpha_{t Y_B}$	-0.0013	-2.172
$\alpha_{K_1 K_3}$	0.0005	1.921	$\alpha_{Y_B Y_B}$	0.0598	3.843	α_{TN}	0.0857	3.174	α_t	-0.0135	-5.635
$\alpha_{K_1 T}$	0.0073	2.815	$\alpha_{Y_A Y_A}$	0.0486	4.939	α_{TEG}	0.0073	-0.101	α_{tt}	0.0017	0.811
$\alpha_{K_1 Y_A}$	-0.0103	-2.484	$\alpha_{N K_1}$	-0.0014	0.003	α_{TLS}	-0.0356	-2.016			

This estimate of technological change means that of about 1.35 percent of the reduction of the variable cost in agricultural are attributed to technical change. The value of the coefficient of second order of neutral technical change (α_{tt}) is 0.0017. The estimates of biased technical change show input saving technical change for fertiliser ($\alpha_{tE} < 0$), seeds ($\alpha_{tS} < 0$), cattle-food ($\alpha_{tN} < 0$) saving and input using technical change for hired labour ($\alpha_{tLS} > 0$) and energy ($\alpha_{tEG} > 0$). With regard to quasi-fixed input, the technical change is saving for building ($\alpha_{tK_2} < 0$), others equipments ($\alpha_{tK_3} < 0$), livestock ($\alpha_{tK_4} < 0$) and land ($\alpha_{tT} < 0$) and technological change is using for machines ($\alpha_{tK_1} < 0$).

Elasticities

Table 7.2.10 presents the short term estimates of Hicksian price elasticities of demand derived, all elasticities are evaluated for 1995. Several interesting conclusions emerge from table 7.2.10:

- Hired labour demand in Sweden, fertiliser demand in Netherlands, seeds demand in Portugal and Finland, energy demand in Denmark and cattle-food demand in United Kingdom are the most responsive to a change in its own price of the sample. The own prices elasticities are -0.98 for Sweden, -0.97 for Netherlands, -1.067 and -1.076 for Portugal and Finland, -0.97 for Denmark and -0.74 for United Kingdom.
- Food of livestock is substitutable with respect to hired labour, seeds and energy in all the countries except in the United Kingdom, which is well below the other country.
- The elasticities between hired labour and energy, hired labour and seeds, hired labour and fertiliser, seeds and fertiliser, energy and seeds, and energy and food of livestock are positive but relatively small. This seems indicate poor substitutes between those variables *i.e.* these variables tend rather to be complementary.

Table 7.2.11 shows the long term Hicksian elasticities for which we assume fixed quasi-fixed factors and both productions. The results can be summarised briefly. With regard to the estimates, all inputs are substitutes and input demands are price elastic, seeds being the most elastic in long-run in all the countries. Seeds own-price elasticities range from -0.92 in Sweden to -1.005 in Denmark *i.e.* a 10% increase of seeds price leads to a decrease by about 9.2% in Sweden and 10% in Denmark. For Hired labour, its own-price elasticities range from -0.633 for Spain to -0.805 in Denmark. Furthermore, we observe similar estimates for energy and fertiliser which are from -0.542 in Spain to -0.88 in United Kingdom for energy, and from 0.862 in Sweden to -0.896 in Denmark and Netherlands for fertiliser. Cross price elasticities reveals higher substitution between hired labour and cattle-food and between

Table 7.2.10: Short term Hicksian elasticities

	DK	GR	ES	FR	NL	PT	FI	SE	UK
ε_{LS}	-0.935	-0.890	-0.838	-0.894	-0.894	-0.857	-0.881	-0.978	-0.862
ε_E	-0.949	-0.927	-0.922	-0.922	-0.973	-0.957	-0.911	-0.932	-0.919
ε_S	-1.023	-0.967	-1.009	-1.019	-0.958	-1.067	-1.076	-0.983	-1.041
ε_{EG}	-0.968	-0.839	-0.930	-0.948	-0.917	-0.930	-0.941	-0.906	-0.952
ε_N	-0.518	-0.626	-0.642	-0.652	-0.668	-0.515	-0.644	-0.642	-0.744
ε_{LSEG}	0.029	0.155	0.067	0.048	0.078	0.067	0.057	0.083	0.046
ε_{LSS}	0.069	0.090	0.061	0.063	0.097	0.044	0.045	0.101	0.051
σ_{LSE}	0.080	0.094	0.094	0.099	0.049	0.061	0.109	0.108	0.098
ε_{LSN}	0.515	0.401	0.379	0.376	0.360	0.506	0.382	0.404	0.282
ε_{EN}	0.480	0.376	0.360	0.350	0.328	0.482	0.358	0.359	0.261
ε_{SE}	0.043	0.068	0.071	0.070	0.024	0.032	0.076	0.063	0.071
ε_{SN}	0.424	0.344	0.310	0.294	0.306	0.396	0.262	0.322	0.191
ε_{EGS}	0.058	0.073	0.055	0.054	0.083	0.036	0.036	0.066	0.047
ε_{EGE}	0.053	0.073	0.079	0.079	0.029	0.044	0.090	0.069	0.082
ε_{EGN}	0.480	0.378	0.360	0.350	0.336	0.486	0.358	0.362	0.260

energy and cattle-food. The elasticities range from 0.402 in Finland to 0.596 in Portugal for hired labour and cattle-food substitution and from 0.434 in Finland to 0.656 in Portugal energy and cattle-food substitution. The cross-price elasticities between quasi-fixed and variable inputs reveals substitutions between all quasi-fixed factors and all variable factors except between machines and fertiliser in Denmark (-0.05), Netherlands (-0.12), Portugal (-0.02) and Finland (-0.017) which are complements. As well as the substitution between other equipment and seeds in Portugal (-0.025), Finland (-0.129) and Sweden (-0.02).

Table 7.2.11: Long term Hicksian elasticities

	DK	GR	ES	FR	NL	PT	FI	SE	UK
LS	-0.805	-0.766	-0.633	-0.763	-0.769	-0.750	-0.798	-0.716	-0.759
EG	-0.824	-0.819	-0.542	-0.855	-0.846	-0.875	-0.844	-0.623	-0.880
S	-1.005	-0.988	-0.978	-0.998	-0.980	-0.990	-0.990	-0.920	-1.001
E	-0.896	-0.882	-0.893	-0.880	-0.896	-0.894	-0.890	-0.862	-0.878
N	-0.567	-0.548	-0.329	-0.551	-0.573	-0.487	-0.635	-0.115	-0.627
LSEG	0.073	0.165	0.091	0.096	0.110	0.110	0.081	0.137	0.091
LSE	0.121	0.146	0.133	0.149	0.116	0.127	0.131	0.150	0.148
LSN	0.476	0.512	0.432	0.498	0.468	0.596	0.402	0.549	0.429
LSS	0.074	0.101	0.076	0.083	0.101	0.074	0.064	0.105	0.076
EN	0.361	0.433	0.365	0.424	0.338	0.468	0.333	0.459	0.371
NS	0.387	0.418	0.347	0.411	0.374	0.534	0.380	0.453	0.353
EGN	0.591	0.506	0.460	0.552	0.486	0.656	0.434	0.565	0.469
EGS	0.070	0.096	0.073	0.081	0.101	0.068	0.057	0.099	0.073
EGE	0.118	0.132	0.128	0.148	0.103	0.117	0.126	0.140	0.149
SE	0.092	0.117	0.106	0.121	0.087	0.099	0.097	0.116	0.121
K1S	0.255	0.227	0.238	0.290	0.234	0.339	0.441	0.234	0.324
K1LS	0.155	0.179	0.134	0.183	0.195	0.140	0.224	0.207	0.174
K1EG	0.060	0.130	0.084	0.118	0.139	0.086	0.171	0.117	0.115
K1N	0.096	0.132	0.099	0.134	0.146	0.103	0.175	0.124	0.132
K1E	0.101	0.136	0.104	0.138	0.145	0.108	0.178	0.125	0.138
K2S	0.080	0.137	0.126	0.145	0.144	0.131	0.053	0.365	0.102
K2LS	0.096	0.147	0.138	0.159	0.154	0.153	0.069	0.403	0.118
K2EG	0.390	0.215	0.295	0.367	0.287	0.310	0.242	0.524	0.336
K2N	0.092	0.142	0.133	0.153	0.147	0.155	0.066	0.388	0.112
K2E	-0.050	0.038	0.040	0.056	-0.120	-0.023	-0.017	0.276	0.019
K3S	0.024	0.111	0.074	0.093	0.080	-0.025	-0.129	-0.020	0.027
K3LS	0.106	0.144	0.108	0.147	0.158	0.111	0.188	0.136	0.144
K3EG	0.172	0.179	0.189	0.228	0.159	0.146	0.048	0.060	0.180
K3N	0.102	0.141	0.131	0.157	0.109	0.102	0.008	0.023	0.106
K3E	0.144	0.180	0.170	0.196	0.176	0.149	0.049	0.068	0.155
K4S	0.058	0.155	0.015	0.126	0.110	0.260	0.050	0.065	0.188
K4LS	0.048	0.149	0.010	0.119	0.104	0.249	0.041	0.053	0.179
K4EG	0.095	0.166	0.030	0.159	0.131	0.293	0.068	0.080	0.230
K4N	0.049	0.141	0.007	0.112	0.097	0.239	0.037	0.055	0.164
K4E	0.052	0.144	0.014	0.116	0.092	0.224	0.044	0.059	0.172

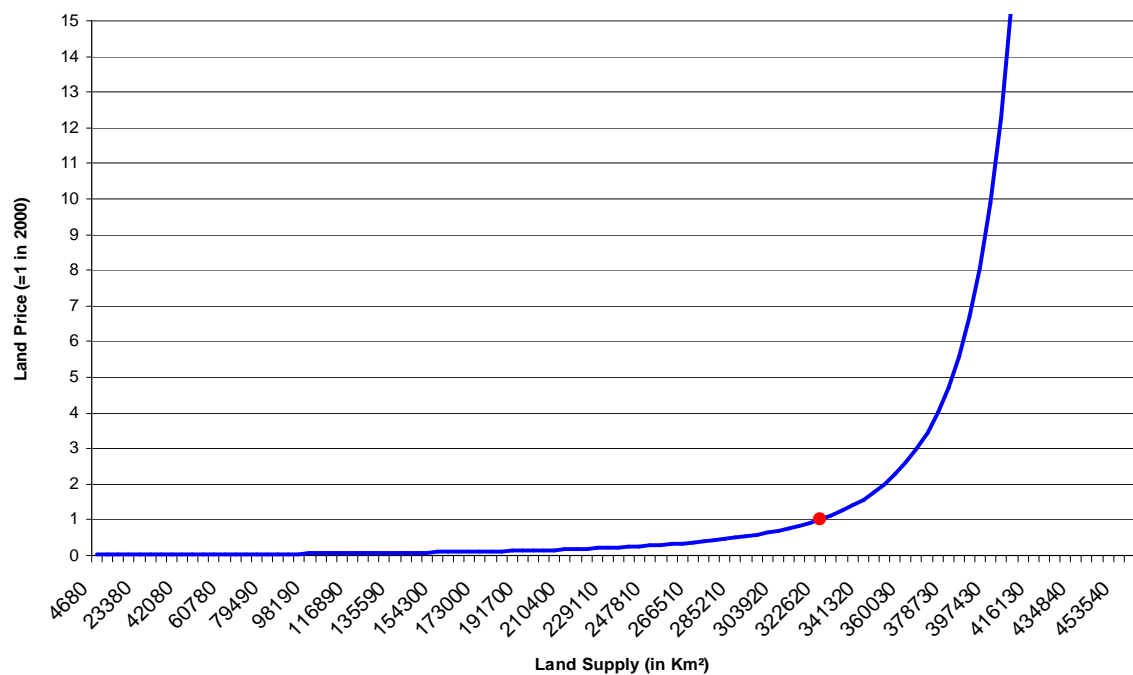
7.2.10.5 Conclusion

The objective, here, is the estimation of the agricultural input demands for Eu countries. Production technology is represented with the help of a dual cost function and the econometric model consists in a dynamic panel model represented by 13 equations. The model is composed by the variable cost function, 5 equations of cost-share demand variable factors, 4 cost-share equations of quasi-fixed demand factors and 2 cost-share equations of two outputs (agricultural and livestock). Globally, the estimates indicate an satisfactory model. Indeed, despite a large number parameters to be estimated, most of them are significant. Furthermore, the regularity properties of the cost function are respected. We found an adjustment delay for the variable cost function of about to one year and half. We also established that there exists a structural effect which introduces a bias in the relationship between variable cost and land. and we decided to neutralise it by normalising the variable cost function with the number of holding. In addition, the estimates showed weak effect of technical change on the cost either at global or individual level.

Price elasticities elasticities in the short term show that demands for seeds, fertiliser, energy and hired labour are very elastic with respect to their own price. The sensitivity of the demand for hired labour, fertiliser and energy are high and remains relatively stronger than cattle-food one in all countries. Partial elasticities of substitution show that there exist substitutions different variable inputs and between variable and quasi-fixed inputs. On one hand, one notes a complementarity hired labour and energy, hired labour and seeds and hired labour and fertiliser and on another hand between seeds and fertiliser, energy and seeds and energy and fertiliser. In the long term, estimates of the long term price elasticities show substitutions between all inputs (variable and quasi-fixed) except between machines and fertiliser in Denmark, the Netherlands, Portugal and Finland which are complementary.

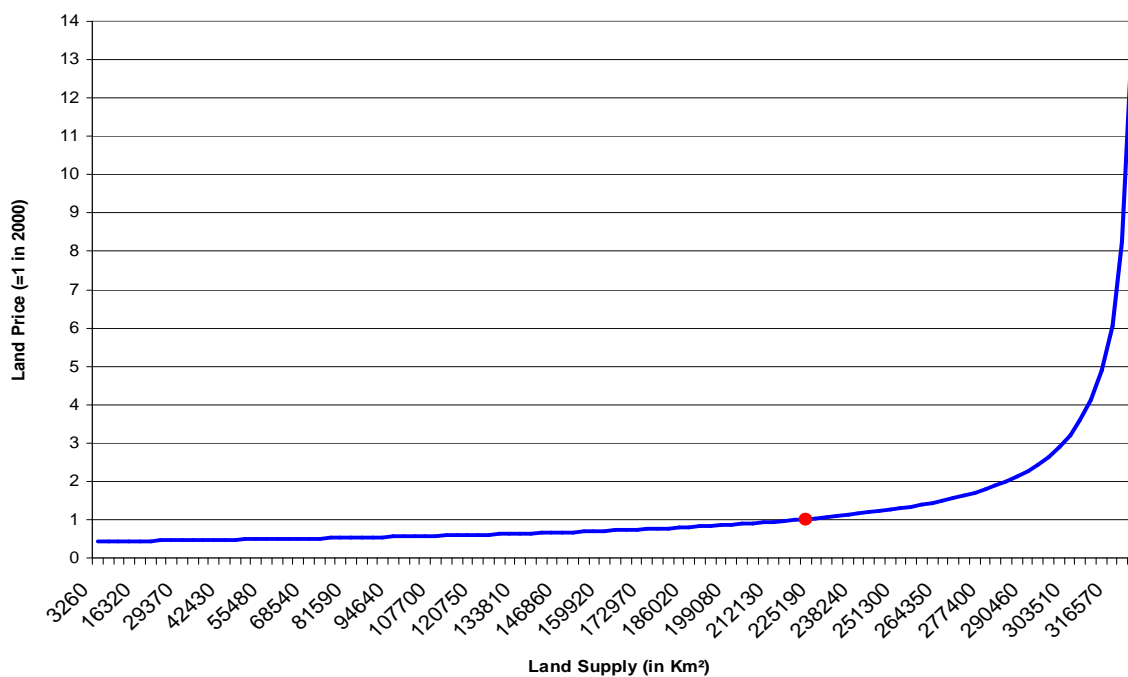
7.3 Appendix C: Inverse land supplies

Figure 7.3.1: French land supply in 2000



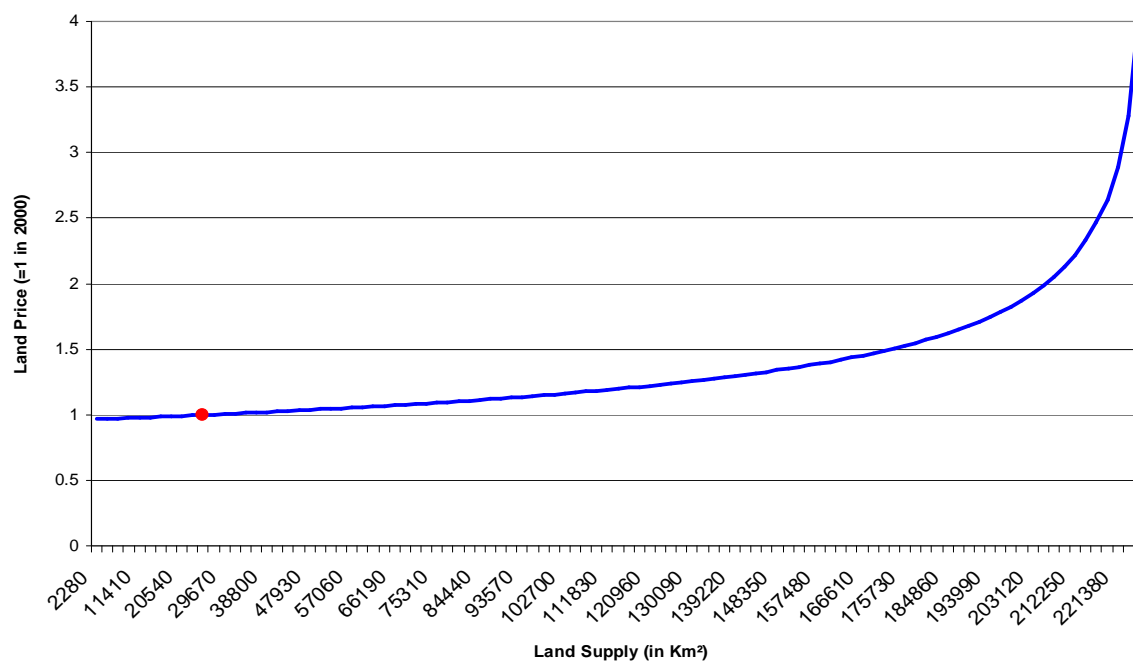
Source: NEMESIS model

Figure 7.3.2: Spanish land supply in 2000



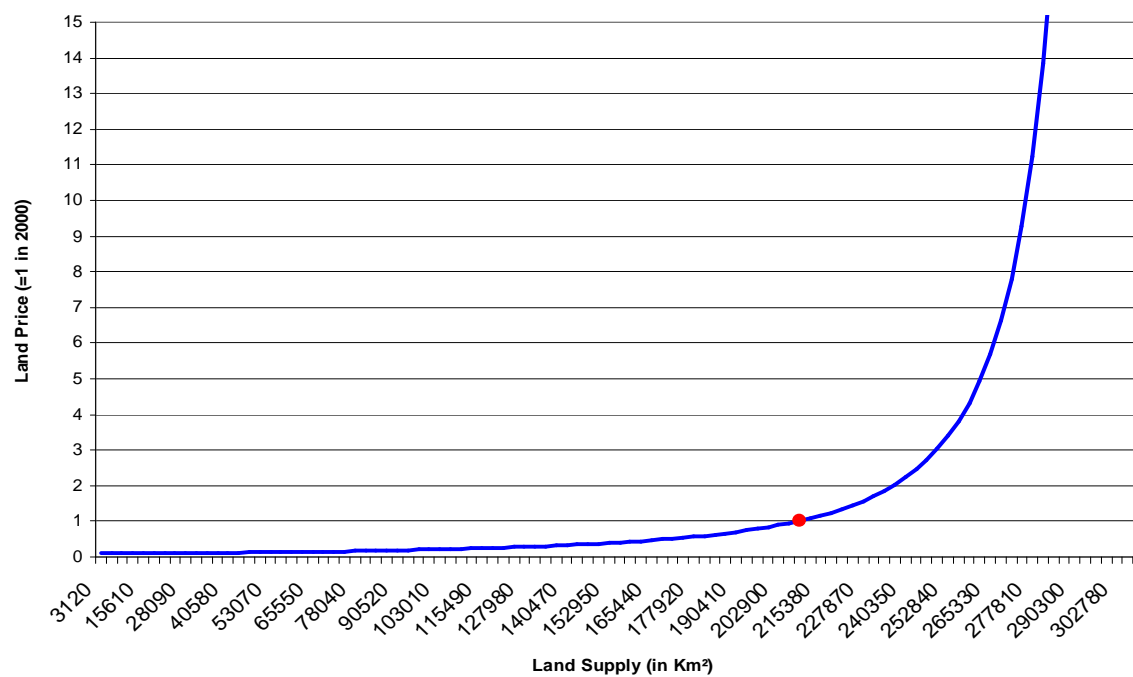
Source: NEMESIS model

Figure 7.3.3: Swedish land supply in 2000



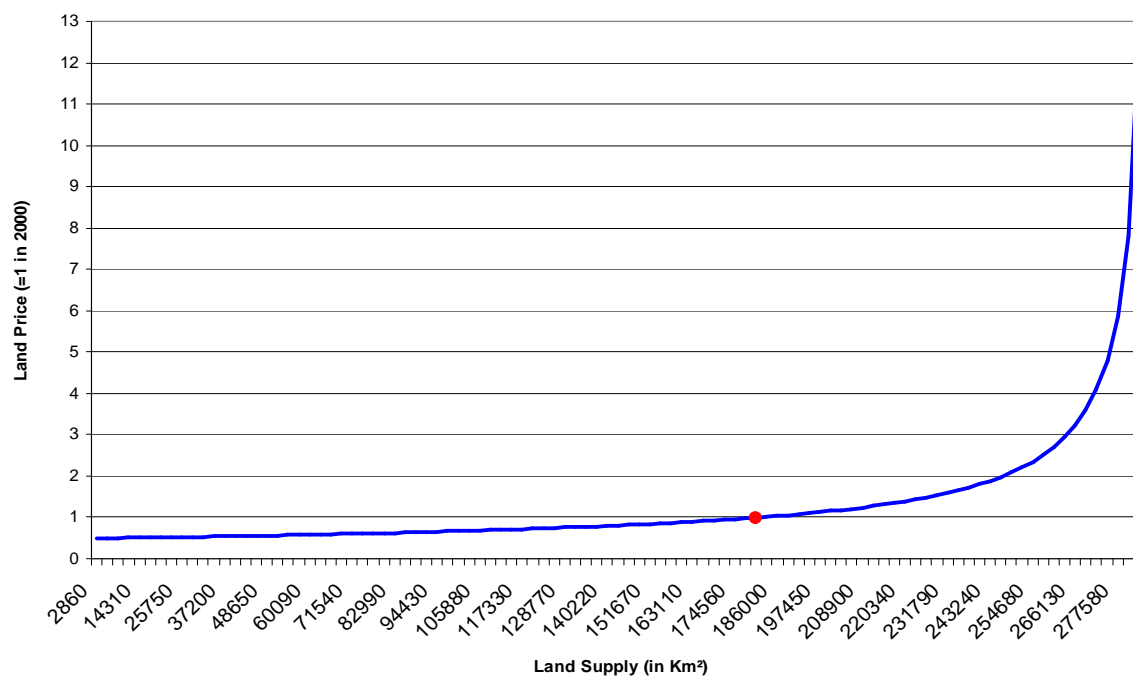
Source: NEMESIS model

Figure 7.3.4: German land supply in 2000



Source: NEMESIS model

Figure 7.3.5: Polish land supply in 2000



Source: NEMESIS model

Figure 7.3.6: Finnish land supply in 2000

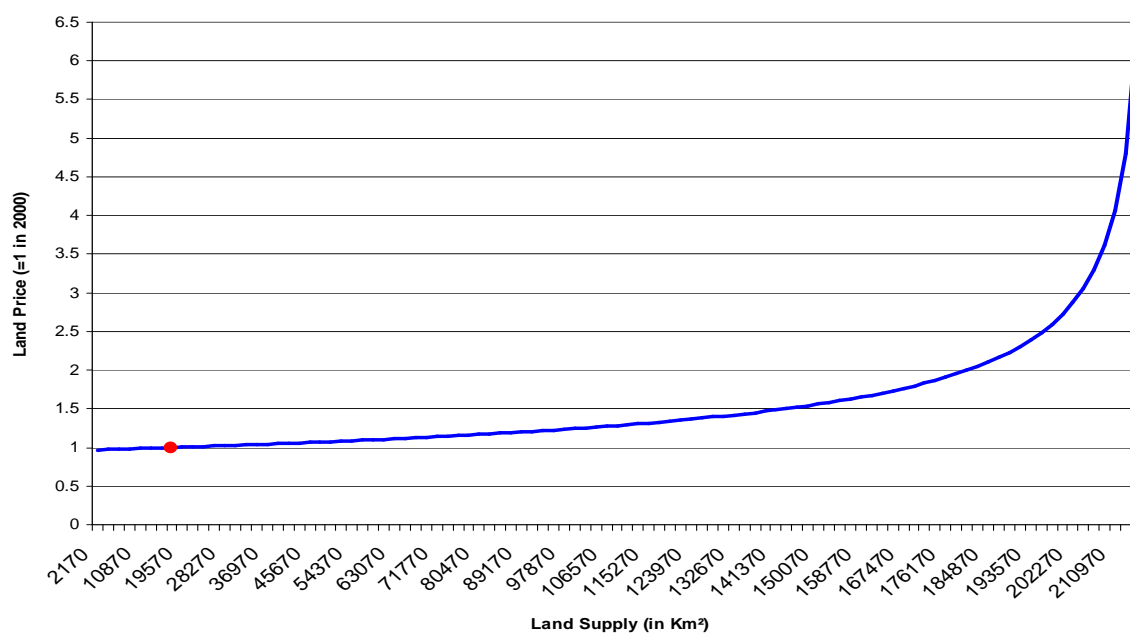
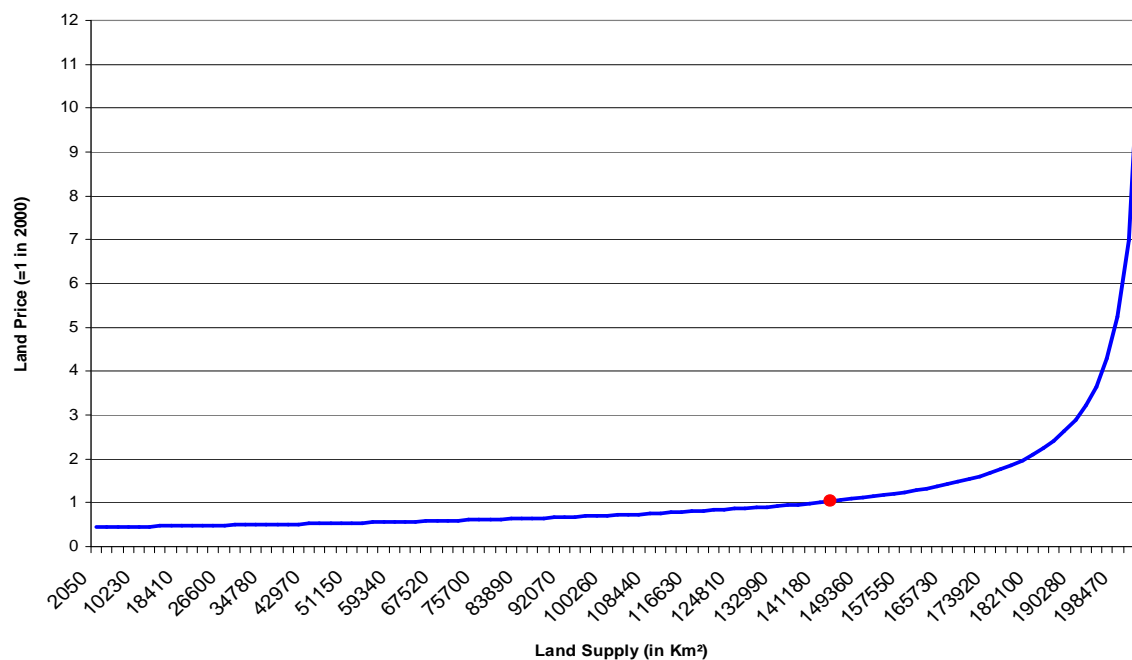
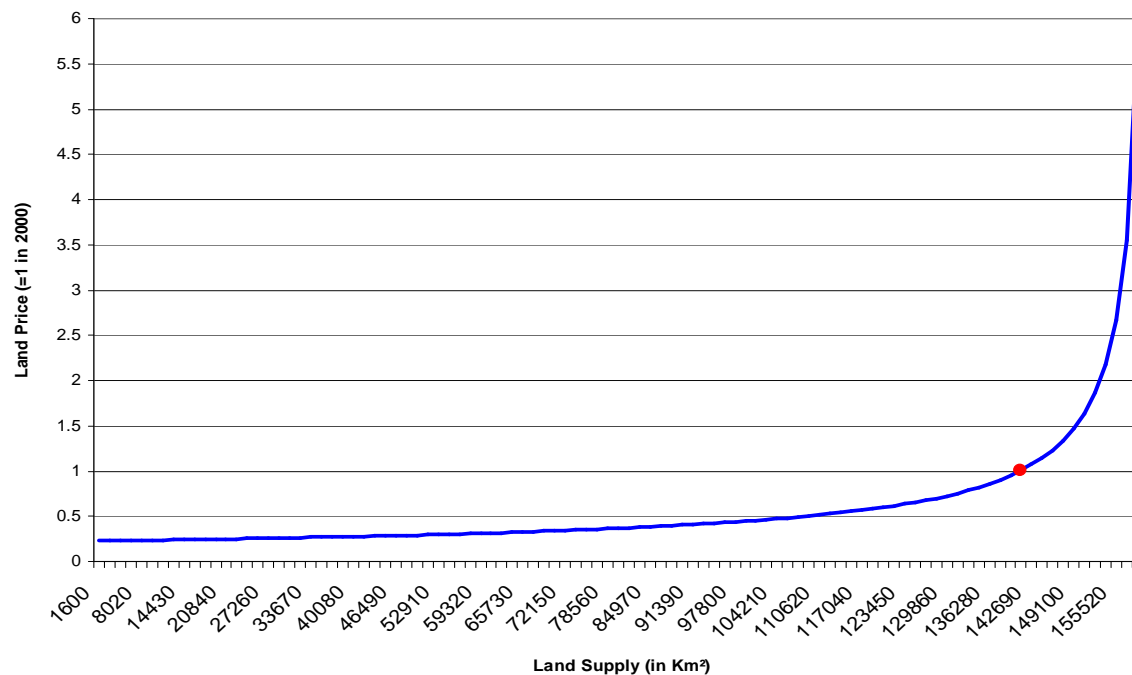


Figure 7.3.7: Italian land supply in 2000



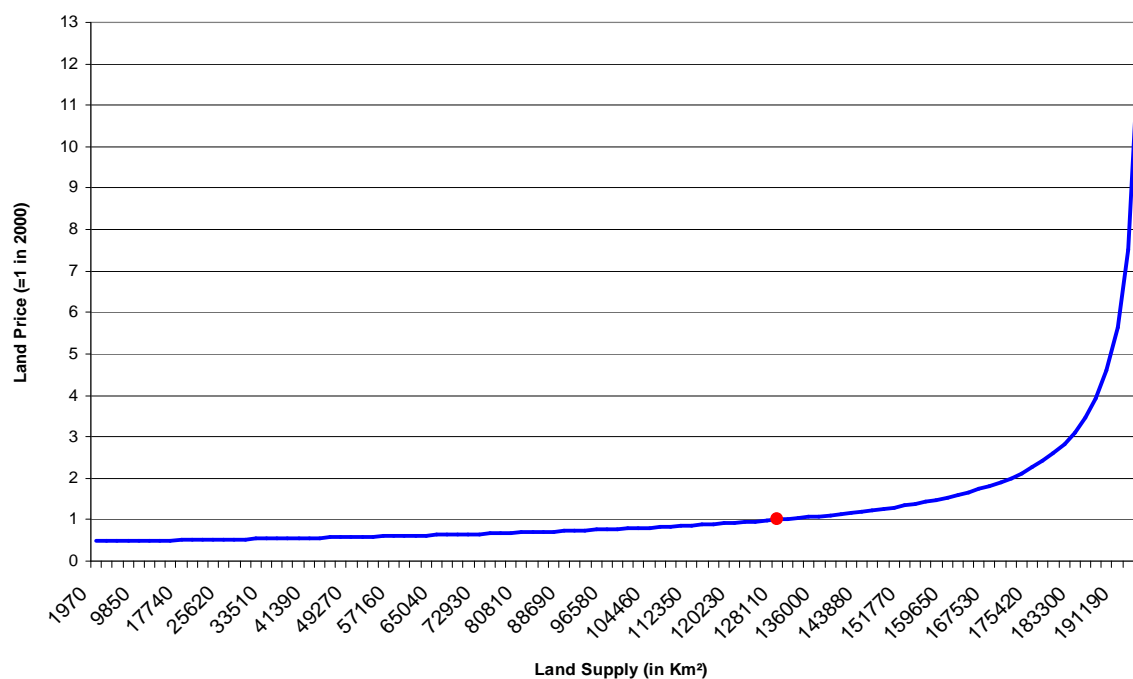
Source: NEMESIS model

Figure 7.3.8: British land supply in 2000



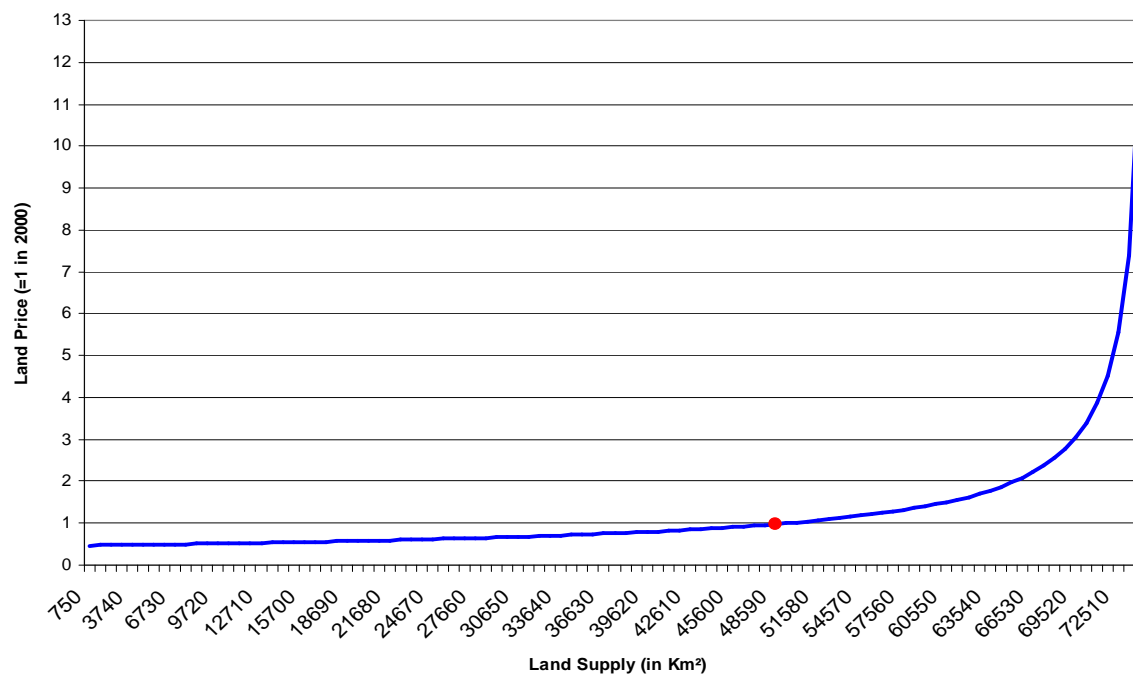
Source: NEMESIS model

Figure 7.3.9: Romanian land supply in 2000



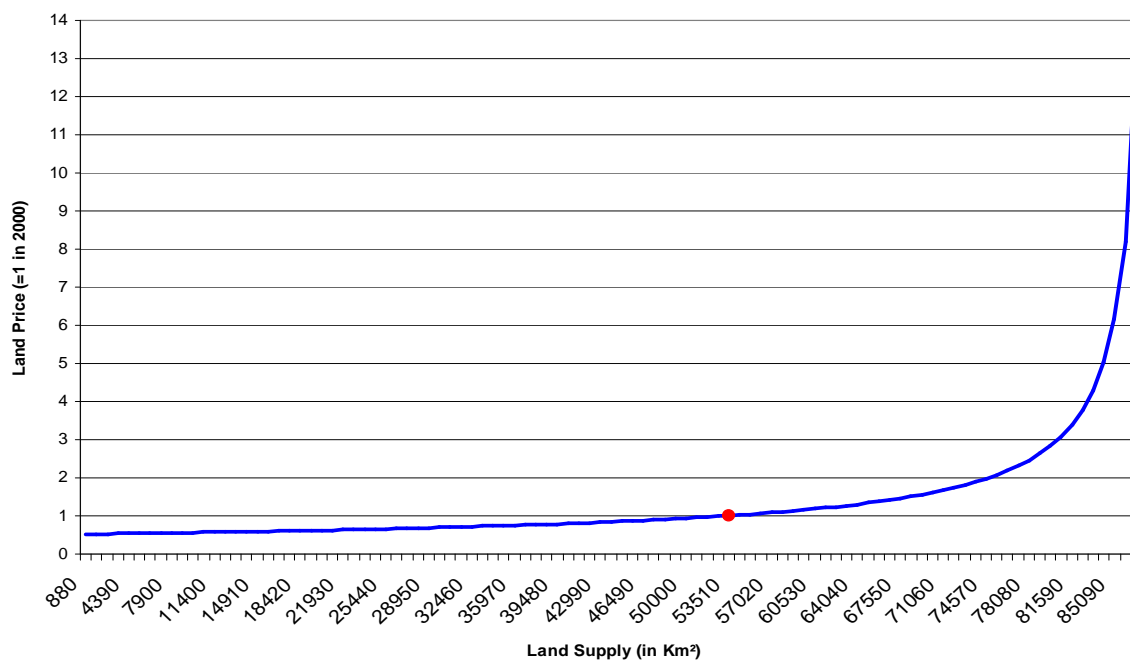
Source: NEMESIS model

Figure 7.3.10: Greek land supply in 2000



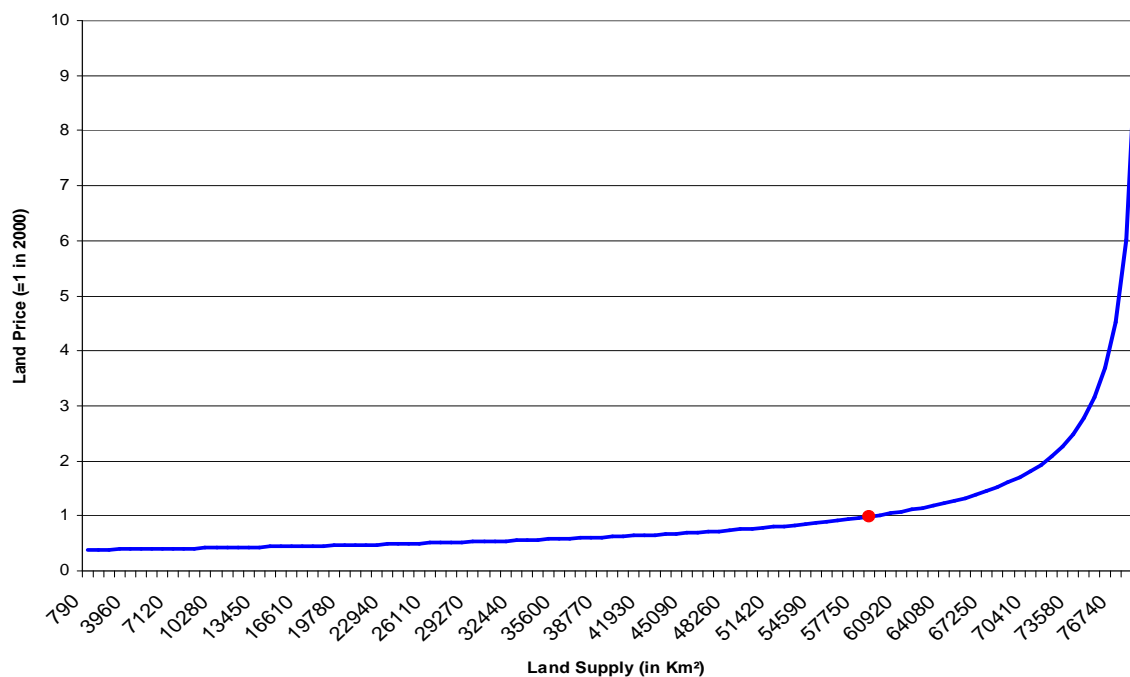
Source: NEMESIS model

Figure 7.3.11: Bulgarian land supply in 2000



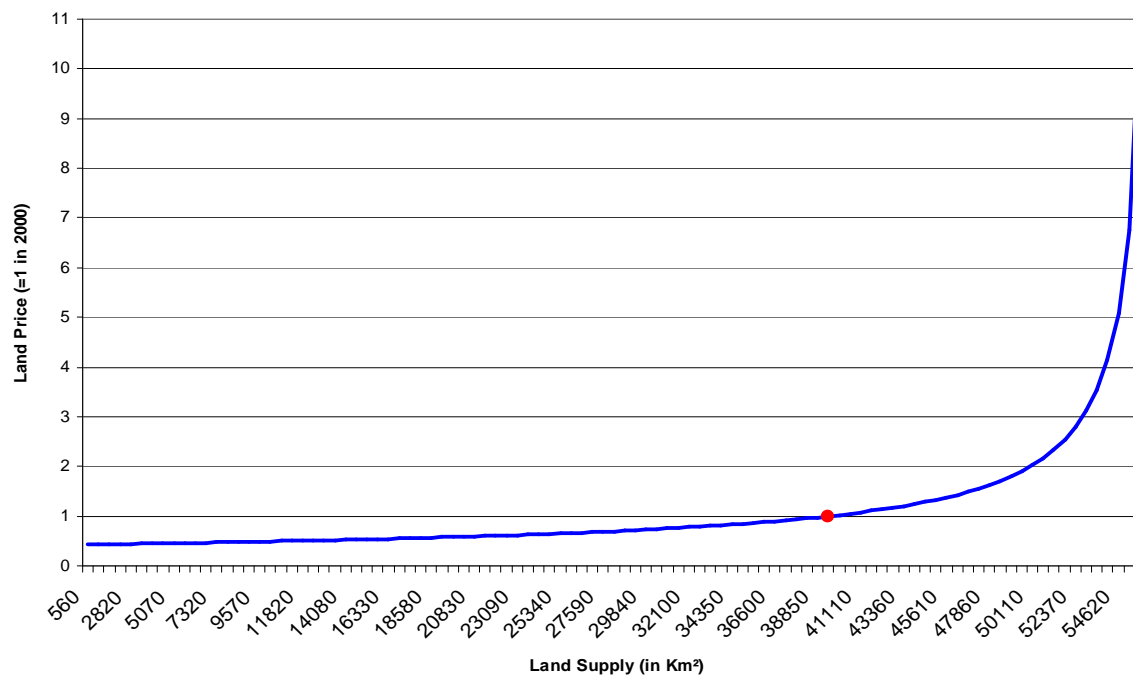
Source: NEMESIS model

Figure 7.3.12: Hungarian land supply in 2000



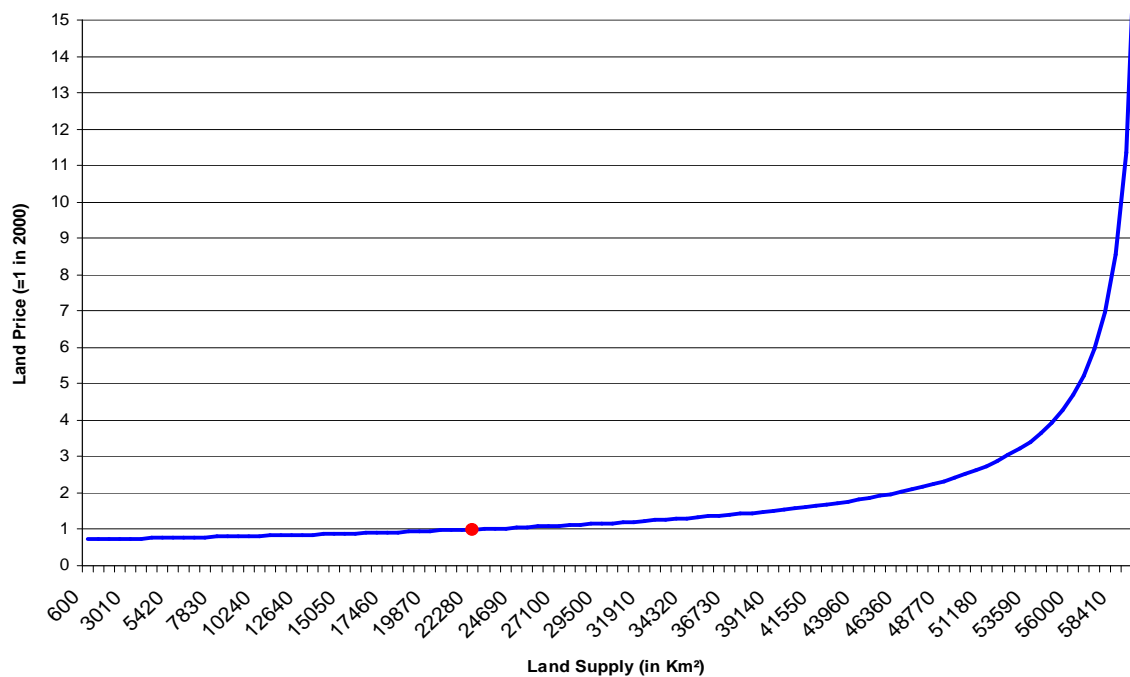
Source: NEMESIS model

Figure 7.3.13: Portuguese land supply in 2000



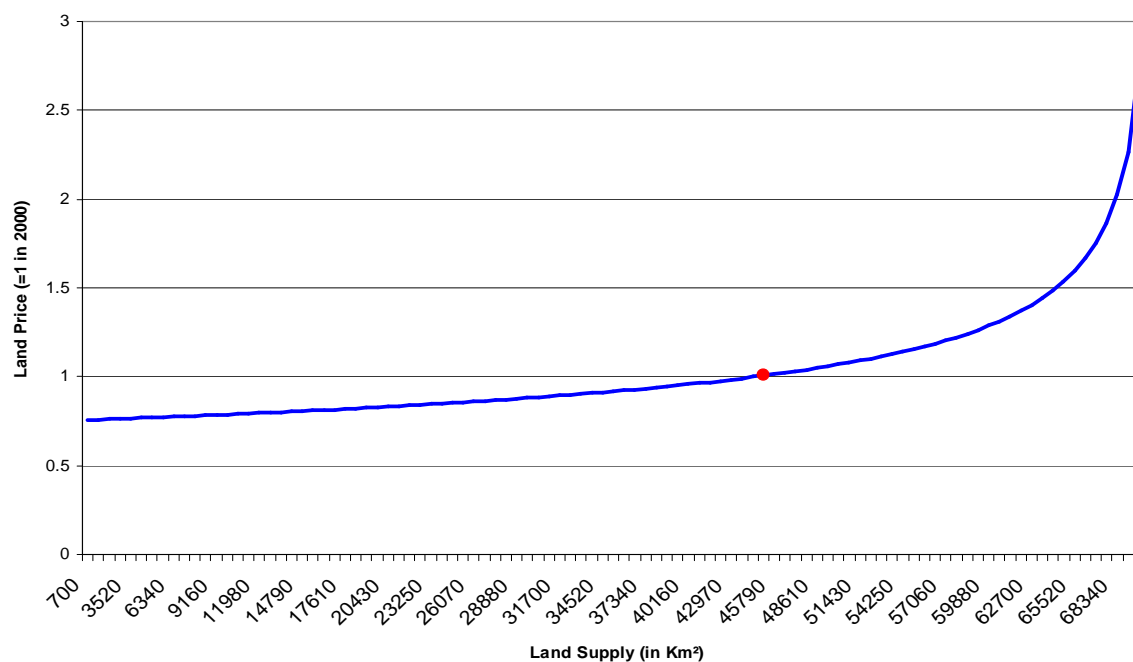
Source: NEMESIS model

Figure 7.3.14: Austrian land supply in 2000



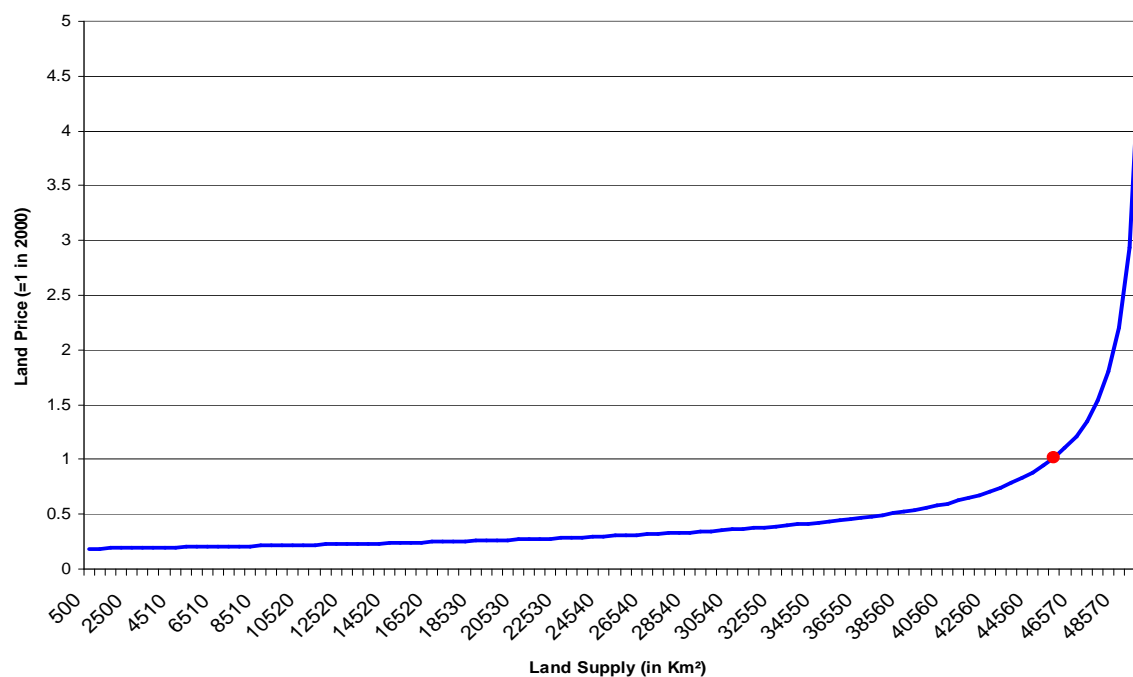
Source: NEMESIS model

Figure 7.3.15: Czech land supply in 2000



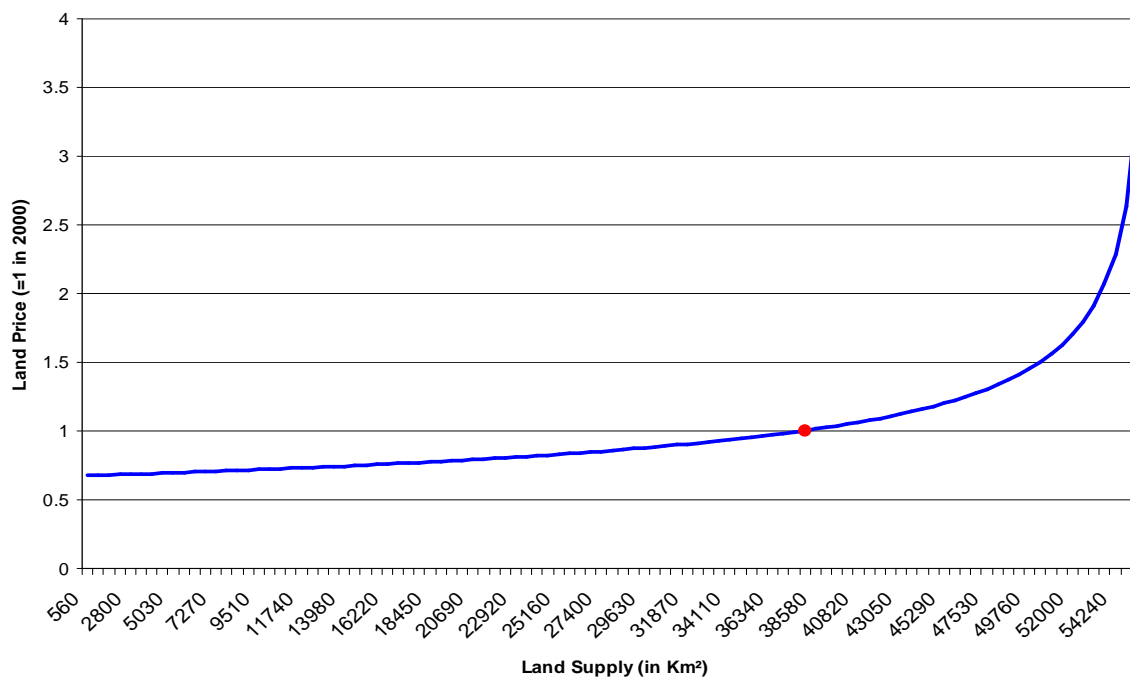
Source: NEMESIS model

Figure 7.3.16: Irish land supply in 2000



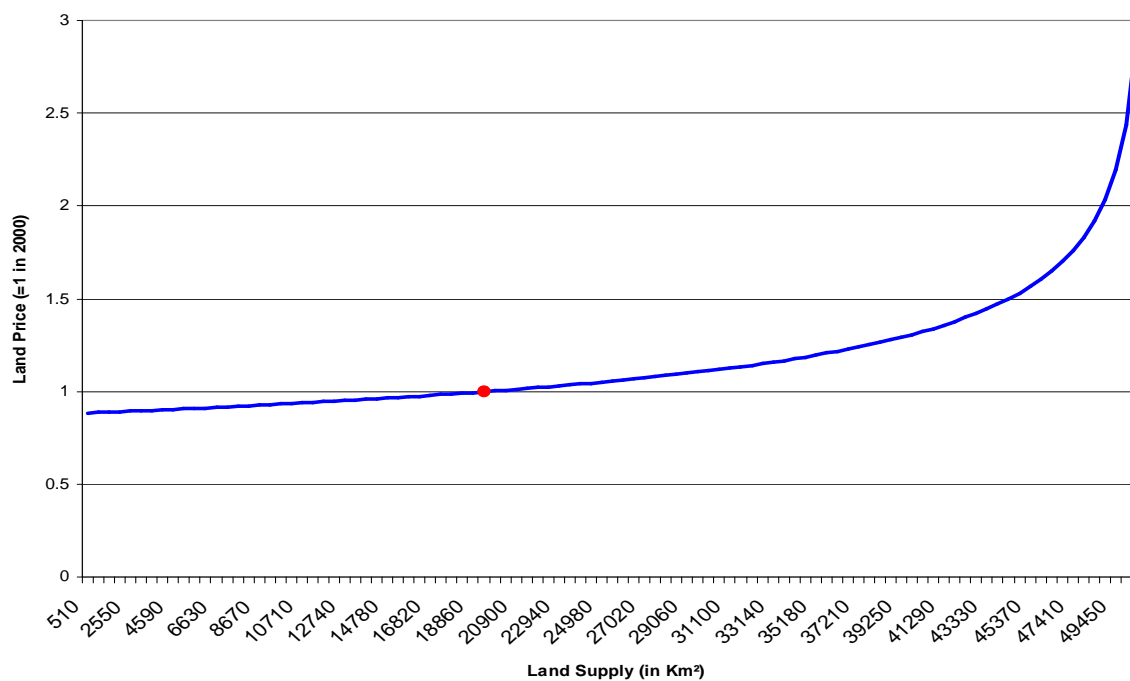
Source: NEMESIS model

Figure 7.3.17: Lithuanian land supply in 2000



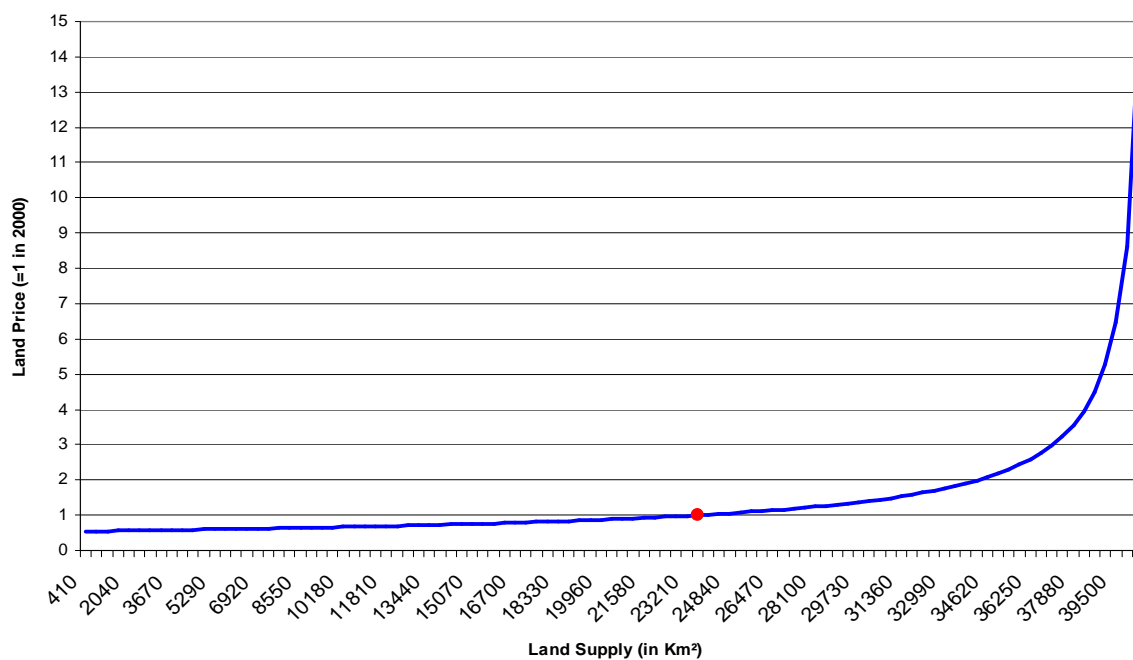
Source: NEMESIS model

Figure 7.3.18: Latvian land supply in 2000



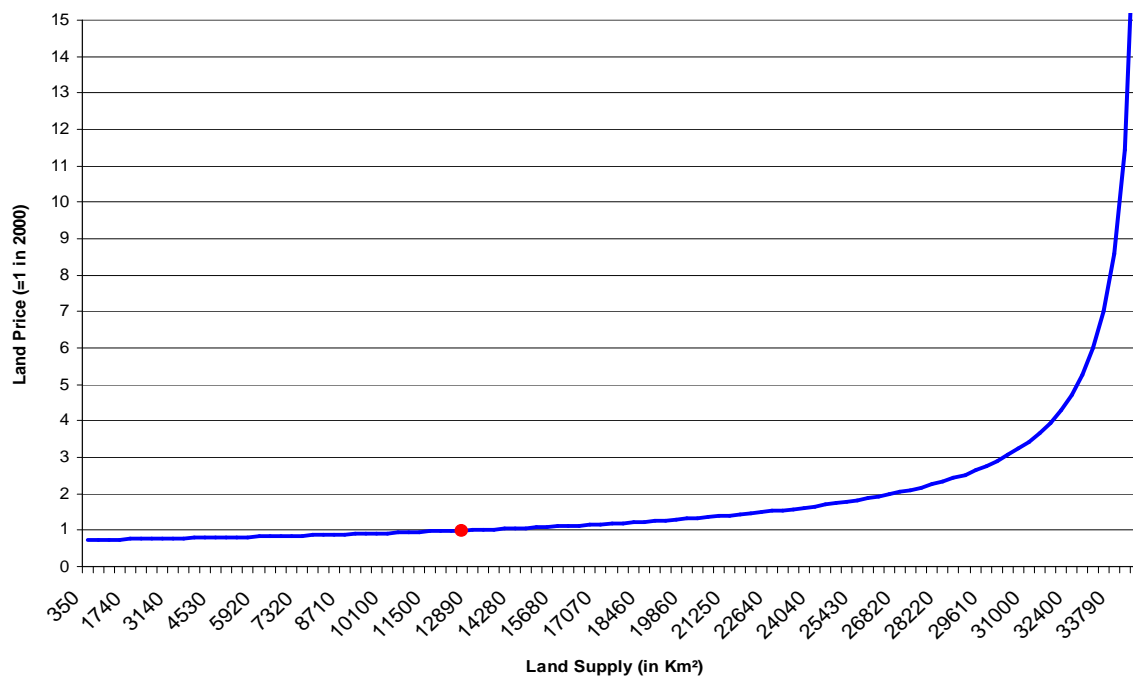
Source: NEMESIS model

Figure 7.3.19: Slovakian land supply in 2000



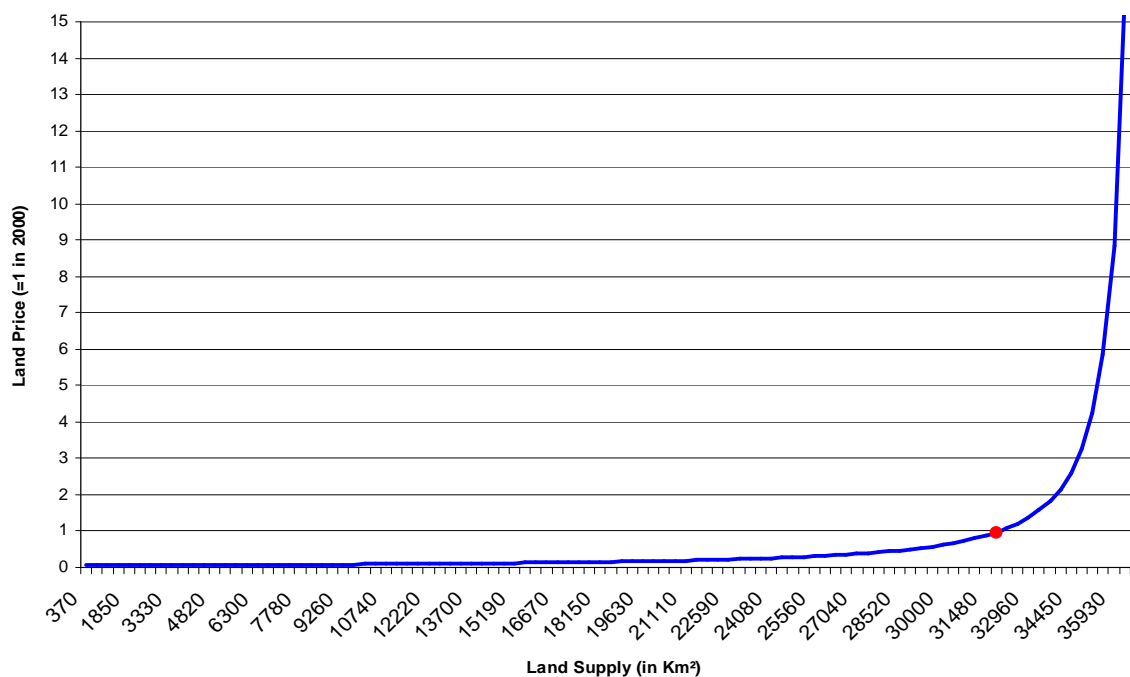
Source: NEMESIS model

Figure 7.3.20: Estonian land supply in 2000



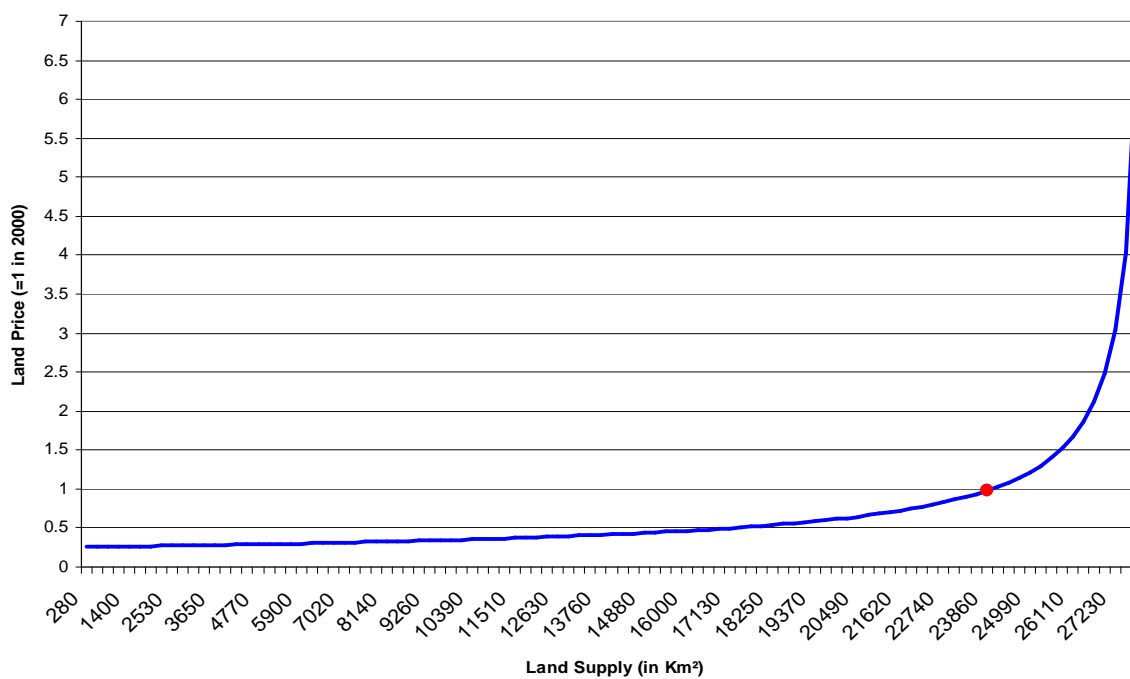
Source: NEMESIS model

Figure 7.3.21: Danish land supply in 2000



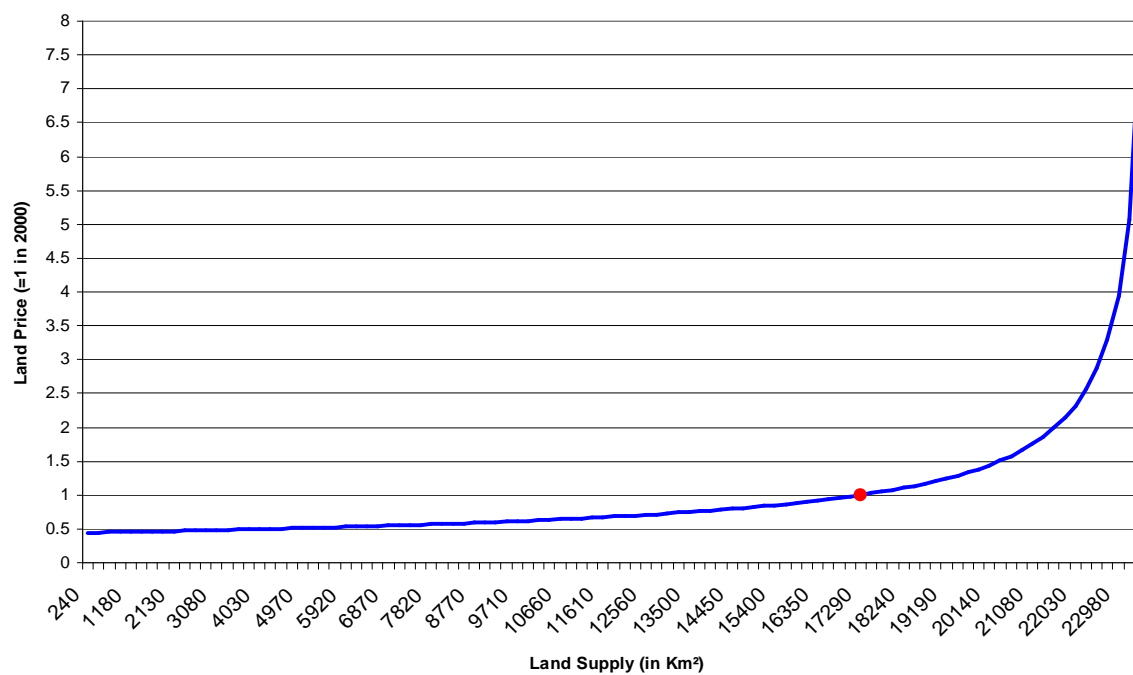
Source: NEMESIS model

Figure 7.3.22: Dutch land supply in 2000



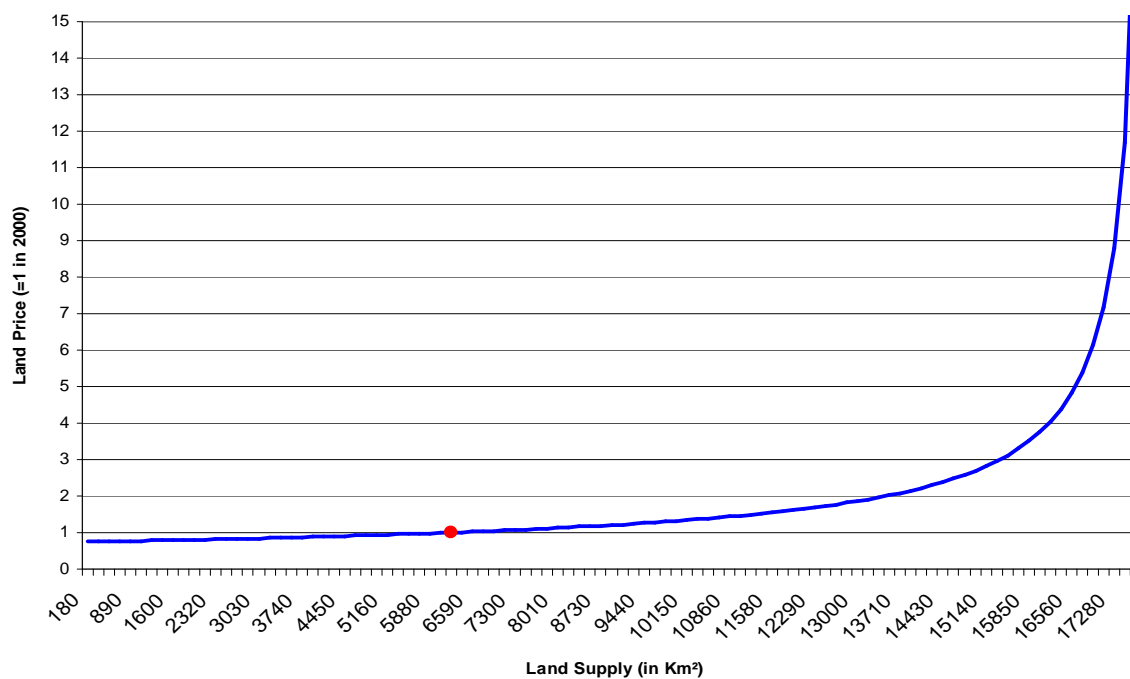
Source: NEMESIS model

Figure 7.3.23: Belgian land supply in 2000



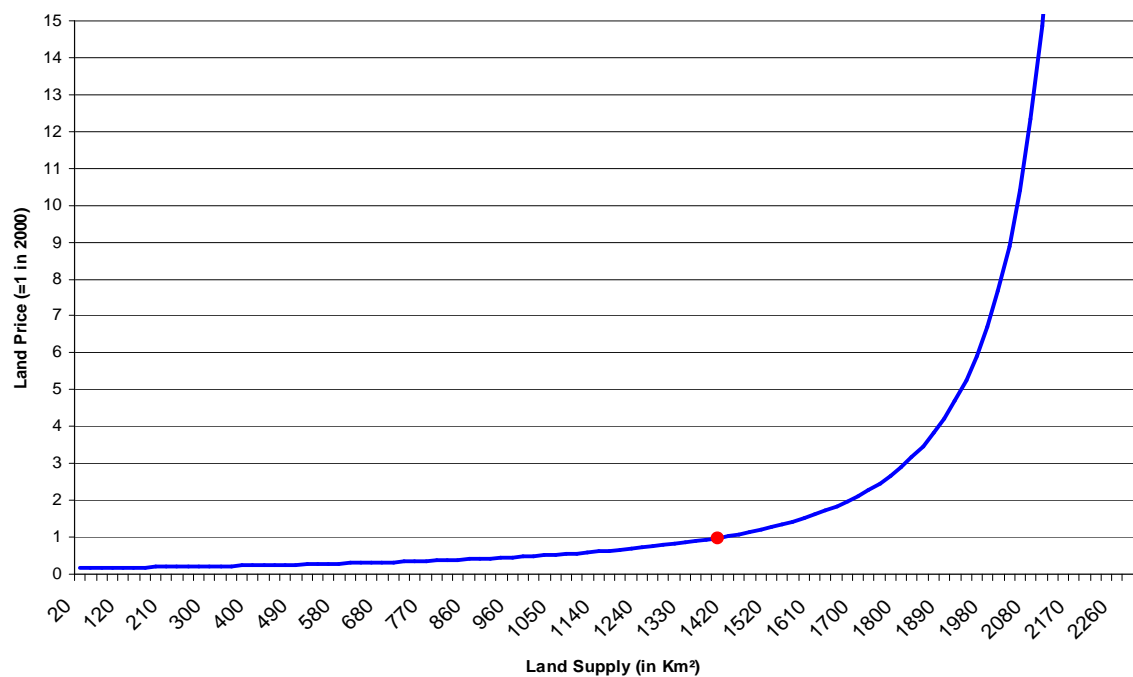
Source: NEMESIS model

Figure 7.3.24: Slovenian land supply in 2000



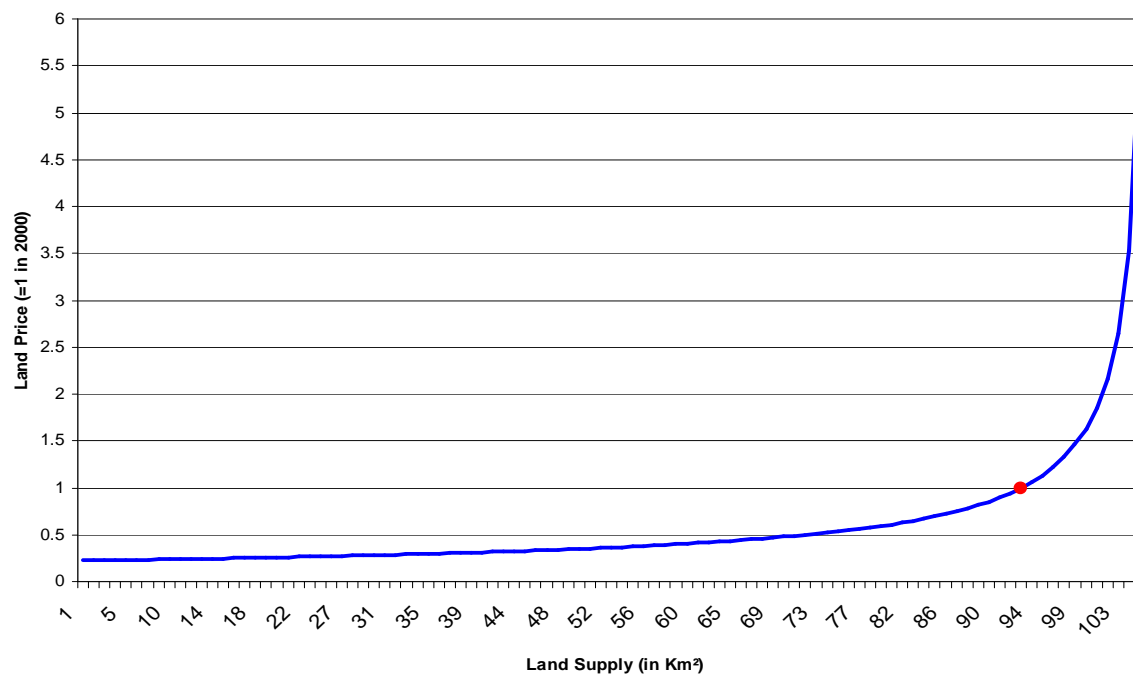
Source: NEMESIS model

Figure 7.3.25: Luxembourgian land supply in 2000



Source: NEMESIS model

Figure 7.3.26: Maltese land supply in 2000



Source: NEMESIS model

7.4 Appendix D: Storylines of alternative scenarios

7.4.1 A1 - “hyper-tech”¹²

“Global cooperation and high economic growth lead to innovation and rapid technological development. Investment in R&D is high and nations share knowledge and pool resources in a global research market place. Mobility of researchers within this marketplace is high. Other workers are also more mobile due to better, faster and cheaper means of transportation. Energy prices decline because supply is driven by new developments in renewable energy production and nuclear fission. There is a narrowing of wealth disparities worldwide and global equity is enhanced. A virtuous circle is created with technological development leading to greater economic growth and in turn more investment in R&D.

This is the golden age of human cooperation and development. Consequences Technological development leads to new ways of working. People are able to reduce commuting through tele-working and consequently there is a re-population of rural areas. Rural areas are more strongly dependent on service industries and agriculture plays a minor part in the rural economy, not least because genetic technology has resulted in unprecedented increases in crop productivity and the need, therefore, for less productive agricultural land. Most farmers are engaged in landscape gardening as they are paid to maintain the countryside for its aesthetic value for residents.

Population increases because of a decline in the mortality rate arising from advances in medicine and better health care. There is also substantial immigration flows due to high levels of economic growth in Europe. However, because of a skill biased technological change, there is less need for low-unskilled labour and governments attempt to decrease the number of low skilled immigrants. Better health implies that people both exit the labour market and suffer disability at a later age. Most people now expect to retire in their mid 70s and living to over 100 years old becomes common place.

Implications for peri-urban development Small polycentric towns and cities become increasingly popular as a place to live as a compromise between the rural idyll and the need for social services such as schools, health care and cultural activities. New transport technologies lead to more rapid journeys and the expansion of the commuting distances around towns and cities. This leads to increased peri-urbanisation and urban sprawl, with consequences for environmental impacts and the provision of urban services. As people move out of larger cities, mono-centric urban areas struggle to generate sufficient tax revenue to maintain infrastructure. Such cities lose further importance as new technologies allow business to be conducted in a decreasing number of mega-finance centres: e.g. London, Frankfurt, Paris and Edinburgh.”

12. All storylines come from Ravetz *et al.* 2008 [401].

7.4.2 A2 - “extreme water”

“Extreme Water, otherwise titled “Europe H2O”, is a scenario based around the SRES A2 family, in which water crises become common place across Europe. Flooding, drought and sea level rise generate social, economic and environmental impacts on an unprecedented scale. A year does not go by without a major event, and in some cities and regions development activities are seriously constrained. Driving forces include climate change and associated impacts including sea level rise, increased precipitation (and hence greater flooding) in northern Europe, and lower rainfall (and therefore droughts) in southern Europe.

Continually increasing population is also a feature of this scenario, driving water crises via complex chains of cause and effect. Essentially there is an increased demand for water resources, contributing to shortages in some areas, alongside a higher demand for land, putting pressure on floodplains and coastal zones. Further, ‘creeping urbanisation’ negatively impacts on natural water cycles. For example, surface sealing contributes to increases in urban flooding due to greater runoff volumes and also reduces groundwater recharge.

Economic growth and technological development is experienced, although in many cases uneven and fragmented. This creates regional winners and losers and introduces an equity dimension into the scenario. More prosperous areas are able to invest in adaptation strategies such as flood defences and water efficiency technologies, whilst others remain more vulnerable and suffer from water crises more acutely. However, the dominance of the free market in political and economic thinking creates problems of its own. There is a general ignorance of the relationship between human societies and the water cycle, which exacerbates the frequency and impact of water crises.

Key features of this scenario, including possible consequences for peri-urban land use relationships, are described in greater detail below.

Sea level rise: A combination of accelerated melting of the icecaps driven by above average temperature increases in the polar regions and thermal expansion of the global oceans generates significant sea level rise of over half a metre by mid century. Coastal urban areas unable to afford enhanced protection are flooded with increasing regularity. Particular problems are experienced on Europe’s Atlantic and North Sea coasts during the winter months, where the increased frequency and intensity of storms combine with higher sea levels to devastating effect. Some nations take this threat more seriously than others. The Netherlands spends billions on upgrading their coastal flood defences whilst England is slower to act. In 2020, a repeat of the notorious North Sea floods of 1953 sees the Dutch population largely spared, although thousands perish in south east England.

Drought: Reduced precipitation due to climate change combines with population growth and increased water abstraction (particularly for tourism and agricultural industries) to create droughts that grip large parts of

the Mediterranean region with increasing regularity. Associated impacts include forest fires, soil erosion and saltwater intrusion into coastal aquifers. South east and central Spain, south east Italy and south east Greece are especially badly affected. The Guadalquivir river basin in Spain experiences regular low flows. Post 2015, the residents of Seville suffer severe water shortages during most summers, leading to significant out-migration from the urban core. However, those with the ability to pay for water supplies live more comfortably in well irrigated suburban 'green enclaves'. Limited uptake of water efficiency devices, an unwillingness to impose comprehensive water pricing, and slow technological progress in the water sector compound these problems. The number of people living in water stressed river basins therefore steadily grows. Impacts of reduced precipitation due to climate change will also lead to a higher disparity between Western and Eastern Europe. In Eastern parts of Europe, where central climate conditions with dry summers, and soil conditions that offer low water storage capacity occur at the same, likewise desertification and extreme yield reduction will take place. Agricultural land use will be abandoned in such areas. Remote areas will depopulate rapidly.

Flooding: More frequent and severe flooding is driven by a changing climate. Also, spatial planning policy frameworks are generally weak due to the strong influence of free market political ideologies. This leads to accelerated development in floodplains and limited implementation of measures to reduce vulnerability and increase resilience of new development to flooding. The numbers of people at risk of flooding increases, and the social, economic and environmental impacts of floods escalate when they do occur. Central Europe and the Black Sea region, badly hit by floods in 2002, are flooded again in 2009 and 2010. Prague is shattered and its burgeoning tourist industry suffers a devastating blow. Local scale flash flooding in urban areas is commonplace. This is caused by increasingly intense rain storms that overwhelm inadequate and outdated drainage systems. Insurance companies are reluctant to offer cover in areas at high risk of flooding, creating urban 'flood ghettos'. As population growth remains high, many people on lower incomes are nevertheless forced to look for housing in these marginalised areas.

Implications for peri-urban land use relationships: An acceleration in the frequency and intensity of water crisis across Europe drives a range of broad changes to peri-urban land use relationships. The most significant of these include:

- Areas that experience limitations in available water supplies and regular flooding become marginalised in favour of more resilient and less vulnerable locations. Pockets of growth and decline emerge.
- Affluent yet vulnerable cities and regions, including London, Madrid and the Randstad, spend huge sums of money implementing adaptation strategies in an attempt to ensure their future growth and prosperity.
- Steady population growth, much of which stems from immigration from beyond Europe's borders, pressurises urban infrastructure and services. This occurs particularly in areas marginalised by more frequent

water crises, increasing the number of people at threat.

- *Extreme summer heat and drought in the Mediterranean basin hits the tourism industry hard. Related businesses suffer leading to urban decay. At the same time, reduced water supplies for irrigation constrain the regions agricultural industry leading to widespread land abandonment. The Baltic States and Scandinavia benefit from these changes.”*

7.4.3 B1 - “peak oil”

“The B1 SRES scenario describes a future world where there is a high level of environmental and social consciousness combined with a globally coherent approach to a more sustainable development. In the B1 storyline, governments, businesses, media and households pay increased attention to the environmental and social aspects of development. Economic development in B1 is balanced, and investments are oriented to improved efficiency of resources uses (“dematerialization”), social equity and environmental protection. A particular effort is devoted to increases in resource efficiency through incentive systems, combined with advances in international institutions, which allow to rapid development of cleaner technology.

Context

High environmental and social concerns lead local, regional, national and international institutions to strengthen incentive policies for reducing environmental impacts of polluting activities. Pollutants are strongly taxed in order to orient the demand on cleaner products. The fiscal resources (from taxation, sale of tradable permits ...) are then used for RTD policies and others public expenditures, such as development of public transports. R&D incentives are used to accelerate the development and the cost efficiency of resource saving technologies. Taxation on “carbon energy” and high cost of cleaner technologies lead to a high final energy cost, reinforced by the past consumption patterns which are not balanced by increases in oil supply. So, household expenditures are progressively oriented toward low energy intensive consumptions.

Consequences

High energy price affects consumer’s choices that spend more income on services than on manufactured goods through substitution effects. In short term, economic growth is also reduced by downward income effects. High transportation cost reduces trade between regions (locally and internationally) and affects the household’s localisation choice: They prefer living closer from economic centres; rural areas are abandoned in favour of urban and peri-urban areas with well developed public transports. Taxation receipts are used by governments and public institutions:

- *to promote public transports infrastructures,*

- to develop energy saving technologies,
- to invest in education, research and health system,
- to reduce social inequalities by income redistributions.

In this context of high transportation costs, economic activity will be more affected in countries with strong dependency on imports and exports, and in sprawled regions where households and producers transportation costs are higher than in concentrated areas. But, the negative sides have some positive counterparts; in a longer term horizon, the incentives for reducing the “carbon energy” allow promoting the development of locally produced ‘environment friendly goods’, intensive in employment; its then partially counterbalance the initial negative impacts of final energy prices rise on final consumption and employment.

Implications for peri-urban land use relationships

The high level of energy prices leads to huge effects on choices of localisation for both production and consumption. Thus very local markets are promoted for goods that are environmental friendly. Indeed these latter goods allow to minimise both transportation costs and environmental impacts what is demanded by consumers whom environmental consciousness is especially high. For example organic goods are produced by farms located near from peri-urban areas and economic centres, where the population is now living. Concerns about environmental impact of international migration and transportation, implies strict regulations and low levels of migration. There is pollution, high oil prices, concern and uncertainty about the future, therefore fertility is depressed.

Indeed the household’s localisation is also rather different because of transportation cost: households live now closer from their offices and jobs localisation. Thus population is concentrated near cities what minimises his spending for transportation. Of course only important public transportation networks can allow this.

Therefore rural areas are rather abandoned by population in favour of urban and peri-urban areas. For the other areas located very far from centres, there is a real risk (or opportunity for nature) to get “economic deserts” which can become areas for biodiversity and protected natural environment (Forest, Natura 2000, etc.). These wide open spaces sparsely populated and protected on its fauna and flora are very favourable to the creation of new recreational areas. Besides it allows for large areas with fast growing bio-mass to capture CO2 emissions and other pollutants. Therefore there are very new economic destinations for these areas.”

7.4.4 B2 - “Fragmentation”

“In this scenario Europe experiences growing social friction due to increasingly fragmented societies in terms of age, ethnicity and lack of international cooperation. The voter-strong elderly population implies a greater level of inter-generational transfers. However, the working-age population is increasingly disinclined

to transfer resources to the elderly; they argue that they will need to save for their own retirement while parts of their pay-as-you-go pension schemes are simultaneously phased out, providing fewer benefits for them. Moreover, the elderly are seen to be healthier than ever, but unwilling to accept the jobs offered to them, causing inter-generational conflicts to increase in magnitude.

Relatively large migrant populations with different sets of values, cultures and religious beliefs have limited social contact with native populations. This leads to increased social fragmentation, mutual distrust and limited willingness to support individuals outside of one's own group. Political voting shifts, due to a decreased willingness to pay for other residents in one's own country, result in a shrinking welfare state. The situation is worsened by increasing problems of tax evasion. Cities are particularly challenged as they are characterised by older native populations and younger migrant populations – which reduce the ability for joint political action.

Cohesion is becoming more of a challenge on the international scale across the European Union. Large structural adjustment programs, which were meant to decrease inequality within the EU, lose support. Member states increasingly prefer to focus on solving their own issues. The effect of less centralised governing increases the difficulties in sharing the burden of international mitigative efforts to reduce environmental challenges, including costly policies to reduce climate change and for more sustainable resource extraction. For example, mutual distrust implies that fewer are willing to share the burden of reducing greenhouse gas emission reductions. This leads to less effective international joint efforts to mitigate climate change. Other joint challenges faced by the EU become less feasible, as member states meet the demands to share reliable data on sensitive issues, such as resource use and pollution levels, with increased suspicion. Overall, trust between states is low, leading to common agreements not being reached – or not being followed.

Cities are more dispersed as younger migrant populations dominate city centres and older natives populate outskirts and green enclaves outside the cities. The ethnic division of cities is driven by the increased immigration of the working-age population from outside and within the EU. The elderly in ethnically diverse cities are more likely to migrate to rural areas and form relatively closed communities.

A change in migration patterns is expected in the future when the working-age migrant population grows older, and the current elderly population becomes more vulnerable and seeks family support from their in-town offspring. High growth in the social sector demand for the care of the elderly is being paid by the working-age population, diminishing their ability to care for their dependants. This in turn increases demand for childcare from the early ages onward. Self-reliance and preservation of local identities is the rule of conduct. Rural centres concentrate on sustainable farming and adequate social support for their population structure. Specialised care is sought in towns.

Economic growth differentials are large among areas and different states alike. The population growing up is more likely to engage in livelihoods and social environments close to their origins. Economic development levels do not converge.”

7.5 Appendix E: CAP reform detailed results by EU country

7.5.1 Instruments effects

7.5.1.1 Agriculture

Table 7.5.1: Total agricultural production change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	-0.73%	-1.13%	-1.66%	-1.93%	0.68%	-0.02%	-0.39%	-0.96%	-1.50%
BE	-0.35%	-0.55%	-0.76%	-0.78%	-1.27%	-1.36%	-1.65%	-1.79%	-1.68%
CZ	-0.68%	-1.12%	-1.59%	-1.98%	0.26%	-0.17%	-0.66%	-1.08%	-1.56%
DE	-0.88%	-1.42%	-1.97%	-2.36%	0.37%	-0.52%	-0.90%	-1.43%	-1.80%
DK	-0.62%	-0.92%	-1.36%	-1.60%	0.26%	-0.15%	-0.44%	-0.77%	-0.95%
EE	-0.87%	-0.93%	-0.85%	-1.21%	-0.42%	-0.48%	-0.60%	-0.43%	-1.19%
ES	-0.54%	-0.98%	-1.52%	-1.82%	-1.12%	-1.55%	-1.96%	-2.54%	-2.88%
EU	-0.58%	-1.03%	-1.50%	-1.78%	-0.69%	-1.23%	-1.65%	-2.09%	-2.41%
FI	-2.70%	-4.94%	-7.34%	-9.15%	-2.52%	-4.93%	-7.13%	-10.12%	-12.21%
FR	-1.01%	-1.64%	-2.25%	-2.75%	-1.67%	-2.54%	-3.16%	-3.80%	-4.34%
GR	-0.01%	-0.06%	-0.16%	-0.23%	0.10%	0.02%	-0.02%	-0.10%	-0.32%
HU	-0.15%	-0.26%	-0.36%	-0.48%	-1.62%	-1.68%	-1.80%	-1.88%	-2.01%
IE	-0.09%	-0.09%	-0.03%	0.01%	0.95%	0.95%	0.90%	0.87%	0.94%
IT	-0.22%	-0.96%	-1.60%	-1.75%	-1.85%	-2.34%	-3.04%	-3.43%	-3.66%
LT	-1.67%	-2.40%	-3.62%	-4.47%	-0.55%	-1.46%	-2.24%	-3.53%	-4.43%
LU	-0.35%	-0.55%	-0.76%	-0.78%	-1.27%	-1.36%	-1.65%	-1.79%	-1.68%
LV	-1.21%	-2.30%	-3.07%	-3.39%	0.80%	0.05%	-1.17%	-1.79%	-2.32%
MT	-0.54%	-0.92%	-1.28%	-1.66%	1.84%	1.34%	0.93%	0.57%	0.14%
NL	-0.35%	-0.57%	-0.83%	-0.98%	2.28%	2.20%	2.06%	1.99%	1.90%
NO	-0.04%	-0.04%	-0.06%	0.00%	0.03%	0.04%	0.05%	0.08%	0.10%
PL	-0.37%	-0.65%	-0.95%	-1.23%	0.28%	0.05%	-0.25%	-0.56%	-0.90%
PT	-0.25%	-0.35%	-0.47%	-0.57%	-0.69%	-0.87%	-0.94%	-0.96%	-1.10%
RO	0.26%	0.24%	0.27%	0.20%	-2.04%	-2.02%	-2.08%	-2.03%	-1.94%
SE	-0.63%	-1.14%	-1.74%	-1.96%	-1.51%	-2.09%	-2.61%	-3.15%	-3.44%
SI	-0.13%	0.07%	0.03%	0.17%	-2.72%	-2.57%	-2.61%	-2.55%	-2.76%
SK	-0.15%	-0.34%	-0.44%	-0.58%	-0.32%	-0.47%	-0.63%	-0.71%	-0.95%
UK	-0.45%	-0.59%	-0.88%	-0.91%	-0.25%	-0.63%	-0.88%	-1.20%	-1.33%

Source: NEMESIS and CAPRI models

Table 7.5.2: Vegetal production change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	-1.37%	-2.02%	-2.90%	-3.25%	-1.21%	-2.43%	-3.08%	-4.17%	-4.81%
BE	-0.49%	-0.73%	-0.91%	-0.62%	-2.04%	-2.46%	-2.50%	-2.55%	-2.69%
CZ	-0.96%	-1.61%	-2.18%	-2.70%	0.47%	0.15%	-0.51%	-0.97%	-1.65%
DE	-1.89%	-3.05%	-4.16%	-5.01%	-1.67%	-3.61%	-4.42%	-5.71%	-6.52%
DK	-1.35%	-1.77%	-2.65%	-3.03%	-1.55%	-2.55%	-3.07%	-3.85%	-4.13%
EE	-2.09%	-2.18%	-1.84%	-2.68%	-0.90%	-0.62%	-0.78%	-0.11%	-1.83%
ES	-0.70%	-1.28%	-1.91%	-2.17%	-1.53%	-2.10%	-2.59%	-3.26%	-3.58%
EU	-0.95%	-1.57%	-2.23%	-2.59%	-1.27%	-2.16%	-2.73%	-3.42%	-3.87%
FI	-5.70%	-7.93%	-10.75%	-10.90%	-4.13%	-7.39%	-9.38%	-11.53%	-12.82%
FR	-1.69%	-2.64%	-3.45%	-4.17%	-1.50%	-3.02%	-3.99%	-5.05%	-5.86%
GR	0.00%	-0.04%	-0.13%	-0.20%	-0.48%	-0.55%	-0.58%	-0.64%	-0.86%
HU	-0.22%	-0.43%	-0.60%	-0.80%	-1.25%	-1.35%	-1.55%	-1.69%	-1.90%
IE	0.11%	0.28%	0.86%	1.15%	0.70%	1.08%	1.53%	1.69%	2.17%
IT	-0.29%	-0.84%	-1.46%	-1.67%	-0.87%	-1.42%	-1.92%	-2.39%	-2.71%
LT	-2.80%	-4.02%	-6.06%	-7.48%	-0.90%	-2.24%	-3.47%	-5.58%	-7.02%
LU	-0.49%	-0.73%	-0.91%	-0.62%	-2.04%	-2.46%	-2.50%	-2.55%	-2.69%
LV	-2.13%	-4.10%	-5.44%	-5.98%	0.70%	-0.38%	-2.49%	-3.44%	-4.22%
MT	1.11%	2.41%	3.77%	4.91%	3.88%	6.63%	7.60%	8.87%	10.01%
NL	-0.29%	-0.43%	-0.59%	-0.64%	-0.92%	-1.14%	-1.42%	-1.41%	-1.53%
NO	0.03%	0.07%	0.11%	0.11%	0.12%	0.22%	0.26%	0.32%	0.35%
PL	-0.54%	-1.01%	-1.46%	-1.91%	0.85%	0.64%	0.16%	-0.33%	-0.87%
PT	-0.31%	-0.40%	-0.51%	-0.59%	-0.93%	-1.17%	-1.22%	-1.28%	-1.44%
RO	0.28%	0.32%	0.43%	0.43%	-0.78%	-0.66%	-0.74%	-0.64%	-0.50%
SE	-0.87%	-1.38%	-2.18%	-2.31%	-1.92%	-2.57%	-3.28%	-3.93%	-4.15%
SI	-0.32%	-0.03%	-0.21%	0.01%	-1.43%	-1.10%	-1.10%	-1.09%	-1.50%
SK	-0.21%	-0.57%	-0.68%	-0.92%	-0.82%	-0.97%	-1.23%	-1.31%	-1.69%
UK	-1.04%	-1.46%	-2.18%	-2.34%	-1.03%	-1.82%	-2.46%	-3.20%	-3.44%

Source: NEMESIS and CAPRI models

Table 7.5.3: Animal production change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	-0.35%	-0.61%	-0.93%	-1.15%	1.79%	1.40%	1.20%	0.92%	0.45%
BE	-0.31%	-0.49%	-0.70%	-0.84%	-0.99%	-0.96%	-1.34%	-1.52%	-1.32%
CZ	-0.41%	-0.66%	-1.04%	-1.31%	0.06%	-0.46%	-0.80%	-1.17%	-1.49%
DE	-0.29%	-0.47%	-0.69%	-0.82%	1.56%	1.27%	1.15%	1.06%	0.96%
DK	-0.40%	-0.66%	-0.97%	-1.17%	0.81%	0.58%	0.35%	0.16%	0.02%
EE	-0.10%	-0.16%	-0.23%	-0.29%	-0.12%	-0.39%	-0.49%	-0.63%	-0.79%
ES	-0.27%	-0.46%	-0.86%	-1.21%	-0.41%	-0.61%	-0.90%	-1.32%	-1.67%
EU	-0.33%	-0.67%	-1.04%	-1.26%	-0.20%	-0.50%	-0.83%	-1.11%	-1.32%
FI	-1.17%	-3.40%	-5.58%	-8.26%	-1.69%	-3.66%	-5.97%	-9.40%	-11.90%
FR	-0.53%	-0.93%	-1.41%	-1.75%	-1.79%	-2.20%	-2.57%	-2.92%	-3.26%
GR	-0.04%	-0.13%	-0.27%	-0.36%	2.65%	2.49%	2.42%	2.26%	2.04%
HU	-0.08%	-0.06%	-0.09%	-0.12%	-2.03%	-2.05%	-2.08%	-2.10%	-2.12%
IE	-0.14%	-0.18%	-0.25%	-0.28%	1.01%	0.92%	0.74%	0.67%	0.63%
IT	-0.13%	-1.12%	-1.78%	-1.86%	-3.13%	-3.52%	-4.49%	-4.76%	-4.89%
LT	-0.11%	-0.17%	-0.25%	-0.31%	-0.06%	-0.37%	-0.52%	-0.69%	-0.85%
LU	-0.31%	-0.49%	-0.70%	-0.84%	-0.99%	-0.96%	-1.34%	-1.52%	-1.32%
LV	-0.14%	-0.21%	-0.32%	-0.40%	0.92%	0.55%	0.36%	0.11%	-0.11%
MT	-0.89%	-1.63%	-2.34%	-3.05%	1.41%	0.23%	-0.47%	-1.17%	-1.94%
NL	-0.37%	-0.62%	-0.91%	-1.11%	3.44%	3.41%	3.33%	3.23%	3.15%
NO	-0.05%	-0.07%	-0.10%	-0.03%	0.00%	-0.01%	0.00%	0.02%	0.03%
PL	-0.19%	-0.30%	-0.44%	-0.55%	-0.28%	-0.53%	-0.67%	-0.79%	-0.93%
PT	-0.17%	-0.28%	-0.42%	-0.54%	-0.37%	-0.47%	-0.56%	-0.56%	-0.65%
RO	0.21%	0.06%	-0.10%	-0.32%	-4.85%	-5.03%	-5.06%	-5.14%	-5.14%
SE	-0.49%	-1.01%	-1.50%	-1.78%	-1.29%	-1.84%	-2.26%	-2.73%	-3.06%
SI	0.03%	0.15%	0.25%	0.30%	-3.84%	-3.84%	-3.91%	-3.82%	-3.85%
SK	-0.11%	-0.15%	-0.24%	-0.30%	0.09%	-0.05%	-0.14%	-0.21%	-0.33%
UK	-0.21%	-0.24%	-0.35%	-0.33%	0.07%	-0.15%	-0.25%	-0.39%	-0.48%

Source: NEMESIS and CAPRI models

Table 7.5.4: Total agricultural product price change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	0.52%	0.94%	1.49%	2.01%	-12.01%	-12.29%	-11.53%	-11.03%	-11.40%
BE	0.59%	1.08%	1.70%	2.25%	-12.73%	-12.75%	-12.13%	-12.10%	-11.71%
CZ	0.90%	1.63%	2.59%	3.45%	-9.00%	-9.26%	-7.52%	-6.57%	-6.84%
DE	0.60%	1.08%	1.72%	2.33%	-10.71%	-11.77%	-9.94%	-9.31%	-9.60%
DK	0.52%	0.94%	1.48%	1.99%	-7.81%	-7.90%	-7.17%	-6.60%	-6.83%
EE	1.06%	1.94%	3.14%	4.22%	-8.70%	-9.15%	-7.17%	-6.16%	-6.56%
ES	0.48%	0.84%	1.29%	1.71%	-7.94%	-8.12%	-7.57%	-7.24%	-7.34%
EU	0.61%	1.02%	1.56%	2.06%	-9.63%	-9.75%	-9.07%	-8.57%	-8.76%
FI	7.66%	5.22%	4.59%	4.42%	-6.21%	-6.28%	-5.39%	-4.78%	-5.15%
FR	0.50%	0.90%	1.41%	1.89%	-10.75%	-11.03%	-10.39%	-9.95%	-10.13%
GR	0.44%	0.72%	1.07%	1.40%	-6.24%	-6.58%	-5.91%	-5.60%	-5.68%
HU	0.47%	0.86%	1.36%	1.81%	-4.82%	-5.01%	-4.14%	-3.69%	-3.81%
IE	1.04%	2.08%	3.35%	4.55%	-23.49%	-23.47%	-22.49%	-21.31%	-21.06%
IT	0.49%	0.86%	1.32%	1.74%	-9.04%	-9.31%	-8.67%	-8.22%	-8.30%
LT	0.86%	1.59%	2.57%	3.45%	-8.74%	-9.26%	-7.11%	-6.27%	-6.56%
LU	0.60%	1.52%	2.66%	3.69%	-22.60%	-22.64%	-21.62%	-21.57%	-20.93%
LV	1.21%	2.17%	3.44%	4.58%	-9.59%	-9.96%	-7.63%	-6.36%	-6.91%
MT	0.35%	0.62%	0.97%	1.28%	-3.60%	-3.91%	-3.11%	-2.81%	-3.08%
NL	0.31%	0.56%	0.86%	1.14%	-7.29%	-4.90%	-6.81%	-6.45%	-6.77%
NO	0.12%	0.24%	0.40%	0.53%	-3.35%	-3.54%	-3.22%	-3.06%	-3.24%
PL	0.78%	1.37%	2.16%	2.87%	-6.41%	-6.64%	-5.34%	-4.67%	-4.91%
PT	0.41%	0.68%	1.02%	1.33%	-7.52%	-7.71%	-7.39%	-7.01%	-7.34%
RO	0.09%	0.20%	0.38%	0.53%	-7.98%	-8.18%	-7.68%	-7.46%	-7.65%
SE	0.56%	1.06%	1.71%	2.32%	-11.07%	-10.94%	-10.31%	-9.66%	-10.12%
SI	0.48%	0.89%	1.41%	1.89%	-9.56%	-10.03%	-9.00%	-8.58%	-9.03%
SK	0.59%	1.11%	1.78%	2.39%	-6.67%	-6.84%	-5.76%	-5.17%	-5.33%
UK	0.76%	1.45%	2.27%	3.05%	-13.52%	-13.50%	-12.67%	-11.88%	-12.14%

Source: NEMESIS and CAPRI models

Table 7.5.5: Vegetal product price change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	0.45%	0.78%	1.23%	1.64%	-6.44%	-6.43%	-5.93%	-5.48%	-5.39%
BE	1.42%	2.51%	3.96%	5.27%	-6.54%	-6.08%	-4.15%	-2.64%	-2.34%
CZ	0.64%	1.12%	1.81%	2.51%	-6.21%	-6.19%	-5.12%	-4.20%	-4.11%
DE	0.77%	1.37%	2.19%	2.97%	-5.15%	-4.94%	-3.93%	-2.88%	-2.74%
DK	2.35%	4.12%	6.64%	8.91%	-2.99%	-2.31%	0.30%	2.41%	2.66%
EE	0.39%	0.62%	0.94%	1.24%	-4.63%	-4.78%	-4.39%	-4.12%	-4.15%
ES	0.64%	0.97%	1.46%	1.93%	-5.32%	-5.36%	-4.72%	-4.18%	-4.19%
EU	17.51%	10.73%	8.05%	6.50%	-3.43%	-3.34%	-2.70%	-2.06%	-2.03%
FI	0.41%	0.63%	0.98%	1.32%	-5.32%	-5.54%	-5.17%	-4.84%	-5.04%
FR	0.43%	0.68%	1.01%	1.31%	-4.55%	-4.70%	-4.23%	-3.92%	-3.94%
GR	0.66%	1.20%	1.90%	2.54%	-4.46%	-4.30%	-3.43%	-2.77%	-2.63%
HU	2.02%	3.88%	6.21%	8.53%	-27.90%	-27.74%	-25.47%	-23.00%	-22.01%
IE	0.38%	0.62%	0.92%	1.20%	-4.35%	-4.46%	-4.06%	-3.76%	-3.75%
IT	1.58%	2.82%	4.50%	6.02%	-4.16%	-4.01%	-1.22%	0.29%	0.53%
LT	0.45%	0.78%	1.23%	1.64%	-6.44%	-6.43%	-5.93%	-5.48%	-5.39%
LU	2.98%	5.00%	7.69%	10.08%	-8.11%	-7.77%	-4.07%	-1.48%	-1.79%
LV	0.34%	0.58%	0.92%	1.24%	-1.00%	-1.03%	-0.45%	-0.18%	-0.39%
MT	0.22%	0.35%	0.52%	0.68%	-2.00%	-1.84%	-1.84%	-1.68%	-1.70%
NL	0.01%	0.06%	0.14%	0.20%	-1.86%	-1.93%	-1.70%	-1.51%	-1.69%
NO	1.04%	1.92%	3.12%	4.22%	-4.30%	-3.91%	-2.55%	-1.53%	-1.29%
PL	0.29%	0.40%	0.55%	0.71%	-4.19%	-4.45%	-4.24%	-4.08%	-4.31%
PT	0.19%	0.32%	0.55%	0.76%	-9.76%	-9.80%	-9.39%	-9.09%	-9.24%
RO	0.81%	1.47%	2.39%	3.27%	-7.03%	-7.02%	-5.71%	-4.64%	-4.68%
SE	0.45%	0.82%	1.31%	1.81%	-3.55%	-3.56%	-2.93%	-2.52%	-2.53%
SI	1.08%	1.94%	3.07%	4.11%	-5.16%	-4.90%	-3.50%	-2.42%	-2.25%
SK	1.24%	2.27%	3.49%	4.71%	-9.25%	-9.05%	-7.73%	-6.38%	-6.27%
UK	0.76%	1.45%	2.27%	3.05%	-13.52%	-13.50%	-12.67%	-11.88%	-12.14%

Source: NEMESIS and CAPRI models

Table 7.5.6: Animal product price change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	0.73%	1.40%	2.20%	2.92%	-19.25%	-19.55%	-18.50%	-17.81%	-18.37%
BE	0.70%	1.32%	2.06%	2.73%	-17.41%	-17.46%	-16.75%	-17.00%	-16.40%
CZ	0.39%	0.78%	1.26%	1.69%	-12.26%	-13.33%	-11.69%	-11.27%	-12.18%
DE	0.60%	1.13%	1.78%	2.37%	-15.45%	-17.52%	-14.89%	-14.46%	-15.08%
DK	0.41%	0.75%	1.17%	1.56%	-8.97%	-9.19%	-8.59%	-8.21%	-8.62%
EE	0.23%	0.54%	0.90%	1.21%	-12.36%	-13.54%	-11.97%	-11.67%	-12.48%
ES	0.68%	1.30%	2.04%	2.72%	-14.44%	-14.69%	-13.82%	-13.35%	-13.58%
EU	0.62%	1.19%	1.88%	2.50%	-15.67%	-15.81%	-15.05%	-14.51%	-14.93%
FI	0.71%	1.50%	2.47%	3.43%	-9.56%	-9.77%	-8.52%	-7.84%	-8.60%
FR	0.70%	1.36%	2.16%	2.87%	-18.85%	-19.25%	-18.19%	-17.56%	-17.75%
GR	0.60%	1.07%	1.63%	2.16%	-13.08%	-14.09%	-12.59%	-12.18%	-12.48%
HU	0.35%	0.66%	1.04%	1.38%	-6.23%	-6.86%	-5.82%	-5.49%	-5.93%
IE	0.83%	1.71%	2.76%	3.72%	-23.69%	-23.72%	-23.03%	-22.14%	-22.08%
IT	0.75%	1.42%	2.22%	2.94%	-18.75%	-19.32%	-18.17%	-17.39%	-17.64%
LT	0.19%	0.47%	0.79%	1.08%	-12.96%	-14.10%	-12.54%	-12.32%	-13.11%
LU	0.70%	1.32%	2.06%	2.73%	-17.41%	-17.46%	-16.75%	-17.00%	-16.40%
LV	-0.04%	0.20%	0.47%	0.72%	-10.63%	-11.49%	-10.11%	-9.77%	-10.48%
MT	0.36%	0.65%	1.00%	1.32%	-5.51%	-6.03%	-5.06%	-4.73%	-5.06%
NL	0.55%	1.03%	1.61%	2.14%	-17.00%	-10.74%	-15.92%	-15.20%	-16.04%
NO	0.20%	0.37%	0.58%	0.76%	-4.43%	-4.70%	-4.32%	-4.19%	-4.37%
PL	0.57%	0.91%	1.32%	1.70%	-9.15%	-10.04%	-8.70%	-8.35%	-9.10%
PT	0.66%	1.22%	1.89%	2.48%	-13.68%	-13.78%	-13.25%	-12.50%	-13.00%
RO	-0.04%	0.04%	0.13%	0.21%	-5.54%	-5.97%	-5.35%	-5.22%	-5.49%
SE	0.48%	0.95%	1.53%	2.05%	-15.20%	-14.99%	-14.69%	-14.22%	-15.01%
SI	0.51%	0.97%	1.51%	1.98%	-15.90%	-16.84%	-15.40%	-14.97%	-15.87%
SK	0.30%	0.64%	1.04%	1.41%	-9.23%	-9.80%	-8.79%	-8.48%	-8.95%
UK	0.63%	1.24%	1.99%	2.67%	-17.90%	-17.97%	-17.27%	-16.64%	-17.14%

Source: NEMESIS and CAPRI models

7.5.1.2 Land use

Table 7.5.7: Agricultural land use change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	-0.58%	-1.22%	-1.93%	-2.55%	-0.49%	-1.17%	-1.82%	-2.52%	-3.37%
BE	-0.58%	-1.20%	-1.84%	-2.39%	-0.87%	-1.54%	-2.19%	-2.82%	-3.66%
CZ	-0.41%	-0.94%	-1.51%	-2.01%	-0.11%	-0.62%	-1.10%	-1.66%	-2.26%
DE	-0.59%	-1.24%	-1.93%	-2.52%	-0.47%	-1.16%	-1.77%	-2.42%	-3.20%
DK	-0.32%	-0.63%	-0.98%	-1.28%	-0.16%	-0.46%	-0.77%	-1.10%	-1.46%
EE	-0.89%	-3.51%	-5.97%	-8.13%	0.42%	-2.05%	-4.30%	-6.44%	-9.51%
ES	-0.61%	-1.37%	-2.18%	-2.87%	-0.31%	-1.07%	-1.82%	-2.58%	-3.51%
EU	-0.45%	-1.02%	-1.61%	-2.13%	-0.27%	-0.84%	-1.38%	-1.95%	-2.63%
FI	-0.17%	-1.06%	-1.93%	-2.68%	0.09%	-0.68%	-1.44%	-2.21%	-3.13%
FR	-0.57%	-1.21%	-1.89%	-2.48%	-0.46%	-1.12%	-1.76%	-2.42%	-3.25%
GR	-0.66%	-1.66%	-2.62%	-3.40%	-0.21%	-1.20%	-2.13%	-2.94%	-4.09%
HU	-0.24%	-0.52%	-0.84%	-1.13%	-0.07%	-0.34%	-0.61%	-0.93%	-1.26%
IE	-0.08%	-0.18%	-0.29%	-0.39%	-0.15%	-0.25%	-0.36%	-0.49%	-0.62%
IT	-0.61%	-1.29%	-2.00%	-2.61%	-0.43%	-1.11%	-1.78%	-2.46%	-3.24%
LT	-0.72%	-1.80%	-2.91%	-3.89%	-0.01%	-1.09%	-2.03%	-3.08%	-4.36%
LU	-0.25%	-0.52%	-0.80%	-1.04%	-0.45%	-0.74%	-1.03%	-1.31%	-1.68%
LV	-0.47%	-1.58%	-2.68%	-3.64%	0.07%	-1.07%	-2.03%	-3.06%	-4.44%
MT	-0.04%	-0.09%	-0.13%	-0.17%	0.02%	-0.04%	-0.05%	-0.09%	-0.16%
NL	-0.34%	-0.70%	-1.10%	-1.45%	-0.22%	-0.48%	-0.94%	-1.33%	-1.79%
NO	0.01%	0.02%	0.04%	0.05%	-0.21%	-0.21%	-0.19%	-0.17%	-0.19%
PL	-0.38%	-0.84%	-1.33%	-1.77%	-0.09%	-0.54%	-0.96%	-1.46%	-1.98%
PT	-0.74%	-1.63%	-2.54%	-3.36%	-0.54%	-1.47%	-2.40%	-3.22%	-4.49%
RO	0.01%	0.01%	0.01%	0.02%	-0.05%	-0.05%	-0.05%	-0.05%	-0.05%
SE	-0.75%	-1.55%	-2.40%	-3.11%	-0.34%	-1.15%	-1.91%	-2.68%	-3.63%
SI	-1.29%	-2.78%	-4.28%	-5.51%	-0.77%	-2.34%	-3.70%	-5.09%	-6.81%
SK	-0.42%	-0.93%	-1.51%	-2.03%	-0.06%	-0.55%	-1.04%	-1.62%	-2.20%
UK	-0.19%	-0.40%	-0.64%	-0.85%	-0.13%	-0.34%	-0.56%	-0.80%	-1.06%

Source: NEMESIS model

Table 7.5.8: Real agricultural land price (with direct supports capitalisation) change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	-3.37%	-10.28%	-17.37%	-24.03%	-5.50%	-5.86%	-13.75%	-21.05%	-24.15%
BE	-7.86%	-16.04%	-24.32%	-32.84%	-11.61%	-17.94%	-28.23%	-37.22%	-43.70%
CZ	-8.22%	-18.01%	-27.74%	-35.60%	-0.33%	-9.34%	-19.28%	-29.26%	-36.90%
DE	-6.43%	-14.63%	-22.67%	-29.65%	-5.95%	-11.33%	-19.89%	-27.65%	-34.40%
DK	-8.55%	-17.51%	-25.58%	-33.02%	-4.30%	-11.15%	-20.08%	-28.28%	-35.84%
EE	-5.78%	-16.01%	-26.72%	-34.02%	2.02%	-7.06%	-17.50%	-28.81%	-34.94%
ES	-5.01%	-10.73%	-12.90%	-17.10%	-2.95%	-8.01%	-15.36%	-17.92%	-21.25%
EU	-6.65%	-13.19%	-20.12%	-26.83%	-4.65%	-10.11%	-17.51%	-24.81%	-30.98%
FI	6.11%	6.73%	6.39%	9.38%	4.85%	5.26%	4.56%	12.59%	14.23%
FR	-6.76%	-15.46%	-24.15%	-31.97%	-6.19%	-12.13%	-21.21%	-29.82%	-37.31%
GR	-9.34%	-18.51%	-26.75%	-33.28%	-3.25%	-11.46%	-20.84%	-29.85%	-32.73%
HU	-10.34%	-21.17%	-31.98%	-40.59%	-1.87%	-12.17%	-23.05%	-34.01%	-42.56%
IE	-9.54%	-19.53%	-29.64%	-37.90%	-9.09%	-19.04%	-30.06%	-40.43%	-48.94%
IT	-6.08%	2.12%	0.52%	-5.98%	-5.58%	-2.39%	0.79%	-4.29%	-9.80%
LT	-5.84%	-15.36%	-23.86%	-31.35%	1.74%	-6.31%	-16.11%	-24.85%	-32.32%
LU	-7.86%	-16.04%	-24.32%	-32.84%	-11.61%	-17.94%	-28.23%	-37.22%	-43.70%
LV	-4.27%	-11.54%	-20.08%	-28.04%	0.83%	-6.22%	-13.61%	-23.17%	-30.67%
MT	-10.16%	-20.30%	-30.30%	-38.15%	5.52%	0.00%	-11.13%	-21.47%	-29.19%
NL	-10.06%	-19.85%	-29.64%	-38.11%	-5.60%	-14.66%	-24.28%	-34.72%	-42.71%
NO	0.23%	0.38%	0.57%	0.28%	-1.40%	-1.05%	-0.91%	-0.83%	-0.77%
PL	-9.00%	-19.01%	-28.71%	-36.59%	-1.27%	-10.21%	-20.39%	-30.48%	-38.07%
PT	-8.13%	-17.46%	-26.18%	-33.59%	-4.68%	-11.85%	-21.16%	-31.24%	-37.67%
RO	2.27%	2.67%	2.97%	3.22%	-6.87%	-6.06%	-5.53%	-5.07%	-5.01%
SE	-5.24%	-11.46%	-17.54%	-24.63%	-3.18%	-7.12%	-13.98%	-20.54%	-26.44%
SI	-8.89%	-19.20%	-28.73%	-36.37%	-2.21%	-11.75%	-22.06%	-31.90%	-38.07%
SK	-9.76%	-20.09%	-30.55%	-38.97%	-1.03%	-10.79%	-21.42%	-32.02%	-40.27%
UK	-8.22%	-17.67%	-26.51%	-34.69%	-4.41%	-12.55%	-21.84%	-30.75%	-38.79%

Source: CAPRI model

Table 7.5.9: Real agricultural land price (without direct supports capitalisation) change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	-2.20%	-4.55%	-6.98%	-9.03%	-1.95%	-4.44%	-6.70%	-8.26%	-11.68%
BE	-2.29%	-4.62%	-6.95%	-8.86%	-3.37%	-5.84%	-8.13%	-10.59%	-12.97%
CZ	-1.89%	-4.20%	-6.60%	-8.62%	-0.51%	-2.84%	-4.91%	-7.03%	-9.61%
DE	-2.10%	-4.33%	-6.59%	-8.44%	-1.71%	-4.09%	-6.08%	-7.80%	-10.49%
DK	-2.58%	-4.98%	-7.49%	-9.58%	-1.20%	-3.61%	-5.90%	-8.32%	-10.73%
EE	-0.84%	-3.24%	-5.40%	-7.22%	0.45%	-1.87%	-3.91%	-6.72%	-8.32%
ES	-1.97%	-4.34%	-6.73%	-8.70%	-1.06%	-3.49%	-5.74%	-7.55%	-10.49%
EU	-1.64%	-3.63%	-5.66%	-7.34%	-1.60%	-3.65%	-5.49%	-7.99%	-9.53%
FI	-0.30%	-3.18%	-5.79%	-7.93%	0.03%	-2.43%	-4.68%	-5.89%	-9.44%
FR	-2.29%	-4.72%	-7.22%	-9.27%	-1.91%	-4.45%	-6.79%	-8.39%	-11.83%
GR	-1.28%	-3.18%	-4.94%	-6.32%	-0.61%	-2.53%	-4.25%	-5.38%	-7.71%
HU	-2.42%	-5.10%	-7.97%	-10.43%	-0.74%	-3.38%	-5.92%	-8.68%	-11.50%
IE	-2.36%	-4.93%	-7.70%	-10.05%	-3.98%	-6.61%	-9.35%	-11.60%	-14.97%
IT	-2.06%	-4.23%	-6.44%	-8.25%	-1.56%	-3.79%	-5.86%	-7.35%	-10.13%
LT	-1.54%	-3.77%	-5.98%	-7.83%	-0.10%	-2.41%	-4.31%	-6.32%	-8.78%
LU	-2.19%	-4.41%	-6.65%	-8.48%	-3.95%	-6.31%	-8.49%	-10.40%	-13.17%
LV	-0.89%	-2.92%	-4.87%	-6.50%	0.09%	-2.07%	-3.78%	-5.31%	-7.88%
MT	-0.08%	-0.17%	-0.25%	-0.31%	0.06%	-0.05%	-0.08%	11.77%	-0.27%
NL	-2.75%	-5.53%	-8.43%	-10.86%	-1.97%	-4.07%	-7.46%	-10.59%	-13.23%
NO	0.03%	0.05%	0.08%	0.10%	-0.48%	-0.49%	-0.44%	0.12%	-0.45%
PL	-2.11%	-4.51%	-6.98%	-9.06%	-0.52%	-2.93%	-5.12%	-7.55%	-10.04%
PT	-1.76%	-3.78%	-5.80%	-7.51%	-1.22%	-3.36%	-5.41%	-6.30%	-9.72%
RO	0.72%	0.81%	0.92%	1.07%	-3.37%	-3.45%	-3.12%	-9.28%	-3.03%
SE	-2.10%	-4.26%	-6.45%	-8.21%	-1.23%	-3.45%	-5.45%	-6.67%	-9.70%
SI	-1.68%	-3.57%	-5.40%	-6.86%	-1.15%	-3.15%	-4.83%	-5.77%	-8.46%
SK	-2.08%	-4.53%	-7.13%	-9.35%	-0.33%	-2.73%	-5.05%	-7.24%	-10.07%
UK	-2.44%	-5.10%	-7.92%	-10.32%	-1.63%	-4.28%	-6.89%	-9.67%	-12.46%

Source: NEMESIS model

7.5.1.3 Economic

Table 7.5.10: Real GDP change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	-0.01%	0.00%	-0.01%	-0.02%	0.56%	0.59%	0.56%	0.56%	0.61%
BE	-0.02%	-0.03%	-0.05%	-0.07%	0.58%	0.59%	0.55%	0.55%	0.55%
CZ	-0.03%	-0.02%	-0.04%	-0.06%	0.49%	0.50%	0.42%	0.42%	0.46%
DE	-0.01%	-0.02%	-0.03%	-0.05%	0.43%	0.45%	0.40%	0.40%	0.42%
DK	-0.07%	-0.06%	-0.10%	-0.09%	0.61%	0.72%	0.64%	0.65%	0.66%
EE	0.02%	0.12%	0.21%	0.28%	0.05%	0.16%	0.21%	0.30%	0.42%
ES	-0.01%	-0.02%	-0.05%	-0.08%	0.79%	0.79%	0.75%	0.76%	0.78%
EU	-0.01%	-0.01%	-0.03%	-0.04%	0.54%	0.56%	0.53%	0.53%	0.57%
FI	-0.10%	-0.05%	-0.01%	0.01%	0.30%	0.33%	0.33%	0.35%	0.39%
FR	-0.01%	-0.01%	-0.03%	-0.04%	0.53%	0.55%	0.52%	0.52%	0.55%
GR	0.00%	0.03%	0.04%	0.06%	1.23%	1.36%	1.33%	1.35%	1.48%
HU	-0.02%	-0.03%	-0.04%	-0.05%	0.37%	0.39%	0.35%	0.35%	0.36%
IE	-0.02%	-0.04%	-0.07%	-0.09%	0.59%	0.60%	0.57%	0.55%	0.56%
IT	-0.02%	-0.02%	-0.05%	-0.06%	0.57%	0.61%	0.57%	0.57%	0.61%
LT	0.03%	0.14%	0.23%	0.31%	0.17%	0.25%	0.26%	0.36%	0.50%
LU	-0.06%	-0.11%	-0.17%	-0.22%	1.05%	1.05%	0.97%	0.93%	0.92%
LV	0.06%	0.20%	0.32%	0.43%	0.20%	0.37%	0.43%	0.57%	0.75%
MT	-0.02%	-0.04%	-0.07%	-0.09%	0.36%	0.36%	0.33%	0.31%	0.32%
NL	-0.01%	-0.01%	-0.02%	-0.03%	0.32%	0.28%	0.30%	0.30%	0.32%
NO	-0.01%	-0.02%	-0.03%	-0.05%	0.31%	0.31%	0.28%	0.28%	0.30%
PL	0.06%	0.11%	0.17%	0.23%	0.83%	1.00%	1.00%	1.10%	1.26%
PT	0.02%	0.07%	0.10%	0.13%	0.84%	0.93%	0.94%	0.98%	1.11%
RO	-0.08%	-0.10%	-0.12%	-0.10%	0.62%	0.59%	0.59%	0.62%	0.59%
SE	-0.01%	-0.01%	-0.02%	-0.03%	0.42%	0.43%	0.41%	0.41%	0.43%
SI	0.08%	0.20%	0.31%	0.40%	0.45%	0.60%	0.66%	0.77%	0.93%
SK	-0.01%	0.00%	-0.01%	-0.01%	0.33%	0.38%	0.34%	0.36%	0.40%
UK	-0.01%	-0.02%	-0.05%	-0.07%	0.48%	0.48%	0.44%	0.44%	0.45%

Source: NEMESIS model

Table 7.5.11: Household consumption price change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	-0.02%	-0.04%	-0.05%	-0.06%	-0.15%	-0.17%	-0.17%	-0.19%	-0.23%
BE	-0.01%	-0.03%	-0.03%	-0.04%	-0.34%	-0.36%	-0.36%	-0.39%	-0.40%
CZ	-0.05%	-0.09%	-0.13%	-0.15%	-0.22%	-0.26%	-0.26%	-0.32%	-0.39%
DE	0.00%	-0.01%	-0.01%	-0.01%	-0.26%	-0.30%	-0.26%	-0.27%	-0.30%
DK	-0.10%	-0.17%	-0.23%	-0.29%	0.31%	0.30%	0.20%	0.14%	0.21%
EE	-0.13%	-0.32%	-0.51%	-0.66%	-0.03%	-0.20%	-0.37%	-0.56%	-0.77%
ES	-0.02%	-0.05%	-0.07%	-0.09%	0.07%	0.05%	0.02%	-0.01%	-0.04%
EU	-0.03%	-0.06%	-0.08%	-0.10%	-0.19%	-0.22%	-0.23%	-0.27%	-0.31%
FI	-0.17%	-0.19%	-0.24%	-0.27%	-0.08%	-0.13%	-0.18%	-0.24%	-0.31%
FR	-0.03%	-0.06%	-0.08%	-0.10%	-0.29%	-0.31%	-0.32%	-0.36%	-0.40%
GR	-0.05%	-0.12%	-0.19%	-0.24%	-0.56%	-0.67%	-0.71%	-0.76%	-0.90%
HU	-0.02%	-0.05%	-0.08%	-0.10%	-0.19%	-0.23%	-0.23%	-0.26%	-0.31%
IE	0.00%	-0.01%	0.00%	0.00%	-0.35%	-0.36%	-0.35%	-0.36%	-0.38%
IT	0.00%	-0.01%	-0.01%	-0.01%	-0.62%	-0.66%	-0.64%	-0.66%	-0.70%
LT	-0.14%	-0.29%	-0.47%	-0.59%	-0.10%	-0.19%	-0.39%	-0.53%	-0.68%
LU	0.01%	0.02%	0.03%	0.05%	-0.69%	-0.70%	-0.68%	-0.68%	-0.70%
LV	-0.24%	-0.50%	-0.76%	-0.98%	-0.20%	-0.46%	-0.68%	-0.97%	-1.27%
MT	0.02%	0.03%	0.05%	0.07%	-0.57%	-0.59%	-0.55%	-0.54%	-0.57%
NL	-0.02%	-0.04%	-0.06%	-0.07%	-0.03%	0.01%	-0.06%	-0.08%	-0.11%
NO	-0.02%	-0.03%	-0.03%	-0.04%	0.13%	0.14%	0.13%	0.11%	0.11%
PL	-0.16%	-0.35%	-0.56%	-0.75%	-0.07%	-0.30%	-0.44%	-0.66%	-0.92%
PT	-0.06%	-0.14%	-0.21%	-0.27%	-0.16%	-0.24%	-0.29%	-0.36%	-0.46%
RO	0.02%	0.00%	-0.02%	-0.04%	-0.41%	-0.50%	-0.41%	-0.42%	-0.57%
SE	-0.03%	-0.06%	-0.08%	-0.10%	-0.18%	-0.20%	-0.22%	-0.25%	-0.29%
SI	-0.10%	-0.22%	-0.33%	-0.41%	-0.16%	-0.27%	-0.36%	-0.47%	-0.60%
SK	-0.04%	-0.08%	-0.12%	-0.15%	-0.12%	-0.18%	-0.17%	-0.22%	-0.30%
UK	-0.01%	-0.02%	-0.02%	-0.03%	-0.02%	-0.01%	-0.02%	-0.03%	-0.04%

Source: NEMESIS model

Table 7.5.12: Total employment change by MS in 2025 w.r.t. *reference scenario* (thousand)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	-3.1	-5.5	-8.3	-10.4	8.9	5.9	3.2	0.7	-0.6
BE	-1.6	-2.5	-3.9	-5.1	16.9	16.4	14.4	13.3	12.8
CZ	-3.0	-4.4	-6.7	-9.0	13.6	12.0	7.7	5.9	4.8
DE	-15.9	-28.1	-43.1	-55.7	97.5	84.6	67.8	56.0	48.5
DK	-3.6	-4.9	-7.3	-8.4	10.1	9.8	7.2	5.8	4.2
EE	-0.3	0.1	0.3	0.6	0.1	0.4	0.5	0.7	1.2
ES	-8.3	-15.1	-25.1	-34.7	91.6	82.5	71.0	67.4	65.6
EU	-331.8	-474.4	-641.0	-768.0	254.8	102.8	-61.9	-197.8	-305.8
FI	-4.3	-4.9	-6.0	-7.1	3.1	1.5	-0.3	-1.7	-2.7
FR	-17.6	-30.4	-46.2	-59.7	75.2	62.9	44.6	31.7	26.1
GR	-5.3	-11.6	-18.1	-22.9	29.4	24.8	18.4	11.7	10.2
HU	-7.3	-12.9	-18.8	-23.4	5.0	-0.4	-6.6	-12.1	-17.3
IE	-4.9	-9.6	-14.5	-18.6	-5.0	-10.7	-15.4	-21.0	-26.2
IT	-11.9	-20.1	-35.8	-43.2	91.0	88.4	75.3	66.2	67.0
LT	-4.7	-7.4	-10.4	-12.9	-5.2	-10.4	-12.5	-15.7	-19.7
LU	-0.1	-0.1	-0.2	-0.3	1.5	1.5	1.4	1.3	1.4
LV	-1.3	-1.7	-2.1	-2.5	-0.7	-1.4	-1.7	-2.0	-2.4
MT	0.0	-0.1	-0.2	-0.2	0.7	0.7	0.6	0.6	0.6
NL	-1.9	-2.8	-4.3	-5.6	16.0	18.9	12.8	12.0	11.5
NO	-0.2	-0.2	-0.4	-0.7	4.8	4.7	4.1	4.2	4.5
PL	-135.0	-194.9	-253.5	-298.5	-93.4	-155.6	-209.0	-265.0	-316.1
PT	-5.3	-8.4	-11.4	-13.2	5.2	0.3	-0.2	-3.4	-4.2
RO	-78.9	-77.7	-75.6	-72.1	-212.0	-218.5	-209.1	-204.0	-213.8
SE	-2.4	-4.4	-6.8	-8.7	11.2	8.5	6.3	4.1	2.2
SI	-0.6	-0.5	-0.4	-0.3	-1.0	-2.2	-1.1	-1.1	-1.6
SK	-1.9	-3.2	-4.9	-6.0	2.8	1.5	-0.3	-1.7	-3.1
UK	-12.4	-23.2	-37.6	-50.2	92.1	81.6	63.4	52.6	45.7

Source: NEMESIS model

Table 7.5.13: Agricultural employment change by MS in 2025 w.r.t. *reference scenario* (thousand)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	-2.9	-5.6	-8.2	-10.3	-10.1	-14.0	-15.9	-18.6	-21.6
BE	-0.9	-1.6	-2.4	-2.9	-6.0	-7.1	-7.7	-8.9	-9.5
CZ	-2.1	-3.9	-5.7	-7.3	-4.9	-7.4	-8.8	-10.8	-13.2
DE	-11.7	-23.2	-34.3	-43.1	-33.9	-55.3	-58.4	-70.1	-84.5
DK	-1.9	-3.5	-5.0	-6.2	-3.1	-5.9	-6.5	-8.1	-10.6
EE	-0.5	-0.8	-1.2	-1.5	-0.6	-1.0	-1.3	-1.7	-2.1
ES	-8.1	-15.6	-22.8	-28.3	-37.0	-46.0	-52.2	-59.4	-67.1
EU	-319.7	-478.1	-634.4	-759.3	-750.6	-966.2	-1082.9	-1247.6	-1435.7
FI	-2.4	-4.3	-6.3	-7.9	-3.7	-6.1	-8.0	-10.0	-12.1
FR	-14.5	-28.1	-41.5	-51.9	-47.2	-65.1	-75.8	-89.7	-104.0
GR	-6.2	-13.9	-21.6	-27.8	-13.2	-22.7	-29.2	-37.1	-44.2
HU	-6.8	-12.3	-17.9	-22.3	-9.0	-15.5	-20.4	-26.2	-31.8
IE	-4.5	-9.0	-13.6	-17.4	-14.3	-20.3	-24.5	-29.8	-35.2
IT	-9.6	-17.9	-25.8	-32.1	-47.9	-59.7	-65.9	-75.1	-83.4
LT	-5.5	-10.2	-15.1	-19.2	-7.4	-14.2	-17.0	-22.1	-28.5
LU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LV	-1.7	-3.2	-4.7	-6.0	-2.3	-4.5	-5.4	-6.8	-8.8
MT	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0
NL	-1.5	-2.6	-3.7	-4.5	-7.5	-3.0	-10.1	-11.2	-13.2
NO	-0.1	-0.1	0.0	0.0	-0.7	-0.7	-0.7	-0.6	-0.7
PL	-142.6	-209.1	-275.5	-328.9	-194.4	-276.3	-331.0	-399.8	-470.7
PT	-7.1	-12.7	-18.1	-22.3	-25.9	-35.5	-37.3	-42.9	-49.9
RO	-74.8	-72.5	-69.2	-66.8	-244.8	-250.2	-240.4	-236.9	-245.3
SE	-2.2	-4.4	-6.5	-8.3	-6.0	-9.3	-10.8	-13.1	-16.3
SI	-1.4	-2.4	-3.3	-4.0	-4.3	-6.8	-6.5	-7.5	-9.3
SK	-1.7	-3.2	-4.8	-6.0	-4.0	-6.2	-7.3	-9.1	-11.2
UK	-9.0	-18.0	-27.0	-34.2	-23.2	-34.1	-42.7	-52.5	-63.1

Source: NEMESIS model

Table 7.5.14: Farmers income change by MS in 2025 w.r.t. *reference scenario* (%)

	Market supports continued				Market supports abolished				
	Removal of direct support to farmers				Removal of direct support to farmers				
	25%	50%	75%	100%	0%	25%	50%	75%	100%
AT	-3.9%	-7.9%	-11.8%	-14.7%	-13.8%	-19.3%	-22.0%	-25.8%	-29.8%
BE	-1.9%	-4.1%	-6.2%	-7.8%	-15.2%	-18.2%	-19.8%	-23.0%	-24.5%
CZ	-10.3%	-20.8%	-31.1%	-39.3%	-15.2%	-27.7%	-36.4%	-46.8%	-56.8%
DE	-4.6%	-9.4%	-14.0%	-17.6%	-13.1%	-21.5%	-23.0%	-27.5%	-32.9%
DK	-4.7%	-9.6%	-14.4%	-18.1%	-7.5%	-15.9%	-18.1%	-22.9%	-29.9%
EE	-9.0%	-18.3%	-27.6%	-35.1%	-12.5%	-24.1%	-31.2%	-40.3%	-49.5%
ES	-2.2%	-4.5%	-6.8%	-8.5%	-7.6%	-10.4%	-12.4%	-14.6%	-16.8%
EU	-3.6%	-7.3%	-11.0%	-13.8%	-11.2%	-15.9%	-18.9%	-22.6%	-26.4%
FI	-8.0%	-16.7%	-24.9%	-31.2%	-13.4%	-23.3%	-30.7%	-38.4%	-46.3%
FR	-4.4%	-8.9%	-13.3%	-16.7%	-14.1%	-19.9%	-23.3%	-27.6%	-31.9%
GR	-4.0%	-8.1%	-12.1%	-15.3%	-6.0%	-10.9%	-14.4%	-18.4%	-21.9%
HU	-6.6%	-13.3%	-19.9%	-25.0%	-8.1%	-15.8%	-21.6%	-28.3%	-34.5%
IE	-8.2%	-16.8%	-25.2%	-31.8%	-25.3%	-35.7%	-42.9%	-51.5%	-59.6%
IT	-1.9%	-4.0%	-6.0%	-7.6%	-8.9%	-11.7%	-13.3%	-15.5%	-17.4%
LT	-10.5%	-21.7%	-32.8%	-41.6%	-14.8%	-30.6%	-36.8%	-47.5%	-60.0%
LU	-1.9%	-4.1%	-6.2%	-7.8%	-15.2%	-18.2%	-19.8%	-23.0%	-24.5%
LV	-9.1%	-19.5%	-29.6%	-37.6%	-12.9%	-27.5%	-33.4%	-42.5%	-53.8%
MT	-1.5%	-3.0%	-4.7%	-6.2%	2.2%	0.0%	-0.9%	-2.7%	-4.6%
NL	-1.0%	-2.2%	-3.2%	-4.1%	-8.8%	-4.8%	-11.3%	-12.3%	-14.3%
NO	0.1%	0.3%	0.4%	0.5%	-1.7%	-1.8%	-1.6%	-1.5%	-1.6%
PL	-5.7%	-11.7%	-17.6%	-22.2%	-9.1%	-16.3%	-21.1%	-26.9%	-32.7%
PT	-2.6%	-5.4%	-7.9%	-9.8%	-9.8%	-14.2%	-15.2%	-17.7%	-20.8%
RO	1.4%	1.7%	2.0%	2.3%	-17.8%	-18.5%	-17.4%	-17.0%	-18.0%
SE	-8.4%	-17.0%	-25.3%	-31.6%	-21.4%	-33.6%	-39.1%	-46.9%	-57.3%
SI	-3.6%	-7.3%	-10.8%	-13.3%	-13.6%	-22.6%	-21.4%	-24.9%	-31.1%
SK	-11.0%	-22.4%	-33.5%	-42.2%	-26.2%	-41.1%	-49.0%	-60.2%	-71.7%
UK	-7.1%	-14.5%	-21.7%	-27.2%	-17.8%	-26.3%	-32.9%	-40.1%	-47.4%

Source: NEMESIS model

7.5.2 Re-allocation of released funds from CAP 1st Pillar abolition

7.5.2.1 Agriculture

Table 7.5.15: Total agricultural production change by MS in 2025 w.r.t. *reference scenario* (%)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	-1.50%	-1.28%
BE	-1.68%	-1.12%
CZ	-1.56%	-1.24%
DE	-1.80%	-1.66%
DK	-0.95%	-0.84%
EE	-1.19%	-0.98%
ES	-2.88%	-2.83%
EU	-2.41%	-2.20%
FI	-12.21%	-11.98%
FR	-4.34%	-4.01%
GR	-0.32%	-0.27%
HU	-2.01%	-1.88%
IE	0.94%	0.96%
IT	-3.66%	-3.47%
LT	-4.43%	-4.33%
LU	-1.68%	-1.12%
LV	-2.32%	-1.80%
MT	0.14%	1.25%
NL	1.90%	2.15%
NO	0.10%	0.39%
PL	-0.90%	-0.58%
PT	-1.10%	-1.05%
RO	-1.94%	-1.38%
SE	-3.44%	-3.42%
SI	-2.76%	-2.96%
SK	-0.95%	-0.32%
UK	-1.33%	-0.96%

Source: NEMESIS and CAPRI models

Table 7.5.16: Vegetal production change by MS in 2025 w.r.t. *reference scenario* (%)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	-4.81%	-4.42%
BE	-2.69%	-2.24%
CZ	-1.65%	-1.25%
DE	-6.52%	-6.23%
DK	-4.13%	-3.97%
EE	-1.83%	-1.18%
ES	-3.58%	-3.51%
EU	-3.87%	-3.71%
FI	-12.82%	-12.21%
FR	-5.86%	-5.62%
GR	-0.86%	-0.83%
HU	-1.90%	-1.69%
IE	2.17%	2.56%
IT	-2.71%	-2.65%
LT	-7.02%	-6.78%
LU	-2.69%	-2.24%
LV	-4.22%	-3.32%
MT	10.01%	10.60%
NL	-1.53%	-1.45%
NO	0.35%	0.49%
PL	-0.87%	-0.34%
PT	-1.44%	-1.37%
RO	-0.50%	-0.18%
SE	-4.15%	-3.98%
SI	-1.50%	-1.86%
SK	-1.69%	-1.04%
UK	-3.44%	-3.08%

Source: NEMESIS and CAPRI models

Table 7.5.17: Animal production change by MS in 2025 w.r.t. *reference scenario* (%)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	0.45%	0.57%
BE	-1.32%	-0.71%
CZ	-1.49%	-1.23%
DE	0.96%	1.00%
DK	0.02%	0.10%
EE	-0.79%	-0.86%
ES	-1.67%	-1.66%
EU	-1.32%	-1.09%
FI	-11.90%	-11.85%
FR	-3.26%	-2.87%
GR	2.04%	2.17%
HU	-2.12%	-2.10%
IE	0.63%	0.56%
IT	-4.89%	-4.54%
LT	-0.85%	-0.95%
LU	-1.32%	-0.71%
LV	-0.11%	-0.05%
MT	-1.94%	-0.72%
NL	3.15%	3.45%
NO	0.03%	0.36%
PL	-0.93%	-0.82%
PT	-0.65%	-0.63%
RO	-5.14%	-4.04%
SE	-3.06%	-3.12%
SI	-3.85%	-3.90%
SK	-0.33%	0.27%
UK	-0.48%	-0.10%

Source: NEMESIS and CAPRI models

Table 7.5.18: Total agricultural product price change by MS in 2025 w.r.t. *reference scenario* (%)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	-11.4%	-11.8%
BE	-11.7%	-12.7%
CZ	-6.8%	-7.0%
DE	-9.6%	-9.8%
DK	-6.8%	-7.2%
EE	-6.6%	-6.6%
ES	-7.3%	-7.6%
EU	-8.8%	-9.0%
FI	-5.2%	-5.0%
FR	-10.1%	-10.5%
GR	-5.7%	-5.9%
HU	-3.8%	-4.2%
IE	-21.1%	-21.9%
IT	-8.3%	-8.6%
LT	-6.6%	-6.7%
LU	-20.9%	-22.6%
LV	-6.9%	-7.5%
MT	-3.1%	-3.1%
NL	-6.8%	-6.7%
NO	-3.2%	-4.0%
PL	-4.9%	-5.0%
PT	-7.3%	-7.5%
RO	-7.6%	-8.2%
SE	-10.1%	-10.3%
SI	-9.0%	-8.9%
SK	-5.3%	-5.7%
UK	-12.1%	-12.5%

Source: NEMESIS and CAPRI models

Table 7.5.19: Vegetal product price change by MS in 2025 w.r.t. *reference scenario* (%)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	-5.9%	-6.8%
BE	-5.4%	-6.2%
CZ	-2.3%	-2.9%
DE	-4.1%	-4.6%
DK	-2.7%	-3.3%
EE	2.7%	2.2%
ES	-4.2%	-4.4%
EU	-4.2%	-4.6%
FI	-2.0%	-2.3%
FR	-5.0%	-5.6%
GR	-3.9%	-4.2%
HU	-2.6%	-3.2%
IE	-22.0%	-24.7%
IT	-3.8%	-4.0%
LT	0.5%	0.0%
LU	-5.4%	-6.2%
LV	-1.8%	-2.6%
MT	-0.4%	-0.5%
NL	-1.7%	-1.9%
NO	-1.7%	-2.7%
PL	-1.3%	-1.7%
PT	-4.3%	-4.6%
RO	-9.2%	-9.7%
SE	-4.7%	-5.2%
SI	-2.5%	-2.8%
SK	-2.3%	-2.8%
UK	-6.3%	-7.3%

Source: NEMESIS and CAPRI models

Table 7.5.20: Animal product price change by MS in 2025 w.r.t. *reference scenario* (%)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	-18.4%	-18.5%
BE	-16.4%	-17.6%
CZ	-12.2%	-11.9%
DE	-15.1%	-15.0%
DK	-8.6%	-8.9%
EE	-12.5%	-12.3%
ES	-13.6%	-13.8%
EU	-14.9%	-15.0%
FI	-8.6%	-8.1%
FR	-17.7%	-18.0%
GR	-12.5%	-12.7%
HU	-5.9%	-6.3%
IE	-22.1%	-22.4%
IT	-17.6%	-17.9%
LT	-13.1%	-12.9%
LU	-16.4%	-17.6%
LV	-10.5%	-10.9%
MT	-5.1%	-5.1%
NL	-16.0%	-15.6%
NO	-4.4%	-4.9%
PL	-9.1%	-9.0%
PT	-13.0%	-13.1%
RO	-5.5%	-6.2%
SE	-15.0%	-15.1%
SI	-15.9%	-15.4%
SK	-8.9%	-9.1%
UK	-17.1%	-17.3%

Source: NEMESIS and CAPRI models

7.5.2.2 Land use

Table 7.5.21: Agricultural land use change by MS in 2025 w.r.t. *reference scenario* (%)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	-3.37%	-3.33%
BE	-3.66%	-3.59%
CZ	-2.26%	-2.24%
DE	-3.20%	-3.16%
DK	-1.46%	-1.43%
EE	-9.51%	-9.42%
ES	-3.51%	-3.47%
EU	-2.63%	-2.58%
FI	-3.13%	-2.97%
FR	-3.25%	-3.13%
GR	-4.09%	-4.00%
HU	-1.26%	-1.25%
IE	-0.62%	-0.61%
IT	-3.24%	-3.21%
LT	-4.36%	-4.30%
LU	-1.68%	-1.67%
LV	-4.44%	-4.35%
MT	-0.16%	-0.15%
NL	-1.79%	-1.76%
NO	-0.19%	-0.26%
PL	-1.98%	-1.96%
PT	-4.49%	-4.36%
RO	-0.05%	-0.05%
SE	-3.63%	-3.50%
SI	-6.81%	-6.66%
SK	-2.20%	-2.15%
UK	-1.06%	-1.04%

Source: NEMESIS and CAPRI models

Table 7.5.22: Real agricultural land use price (with capitalisation) change by MS in 2025 w.r.t. *reference scenario* (%)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	-24.2%	-26.5%
BE	-43.7%	-43.5%
CZ	-36.9%	-36.6%
DE	-34.4%	-34.9%
DK	-35.8%	-35.2%
EE	-34.9%	-35.2%
ES	-21.2%	-21.8%
EU	-31.0%	-30.9%
FI	14.2%	15.6%
FR	-37.3%	-36.7%
GR	-32.7%	-33.1%
HU	-42.6%	-42.0%
IE	-48.9%	-48.5%
IT	-9.8%	-9.7%
LT	-32.3%	-32.3%
LU	-43.7%	-43.5%
LV	-30.7%	-30.3%
MT	-29.2%	-28.0%
NL	-42.7%	-43.2%
NO	-0.8%	-0.9%
PL	-38.1%	-37.7%
PT	-37.7%	-37.3%
RO	-5.0%	-4.4%
SE	-26.4%	-25.8%
SI	-38.1%	-36.4%
SK	-40.3%	-39.3%
UK	-38.8%	-38.5%

Source: CAPRI model

Table 7.5.23: Real agricultural land use price (without capitalisation) change by MS in 2025 w.r.t. reference scenario (%)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	-11.7%	-11.5%
BE	-13.0%	-12.6%
CZ	-9.6%	-9.4%
DE	-10.5%	-10.3%
DK	-10.7%	-10.5%
EE	-8.3%	-8.2%
ES	-10.5%	-10.3%
EU	-9.5%	-9.5%
FI	-9.4%	-8.9%
FR	-11.8%	-11.4%
GR	-7.7%	-7.5%
HU	-11.5%	-11.3%
IE	-15.0%	-14.8%
IT	-10.1%	-10.0%
LT	-8.8%	-8.6%
LU	-13.2%	-13.1%
LV	-7.9%	-7.6%
MT	-0.3%	-0.2%
NL	-13.2%	-13.0%
NO	-0.4%	-0.6%
PL	-10.0%	-9.8%
PT	-9.7%	-9.4%
RO	-3.0%	-2.1%
SE	-9.7%	-9.3%
SI	-8.5%	-8.2%
SK	-10.1%	-9.8%
UK	-12.5%	-12.1%

Source: NEMESIS model

7.5.2.3 Economic

Table 7.5.24: Re-allocation effect in *R&D investment* scenario by MS in 2025 (in GDP %)

	Re-allocation effect in <i>R&D investment</i> in 2025 (in GDP %)
AT	+0.04%
BE	+0.09%
CZ	-0.20%
DE	+0.06%
DK	-0.10%
EE	-0.01%
ES	-0.09%
EU	–
FI	-0.02%
FR	-0.10%
GR	-0.34%
HU	-0.83%
IE	-0.18%
IT	+0.03%
LT	-0.39%
LU	+0.07%
LV	-0.03%
MT	+0.23%
NL	+0.13%
NO	–
PL	-0.25%
PT	-0.06%
RO	-0.09%
SE	+0.10%
SI	+0.05%
SK	-0.20%
UK	+0.12%

Source: NEMESIS and CAPRI models

Table 7.5.25: Real GDP change by MS in 2025 w.r.t. *reference scenario* (%)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	0.61%	2.93%
BE	0.55%	3.02%
CZ	0.46%	2.71%
DE	0.42%	2.77%
DK	0.66%	2.35%
EE	0.42%	1.86%
ES	0.78%	2.33%
EU	0.57%	2.56%
FI	0.39%	3.59%
FR	0.55%	2.58%
GR	1.48%	2.69%
HU	0.36%	1.56%
IE	0.56%	2.10%
IT	0.61%	2.62%
LT	0.50%	1.12%
LU	0.92%	2.25%
LV	0.75%	2.02%
MT	0.32%	0.50%
NL	0.32%	2.07%
NO	0.30%	2.37%
PL	1.26%	2.49%
PT	1.11%	2.49%
RO	0.59%	2.72%
SE	0.43%	2.73%
SI	0.93%	3.05%
SK	0.40%	1.69%
UK	0.45%	2.43%

Source: NEMESIS model

Table 7.5.26: Total employment change by MS in 2025 w.r.t. *reference scenario* (thousand)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	-0.6	44.4
BE	12.8	58.7
CZ	4.8	71.3
DE	48.5	416.1
DK	4.2	23.5
EE	1.2	6.8
ES	65.6	235.7
EU	-305.8	1819.0
FI	-2.7	30.4
FR	26.1	284.3
GR	10.2	50.3
HU	-17.3	22.4
IE	-26.2	-7.4
IT	67.0	360.5
LT	-19.7	-9.6
LU	1.4	0.4
LV	-2.4	7.4
MT	0.6	1.2
NL	11.5	80.7
NO	4.5	37.5
PL	-316.1	-193.6
PT	-4.2	35.7
RO	-213.8	-101.2
SE	2.2	41.1
SI	-1.6	10.3
SK	-3.1	18.4
UK	45.7	331.5

Source: NEMESIS model

Table 7.5.27: Total agricultural employment change by MS in 2025 w.r.t. *reference scenario* (thousand)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	-21.6	-22.2
BE	-9.5	-9.8
CZ	-13.2	-12.7
DE	-84.5	-84.5
DK	-10.6	-9.9
EE	-2.1	-2.0
ES	-67.1	-68.5
EU	-1435.7	-1397.6
FI	-12.1	-11.8
FR	-104.0	-104.4
GR	-44.2	-45.1
HU	-31.8	-31.3
IE	-35.2	-34.5
IT	-83.4	-86.2
LT	-28.5	-26.9
LU	0.0	0.0
LV	-8.8	-8.3
MT	0.0	0.0
NL	-13.2	-13.7
NO	-0.7	-0.8
PL	-470.7	-452.1
PT	-49.9	-47.5
RO	-245.3	-229.7
SE	-16.3	-15.4
SI	-9.3	-8.6
SK	-11.2	-10.7
UK	-63.1	-62.0

Source: NEMESIS model

Table 7.5.28: Farmers income change by MS in 2025 w.r.t. *reference scenario* (%)

	<i>Tax rebate</i>	<i>R&D investments</i>
AT	-29.8%	-29.5%
BE	-24.5%	-24.4%
CZ	-56.8%	-55.7%
DE	-32.9%	-31.7%
DK	-29.9%	-27.2%
EE	-49.5%	-48.5%
ES	-16.8%	-16.6%
EU	-26.4%	-25.6%
FI	-46.3%	-44.8%
FR	-31.9%	-31.1%
GR	-21.9%	-21.7%
HU	-34.5%	-33.9%
IE	-59.6%	-58.2%
IT	-17.4%	-17.2%
LT	-60.0%	-56.9%
LU	-24.5%	-24.4%
LV	-53.8%	-51.5%
MT	-4.6%	-2.5%
NL	-14.3%	-13.2%
NO	-1.6%	-1.4%
PL	-32.7%	-32.0%
PT	-20.8%	-19.9%
RO	-18.0%	-15.8%
SE	-57.3%	-53.6%
SI	-31.1%	-28.1%
SK	-71.7%	-68.9%
UK	-47.4%	-45.7%

Source: NEMESIS model

Résumé (en français)

Depuis longtemps dans l'histoire de la pensée économique, la terre a été au centre de l'analyse économique notamment avec les Physiocrates tels que François Quesnay ou Richard Cantillon. Néanmoins avec le développement industriel, son importance dans l'analyse économique a progressivement diminué. Nous sommes alors passés d'une représentation où, pour les Physiocrates, la terre était l'unique facteur de production à une représentation où, pour les économistes classiques, la terre n'était plus que l'un des trois principaux facteurs de production avec le travail et le capital. Par la suite, la terre a progressivement disparu de la fonction de production macro-économique, cette dernière n'incluant plus que le travail et le capital, la terre devenant seulement un intrant fixe de l'agriculture. Toutefois, la terre n'a pas complètement disparu de l'analyse économique et est restée le point central de certaines problématiques liées notamment à la localisation des activités économiques (sciences régionales ou économie spatiale) ou à la valorisation des services liés à la terre, et ceci dans une vue principalement utilitariste. Récemment, l'importance croissante des problématiques environnementales dans l'analyse économique, a permis au facteur "terre" de retrouver un rôle non négligeable. La terre ou l'utilisation des sols est alors revenue au cœur de nombreuses politiques environnementales comme, par exemple, la Politique Agricole Commune de l'Union Européenne qui combine des aspects économiques et environnementaux, surtout depuis ses récentes réformes.

En parallèle, la demande d'outils permettant de quantifier de manière relativement précise les impacts économiques, sociaux et environnementaux des politiques économiques est devenue de plus en plus importante. Par exemple, les Conseils Européens de Göteborg et de Laeken en 2001 ont demandé à la Commission Européenne de mettre en place des méthodes et des outils permettant l'évaluation *ex-ante* de toute modification ou nouvelle proposition de loi. L'analyse d'impact *ex-ante* devenant de plus en plus importante, il est devenu nécessaire de construire des outils quantitatifs adéquats pour ces analyses.

Ainsi, les travaux présentés dans cette thèse ont pour objet le développement d'un module d'utilisation des sols compatible avec le modèle NEMESIS, qui est un modèle économique détaillé pour l'Union Européenne. Ils cherchent également à utiliser conjointement le modèle NEMESIS et le module d'allocation des sols pour analyser les effets de plusieurs politiques européennes et notamment leurs impacts sur l'économie et l'utilisation des sols. Cette thèse est organisée autour de quatre chapitres. Le premier chapitre décrit d'une part la construction de la base de données d'utilisation des sols et d'autre part, explique le développement du module d'allocation des sols au niveau des états de l'Union Européenne, en utilisant des fonctions d'offre et de demande de terre agricole et un modèle d'expansion des terres urbaines. Le second chapitre traite, au travers de deux applications, du problème de la construction de scénarios en modélisation appliquée. Un premier scénario, construit suivant une approche dite tendancielle, est présenté de façon détaillée puis analysé. Ce scénario sert également de référence pour les évaluations des politiques européennes. Une seconde application propose quatre scénarios élaborés suivant une approche dite « imaginative », c'est-à-dire en envisageant différentes possibilités d'évolution des principales variables motrices de la croissance économiques. Le troisième chapitre présente la construction et le fonctionnement d'une combinaison de différents modèles ou « chaîne de modèles ». Celle-ci sera utilisée pour l'évaluation économique et environnementale d'une politique de libéralisation de l'agriculture européenne avec réallocation des fonds aux contribuables ou à l'aide à la recherche et au développement. Cette « chaîne de modèles » combine le modèle NEMESIS avec un modèle agricole détaillé (CAPRI), un modèle de gestion des forêts (EFISCEN) et un modèle détaillé d'allocation des sols (Dyna-CLUE). Enfin le dernier, et quatrième chapitre, présente, après la construction d'indicateurs sur l'utilisation des nutriments dans l'agriculture, l'évaluation des conséquences économiques de deux politiques européennes : d'une part, une politique de biodiversité caractérisée par l'augmentation des forêts protégées ou par une production agricole extensive et, d'autre part, une politique de soutien au développement des biocarburants au niveau européen.

Nous commençons donc par un premier chapitre composé de trois sections. La première présente la construction d'une base de données d'utilisation des sols, complète et cohérente, pour chaque pays de l'Union Européenne, les différentes sources de données utilisées ainsi que les hypothèses d'harmonisation et de mise en cohérence permettant cette construction sont décrites. Cette base de données distingue quatre principales catégories d'utilisation des sols qui sont subdivisées en dix sous-catégories : les terres agricoles (les terres arables, les pâturages et les terres agricoles non utilisées), les zones construites (les logements, les bâtiments commerciaux et industriels, les routes et les rails), les forêts (forêts protégées

et forêts commerciales) et les autres terres.

Dans la deuxième section dédiée aux terres agricoles, nous commençons par présenter la construction d'une asymptote pour l'utilisation des terres agricoles en supposant que l'agriculture est prioritaire par rapport aux autres utilisations sur les terres agricoles non utilisées. Néanmoins après conversion de ces terres en terres urbaines ou en forêts protégées, nous supposons une non réversibilité de leur usage. Ainsi, avec cette méthodologie, nous avons estimé les terres agricoles disponibles à environ 1.3 million de km² en Union Européenne pour l'année 2000. Au niveau des pays européens, nous avons trouvé une disparité des terres non utilisées assez large entre pays européens, avec par exemple plus de 80% de terres potentiellement disponibles pour l'agriculture en Suède et en Finlande et moins de 15% aux Pays-Bas, Danemark, Royaume-Uni, Malte et Irlande. Néanmoins, le fait d'inclure l'ensemble des forêts commerciales comme terres potentiellement disponibles pour l'agriculture peut tendre à surestimer les zones disponibles.

Dans la suite de ce premier chapitre, nous présentons une rapide revue de la littérature empirique sur les déterminants du prix de la terre que nous complétons par une étude sur la modélisation de l'offre de terres agricoles dans les modèles économiques appliqués. Ainsi en comparant les avantages et les inconvénients de différentes formes fonctionnelles utilisées par les modèles économiques appliqués pour la modélisation de l'offre de terre, nous démontrons la supériorité de la fonction en "L-inversé". En effet, l'élasticité du prix de la terre par rapport à l'offre de terre avec cette forme fonctionnelle est croissante avec la raréfaction des terres disponibles. Par ailleurs, nous montrons que l'estimation de cette fonction d'offre de terre en "L-inversé" est plus aisée comparé à d'autres formes fonctionnelles lorsque les données sont peu nombreuses, dans la mesure où nous pouvons, avec cette fonction d'offre, calibrer un des deux paramètres. Cette fonction d'offre de terre est ensuite estimée pour certains pays européens, ce qui nous permet de déterminer l'élasticité de l'offre de terre par rapport à son prix. Pour l'année 2000, ces élasticités varient de 4.6% en Finlande à 0.1% à Malte et au Royaume-Uni ; en d'autres termes, l'offre de terre est très élastique en Finlande alors qu'elle est inélastique à Malte et au Royaume-Uni. Et en agrégeant les résultats au niveau européen, nous obtenons une élasticité de l'offre de terre par rapport à son prix de 0.5% en 2000.

La troisième et dernière partie de ce premier chapitre est consacrée à la modélisation des terres urbaines. La méthodologie générale consiste à convertir les investissements en bâtiments en stocks de bâtiments qui sont ensuite convertis en terres urbaines grâce à des coefficients de conversion. Nous considérons également deux types d'utilisation de terres urbaines : les logements et les bâtiments

industriels et commerciaux. Ces derniers utilisent l’investissement adressé par les entreprises au secteur construction comme une approximation de la mesure de l’investissement en bâtiments commerciaux et industriels. Concernant les logements, nous construisons un modèle à correction d’erreur pour modéliser l’investissement logement des ménages.

Le second chapitre est consacré au développement de différents scénarios du futur de l’économie européenne. Dans un premier temps, nous construisons un scénario appelé “*reference scenario*” que nous prendrons comme base pour les évaluations des chapitres suivants. Ce scénario est principalement basé sur la reproduction des tendances passées mais il intègre également des expertises extérieures pour quelques variables motrices comme la population. L’application de la modélisation, développée dans le chapitre précédent, a permis de projeter l’évolution de l’utilisation des sols jusqu’en 2025. Ainsi, dans le cadre du “*reference scenario*”, nous nous attendons à un déclin des terres agricoles en exploitation en Europe avec un abandon de 29 000 km² en Union Européenne qui se caractérise par une importante diminution des pâturages (-42 000 km²) et une légère augmentation des terres arables (+13 000 km²). Par ailleurs, nous projetons également un accroissement des terres urbaines de plus de 10% entre 2005 et 2025 soit +16 000 km². L’expansion des zones urbaines est un résultat relativement commun aux études prospectives sur les changements dans l’utilisation des sols en Europe et l’ampleur de cette expansion (+10%) se situe dans l’éventail des autres publications. Nos projections pour les terres agricoles sont également dans la tendance des autres études qui anticipent une baisse future des terres agricoles utilisées. Mais ces autres études projettent généralement une diminution des terres arables alors que nous avons dans le “*reference scenario*” une légère augmentation. Cette différence provient d’une productivité tendancielle plus faible dans notre scénario que dans les autres études.

Dans une seconde section, nous développons quatre scénarios alternatifs en les différenciant par des évolutions contrastées des principales variables motrices (la démographie, le prix des énergies, la dynamique économique à l’extérieur de l’Europe et les investissements en R&D). Les scénarios comprenant d’importants investissements en R&D permettent d’atteindre les productivités agricoles constatées dans les autres études, mais nous convenons que sans ces efforts supplémentaires la productivité tendancielle des terres agricoles est plus faible dans notre étude que dans d’autres.

Nous commençons l’évaluation de politiques européennes avec le modèle NEMESIS et le modèle d’utilisation des sols dans le troisième chapitre. L’évaluation d’un ensemble de réformes de la Politique Agricoles Communes (PAC) est réalisée en à l’aide d’une “chaîne de modèles”. Les modèles utilisés regroupent (i) un modèle détaillé de l’agriculture européenne (CAPRI), (ii) un modèle européen de

gestion des ressources forestières (EFISCEN), (iii) un modèle détaillé d'allocation des sols en Europe (Dyna-CLUE) et (iv) un modèle économique couvrant tous ces secteurs (NEMESIS). Ces modèles sont reliés pour évaluer les impacts de politiques européennes en se focalisant sur leur soutenabilité. La principale originalité de cette "chaîne de modèles" réside dans le lien entre le modèle CAPRI et le modèle NEMESIS qui s'établit entre autre sur une procédure permettant de trouver un équilibre joint entre les deux modèles pour les terres agricoles à la suite d'un choc externe. Par un processus itératif de calibration, cette procédure permet au modèle NEMESIS de bénéficier des résultats du modèle CAPRI pour la demande de terres agricoles, compte tenu d'une description détaillée des produits agricoles dans ce dernier. De plus, cette procédure permet au modèle CAPRI, dont l'offre de terres agricoles est fixe, de tirer avantage de l'offre flexible du modèle NEMESIS.

Dans la seconde partie de ce chapitre, nous présentons une analyse d'impact d'un ensemble de réformes de la PAC qui consiste en une combinaison de réformes visant à supprimer les aides directes aux agriculteurs et/ou à supprimer les aides de marché au secteur agricole. Ces aides sont alors redistribuées soit aux consommateurs européens soit sous forme d'une subvention à la R&D. Les résultats avec la "chaîne de modèles" nous montrent un faible impact de la suppression des aides directes sur la production agricole, ce qui est un résultat généralement admis dans la littérature. En effet, les aides directes n'étant pas liées à la production, leur suppression n'affecte pas la production agricole. Néanmoins, comme identifié dans la littérature, les aides directes sont capitalisées dans les prix des terres agricoles. Ainsi, lors d'une suppression totale des aides directes aux agriculteurs, nous projetons une baisse du prix des terres agricoles (en terme réel) de 21% au niveau européen si les aides directes sont entièrement capitalisées et de 7% si elles ne le sont pas. Concernant la suppression des aides de marché (quotas, tarifs douaniers, ...), les conséquences sur les productions agricoles sont plus remarquables et en particulier pour les produits encore fortement protégés tels que le sucre (-14.5% de production) et la viande bovine (-9%). L'impact de la suppression des aides de marché est hétérogène parmi les pays européens et dépend de la contribution des productions les plus pénalisées par la libéralisation dans la production totale du pays considéré mais aussi de la rente liées aux quotas sur le marché laitier (c'est-à-dire la différence du coût marginal de production entre pays européens). Du point de vue de l'efficacité économique, la redistribution des fonds économisés suite à la libéralisation de l'agriculture européenne sous forme de subvention à la R&D montre des résultats significativement positifs. En effet, avec une redistribution sous forme de subvention aux activités de R&D, le PIB européen s'accroît de 2.5% et l'emploi augmente de 1.8 million alors que lorsque que les fonds sont redistribués directe-

ment aux consommateurs européens, le PIB européen croît de +0.5% et l'emploi diminue de 300 000 avec une très importante perte d'emploi dans le secteur agricole européen (-1.4 million). Malgré un multiplicateur des dépenses de R&D quelquefois supérieur à ceux d'autres études, dû par exemple à l'absence de capital humain, les résultats que nous obtenons montrent que la réallocation des fonds de la PAC vers l'économie de la connaissance semble améliorer les performances économiques de l'Europe et surtout ne pénalise pas trop fortement la production agricole européenne. Néanmoins, ce faible effet sur la production agricole se traduit ici par une forte augmentation de la productivité du travail dans le secteur agricole (+14%), l'ajustement se faisant au détriment de l'emploi du secteur agricole. Cependant, nous convenons que notre évaluation ne prend en compte un certain nombre de facteurs. Ainsi, si l'on considère la volatilité des prix agricoles et les spécificités de production de ce secteur, certaines études ont établi que les bénéfices d'une libéralisation des marchés agricoles peuvent être très incertains. Par ailleurs même si la production agricole agrégée est faiblement affectée par cette libéralisation, un certain nombre de produits peuvent, quant à eux, être beaucoup plus fortement pénalisés. Enfin, les autres fonctions économiques et sociales de l'agriculture, tel le développement rural et la régulation de l'environnement, peuvent être affectées, notamment par les pertes d'emploi dans l'agriculture et l'abandon des terres agricoles. En résumé, la redistribution de fonds européens de l'agriculture vers l'économie de la connaissance montre d'importants bénéfices du point de vue économique mais un minimum d'intervention dans le secteur agricole doit être maintenu ainsi que des transferts du premier pilier de la PAC vers le second pour assurer la pérennité d'une agriculture européenne de qualité.

Le quatrième et dernier chapitre utilise le modèle NEMESIS ainsi que le module d'utilisation des sols pour l'évaluation de politiques environnementales européennes. En amont de cette analyse d'impact, nous construisons une base de données sur l'utilisation des nutriments dans l'agriculture pour chaque pays européen. Avec l'aide d'études antérieures, nous calculons les intrants en nitrates et phosphores dans l'agriculture européenne pour l'année 2008 en distinguant les nutriments selon leur origine : animale, minérale, fixation biologique et déposition atmosphérique. Nos calculs pour l'année 2008 montrent, au niveau européen, une utilisation de l'ordre de 22 millions de tonnes de nitrates et de 3.1 millions de tonnes de phosphores ce qui représente respectivement 118 kg/ha et 17 kg/ha. La principale source de nutriments est d'origine minérale avec 11 millions de tonnes de nitrates et 2 millions de tonnes de phosphores, et la seconde source est d'origine animale avec 7.8 millions de tonnes et 1 million de tonnes respectivement. Les résultats d'utilisation des nutriments sont très hétérogènes parmi les pays de l'Union Européenne, nous trouvons ainsi les plus fortes quantités d'intrants par

hectare aux Pays-Bas avec 118 kg/ha de nitrates et à l’opposé, nous avons seulement 58 kg/ha de nitrates en Estonie. Par la suite, nous modélisons ces différentes sources de nutriments et nous les projetons jusqu’en 2025 pour le “*reference scenario*”. Ces projections à l’horizon 2025 montrent une légère augmentation des nutriments au niveau européen, avec 0.2 million de tonnes additionnelles de nitrates. Nous projetons une augmentation relativement forte de l’usage des nitrates en Espagne (+0.3 million de tonnes soit +12 kg/ha) et une baisse de -13 kg/ha aux Pays-Bas entre 2005 et 2025, qui restent tout de même le plus important consommateur d’intrants de nutriments.

La seconde section de ce chapitre a pour but d’évaluer les deux politiques européennes de conservation de la biodiversité. La première politique consiste en une extension des forêts protégées dans l’Union européenne ce qui implique une réduction des terres potentiellement disponibles pour l’agriculture, tandis que la seconde vise à évaluer les conséquences d’une extensification de la production agricole en Europe. Nous trouvons ainsi, un coût de conservation de la biodiversité en Europe de l’ordre de 800 €/2000/ha/an pour l’accroissement des forêts protégées et de 900 €/2000/ha/an pour l’extensification de l’agriculture. Par ailleurs, en confrontant ces valeurs avec d’autres estimations de la littérature, nous avons conclu qu’il s’agissait de bornes hautes pour la valorisation des coûts de la biodiversité. En effet, le niveau de protection requis et l’exclusion de l’ensemble des forêts protégées des terres potentiellement disponibles pour l’agriculture, ont renforcé le coût de conservation de la biodiversité pour les forêts européennes. Par ailleurs, la forte diminution de l’intensité de production sur les nouvelles terres agricoles protégées, quatre fois inférieures à celle du “*reference scenario*”, explique que notre estimation du coût de conservation de la biodiversité dans l’agriculture soit haute.

Enfin la dernière section de ce chapitre présente une évaluation normative de l’objectif européen cherchant à atteindre une part de 10% de biocarburants dans les transports en 2020. Nous montrons que ce développement des biocarburants pourrait entraîner une forte substitution favorable aux productions agricoles végétales au détriment des productions animales, ces premières bénéficiant de l’augmentation de la demande pour les cultures destinées à la fabrication de biocarburants. Nous avons aussi constaté cette substitution au niveau des terres agricoles avec une augmentation des terres arables de 41 000 km² et une diminution des pâturages de 6 000 km² dans l’Union Européenne. En comparant ces résultats avec d’autres évaluations, nous constatons que ces études projettent également une augmentation des terres agricoles mais d’une ampleur moins importante. Cette différence peut s’expliquer, en plus de l’absence de prise en compte de biocarburants de seconde génération dans notre étude, par un manque de détails en terme de produits agricoles dans le modèle NEMESIS ce qui peut réduire les possibilités

de substitution entre produits qui pourraient atténuer l’ampleur du changement dans l’utilisation des terres agricoles.

Le travail réalisé dans cette thèse a inévitablement de nombreuses limites que nous espérons avoir en grande partie identifiées. De futurs travaux pourraient permettre d’en dépasser certaines en appliquant par exemple aux réformes de la PAC présentées ici la modélisation des nutriments que nous avons développée, en calculant les surplus en nutriments et non pas uniquement les intrants et en mettant à jour la base de données sur l’utilisation des sols à l’aide des nouvelles données d’Eurostat publiées en octobre 2010. Il serait également intéressant de poursuivre l’utilisation du couplage des modèles NEMESIS et CAPRI pour d’autres analyses d’impacts ou encore de détailler le secteur agricole dans le modèle NEMESIS.

Résumé :

Cette thèse a pour objet le développement d'un module d'utilisation des sols compatible avec le modèle NEMESIS, qui est un modèle économique détaillé de l'Union Européenne. Cette thèse a également pour objectif d'utiliser conjointement le modèle NEMESIS et le module d'allocation des sols pour analyser les effets de plusieurs politiques européennes et notamment leurs impacts sur l'économie et l'utilisation des sols. Le premier chapitre décrit d'une part la construction de la base de données d'utilisation des sols et d'autre part, explique le développement du module d'allocation des sols au niveau des États de l'Union Européenne, en utilisant des fonctions d'offre et de demande de terre agricole et un modèle d'expansion des terres urbaines. Le second chapitre traite, au travers de deux applications, du problème de la construction de scénarios en modélisation appliquée. Un premier scénario, construit suivant une approche dite tendancielle, est présenté de façon détaillée et analysé. Ce scénario sert également de référence pour les évaluations des politiques européennes. Une seconde application propose quatre scénarios élaborés suivant une approche dite « imaginative », c'est-à-dire en imaginant différentes possibilités d'évolution contrastée des principales variables motrices de la croissance économiques. Le troisième chapitre présente la construction et le fonctionnement d'une combinaison de différents modèles ou « chaîne de modèles ». Celle-ci sera utilisée pour l'évaluation économique et environnementale d'une politique de libéralisation de l'agriculture européenne avec ré-allocation des fonds aux contribuables ou à l'aide à la recherche et développement. Cette « chaîne de modèles » combine le modèle NEMESIS avec un modèle agricole détaillé (CAPRI), un modèle de gestion des forêts (EFISCEN) et un modèle détaillé d'allocation des sols (Dyna-CLUE). Enfin le dernier, et quatrième chapitre, présente, après la construction d'indicateurs sur l'utilisation des nutriments dans l'agriculture, l'évaluation des conséquences économiques de deux politiques européennes : d'une part, une politique de biodiversité caractérisée par l'augmentation des forêts protégées ou par une production agricole extensive et d'autre part une politique de soutien au développement des biocarburants au niveau européen.

Mots clés :

Modélisation économique, Utilisation des sols, Étude d'impact, Environnement, Politique européenne, Nutrient, Biodiversité, Biocarburants

English:

This thesis aims to develop a land use module for the applied economic model NEMESIS which is a detailed model for European Union. This dissertation also proposes the use of the land use module with the NEMESIS model in order to analyse the effects of European policies especially their economic and land use impact. The first chapter describes, on one hand, the construction of a database on land use and, on another hand, explain the development of a land use module for the EU countries by using agricultural land supply and demand but also an modelling of urban land use. The second chapter regards, using two applications, the problem of scenario construction in applied modelling. A first scenario, constructed with an extrapolating approach, is presented and analysed. This scenario is also used as reference scenario for the assessment of European policies. A second application shows four scenario developed using an imaginative approach i.e. assuming different possibilities for the future change in main drivers. The third chapter presents and describes the functioning of four linked models which is used for the economic and environmental assessment of a European agriculture liberalisation with re-allocation of released funds either by consumer tax rebate or a subsidy to R&D investments. The linked models included (i) the NEMESIS model, (ii) the CAPRI model a detailed agricultural model, (iii) the EFISCEN model, a forest resource management model and (iv) the Dyna-CLUE model, a detailed model for land use allocation. Finally, the last chapter presents, after the construction of indicators about nutrient use in agriculture, the economic assessment of two European policies: firstly, a biodiversity conservation policy in forest area or in agricultural land and secondly a biofuel development policy at European level.

Keywords:

Economic modelling, land use, Impact assessment, Environment, European policy, Nutrient, Biodiversity, Biofuel.