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Université d'Auvergne Clermont-Ferrand I  
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Centre d'Etudes et de Recherches sur le Développement International (CERDI)

# **ESSAYS ON ENVIRONMENTAL DEGRADATION AND ECONOMIC DEVELOPMENT**

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Par

**Somlanare Romuald KINDA**

Sous la direction de  
Mme le Professeur Pascale COMBES MOTEL

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A feu mon père

A ma mère, Marceline et à mon frère Berenger



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# **General Introduction and Overview**



Over the last two decades, substantial changes in social indicators have been observed. According to the Human Development Report (UNDP 2013), many developing countries have improved their human development indicators.<sup>1</sup> Between 2000 and 2012, all countries<sup>2</sup> accelerated their achievements in the dimensions of human development (life expectancy, educational attainment, and child and mother mortality). This progress has been faster in countries with medium and low human development indicators than in those with high human development indicators. Moreover, according to the Human Development Report (UNDP 2013) and Chen and Ravallion (2010), the proportion of people living below the international poverty line has fallen from 52% in 1980 to 24% in 2008. This unprecedented progress in the world has been driven by a combination of economic growth, better policies and the Millenium Development Goals (MDGs).

Despite significant progress in human development, two trends may be noticed. First, economic progress has differed between regions and between countries. Income inequality has worsened between population groups within countries even if the human development indicators (health and education achievement) between countries have been improved. Indeed, despite the poverty reduction, one-quarter of the world's population remains in extreme poverty.<sup>3</sup> According to the Millennium Development Goals Report (2012), the number of extreme poor in developing countries was about 1.4 billion in 2008. Three-quarters of the people living in extreme poverty will be in Southern Asia and sub-Saharan Africa by 2015. Second, population growth and income are associated with deterioration in key environmental indicators (carbon dioxide emissions, soil and water quality and forest cover) and an overexploitation of natural resources. Indeed, the human population, economic growth and social development potentially increase the pressure on environmental resources. These situations may undermine sustainable development in developing countries. Dasgupta (1995) shows the existence of the poverty trap. In many developing countries, demographic transition is not achieved (low natality and low mortality). Therefore, there is a high population growth rate, which increases the depletion of environmental resources and the deterioration of environmental quality. When this situation occurs, poverty, high fertility rates and environmental degradation can reinforce one another in a negative spiral and undermine future economic development. In other words, the MDGs have fallen short of integrating the economic, social and environmental aspects of sustainable development.

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<sup>1</sup> The Human Development Indicator (HDI) is a composite measure that includes three dimensions: life expectancy, educational attainment and income.

<sup>2</sup> Only two countries (Lesotho and Zimbabwe) had a lower HDI value in 2012 than in 1990.

<sup>3</sup> The proportion of people living on less than \$1.25 per day.

There are discussions on the Post-2015 Development Agenda. According to the report of the United Nations High Level Panel (UN 2012), the vision for the Post-2015 Development Agenda should be guided by the objective of eradicating extreme poverty in the context of sustainable development.<sup>4</sup>

This thesis contributes to the debate on environmental degradation and development. The next sections (sections 1 and 2) review the drivers of environmental degradation and their macroeconomic effects on development that are put forward in the literature. Section 3 presents an outline of this dissertation and the main results.

### **1 Understanding the causes of environmental degradation**

Economic growth seems to be the main driver of environmental degradation. We examine two countervailing factors in this section.

#### **1.1 Economic growth**

According to Grossman and Krueger (1995), economic development can affect environmental quality through the scale of economic activity, its composition (or structure) and the effect of income on the demand and supply of the pollution abatement effort. The larger the scale of economic activity, other things being equal, the higher the level of environmental degradation (pollution, resource depletion) is likely to be, since increased economic activity results in increased levels of resource use and waste generation. The composition of economic activity affects environmental quality. Indeed, the primary sector tends to be more resource-intensive than the secondary or tertiary sectors. Industry (especially manufacturing), on the other hand, tends to be more pollution-intensive than either agriculture or services. Since the structure of the economy changes, part of the effect of income per capita reflects the effects of the changing composition of output. In other words, the composition effect can have a positive or negative impact on the environment because it measures the evolution of the economy towards a more or less appropriate productive structure. The technical effect is the positive environmental consequences of increases in income that call for cleaner production methods. Higher incomes enable higher public expenditure on environmental infrastructure as well as environmental regulations that drive private sector expenditure on abatement technologies. These three effects are illustrated by the Environmental

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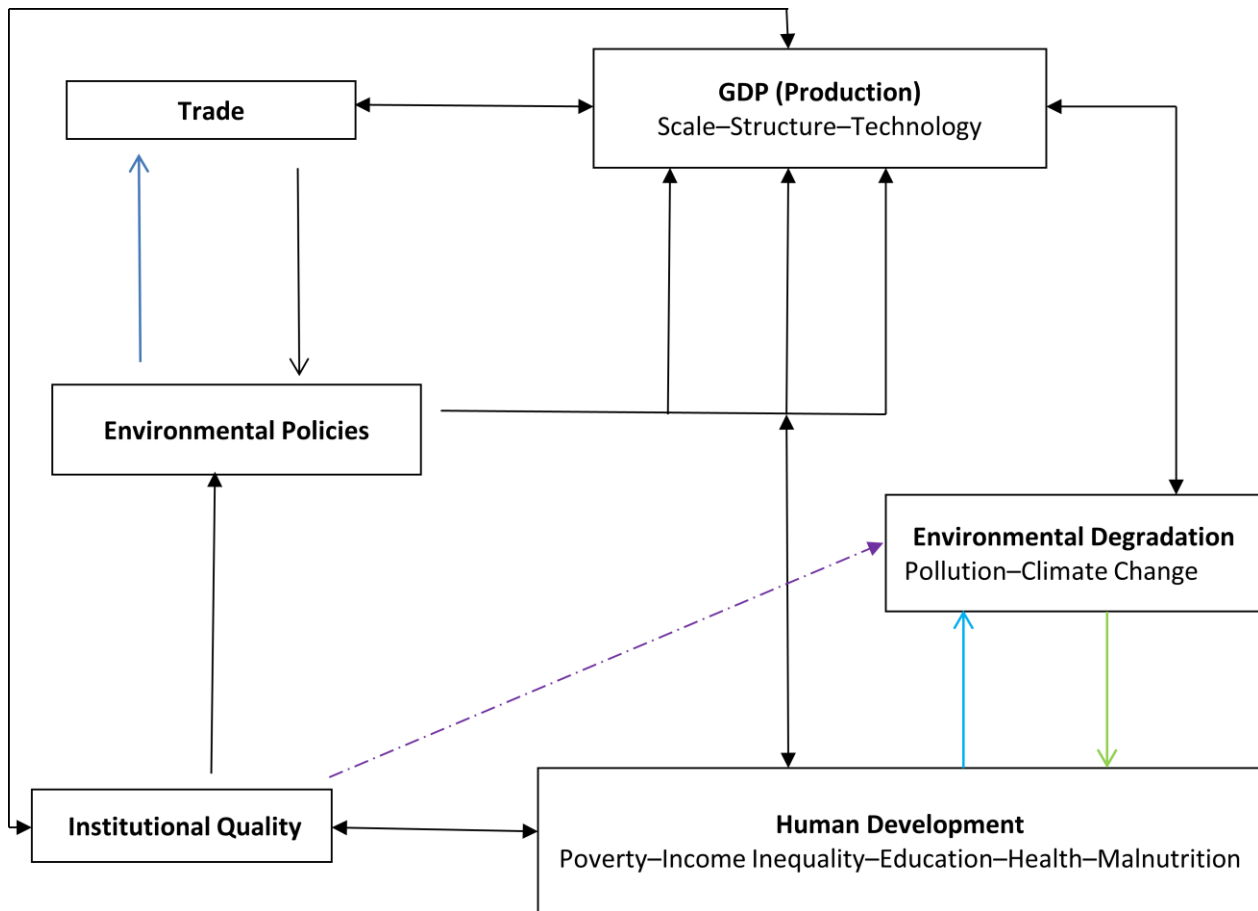
<sup>4</sup> The post-2015 agenda should be driven by five “transformative shifts”: 1) leave no one behind; 2) put sustainable development at the core; 3) transform economies for jobs and inclusive growth; 4) build peace and effective, open and accountable institutions for all; 5) forge a new global partnership.

Kuznets Curve (EKC). It assumes that environmental degradation increases up to a certain level of income; after this level, it decreases. In addition, several authors consider that international trade may affect environmental quality through economic growth. Indeed, trade can influence environmental degradation through the scale, composition and technique effects. First, it raises economic activities that increase natural resource extraction and pollution (scale effect). It may change the type of economic activities to either less or more polluting industries (composition effect). Third, trade openness may encourage environmental production techniques.

The EKC has been found for some pollutants and rejected for others. Indeed, Bimonte (2002) and Grossman and Krueger (1995) find an EKC for pollutants such as sulphur dioxide, carbon monoxide or nitrogen oxides. For carbon dioxide emissions, the hypothesis is rejected by Holtz-Eakin and Selden (1995). It is highlighted by Carson (2010), who shows that the corroboration of an EKC depends on econometric techniques, the quality of the data and the inclusion of other variables (Dinda 2004; Stern 2003; Stern 2004). Moreover, the EKC is a reduced form and does not shed light on the channels of transmission from economic activity to environmental degradation. Figure 1 below is an attempt to sort out several linkages that will be explored within this thesis. It illustrates for instance how environmental degradation may be dampened. This point is developed in the following section.



**Figure 1: Relationship between environmental degradation and economic development**



Source: Author’s construction

- Chapter 1: Does Education Really Matter for Environmental Quality?
- - - - - → Chapter 2: Are Democratic Institutions Really Good for Environmental Quality?
- Chapter 3: Climatic Variability and Food Security in Developing Countries
- Chapter 4: Do Environmental Policies Hurt Trade Performance?

## 1.2 The demand for environmental quality

It may be theoretically argued that the demand for environmental quality rises along with income (Vogel 1999). Indeed, economic growth is associated with increasing consumption and environmental degradation (waste and emissions). When people become rich and have higher living standards, their preferences for environmental protection increase. They are incited to accept the

opportunity cost of protection. They may express their willingness to pay for environmental quality by supporting environmental policies in elections. The quality and the type of political institutions may allow people to express and support environmental policies.

### *1.2.1 Political institutions*

A large body of literature has analysed the effect of political institutions on environmental quality. In cases in which environmental degradation has been mitigated, this may be attributed to local institutional reforms (Arrow et al. 1995). Payne (1995) argues that the members of the population in democratic countries are free to collect information about environmental degradation and are able to express their preferences and put pressure on their governments. With democracy, citizens are more aware of environmental problems (freedom of media). They can also express their preferences for the environment (freedom of expression) and create lobbying groups (freedom of association). Political leaders may become prompted (rights to vote) to implement environmental policies at the national and international levels. McCloskey (1983) and Payne (1995) highlight an important ability of democratic countries to satisfy people's environmental preferences and their willingness to commit themselves to international negotiations and agreements. Deacon (2009) and Olson (1993) argue that political freedoms favour environmental protection because non-democratic regimes will underproduce the environment considered as a public good. Autocratic governments are led by political elites who monopolize and hold a large share of the national incomes and revenues. The implementation of rigorous environmental policies can lower the levels of production, income and consumption, which, in turn, impose a higher cost on the elite in an autocracy than on the population, whereas the marginal benefit is uniform for both elite and population. Elites in an autocracy are therefore relatively less pro-environment than people in a democracy.

The empirical results are, however, not clear-cut. It may first be argued that democracy is positively linked with environmental commitment, but this is not necessarily the case with environmental outcomes (Neumayer 2002). Desai (1998) postulates that democracy does not protect the environment. Democracy is a factor of economic growth and prosperity, which may have a negative impact on the environment. Democracy is also correlated with factors such as property rights and social infrastructures that boost economic growth. First, Hardin (1968) worries about the management and overexploitation of natural resources. The property rights of environmental and natural resources (for example air, oceans, forests) are not well defined. This exploitation is accelerated in democracies where individuals have business and economic freedom. Moreover,

Dryzek (1987) notices that democracies are also economic markets wherein lobbying groups are very important. Political leaders may be influenced by lobbying groups and multilateral companies. Democracies are not considered as protecting environmental quality as they are supposed to satisfy the preferences of markets and lobbying groups that aim to maximize their economic profit, which does not favour a better environmental quality.

### *1.2.2 The role of education*

Educational attainment is generally considered a determinant of environmental preferences as well as an essential tool for environmental protection. Education enhances one's ability to receive, to decode and to understand information, and information processing and interpretation have an impact on learning and change behaviours (Nelson & Phelps 1966). In recent years (see Human Development Report (UNDP 2013); Global Environment Outlook-5 (UNEP 2012)), education has been considered as a vehicle for sustainable development. Some authors show that an increase in people's education is often accompanied by higher levels of environmental protection. Moreover, Farzin and Bond (2006) consider that educated people are more likely to generate an environmentally progressive civil service, and therefore have democratically minded public policymakers and organizations that are more receptive to public demands for environmental protection.

## **2 Macroeconomic effects of environmental degradation**

### **2.1 Does environmental degradation undermine human welfare?**

During the last decades, one of the greatest challenges facing countries has been the effects or consequences of global environmental degradation (desertification, solid and hazardous waste, water scarcity, soil degradation, pollution, deforestation, biodiversity and climate change). The economic literature on the impact of global environmental degradation can be split into two groups: climate change and other environmental indicators.<sup>5</sup> In this section, we focus only on climate change.<sup>6</sup> This focus may be partially explained by the fact that climate change will potentially undermine all the efforts at environmental conservation and may threaten human welfare.

Environmental degradation may have negative effects on economic development through several channels, such as migration, economic growth, health, conflicts and agriculture. Some

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<sup>5</sup> Desertification, solid and hazardous waste, water scarcity, soil degradation, pollution, deforestation, etc.

<sup>6</sup> Many authors (Aunan & Pan 2004; Gangadharan & Valenzuela 2001; Jerrett et al. 2005) have studied the effects of local, regional and global other environmental indicators (air pollution, water, etc.)

authors (Aunan & Pan 2004; Jerrett et al. 2005) find that air quality degradation has a specific negative effect on mortality or morbidity, while others (Gangadharan & Valenzuela 2001) show an effect on all causes of mortality. It has been shown that environmental degradation may be a factor of migration. Naudé (2008) shows that climate change intensifies migration through scarcity of land and water and conflicts for natural resources. Barnett and Adger (2007) find that climate change may have a negative effect on the livelihoods of the populations receiving the migrants by reducing the available resources (water, access to land) and increasing the pressure on local wages and jobs.

Many theoretical papers conclude that climate change has a negative impact on agricultural production and decreases national food availability. Christensen et al. (2007) show that food production remains highly vulnerable to the influence of adverse weather conditions. Dilley et al. (2005) and Haile (2005) confirm that the recent food crises in Africa, which required large-scale external food aid, may be attributed fully and partially to extreme weather events. Ringler et al. (2010) conclude that climate change is a factor of childhood malnutrition in sub-Saharan Africa. Stern (2007) establishes that developing countries are more vulnerable to climate change. According to the Human Development Report (UNDP 2011), an increase in environmental and climatic risks at the global level (climate change), regional and urban level (outdoor air pollution), local level (water and sanitation) and household level (indoor solid fuel) reduces the human development indicators from 8%. Moreover, under an environmental disaster scenario, the global human development indicators would be 15% below the baseline scenario.

### **2.2 Environmental policies and countries' competitiveness**

Because environmental degradation may threaten the ability of developing countries to reduce poverty and to target the Millennium Development Goals for 2015, the international community is solicited to increase the efforts to stabilize the concentration of greenhouse gases. However, many developed countries are not motivated to implement environmental policies because they may reduce their competitiveness (trade, foreign direct investments). There is extensive literature on the relationship between environmental regulations and trade, but the results are mixed and inconclusive, raising the importance of reassessing them.

The economic literature shows a complex relationship between economic development and environmental degradation. As shown in figure 1, several linkages (institutional quality, human development indicators, environmental policies, etc) may be identified.

The first motivation of this dissertation is to offer additional empirical evidence on the relationship between economic growth and environmental degradation. Indeed, many empirical papers have failed to evidence an EKC for carbon dioxide emissions per capita; the latter seems to increase monotonically with economic growth. We reexamine this issue following an augmented Green Solow model (Brock & Taylor 2010) by taking into account the role of education (*chapter 1*). Moreover, we analyse the mechanisms by which democratic institutions may improve environmental protection (*chapter 2*).

The second motivation of this dissertation is to analyse the effect of environmental degradation on economic development. Even though the existing literature on the effects of environmental degradation is exhaustive, nothing (or little) is said about the macroeconomic effects of climatic variability on food security (*chapter 3*). Indeed, most papers are theoretical and focus on the effect of climate change on agriculture. *Chapter 4* reanalyses the effect of environmental policies on trade. Before examining all these issues in detail in the following chapters (essays), let us explore the outline and main results of this dissertation.

### 3 Outline and main results

This dissertation focuses on trying to add to this literature on the determinants and macroeconomic effects of environmental degradation. It is structured in two parts. The first part (chapters 1 and 2) analyses the effects of education and democratic institutions on environmental quality. In the second part, the dissertation provides two essays on the effects of environmental policies and climate change on development. The next sections summarize the main findings of this dissertation.

Previous empirical studies have failed to evidence an Environmental Kuznets Curve for carbon dioxide emissions per capita: the latter seem to increase steadily with economic growth. Using an augmented Green Solow model (Brock & Taylor 2010), the **first chapter** examines this issue by taking into account the role of education, which is shown to play a significant role in economic growth performances. The environment–income relationship is more complicated than the assumed environmental Kuznets curve. A positive link between income and environmental quality might overstate the importance of income and overlook the fact that poor people are likely to be less informed about environmental risks than rich people. Less attention has been paid to the possibility that environmental quality could also be explained by the lack of awareness about the effects of environmental pollution. In other words, the people’s level of education may explain environmental quality. The rationale behind this question is based on four arguments linking

education and environmental quality. First, education increases environmental preferences because it enhances one's ability to receive, to decode and to understand information, and information processing and interpretation have an impact on learning and change behaviours (Bimonte 2002; Nelson and Phelps 1966). Second, education facilitates the development and adoption of new technologies. Because educated people adopt innovations sooner than less educated people (Wells 1972), it may be important for the diffusion of green technology from developed to developing countries. Third, education can have an opposite effect on environmental quality through productivity factors. Indeed, an accumulation of education has a positive impact on labour productivity and leads to higher incomes, consumption and then pollution (Jorgenson 2003). However, it increases the resources that are necessary for pollution abatement through its positive effect on economic growth. Fourth, education can affect the quality of the environment through population growth. The education of people (especially women) contributes to slower population growth and reduces the degradation of the environment. Our results suggest that education has no impact on the growth of air pollution for the whole sample (85 countries). However, this effect is heterogeneous between the countries according to their level of development. Indeed, while the effect remains insignificant in the developing countries sub-sample, it proves significant in the developed countries. In these countries, education is a factor of air pollution growth. More interestingly, when controlling for the quality of democratic institutions, the positive effect of education on air pollution growth is mitigated in the developed countries while being insignificant in the developing countries.

The disappointing outcomes of international conferences like the Copenhagen summit held in 2009 highlight real and enormous problems in international cooperation between countries to fight climate warming. Though scientists' reports emphasize that countries should act rapidly to reduce the greenhouse effect gases responsible for climate warming, they also mention the huge challenge that the international community must face, especially democratic countries, to improve the situation. The literature on the link between democratic institutions and environmental quality has found mitigated results. Indeed, some authors find that democratic institutions favour environmental protection, whereas others conclude a negative effect. Moreover, Held and Hervey (2010) show that among the 40 highest carbon emitters internationally (cumulatively responsible for 91% of the total world emissions), the countries that have the best records are all democracies. The **second chapter** contributes to the controversial link between democratic institutions and environmental protection. It explores the effect of democratic institutions on environmental quality for 122 developed and developing countries from 1960 to 2008. The main contribution of this chapter is that we identify

and test four potential transmission channels: income inequality, investments, foreign direct investments and trade openness. The environmental economic literature establishes that democratic institutions can have both virtuous and vicious effects on environmental quality. Democracy can be characterized by the effective existence of institutional rules framing the power and the presence of institutions enabling citizens to express their expectations and choose political elites. It allows people to express their preferences about policies and social choices (environmental protection, economic growth, redistribution policies). Moreover, democracy allows freedom of association and lobbying groups, which may protect or fight environmental quality. The results are as follows. First, we show that democratic institutions have opposite effects on environmental quality: a positive direct effect on environmental quality and a negative indirect effect through domestic investments and income inequality. Second, we find that the direct negative effect of democratic institutions is higher for local pollutants ( $\text{SO}_2$ ) than for global pollutants ( $\text{CO}_2$ ). Third, the nature of democratic institutions (presidential, parliamentary) is conducive to environmental quality. Fourth, the results suggest that the direct positive effect of democratic institutions on environmental quality is higher in developed countries than in developing countries.

While most studies are based on theoretical or prospective studies, the **third chapter** provides a macroeconomic and empirical analysis of the impact of climatic shocks on food insecurity for 71 developing countries from 1960 to 2008. Moreover, this chapter investigates the mechanisms by which climate variability increases food insecurity in developing countries. Indeed, there are many channels through which climate variability is likely to affect food security in developing countries. First, climatic variability may have a negative effect on agricultural production (through farm yields). Most developing countries are particularly vulnerable to and consequently threatened by climatic variability because their economies are closely linked to agriculture (Mendelsohn, Dinar & Williams 2006; World Bank 2002). Moreover, by reducing agricultural production, climatic variability has direct and indirect negative effects on agriculture incomes. This effect is particularly high in African countries, where agricultural production is the primary source of livelihoods for 66% of the total active population (International Labor Organization 2007). Second, climatic variability may negatively affect economic growth and resources. It reduces countries' ability to purchase food on international markets. Third, climatic variability may be a factor in food insecurity by increasing the risk of civil conflicts. Indeed, several authors (Buhaug 2008) suppose that climate variability will be likely to lead to greater scarcity and variability of renewable resources in the long term. Empirically, we test the potential heterogeneities in the relationship between climate variability and food security. First, we test whether the effects of climate variability can differ

depending on whether the country is under conflict. Second, we analyse the impact of climate variability on food security in the context of vulnerability to food price shocks. The findings from the empirical analysis provide evidence that climatic variability reduces the food supply in developing countries. The adverse effect is higher for African sub-Saharan countries than for other developing countries. Second, food supply is a channel by which climatic shocks increase the proportion of undernourished people. Third, the negative effects of climatic shocks are exacerbated in the presence of civil conflicts and are high for countries that are vulnerable to food price shocks.

The **fourth and final chapter** makes a contribution to the controversial literature on the relationship between environmental regulations and international trade. It provides new evidence on the effect of the gap in environmental policies between trading partners on trade flows for 122 countries during the period 1980–2010. According to the conventional wisdom (the pollution haven hypothesis), environmental policies entail additional costs and may erode the competitiveness of firms or countries (Cagatay & Mihci 2006; Keller & Levinson 2002; Van Beers & Van Den Bergh 1997). This paradigm is challenged by the Porter hypothesis (Porter 1991; Porter & Van der Linde 1995), which considers that strong environmental policies can stimulate competitiveness through innovations. While previous papers have used partial measures of environmental regulations (input-oriented or output-oriented indicators), we compute an index of a country's environmental policy. Indeed, the main limit of these indicators is that input-oriented indicators are not always available for all countries and output-oriented indicators may depend on other factors than policy. Following previous authors, such as Boussichas and Goujon (2010), Combes Motel, Pirard and Combes (2009) and Combes and Saadi-Sedik (2006), we develop a new approach to measuring an index of policy against environmental degradation. It is a measure of countries' domestic policy. The results suggest that similarity in environmental policies has no effect on bilateral trade flows. Moreover, the results are not conditional on the level of development of trading countries or the characteristic of exported goods (manufactured goods and primary commodities).





# **PART1: DETERMINANTS OF ENVIRONMENTAL DEGRADATION**



# Chapter 1: Does Education Really Matter for Environmental Quality?<sup>7</sup>

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<sup>7</sup> This chapter has previously been published in two journals. The references are as follows: Kinda, S. R., 2011. "Education, convergence and growth in carbon dioxide per capita", *African Journal of Science, Technology, Innovation and Development* (AJSTID), 3(1), pp.65–85; Kinda, S. R., 2010. "[Does education really matter for environmental quality?](#)" *Economics Bulletin, AccessEcon*, 30(4), pp. 2612–2626

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***Abstract***

Several empirical studies have failed to evidence an Environmental Kuznets Curve on carbon dioxide emissions per capita: the latter seem to increase steadily with economic growth. The aim of this paper is to reexamine this issue following the Brock and Taylor (2010) Green Solow model taking into account the role of education, which is shown to play a significant role in growth performance. No evidence of an effect of education on carbon dioxide emissions is found using a panel of developed and developing countries over the 1970–2004 period. However, this effect depends crucially on the sample of countries according to their levels of development. While the effect remains insignificant in developing countries, education does matter for carbon dioxide emissions in developed ones. Moreover, when controlling for the quality of democratic institutions, the positive effect of education on carbon dioxide emissions is mitigated in developed countries while remaining insignificant in developing ones.

*Keywords: Air pollution; Education; Democratic institutions*

*JEL Classification: I2; O43; Q53*



## 1 Introduction

Developing countries, particularly the poorest, are more exposed and less resilient to climate hazards. They will bear the burden of climate change (low agricultural productivity, increased hunger, malnutrition and disease) even if they strive to overcome poverty. Moreover, Mendelsohn et al. (2006) explain this vulnerability by the fact that their economies are closely linked to climatic sensitive sectors such as agriculture. According to the World Development Report 2010 (World Bank 2009), many other factors can explain the vulnerability of these countries to climate change. They have limited human and financial resources, weak institutions and their economies are highly dependent on primary economic activities (agriculture, forestry, mining and fishing) and natural resources (air, soil and water) that are affected by climate change. In this regard, Barbier (2006) shows that sub-Saharan African countries have been the most dependent since 1960. To mitigate and to reduce vulnerability to climate change, countries need international funds and technology transfers to implement policies that foster economic performance associated with adequate and efficient management of natural resources. They also need capacity building that depends critically on human capital.

The natural resource literature has highlighted the consequences of poor management of natural resources on human capital investments and economic performance. Gylfason (2001) argues that the poor economic performance of countries rich in natural resources can be explained by the fact that they have neglected human capital. In other words, education and natural resources would be substitutes for each other and education would be negatively related to the abundance of natural resources. An abundance of natural resources may reduce private and public incentives to accumulate human capital due to a high level of non-wage income (dividends, social spending and low taxes). Empirically, Gylfason et al. (1999) and Gylfason (2001) show that the level of education, the share of public expenditure on national income and expected years of schooling are inversely related to the abundance of natural and environmental resources. Drawing on that body of the literature, the role of human capital in environmental performance may be assessed.

In this paper, we hypothesise that a high level of education fosters both economic development and environmental performance. According to the literature on the environmental Kuznets curve, environmental quality does not steadily deteriorate with



economic growth. Grossman and Krueger (1995) and the World Development Report (World Bank 1992) explain this result by an improvement in the demand for environmental quality in richer countries. Empirical results on the subject are not clear-cut. Studies show that some environmental indicators (carbon dioxide emissions and municipal solid wastes) decrease with an increase in income, which implies that they worsen with economic growth. Other environmental indicators (the lack of safe water and urban sanitation) improve as income rises, implying that growth can improve environmental quality. Finally, many indicators (sulphur dioxide and nitrous oxide emissions) show an inverted U relationship with income, so that environmental degradation worsens in the early stages of growth, but eventually reaches a peak and starts declining as income passes a threshold level. However, the relationship between the environment and income is still controversial. In an effort to understand it, several authors use meta-analyses. In this regard, using a meta-analysis of 25 studies covering 11 categories of environmental goods, Cavlovic et al. (2000) demonstrate that methodological choices (econometric specification) can influence the income turning points. Li et al. (2007) and Koirala et al. (2011) find similar results. A positive link between income and environmental quality might overstate the importance of income and overlook the fact that poor people are likely to be less well informed about environmental risks than rich people. Less attention has been paid to the possibility that environmental quality could also be explained by the lack of awareness about the effects of environmental pollution. Indeed, education may increase demand for better environmental quality through factors such as productivity (income), population size and changes in preferences. Moreover, it may foster the supply of environmental goods through green technologies.

This paper aims to highlight the importance of education in relation to environmental quality over the period 1970–2004 in 85 developing and developed countries. We use panel data and apply modern GMM-System estimations. Because many studies have failed to explain the existence of the environmental Kuznets curve, we consider the issue in relation to a different empirical framework following Brock and Taylor (2010). Our results suggest that education has no impact on the growth of air pollution for the whole sample (85 countries). However, this effect is heterogeneous between the countries according to their level of development. Indeed, while the effect remains insignificant in the developing country subsample, it proves significant in developed countries. In these countries, education is a factor related to an increase in air pollution. More interestingly, when controlling for the quality of

democratic institutions, the positive effect of education on air pollution growth is mitigated in developed countries while being insignificant in developing countries. Low education levels and the relative weakness of democratic institutions might explain the absence of the effect of education in developing countries. The combination of these factors strongly reduces the capability of people to express their preferences for a better environment. Our results are robust and relevant by virtue of taking into account income per capita, international environmental agreements and alternative education measures.

The remainder of the paper is organized as follows. Section 2 shows how education can influence environmental quality. Section 3 derives an estimating equation and shows results and the last section (section 4) is devoted to the conclusion.

## **2 How may education affect environmental quality?**

In this section, we highlight theoretical arguments linking education and environmental quality. First, education may increase demand for better environmental quality through factors such as productivity, population size and changes in preferences. Second education may foster the supply of environmental goods through green technologies.

### **2.1 Education and demand for better environmental quality**

#### *2.1.1 Education and income*

Education can have an effect on environmental quality through capital and labour productivity. Firstly, an accumulation of education has a positive impact on labour productivity (skilled labour). This leads to higher income levels, higher consumption and then pollution. Jorgenson (2003) finds that education has a positive effect on the ecological footprint. Educated people have more income and purchasing power and are encouraged to overconsume material goods. Indeed, they desire to live well by accumulating material goods without necessarily caring about the consequences and the ideological model of “consume more to be happier” conveyed by advertising and the media leads to a greater consumption of material goods (Princen 2001). Because overconsumption of goods is a factor in the over-exploitation of natural resources, educated people contribute to environmental degradation (air, soil and water). These empirical results show a positive and significant effect of enrolment on the ecological footprint per capita. Because education has a positive effect on economic growth, it also increases the resources that are necessary for pollution abatement.

Secondly, education can change economic structure, which can become relatively more intensive and relatively less polluting, increasing the capacity to implement environmental policies. Indeed, if an economy grows initially with the accumulation of polluting physical capital and later with the accumulation of non-polluting human capital, then pollution can appear in the shape of a reversed U curve.

### 2.1.2 *Education and population*

Education can affect the quality of the environment through population growth. The education of women contributes to slowing population growth and pressure. Slower population growth may reduce the pressures on the environment (Cropper & Griffiths 1994). Some scholars highlight three dimensions of education that affect individual choice and influence their preferences for fertility. Firstly, education can be considered a *source* of knowledge. Knowledge transmission is probably the school's most explicit goal. Schooling enables pupils to process a wide range of information and stimulates cognitive changes that shape an individual's interaction with the surrounding world. Secondly, education is a *vehicle* of socioeconomic advancement. Education not only enhances cognitive abilities, it opens up economic opportunities and social mobility. In most societies, educational credentials are the primary criteria for entry into formal employment and for sorting individuals into the hierarchy of occupations. Thirdly, education is a *transformer* of attitudes. The role of schooling in attitude formation goes far beyond the enhancement of conceptual reasoning and may lead to crucial transformations in aspirations and eventually to questioning traditional beliefs and authority structures.

Martin and Juarez (1995) consider that these three dimensions of education affect women's reproductive preferences. First, the impact of knowledge on fertility is clear in that literacy conditions access to information and is therefore instrumental to making informed fertility choices. Secondly, schooling increases reliance on scientific explanations to make sense of the world and provides greater awareness of alternative lifestyles. Furthermore, education raises the opportunity costs of children by enhancing women's opportunities to pursue wage-earning activities, which are likely to compete with domestic and childrearing responsibilities. Thirdly there are abundant indications that the influence of education on fertility can be traced in part to the impact of attitudes on fertility. With the increasing recognition of reproductive behaviour as normatively bounded, schooling has come to be

regarded as a decisive stimulus in the shift from a traditional value scheme (where major decisions, such as the number of children, are routinely left to fate or God) to a value system where belief in a controllable destiny also applies to childbearing. Education also imparts a sense of trust in science and technology, which is indispensable for daily use of modern contraception. In addition, education induces crucial transformations in the locus of reproductive and contraceptive decisions within the family.

### *2.1.3 Education and environmental preferences*

Education is an essential tool for environmental protection. Nelson and Phelps (1966) consider that education enhances one's ability to receive, decode and understand information, and that information processing and interpretation have an impact on learning and change behaviours. In recent years, education has been considered a vehicle for sustainable development and thus for the fight against pollution. For Robitaille et al. (1998), education is "a permanent learning process that contributes to the training of citizens whose goal is the acquisition of knowledge, soft skills, know-how and good manners. It enables them to get involved in individual and collective actions, based on the principles of interdependence and solidarity. This will help coordinate 'person-society-environment' relationships and support the emergence of sustainable societies that are socio-politically and economically fair, here and elsewhere, now and for future generations."

Education can change the preferences of people and increase demand for environmental quality. Educated people have higher preferences. According to Farzin and Bond (2006), the positive effect of education on environmental quality can be channelled in three ways. Firstly, educated people tend to be more conscious of environmental problems and therefore would have behaviors and lifestyles in favour of environmental improvement. Educated people have better access to information on environmental damage and may consequently change their behaviour. Bimonte (2002) shows that an increase in people's education is often accompanied by higher levels of environmental protection.

Secondly, educated people have a higher capacity or ability to use existing means and channels in order to express their environmental preferences. They can also organize themselves in pressure groups or lobbies to obtain the implementation of environmental public policies. Dasgupta and Wheeler (1997) analyse the factors that encourage people to complain about environmental damage in China. They show that Chinese provinces with

relatively low education levels have a lower marginal propensity to complain about environmental damage. Without education, people have little information about harmful risks and the effects of environmental damage in the long term and are only interested in the obvious impact. This could also be explained by the fact that less educated people have little confidence in their own capacity to influence authorities. Some empirical studies from the World Bank show that without effective government policies, communities with higher levels of education take favourable actions to control or reduce pollution emissions.

Thirdly, Farzin and Bond (2006) consider that educated people are “more likely to generate an environmentally progressive civil service, and therefore have democratically-minded public policymakers and organizations that are more receptive to public demands for environmental quality”.

## **2.2 Education and the supply of environmental goods and technologies**

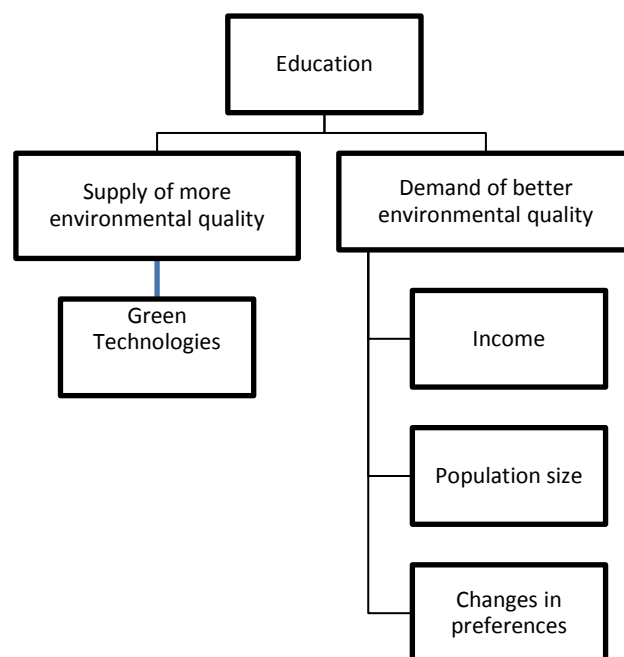
Education facilitates the development and adoption of new technologies that are more productive. According to Wells (1972), educated people adopt innovation sooner than less educated people. The marketing literature shows that early (consumers) purchasers of new products are more educated. Nelson and Phelps (1966) conclude that “a better educated farmer is quicker to adopt profitable new processes and products since for him, the expected payoff from innovation is likely to be greater and the risk likely to be smaller; for he is better able to discriminate between promising and unpromising ideas, and hence less likely to make mistakes. The less educated farmer, for whom the information in technical journals means less, is prudent to delay the introduction of a new technique.”

Education also stimulates the creation of knowledge; innovation is a result of research and dissemination from research centres and institutions and promotes new ideas and knowledge. These institutions can train many engineers and scientists and develop a research sector that is favourable to pollution abatement. Formal research and development (R&D) spending is concentrated in OECD countries and developing countries spend relatively less on basic science and innovations. Therefore, they rely even more on the international diffusion of technology. Studies (Eaton & Kortum 1999; Keller 2004) have concluded that international technology transfers are the major sources of technical progress for both developed and developing countries. Keller (2004) argues that technology comes more from abroad (90% or more) than from inside a country. The important question is then: is human capital also

important for international technology adoption and diffusion? Empirical and theoretical articles suggest this story has gained some support. For example, Eaton and Kortum (1999), Caselli and Coleman (2001) and Xu (2000) show that inward technology diffusion increases with a country's human capital.

The review of the literature identifies two main channels of transmission of the effect of education on environmental quality. This is summarized in Figure 2.

**Figure 2:** How Education matters for environmental quality



Source: Author

### 3 Empirical analysis

Our paper seeks to analyse the effect of education on environmental quality. We follow Brock and Taylor (2010) who develop a model generating an environmental Kuznets curve (EKC) when economies approach their balanced growth path. In other words, there is considerable heterogeneity across countries in terms of differences in initial conditions and the path for emissions, the peak of emissions, and income per capita at peak emissions are unique for each country. However, we suppose that countries differ in much more than just initial conditions (initial levels of emissions per capita) and this heterogeneity can be

explained by the level of education and other determinants of environmental quality (see Appendix 1 for a list of factors).

### 3.1 Econometric specification

We estimate the growth of carbon dioxide emissions per capita on the level of education and a set of control variables. The baseline model is written as follows:

$$\log\left(\frac{e_{i,t}}{e_{i,t-1}}\right) = \beta_1 \log(e_{i,t-1}) + \beta_2 \log(h_{i,t}) + \delta x_{i,t} + \gamma_t + \alpha_i + \varepsilon_{i,t} \quad (1)$$

where  $e_{i,t}$  is the average quantity of carbon dioxide emissions per capita (in metric tons) in a country  $i$  over a period  $t$ ,  $h_{i,t}$  is education,  $\varepsilon_{i,t}$  is the error term,  $\gamma_t$  denotes time effects and  $\alpha_i$  represents country specific effects.  $x_{i,t}$  is a vector of control variables; these variables are domestic investments, population growth rate, trade openness and democratic institutions.

The period considered is 1970–2004 and data are compiled in five-year averages. Our sample is taken from 85 countries, including 22 developed countries and 63 developing countries (see appendix 3).

#### 3.1.1 Determinants of growth rate of carbon dioxide emissions per capita

A large number of variables have been considered in the literature as possible determinants of dioxide carbon emissions. We follow the literature on environmental economics and select control variables reflecting investment rate, population growth, trade openness and democratic institutions.

##### 3.1.1.1 Level of carbon dioxide emissions per capita.

We consider that carbon dioxide per capita at the beginning of the period could be an important determinant of the current level of carbon dioxide per capita. It takes into account the degree of inertia in relation to pollution and the time necessary to implement environmental policies or to reduce air pollution. Moreover, it is the key variable in the convergence hypothesis. If the estimated coefficient is negative and significant, then it can be concluded that countries with low carbon dioxide emissions per capita will catch up with countries with high carbon dioxide emissions per capita. In other words, convergence occurs

when countries with a high initial level of CO<sub>2</sub> emissions per capita have a lower emission growth rate than countries with a low initial level of CO<sub>2</sub> emissions per capita.

### ***3.1.1.2 Investment and population growth***

According to Brock and Taylor (2010), a high investment rate leads to high physical capital stock in steady state and increases carbon dioxide emissions per capita during transitional dynamics. Investments are the engine of economic growth.

Many authors have analysed the impact of population on the environment. Birdsall and Sinding (2001) and Cropper and Griffiths (1994) identify two channels through which population growth could contribute to greenhouse gas emissions. Firstly, a larger population in the world could result in an increased demand for fuel for food, energy, clothing, shelter, industry and transportation. Secondly, a rapid population growth can cause deforestation, changes in land use and the combustion of wood for fuel. These can contribute to greenhouse gas emissions (20% of greenhouse gas emissions come from deforestation).

### ***3.1.1.3 Trade openness***

Many authors have analysed the effect of international trade on environmental quality. The results are mixed because several authors have concluded that trade openness improves the quality of the environment whereas others have found the opposite result. These ambiguous empirical signs of the link between trade and environmental quality can be explained by offsetting forces (the technical effect, the composition effect and the effect on the scale of production). Thus, Antweiler et al.(2001) conclude that trade reduced pollution in 43 countries over the period 1971–1996. Frankel and Rose (2005) argue that trade is favourable to the reduction of pollution. However, other authors such as Managi (2004) conclude that trade has a negative impact on carbon dioxide emissions. Ferreira (2004) concludes that trade affects environmental quality (deforestation) through institutions (ownership security).

### ***3.1.1.4 Democratic institutions***

A free political and civil system allows people to express their preferences for better environmental protection. Many authors have analysed the relationship between political freedom and the quality of the environment. Deacon (1999) and Olson Mancur (1993) argue that political freedom is favourable to environmental protection because non-democratic



regimes will underprovide public goods that include environment quality. For them, political elites monopolize and hold a large share of national incomes and revenues. The implementation of rigorous environmental policies can lower production, income and consumption, which in turn, in an autocracy, impose a higher cost on the elite than on the population, whereas the marginal benefit is uniform for both the elite and the population. Therefore, in an autocracy, elites are relatively less pro-environment than people in a democracy. However, Congleton (1992) thinks that political freedom can have a positive impact on pollution. According to him, contrary to non-democratic rulers, democratic governments can be affected by political shortsightedness, so that they make decisions on a short term horizon that is detrimental to environmentally-oriented policies.

### *3.1.2 Estimation method*

As our model is a dynamic panel and the dependent variable is lagged and endogenous, we use dynamic panel techniques which take into account individual and temporal dimensions, as well as unobserved heterogeneity. These are preferred over estimations using ordinary least squares (OLS) analysis, which would be weak and biased in this instance. Thus, we use the generalized method of moment (GMM) system. The first-differenced generalized method of moments estimators applied to panel data models addresses the problem of the potential endogeneity of some explanatory variables, measurement errors and omitted variables. The idea of the first-differenced GMM is “to take first differences to remove unobserved time invariant country specific effects, and then instrument the right-hand-side variables in the first-differenced equations using levels of the series lagged one period or more, under the assumption that the time varying disturbances in the original levels equations are not serially correlated” (Bond, Hoeffler & Temple 2001). The GMM system estimator combines the previous set of equations in first differences with suitable lagged levels as instruments, with an additional set of equations in levels with suitably lagged first differences as instruments. Blundell and Bond (1998) provide evidence using Monte Carlo simulations that the GMM system performs better than first-differenced GMM, the latter being seriously biased in small samples when the instruments are weak.

To test the validity of lagged variables used as instruments, we use the standard Hansen test of over-identifying restrictions, where the null hypothesis is that the instrumental variables are not correlated with the residual, and the serial correlation test, where the null

hypothesis is that the errors exhibit no second-order serial correlation. In order to guarantee a parsimonious use of instruments, we do not use more instruments than the number of countries included in our regressions. Indeed, on the one hand, adding more instruments raises the validity of the instruments, i.e. the probability of accepting the null hypothesis of the Hansen test is increased. On the other hand, using too many instruments can overfit instrumented variables (Roodman 2009) and reduce the power properties of the Hansen test. In our regressions, none of the statistical tests allows us to reject the validity of the lagged variables as instruments or the lack of second order autocorrelation.

### **3.2 Descriptive analysis of data**

The data on carbon dioxide emissions per capita, investment rates, trade openness and population growth rates are from the World Development Indicators (World Bank 2005). The data on education and democratic institutions come respectively from Barro and Lee (2012) and Polity IV (2002). The emissions of carbon dioxide per capita are measured in metric tons per capita and are estimated from the combustion of fossil energies and cement industries in the liquid, solid or gas form. Trade openness and investment respectively correspond to the share of the sum of exports and imports and investments in gross domestic product (GDP). As a democratic institutions variable, we chose the index of polity 2, which is a score obtained by differentiating the index of democracy and the index of autocracy on a scale from +10 (democracy) to -10 (autocracy). The indicator of democracy is characterized by the effective existence of institutional rules framing the power and the presence of institutions enabling citizens to express their expectations and to choose political elites. Autocracy is characterized by the absence or the restriction of political competition, economic planning and control. The exercise of power is slightly constrained by institutions and the leaders are only selected within a “political elite”. The data on education resulting from Barro and Lee (2012) correspond to the average years of schooling in the total population.

Table 1 presents descriptive statistics relating to education, carbon dioxide emission levels and growth rates according to economic development. It shows a high growth rate of carbon dioxide emissions per capita in the world (8.23%). This can be explained by the pollution growth rate in developing countries (9.4%), indicating their importance in the pollution phenomenon, in contrast to developed countries (4.3%). We also notice that

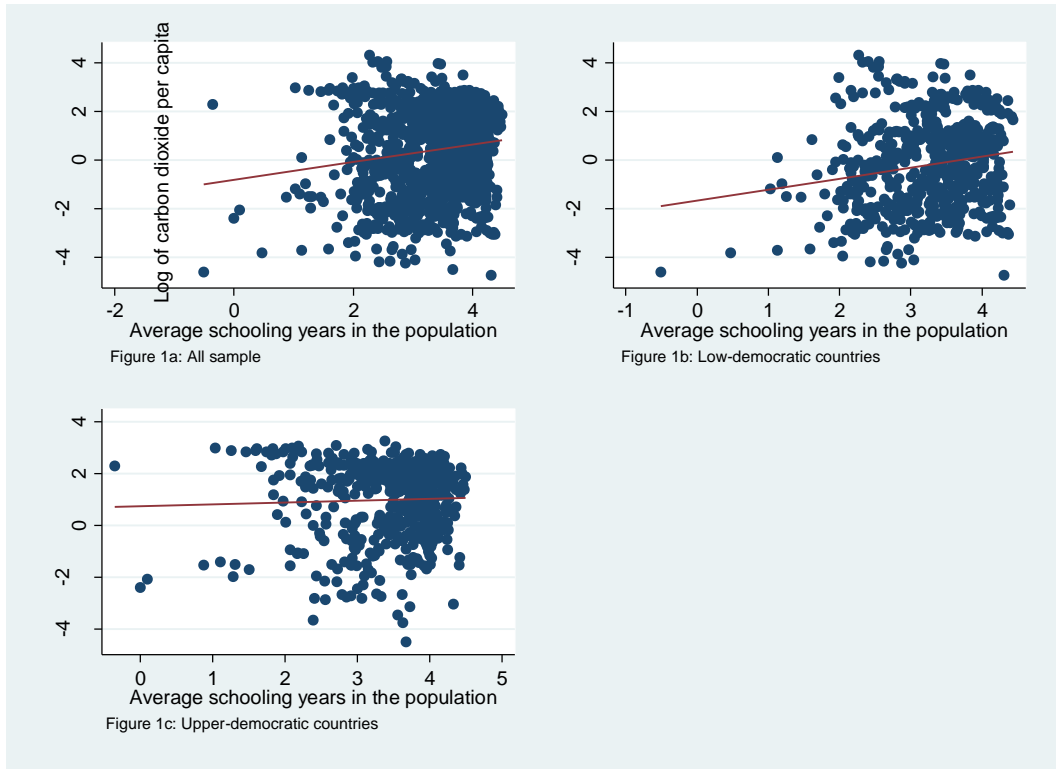
countries (developed countries) with high carbon dioxide emissions are relatively more educated and have a low carbon dioxide growth rate.

**Table 1:** Descriptive statistics of emissions of dioxide carbon and education according to economic development

	Average	Standard deviation	Min	Max
<b>World</b>				
Growth of emissions per capita	0,08	0,35	-4,44	2,76
Emissions per capita	4,56	7,91	0,001	78,61
Education	4,67	2,06	0,042	12,21
<b>Developed countries</b>				
Growth of emissions per capita	0,04	0,29	-1,03	2,76
Emissions per capita	12,26	12,11	1,72	78,61
Education	7,93	2,05	2,44	12,21
<b>Developing countries.</b>				
Growth of emissions per capita	0,09	0,37	-4,44	2,59
Emissions per capita	2,17	3,55	0,001	29,10
Education	3,41	2,19	0,04	10,27

Notes: the total sample is composed of developed and developing countries over the period 1970 -2004.

Figure 3 plots a measure of education (average years of schooling in the population) and a measure of air pollution (log of carbon dioxide per capita). Figure 3a seems to indicate a positive link between education and environmental degradation. However the wide dispersion of countries may show the importance of a third element by which education fosters environmental performance. In Figures 3b and 3c, we split the sample into low-democratic countries and higher-democratic countries. These graphics suggest that the positive link between education and environmental degradation prevails in the low-democratic countries but less in the higher-democratic countries. The relationship between education and environmental quality depends on the quality of the democratic institutions. Our graphics show that educated people tend to pollute and damage environmental quality. However, countries that have established democratic institutions tend to handle the environmental degradation better.

**Figure 3: Correlation between education and carbon dioxide per capita**

### 3.3 Results

Table 2 presents the results obtained using the GMM system. Column 1 shows the absence of conditional convergence in carbon dioxide emissions per capita in the world because the coefficient is insignificant and equals  $-0.003$ . This result conforms to previous studies (Stegman 2005; Ordás Criado & Grether 2011) concluding the absence of a convergence in air pollution at the international level. Investment, which is the driving force behind economic growth and economic development, makes a considerable contribution to pollution growth. Education and democratic institutions have no impact on pollution growth.

Our results suggest that education has no impact on the growth of air pollution for the whole sample (85 countries). These results are surprising and are not similar to previous authors who find that education has an effect on environmental quality. Indeed, Farzin & Bond (2006) conclude that education improves environmental protection, whereas Jorgenson (2003) finds the opposite result. It is interesting to analyse why our results are different from theirs.

A first argument can be the presence of heterogeneity between countries. Indeed, the descriptive statistics in Table 1 indicate that education levels are not similar in relation to economic development. Education level is higher in developed countries (7.93)<sup>8</sup> than in developing countries (3.41), whereas the world average is 4.67. The average effect of education on environmental quality may hide a heterogeneous effect according to development level. Columns 2 and 3 in Table 2 show the results when the sample is restricted to developing countries or developed countries. Interestingly, conditional convergence in carbon dioxide emissions per capita is found in developed countries only. It is also worth noting that the effects of education and democratic institutions on pollution growth are significantly different according to the level of development. Our results suggest that education favours pollution growth in developed countries, in contrast to developing countries. We obtain the same result for democratic institutions, which contribute respectively to pollution (depollution) in developing (developed) countries.

The role of institutions and human capital as fundamental sources of difference in economic development, highlighted by the economic literature, leads us to question the possibility that the effect of education on the environment could differ according to the quality of institutions in a given country.

### *3.3.1 Interaction between education and democratic institutions*

Whether considered a public or private good, the improvement of the quality of the environment could not be solely determined by people's preferences. The quality of democratic institutions may also have an impact. In other words, the interaction between education and democratic institutions could affect environmental protection. We consider that the effect of education on the quality of the environment could be more effective in the presence of stable political institutions that are considered a channel of expression for the people. Including an interactive variable between education and institutions in our equation suggests that the effect of education on pollution growth would be conditional on democratic institutions.

Columns 4 and 5 confirm that the growth rate of carbon dioxide per capita positively and significantly depends on the investment rate. This variable is an important determinant of

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<sup>8</sup> Average years of schooling.

air pollution in developing countries. In these countries, people are not overly concerned with environment problems. They are worried by many development problems such as low and unstable growth, unemployment, etc. Investment can also reduce poverty, being a driving force of economic growth. Investment allows countries to access international markets, trade, new technologies and competences. However, these opportunities can differ with the development of countries. In several countries, investments are directed towards the building and construction sectors, services and manufacturing sectors. In other countries, they are directed towards the natural resources sectors, in particular oil firms and wood companies, which are major energy consumers and thus pollutants. The expected effects are a rise in employment, a rise in taxes, a rise in state revenues and the reduction of poverty. These countries can also be less sensitive to environmental problems.

Democratic institutions have a significant and opposite effect according to the level of development. In developing countries, the positive effect can be explained by the free rider behaviour. Political leaders consider pollution a public good and have no willingness to address it. In developed countries, democratic institutions reduce carbon dioxide per capita growth. This effect is more important and significant with education. Columns 3 and 5 show that the effect of democratic institutions on pollution growth is conditioned by the level of education.

Education seems to be a factor of environmental pollution in developed countries although its effect is slightly mitigated in the presence of democratic institutions. Without democratic institutions, education increases pollution. Our results are similar to those of Jorgenson (2003). As mentioned in the literature review, a possible explanation is that educated people have a higher income and are encouraged to overconsume. They also desire to live well by accumulating material goods without caring about the consequences and they follow the ideological model of “consume more to be happier” (Princen 2001). Political institutions mitigate the effect of education. Although they pollute, educated people are also more conscious of environmental problems. Their education level will increase their preferences in favour of a higher level of environmental protection. They will reflect their preferences through democratic institutions. In developing countries, education and its interactive variable have no effect on the growth of carbon dioxide emissions per capita. Low education levels and the relative weakness of democratic institutions might explain the

absence of the effect of education in developing countries. Firstly, less educated people (relative to those in developed countries) are also poorer and consume fewer material goods, which is a factor in environmental degradation. Secondly, information about environmental risks is less available in developing countries. According to Somanathan (2010), information concerning environmental risks is a public good and its analysis requires specialized training and expensive data collection. Thirdly, the low level of political institutions in developing countries does not allow the regulation of environmental quality. The combination of these factors strongly reduces the ability of people to express their preferences for a better environment. Therefore, the average effect of education on emissions growth is negligible.

Table 2: Effect on education on the growth of carbon dioxide per capita (GMM-System)

	All countries (1)	Developing countries (2)	Developed countries(3)	Developing countries(4)	Developed countries(5)
Lagged carbon dioxide per capita (log)	-0.003 (-0.18)	0.008 (0.05)	-0.305 (-2,17)**	-0.009 (-0.72)	-0.201 (-2,14)**
Log of investment	0.326 (2.50)**	0.315 (2.40)**	0.549 (3.19)**	0.401 (3.29)**	0.337 (2.85)**
Log of trade openness	0.086 (0.93)	0.203 (1.51)	0.027 (0.48)	0.151 (1.32)	0.017 (0.43)
Democratic Institutions	0.036 (1.73)	0.043 (2.07)**	-0.049 (10.56)***	0.034 (1.75)**	-0.035 (1.36)
Population Growth	-0.034 (0,30)	-0,160 (1,43)	-0,104 (2,47)**	-0,15 (1,37)	-0,026 (1,84)**
Education	0.253 (0.83)	-0.219 (0.96)	0.445 (3.76)***	-0.047 (0.27)	0.545 (12.45)***
Education* Democratic Institutions				-0.008 (0,94)	-0,035 (2,91)***
Constant	-1.293 (1.84)*	-1.329 (1.90)*	-0.294 (1.91)*	-1.562 (2.32)*	-1.269 (2.51)**
Observations	229	182	47	182	47
Countries	85	63	22	63	22
AR(2) p value	0,21	0,75	0,40	0,36	0,18
Hansen Test p value	0,40	0,69	0,91	0,82	0,62
Number of Instruments	17	17	14	17	14

Note: \* significant at 10%; \*\* at 5%; \*\*\* at 1%. Temporal dummy variables are included. The period is 1970 to 2004 and data are compiled in five-year averages (70-74, 75-79, etc)



### 3.3.2 Robustness checks<sup>9</sup>

Our results suggest that education (average years of schooling in the total population) has no impact on environmental quality for the whole sample (85 countries). However, this effect is heterogeneous according to the level of development and the quality of democratic institutions. The robustness of the results is checked by considering other educational measures.<sup>10</sup> As suggested by Tables 3 and 4, our results remain stable despite the use of eight alternative measures. Thus, the average years of primary, secondary and high school education in the population have similar effects on the growth of carbon dioxide emissions per capita and these effects are different according to levels of development.

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<sup>9</sup> Additional robustness checks have been applied in a previously published article. First, we check whether the effect of education on the growth of emissions per capita is simply due to the omission of the income variable (income per capita). Second, we take into account the effect of international agreements (ratification of the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol).

<sup>10</sup> These are: the average years of schooling in general for individuals over 25 years old, the average years of schooling at a higher level for individuals over 15 years old, the average years of schooling at a higher level for individuals over 25 years old, the average years of schooling at secondary level for individuals over 15 years old, the average years of schooling at secondary level for individuals over 25 years old, the percentage of the population who have completed higher education, the percentage of the population who have completed secondary school and the percentage of the population who have completed primary school.

Table 3: Effect of alternative education variables on the growth of carbon dioxide per capita (GMM-System) in developed countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged carbon dioxide per capita (log)	-0.16 (-2,05)**	-0,15 (-2,98)***	-0,14 (-2.89)***	-0,24 (-2.64)***	-0,16 (-2.02)**	-0,13 (-2.71)***	-0,14 (-2.28)**	-0,30 (-2.30)**
Educ1	0.539 (12.52)***							
PolityEduc1	-0.040 (3.89)***							
Educ2		0.447 (13.27)***						
PolityEduc1		-0.038 (6.68)***						
Educ3			0.439 (13.62)***					
PolityEduc3			-0.039 (7.22)***					
Educ4				0.588 (10.91)***				
PolityEduc4				-0.039 (4.37)***				
Educ5					0.487 (10.46)***			
PolityEduc5					-0.044 (10.02)***			
Educ6						0.442 (11.70)***		
PolityEduc6						-0.038 (8.53)***		
Educ7							0.522 (9.76)***	
PolityEduc7							-0.048 (11.79)***	
Educ8								0.551 (10.49)***
PolityEduc8								-0.043 (8.72)***
Number of countries	22	22	22	22	22	22	22	22

Notes: \* significant at 10%, \*\* significant at 5%, \*\*\* significant at 1%. Other variables of controls and temporal dummies are taken into account in estimations. Educ1 to Educ8 variables are respectively the logarithm of: the average of schooling years in general for individuals being over 25 years old, the average of schooling years at a higher level for individuals being over 15 years old, the average of schooling years at a higher level for individuals being over 25 years old, the average of schooling years at a secondary level for individuals being over 15 years old, the average of schooling years at a secondary level for individuals being over 25 years old, the percentage of the population having completed a higher education, the percentage of the population having completed a secondary school and the percentage of the population having completed a primary school

Table 4: Effect of alternative education variables on the growth of carbon dioxide per capita (GMM-System) in developing countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged carbon dioxide per capita (log)	-0.11 (-0,28)	0.05 (-0,10)	-0,16 (-0,42)	-0,47 (0,69)	-1,15 (-0,67)	-0,03 (-0,08)	0,42 (0,52)	-0,41 (0,74)
Educ1	-0.204 (0.37)							
PolityEduc1	-0.001 (0.09)							
Educ2		-0.114 (0.30)						
PolityEduc1		-0.002 (0.34)						
Educ3			0.074 (0.31)					
PolityEduc3			-0.001 (0.28)					
Educ4				-0.531 (0.89)				
PolityEduc4				-0.013 (0.85)				
Educ5					-0.429 (0.62)			
PolityEduc5					0.001 (0.05)			
Educ6						-0.047 (0.15)		
PolityEduc6						-0.002 (0.35)		
Educ7							1.102 (0.65)	
PolityEduc7							0.016 (0.54)	
Educ8								-0.619 (0.83)
PolityEduc8								-0.009 (0.69)
Number of countries	65	63	65	63	65	63	63	63

Notes: \* significant at 10%, \*\* significant at 5%, \*\*\* significant at 1%. The period is 1970-2004. Other variables of controls and temporal dummies are taken into account in estimations. Variables Educ1,... Educ8 correspond respectively to the logarithm of: the average of schooling years in general for individuals being over 25 years old, the average of schooling years at a higher level for individuals being over 15 years old, the average of schooling years at a higher level for individuals being over 25 years old, the average of schooling years at a secondary level for individuals being over 15 years old, the average of schooling years at a secondary level for individuals being over 25 years old, the percentage of the population having completed a higher education, the percentage of the population having completed a secondary school and the percentage of the population having completed a primary school.

## 4 Conclusion

This study highlights the effect of education on the growth of carbon dioxide emissions per capita over the period 1970–2004 in 85 countries. Our results suggest that education has no impact on the growth of air pollution in a sample of developing and developed countries. This effect is however heterogeneous according to the levels of development. Indeed, while the effect of education remains insignificant in developing countries, education does matter for pollution growth in developed ones. More interestingly, when controlling for the quality of democratic institutions, the positive effect of education on air pollution growth is mitigated in developed countries while being insignificant in developing countries.

Our results also show a divergence in carbon dioxide per capita at a global level during the period 1970–2004. Carbon dioxide emissions per capita diverge in developing countries. Investment, which is the driving force behind economic growth, contributes to pollution in both developing countries and developed countries. Convergence in carbon dioxide emissions in developed countries and divergence in developing ones highlight the interests and difficulties of multilateral negotiations on global warming.

Our results are important for economic policies. Initially, they highlight the importance of education in environmental protection. The current accumulation of knowledge is a factor in economic growth as well as pollution growth. We do not question educational policies. On the contrary, there is a need to introduce a change in perception and the role of education in favour of the environment. This is urgent in developing countries because the achievement of the Millennium Development Goals (MDG) regarding education could be followed by environmental pollution. The ongoing debate on Sustainable Development Goals evidences the need to include the environment to a greater extent in development objectives. In addition, investment being a key factor in economic growth and a determinant of pollution, the reduction of its effects will necessarily be followed by the establishment of ecologically appropriate investments. Finally, the divergence of pollution at an international level and at the level of developing countries requires the transformation of the Kyoto protocol, which should include agreements on technology transfers and promote ecological development.

This paper opens up leads for future research. Indeed, it highlights a differentiated impact on the environment of democratic institutions in developed and developing countries. Thus, it

will be interesting to analyse the determinants of this behaviour in depth in relation to free riders in developing countries.

## 5 Appendices

### Appendix 1: Data definition and sources

Variables	Definitions	Source
Emissions of carbon dioxide per capita	Carbon dioxide per capita (metric ton per capita)	World Development Indicators (2006)
Population growth rate	Population growth rate	
Investment rate	Investment/PIB	
Trade openness rate	$(\text{Exportations} + \text{Importations}) / \text{Gross Domestic Product}$	
Democratic institutions	Combined score of democracy and autocracy on a scale going from -10 (autocracy) to 10 (democracy).	Polity IV
Education	Average schooling years in the total population	Barro & Lee 2012

**Appendix 2:** Descriptive statistics

<b>Variables</b>	<b>Average</b>	<b>Standard deviation</b>	<b>Minimum</b>	<b>Maximum</b>
Log of initial per capita dioxide carbon emissions	4,56	0,35	0,0015	78,61
Growth rate of dioxide carbon emissions per capita	0,08	7,91	-4,44	2,76
Investment rate	21,42	7,39	2,53	86,79
Trade openness rate	71,14	41,51	5,71	297,33
Democratic Institutions	0,49	7,47	-10	+10
Population growth rate	1,97	1,61	-20,36	16,17
Education	4,67	2,95	0,042	12,21
the average of schooling years in general for individuals being over 25 years old	5.904692	3.148602	0	13.27008
the average of schooling years at a higher level for individuals being over 25 years old	.2693572	.2761739	0	1.711157
the average of schooling years at a secondary level for individuals being over 25 years old	1.832526	1.395012	0	7.760132
the average of schooling years at a higher level for individuals being over 15 years old	.2511686	.2573782	0	1.565863
the average of schooling years at a secondary level for individuals being over 15 years old	2.017054	1.373257	.0045298	7.476144
the percentage of the population having completed a higher education	4.426598	4.668537	.0142372	26.36434

the percentage of the population having completed a secondary school	16.45794	12.90832	.0167305	69.75109
the percentage of the population having completed a primary school	18.64082	11.92099	.2268805	68.97472

Source: WDI (2006), Polity IV, Barro and Lee 2012

### **Appendix 3:** List of countries included in the sample

#### **Developed countries:**

Australia, Austria, Belgium, Canada Denmark, France, Finland, Germany, Greece, Holland, Israel, Italy, Japan, Luxemburg, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, The USA.

#### **Developing countries**

Algeria, South Africa, Burundi, Benin, Bangladesh, Bahrain, Bolivia, Brazil, Botswana, Central Africa, Chile, China, Cameroun, Congo, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, Fiji, Ghana, Guatemala, Honduras, Haiti, Hungary, Indonesia, India, Iran, Jamaica, Jordan, Kenya, Mexico, Mali, Mauritania, Malawi, Malaysia, Niger, Nicaragua, Nepal, Pakistan, Peru, Philippines, New Guinea, Guinea, Poland , Paraguay, Rwanda, Senegal, Sri Lanka, Sierra Leone, El Salvador, Syria,Togo, Thailand, Trinidad and Tobago, Tunisia, Turkey , Uganda,Uruguay, Zambia.

## **Chapter 2: Are Democratic Institutions Really Good for Environmental Quality<sup>11</sup>?**

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<sup>11</sup> I would like to thank participants from European Network on Industrial Policy International Conference (EUNIP, June 2010, Reus, Spain), 3rd Workshop on Development Sciences (May 2010, Orléans, France), the 12th annual Conference of the Association of Heterodox Economics (AHE, July 2010), the 11th Biennial ISEE Conference (2010), the 2nd UNITAR'-Yale Conference on Environmental Governance and Democracy (17-19 Sept, New Haven, USA) and the 2011 Spring Meeting of Young Economists.





### **Abstract**

This paper is a contribution to the controversial link between institutional quality and environmental protection. It explores the effect of democratic institutions on environmental quality. Using panel data from 1960 to 2008 in 122 developing and developed countries, it is found that democratic institutions do have a direct and positive effect on environmental quality. This positive effect is stronger for local pollutants than for global ones. More interestingly, this paper identifies the indirect channels through which democracy affects environmental degradation. Indeed, by increasing people's preferences for redistribution and economic policies, democratic institutions have indirect and negative effects on environmental protection through income inequality and investments.

*Keywords: Democratic institutions; Air pollution; Panel data; Income inequality; Investments*

*JEL Classification: C23; D31; E22; 043; Q53*



## 1 Introduction

There is a presumption that institutions are determinants of economic development. The evidence suggests that rich countries are democratic, whereas many poor countries (for example, those in sub-Saharan Africa and Southeast Asia) are not. Over the past two decades, the economic literature has analysed the link between institutional quality and economic performance. Two controversies are involved. First, several authors (Acemoglu et al. 2001; Glaeser et al. 2004; Hall & Jones 1999) consider that institutions are the fundamental factor in explaining economic development. Indeed, they argue that the nature of property rights (Acemoglu & Johnson 2005), legal institutions (Levine 1998) and labour market institutions (Besley & Burgess 2004) have an effect on economic performance (production efficiency, investment, economic growth). However, other authors reject the primacy of institutions in economic development and highlight the importance of geography (Diamond 1997; Sachs 2003). According to them, geography<sup>12</sup> refers to the location, distribution and spatial organization of economic activities. Proximity to international markets reduces transport costs, improving the opportunities for countries to specialize in the activities in which they have comparative advantages and to access international technologies. Moreover, countries with a large population and agglomerations can have effective labour and product markets (Prager & Thisse 2010). Firms can benefit from agglomerations because they are near to each other. They can access a large pool of suppliers, customers and labour, as well as benefiting from lower infrastructures costs. Consequently, Diamond (1997) and Sachs (2003) conclude that geography is the key determinant of economic development. A parallel stream of literature considers trade as a driver of income and productivity growth in the long term. Frankel and Romer (1999) show that trade has a positive effect on economic growth. They also show that their ability to trade is not entirely related to geographical factors but probably to institutions. Dollar and Kraay (2003) show that trade and institutions have a joint role in economic growth in the long term.

The emergence of natural resources and environmental protection often highlight institutional quality failure and poor governance methods. For instance, the institutional quality may influence the non-linear relationship between development and the environment. Bhattarai

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<sup>12</sup> It includes many elements, like a country's location in the world, climate, topography, natural resource endowments, size and population.

and Hammig (2001) and Culas (2007) find complementarity between the institutional factors and the environmental quality (forest sector policies). Moreover, Torras and Boyce (1998) show that pollution decreases with the quality of policies and institutions. At the international level, two additional problems appear. First, it is difficult to elaborate efficient and equitable systems for the management of local and global public goods (oceans and climate warming). Second, there are real and enormous problems in international cooperation between countries to protect global public goods fighting climate warming (the Summit of Copenhagen 2009). Though scientists' reports emphasize that countries should act rapidly to reduce the greenhouse gases responsible for climate warming, they also mention the huge challenge that the international community must face, especially democratic countries, to improve the situation.

Political determinants deserve attention in the analysis of the drivers of environmental quality. Among the 40 highest carbon emitters internationally (cumulatively responsible for 91% of the total world emissions), the countries that have the best records are all democracies (Held & Hervey 2010). The biggest polluters are also the countries with the highest scores for the quality of institutions. However, there is a correlation. Moreover, the literature on the link between democratic institutions and environmental quality has found mitigated results. Some authors (Barrett & Graddy 2000; Bernauer & Koubi 2009; Li & Reuveny 2006) find that democratic institutions improve environmental protection, whereas others (Congleton 1992) conclude a negative or no effect.

From these two apparent paradoxes, the aim of this paper is to analyse the effect of democratic institutions on environmental quality. The main contribution of this paper is that the transmission channels from democratic institutions to environmental quality are explicitly modelled. We identify and test four channels (trade openness, domestic and foreign direct investments and income inequality). We use panel data from 1960 to 2008 for 122 countries and alternative econometric methods (one-step GMM system, two-step GMM system, fixed-effects estimator). The results suggest that democratic institutions have opposite effects on environmental quality: a positive direct effect on environmental quality and a negative indirect effect through investments and income inequality. Indeed, democratic institutions attract investments that harm the environmental quality. Moreover, as democratic institutions reduce income inequality, they also damage the environment. Second, the direct negative effect of democratic institutions is higher for local pollutants (SO<sub>2</sub>) than for global pollutants

(CO<sub>2</sub>). Third, the nature and the characteristic of democracy are conducive to environmental quality. Fourth, the positive effect of democratic institutions on environmental quality is higher in developed countries than in developing countries. Adding more control variables, alternative measures of democratic institutions and other econometric methods and strategies does not alter our main results.

The paper is organized as follows. The next section outlines the arguments on the relation between democratic institutions and environmental quality. In section 3, we identify the potential transmission channels between democratic institutions and environmental quality. Sections 4 and 5 derive the estimating equations and present the empirical results, and the last section is devoted to the conclusion.

## **2 Effect of democratic institutions on environmental quality**

According to the environmental economic literature, democratic institutions can have both virtuous and vicious effects on environmental quality. Democracy can be characterized by the effective existence of institutional rules that frame the power. The presence of institutions also enables citizens to express their expectations and choose political elites. It allows citizens to express their preferences for policies and social choices with respect to fiscal and distributional policies as well as to environmental ones. Democracy, however, allows freedom of association and lobbying groups, which do not always aim to implement better environmental practices.

### **2.1 Democracy and environmental preferences**

#### *2.1.1 Democracy and environmental consciousness*

Populations are free to collect information about environmental quality in democratic countries. They can express their preferences and put pressure on their government. Citizens are more aware of environmental problems (freedom of media). They can also express their preferences for the environment (freedom of expression) and create lobbying groups (freedom of association). Political leaders are prompted (right to vote) to implement environmental policies at the national and international levels. McCloskey (1983) and Payne (1995) show the ability of democratic countries to satisfy people's environmental preferences and their will to commit themselves to international negotiations and agreements. The economics models by Page and Shapiro (1983) suggest that when people are well informed about major problems,

political decisions are more likely to be influenced. In autocratic regimes, populations cannot access information and create lobbying groups.

Acemoğlu and Robinson (2006) consider that, in democratic countries, the majority of citizens have the right to vote and thereby express their preferences. As the preferences of the median voter are important and the marginal costs of environmental policies' implementation are lower than in autocracies, the adoption and implementation of environmental policies will prevail in democratic countries.

Deacon (1999) and Olson (1993) argue that political freedoms favour environmental protection because non-democratic regimes will underproduce environmental public goods. Autocratic regimes are led by political elites who monopolize and hold large shares of the national incomes and revenues. The implementation of rigorous environmental policies can lower the levels of production, income and consumption, which, in turn, impose a higher cost on the elite in an autocracy than on the population, whereas the marginal benefit is uniform for both elite and population. Elites in an autocracy are less likely to adopt environmentally friendly policies. Deacon (2009) found that democratic governments implement more stringent environmental policies than autocratic governments.

Li and Reuveny (2006) show that democracy reduces environmental degradation (carbon dioxide emissions, nitrogen oxide, land degradation, deforestation, organic pollution in water). The effect of democracy varies in size across the five environmental indicators. Bernauer and Koubi (2009) analyse the effects of political institutions on air quality in 42 countries over the period 1971–1996. They show that democratic institutions have an independent positive effect on air quality. Environmental protection is favoured in presidential systems with respect to parliamentary ones.

### *2.1.2 Effect of democracy on rent-seeking*

Democratic institutions allow freedom of association and people's creation of lobbying groups to protect their own interests. Firstly, Dryzek (1987) notices that democracies are also economic markets wherein lobbying groups are very important. According to him, there are many countries where political leaders are influenced by lobbying groups and multilateral companies. Democracies are not considered as protecting environmental quality as they are

supposed to satisfy the preferences of markets and lobbying groups that aim to maximize their economic profit, which does not favour a better environmental quality.

Secondly, when a democracy is established, institutions become more complex and rigid. Therefore, Olson (1993) claims that lobbying groups are partially responsible for the rigidity of institutions in mature democracies. In other words, in mature and democratic countries, the supply of public goods could be reduced by an important number of lobbying groups that are less or not incited to take care of the society's interests. They can try to influence or to control the legislative and administrative process. Consequently, public policies could be less favourable to environmental quality when they are influenced by lobbying groups.

### *2.1.3 Geographical aspects of democracy: local or global governance*

The government's decision to ratify environmental treaties may be affected by the level of democracy. By allowing citizens to be informed about environmental problems (freedom of media), to express their preferences for the environment (freedom of expression) and to create lobbying groups (freedom of association), democracy increases the probability that the government will ratify international or regional environmental treaties. Neumayer (2002) confirms that democratic countries sign and ratify more multilateral environmental agreements<sup>13</sup> than autocratic ones. Moreover, environmental lobbying groups may influence the probability of environmental treaties' ratification. Using panel data for 170 countries, Fredriksson et al. (2007) show that governments are more responsible to environmental lobby groups and the effect increases with the level of government corruption. However, Fredriksson and Ujhelyi (2006) find that environmental lobby groups raise the probability of environmental treaty ratification, but the effect decreases with the number of individual or collective government units (the president, the prime minister, the chambers of parliament, the majority party or the government coalition parties).

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<sup>13</sup> The author uses several measures: (1) the signing and ratification of multilateral environmental agreements (M EAs); (2) the membership of environmental intergovernmental organizations (EIOs); (3) the extent to which the reporting requirements for the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) are met; (4) the percentage of a country's land area under protection status; (5) the existence of a National Council on Sustainable Development (NCSD) in a country; and (6) the availability of environmentally relevant information concerning a country.



Paehlke (1996) thinks that the nature of the environment and that of democracy differ. The environment is a global phenomenon, whereas democracy works on national and local levels. Consequently, environmental problems could not be resolved in an adequate and opportune way. For example, Heilbrunner (1974) supports the idea that the global population growth threatens environmental quality. Autocratic countries can restrain the demographic dynamic, while democratic countries must respect people's freedoms. In democratic countries, governments are accountable to people. They often avoid compliance with multilateral actions and decisions if this weakens their relationship with their electorate. There is an exception when strong democratic governments can control the multilateral game.

## **2.2 Democracy and property rights**

Some authors believe that democracy does not favour environmental protection. The implementation of democratic institutions comes with individual freedoms. Desai (1998) thinks that democracy does not protect the environment because democracy is a factor in economic growth and prosperity, which damages the quality of the environment. Democracy is also correlated with factors such as property rights and social infrastructures that boost economic growth. Moreover, Hardin (1968) worries about the management and overexploitation of environmental resources. The property rights of environmental resources (for example, air, oceans, forests) are not well defined. This overexploitation is accelerated in democracies in which individuals have business and economic freedom.

This argument is rejected by authors who focus on the institutional and ideational features of democratic institutions. Democracies are more likely to comply with environmental agreements because they respect the rule of law. Weiss and Jacobson (1999) argue that democratic countries respect economic freedom and, therefore, have market economies that, in turn, improve environmental protection. Barrett and Graddy (2000) conclude that political and civic freedoms reduce some pollutants (sulphur dioxide) but have no effect on other pollutants (water pollution). Torras and Boyce (1998) also find that political and civic freedoms have a positive effect on air and water quality in developing countries.

## **2.3 Democracy and electoral cycles**

The literature on political economy and public choice has shown that electoral cycles may affect the decision of political leaders to protect the environment.

Congleton (1992) supposes that short temporal horizons contribute to less stringent environmental regulation. Because the consequences of environmental degradation appear in the long term, political leaders can be prone to myopic behaviour and underprovide environmental goods.

Indeed, Nordhaus (1975) argues that political leaders may boost economic performances in the pre-electoral period in order to be re-elected. They may be incited to postpone the implementation of environmental policies. Moreover, political leaders may consider the implementation of international and regional agreements as a new tax imposed on citizens. They will not be incited to adopt and implement them before election. For instance, Ferraz (2007) finds that the implementation of environmental taxes is delayed by local elections in Brazil. He explains this result by the fact that environmental regulations may be perceived as a barrier to job creation. However, Sauquet and Cazals (2013) show that the electoral agenda concerning the probability of participating in international environmental agreements' ratification depends on the level of development of countries. In developed countries (OECD), environmental agreements' ratification is a new tax leading political leaders to adopt them the second semester after an election. For developing countries, they observe a high rate of international environmental agreements' ratification before the election period. Leaders may benefit from preferential conditions (more financial programmes) and be incited to trade their participation. Indeed, Rose and Spiegel (2009) and Schulze and Tosun (2013) provide evidence that participation in the IEA is used to obtain more foreign aid and access to markets.

### **3 Democratic institutions and environmental quality: transmission mechanisms**

Our main argument in this chapter is that the previous arguments linking democracy may not have a direct effect on environmental quality. It is more likely that democracy's effects on environmental quality are channelled by policies implemented by democratic governments. First, democratic transition often entails political and economic liberalization, thereby enhancing the business environment. For instance, economic liberalization often leads to increases in trade openness. Moreover, it may contribute to countries' attractiveness and thus favours either foreign direct or domestic investments. Second, democracy produces

political competition among parties, which makes the redistribution of income a most salient issue. In this section, we discuss the transmission channels of democratic institutions.

### **3.1 Trade openness**

Democracy (political freedom) can influence trade openness. Indeed, protectionist policies can be adopted in autocratic regimes because they benefit only a few producers (or political elites) at the expense of the majority of people (or consumers). By reducing the price of imported goods and increasing their incomes, democracy may incite people, as represented by the median elector, to choose trade policy.

Many authors have analysed the effect of trade openness on environmental quality. Some of them conclude that trade openness has a negative effect on environmental quality, whereas others conclude a positive link between democracy and environmental quality. Grossman and Krueger (1995) decompose the effects of trade on environment into scale, technical and composition effects. The scale effect of trade measures the negative environmental consequences of scalar increases in economic activity. The technical effect is the positive environmental consequences of increases in income that call for cleaner production methods. The composition effect can have a positive or negative impact on the environment because it measures the evolution of the economy towards a more or less appropriate productive structure. Thus, Antweiler et al. (2001) conclude that trade reduced the emissions of pollution of 43 countries over the period 1971–1996. Frankel and Rose (2005) also conclude that trade is favourable to the reduction of pollution. However, other authors, such as Magnani (2000), conclude that trade has a negative impact on carbon dioxide emissions.

### **3.2 Domestic and Foreign Direct Investments**

The degree of democratization may affect the accumulation of domestic and foreign direct investments (FDI). In theory, democratic institutions can favour investments in several ways. First, the establishment of a political democratic system requires a broad social consensus allowing the political process to be more stable and more efficient than autocratic regimes. Economic agents would also be more incited to invest in democratic countries than in autocratic countries where the social consensus is low. Moreover, democratic regimes are politically stable, so they attract FDI. In political instability, economic agents consume more and reduce their saving. Second, political instability is also a factor of uncertainty because it

increases risks and the perception of investment risks and may reduce the rights and safety of investors. Feng (2001) shows that institutions lead to improved property rights and political freedoms, which in turn increase domestic investments and FDI, while uncertainty and political instability reduce them.

The relationship between investments (domestic and FDI) and environmental quality have been analysed. According to Brock and Taylor (2010), a high investment rate leads to a high physical capital stock in a regular state and increases the carbon dioxide per capita emissions during the transitional dynamic. Concerning the effect of FDI on pollution, one major debate is about the pollution haven hypothesis (PHH), which assumes that developing countries attract polluting industries to engage in FDI by taking advantage of the lower environmental standards. Similarly to trade openness, Grossman and Krueger (1995) consider that FDI can affect environmental quality through the scale effect, the technique effect and the composition effect. The scale effect is related to the effect on environmental degradation as a consequence of an increase in economic output due to the expansion of FDI. The composition effect means that FDI can have an impact on environmental degradation by changing the industrial structure of the economy. The technique effect considers that FDI favours the development, diffusion and transfer of clean technologies, which improve environmental quality.

### **3.3 Income inequality**

An important characteristic of democracy is the right to vote. Indeed, the exclusion of an important part of the population leads to a bias in political leaders' preferences. Many authors assert that an improvement in democratic institutions increases people's possibilities to ask for a better distribution of income (Boix 2003). As they are democratically elected, democratic leaders are incited to adopt redistribution policies, such as minimum wage, price subsidies and progressive taxation for the poor and middle classes. In other words, the democratic process is supposed to reduce income inequality. On the contrary, autocratic leaders will tend to adopt policies that favour the elite in power; consequently, they maintain income inequality. Li and Reuveny (2006) and Scully (1992) find that democracies have a positive effect on income distribution.

The effect of income inequality on environmental quality has been analysed by many scholars. Magnani (2000) and Koop and Tole (2001) find that income inequality tends to exacerbate pollution and deforestation, respectively. Developing theoretical arguments from

political economy, Boyce (1994) assumes that income inequality increases environmental degradation through the rate of time preference. He supposes that income inequality reduces the awareness of environmental quality for both rich and poor. Indeed, the poor would overexploit natural and environmental resources because of their survival motivation. Moreover, because income inequality and the polarization of resources increase and exacerbate conflicts (violence, social trouble), rich people can prefer a policy of overexploiting the environment and natural resources and investing the returns abroad. Torras and Boyce (1998) assume that political power is highly correlated with income inequality. In unequal societies, those (the rich) who benefit from environmental degradation are more powerful than those (the poor) who bear the cost. Therefore, a cost–benefit comparison predicts environmental degradation. Borghesi (2006) argues that the implementation of environmental policies is likely with social consensus. It is easier to gain this consensus in an equal society than in an unequal society with conflicts among political agents and social instability.

However, other scholars consider that income inequality may have no effect on or may improve environmental quality. Ravallion et al. (2000) claim that the impact of income inequality on environmental degradation depends on the marginal propensity to emit (MPE). If the poor have a higher (lower) MPE than the rich, a reduction of income inequality will increase (reduce) the pollution emissions, respectively. One cannot say a priori which of these two effects will happen. Indeed, the poor may consume goods with more (or less) pollution than the rich. Therefore, the effect of income inequality is not clear and depends on whether the MPE increases or decreases as the income grows.

## **4 Empirical analysis**

The previous sections have analysed the effect of democratic institutions on environmental quality and identified the potential transmission channels. This section describes the empirical method, the econometric specifications and the data set.

### **4.1 Empirical approach**

Our empirical approach consists of identifying the potential transmission channels as discussed in section 3 and implementing consistent estimates relying on dynamic panel techniques (section 4.1.2).

#### 4.1.1 *Identifying the transmission channels from democratic institutions to environmental quality*

We rely on Brock and Taylor's (2010) Green solow model, which establishes convergence in pollution. Environmental quality is thus proxied by polluting emissions. We augment the model and take into account the role of democratic institutions. The baseline model is written as follows:

$$\text{Log}(e_{i,t}) = \alpha_i + \rho \text{Log}(e_{i,t-1}) + \delta_1 DI_{i,t} + \omega X_{i,t} + \gamma_t + \varepsilon_{i,t} \quad (1)$$

with  $e_{i,t}$  the level of environmental quality in country (i) in period t. The time coverage extends from 1960 to 2008 and the data are compiled in five-year averages. Our sample is made up of 122 developed and developing countries.  $DI_{i,t}$  is a measure of democratic institutions;  $X_{i,t}$  are control variables without transmission channels. Derived by Brock and Taylor (2010), they are lagged emissions per capita and population growth. Moreover, we include the level of education (Bimonte 2002; Kinda 2010).

$\delta_1$  in equation (1) identifies the effects of democratic institutions on environmental quality. Because equation (1) does not include potential transmission channels,  $\delta_1$  captures the total effect of democratic institutions.

Democratic institutions may also affect the environmental quality through foreign direct investments (FDI), trade openness, income inequality and domestic investments. The transmission channels are modelled as having an additive effect on environmental quality in equation (2):

$$\text{Log}(e_{i,t}) = \alpha_i + \rho \text{Log}(e_{i,t-1}) + \delta_2 DI_{i,t} + \beta T C_{i,t}^j + \omega X_{i,t} + \gamma_t + \varepsilon_{i,t} \quad (2)$$

$T C_{i,t}^j$  is the vector of potential transmission channels.

$\delta_2$  in equation (2) captures the direct effect of democratic institutions on environmental quality. The indirect effect, which passes through the transmission channels, may be derived as the difference between the total effect ( $\delta_1$ ) and the direct effect ( $\delta_2$ ).

Moreover, what is important in the identification of the transmission channels is to have a significant relationship between democratic institutions and transmission channels on one hand and a significant relationship between transmission channels and environmental quality in another hand.

We therefore empirically test the effect of democratic institutions on each transmission channel (equation 3):

$$TC_{i,t}^j = \alpha_i + \beta Institutions + \gamma_t + \varepsilon_{i,t} \quad (3)$$

#### 4.1.2 Estimation strategy

It is inadequate to estimate equations (1) and (2) using either OLS (Ordinary Least Square) or fixed effects (FEs) or random effects (REs). OLS does not take the unobserved heterogeneity of countries into account. The FE and RE estimators are inadequate for when the lagged endogenous variable is one of the regressors. We thus rely on GMM system estimators (Generalized Method of Moments) following Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998).

The GMM system (Generalized Method of Moments) is a method that estimates a system of two equations: one equation in level and the other in first difference. In the first estimate, we use lagged variables in level of at least one period as instruments of the equation in first difference. This removes unobserved time-invariant and unobserved individual characteristics. The conditions to be met are that the error terms are uncorrelated and that the explanatory variables are weakly exogenous. In the second estimate, we use variables in first differences lagged of at least one period as instruments of the equation in level.

To check the validity of the results, we use the standard Hansen test of overidentifying restrictions (in which the null hypothesis is that the instrumental variables are not correlated with the residual) and the serial correlation test (AR(2), in which the null hypothesis is that the errors exhibit no second-order serial correlation).

## 4.2 Sources and description of the variables

The data on carbon dioxide per capita, domestic and foreign direct investments, trade openness and population growth are from the World Development Indicators (2010). Those on democratic institutions, income inequality, sulphur dioxide per capita and education come

respectively from Polity IV (2008), the Texas Inequality Project (UTIP 2008) database, David Stern (2004) and Barro and Lee (2012). The definitions, sources and descriptive statistics of the variables are in Appendices 4 and 5.

#### 4.2.1 *Environmental quality*

In the absence of a single measure of environmental quality, many indicators have been used in the literature as a proxy for environmental quality. For the purpose of our study, we use two pollutant variables. These are carbon dioxide ( $CO_2$ ) per capita and sulphur dioxide ( $SO_2$ ) per capita. The choice of  $CO_2$  as an environmental indicator is based on two reasons. Firstly, data on carbon dioxide emissions are available for longer time series than any other pollution indicator. Secondly, at the global level,  $CO_2$  is an immediate cause of greenhouse gas, responsible for global warming and climate change. Moreover, carbon dioxide emissions contribute to global warming more than any other greenhouse gas. At the domestic level, while  $CO_2$  by itself does not pose any immediate health hazard to human beings, it is usually a by-product of increased industrial activity, which, in the absence of stringent regulation, can be a source of toxic emissions and particulates that pose environmental concerns.

The choice of  $SO_2$  as another environmental variable is also based on two arguments. Firstly, contrary to carbon dioxide emissions, sulphur dioxide is a local pollutant. It is widely regarded as one of the most prominent forms of air pollution worldwide, since it has direct and visible effects on human health, ecosystems and the economy (Konisky 1999).  $SO_2$  has negative effects on the human body. It causes acid rain, which damages forests, lakes, buildings, cultural objects and agricultural production. It also reduces visibility, from light mist to dense grey smog. Moreover, particles (smoke and soot), sulphur dioxide ( $SO_2$ ), ozone ( $O_3$ ), nitrogen oxides (NO,  $NO_2$ , together  $NO_x$ ) and carbon monoxide (CO) constitute the so-called criteria pollutants. These indicators are used to measure and describe the air quality in a country. Secondly, the data for  $SO_2$  emissions are more reliable than the data for other forms of air pollution (so-called criteria pollutants), and have also been available for a rather large number of countries since the 1970s. Data with similar properties are not available for most other environmental quality indicators, such as  $NO_x$ , VOC, CO and ozone.



#### 4.2.2 *Democratic institutions*

As democratic institutions, we chose the index of polity (2) from Polity IV, which is a score obtained by differencing the index of democracy and index of autocracy on a scale from +10 (democracy) to -10 (autocracy). The indicator of democracy is characterized by the effective existence of institutional rules framing the power and the presence of institutions enabling citizens to express their expectations and choose political elites. Autocracy is characterized by the absence or the restriction of political competition, economic planning and control. The exercise of power is slightly constrained by institutions and the leaders are only selected within a “political elite”.

## 5 Results

### 5.1 Baseline results

Table 5 reports the GMM system estimates for equation 1 using panel data of five-year averages and controlling for time and country fixed effects. They summarize the results of the effect of democratic institutions on environmental quality. Columns (1) and (4) show that an improvement in democratic institutions contributes to a reduction in carbon dioxide emissions per capita and sulphur dioxide emissions per capita. The effect is -0.00995 (-0.0243) and significant at 10% (1%), respectively, for  $CO_2$  and  $SO_2$ . These results are similar to those of previous authors, such as Bernauer and Koubi (2009) and Li and Reuveny (2006), who conclude that democratic institutions improve environmental quality.

The economic literature considers that democracy differs in the form of democratic government and the duration of democratic institutions. These differences may affect the protection of the environment.

#### 5.1.1 *The form of democratic system*

Recent research on the provision of public goods argues that the form of government is an important factor in environmental protection. Persson et al. (2000) consider that a presidential system would underproduce public goods because legislative coalitions are unstable and leaders promote the allocation of spending to powerful minorities. The parliamentary system would increase spending on public goods and satisfy the majority of voters. However, Bernauer and Koubi (2009) and Mesquita et al. (2005) show that the presidential system would produce more public goods (prosperity, peace, transparency,

political rights, civil liberties, sulphur dioxide emissions) than the parliamentary system. We include in our analysis an index of the type of democratic system. There are three dichotomous variables: a) *president*, which takes the value of 1 for presidential democracies and 0 otherwise; b) *assembly elected*, which takes the value of 1 for assembly-elected presidential democracies and 0 otherwise; c) *parliamentary*, which takes the value of 1 for parliamentary democracies and 0 otherwise. The results<sup>14</sup> (columns 2 & 5, table 5) suggest that presidential democracies seem to be the best system to protect environmental quality (carbon dioxide per capita and sulphur dioxide per capita).

### 5.1.2 *The age of democratic institutions*

Democratic institutions can also differ in how long they have existed. Do old and new democratic institutions have similar effects on environmental protection? Contrary to young democracies, older democracies may have better institutions that collect data on environmental degradation and experience by media in analysing this information and expressing the expectation of citizens in favour of environmental protection. We include in the baseline regression a variable measuring the age<sup>15</sup> (duration or persistence) of democratic institutions. The findings (columns 3 & 6, table 5) suggest that the age of democratic institutions only reduces sulphur dioxide emissions and may be explained by the nature of the pollutants. Because the consequences of  $SO_2$  are direct and visible (for human health, ecosystems and the economy), citizens would punish political leaders who do not implement policies that reduce them. On the contrary, they would not use the electoral process to punish political leaders who do not implement policies that reduce  $CO_2$ , which is not visible pollutant (at the domestic level,  $CO_2$  poses no immediate health hazard for human beings). In other words, the age of democratic institutions incites political leaders to provide only visible environmental public goods that affect citizens' or voters' health or life. The implementation of visible environmental public goods is important because they are observable outcomes by which voters can re-elect or punish political leaders.

<sup>14</sup> We include in the baseline regression two of three dichotomous variables.

<sup>15</sup> See Appendix 4 for the definition.

**Table 5:** Effect of democratic institutions on environmental quality and the importance of democracy characteristics

Dependent variable	Log of carbon dioxide emissions per capita			Log of sulphur dioxide emissions per capita		
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged emission per capita (log)	0.972*** (0.0352)	0.908*** (0.0923)	0.858*** (0.0769)	1.086*** (0.0700)	1.102*** (0.0726)	1.177*** (0.0950)
Democratic Institutions	-0.00995* (0.00592)	-0.0300*** (0.0107)	-0.0310*** (0.0109)	-0.0243*** (0.00905)	-0.0240** (0.00959)	-0.0348*** (0.0105)
Population growth	0.0111 (0.00908)	-0.0362 (0.0294)	-0.00661 (0.0168)	0.0608** (0.0286)	0.0645** (0.0271)	0.0620** (0.0301)
Education	0.00563 (0.00849)	-0.0120 (0.0340)	-0.0267 (0.0287)	-0.0156 (0.0119)	-0.0152 (0.0107)	0.0148 (0.0220)
Democratic Institutions* parlementary		0.0252 (0.0168)			0.0146 (0.0144)	
Democracy*assembly elected		0.0492** (0.0210)			-0.0104 (0.0102)	
Age of democracy			-0.00375 (0.0287)			-0.00864* (0.00487)
Intercept	0.0987*** (0.0268)	0.253*** (0.0709)	0.102 (0.0636)	1.276 (0.855)	1.498* (0.893)	2.468** (1.189)
Observations	867	800	867	800	800	800
Countries	121	120	121	104	104	104
AR (1)	0.01	0.004	0.01	0,02	0.03	0.01
AR (2)	0.464	0.550	0.869	0 ,24	0.308	0.316
Hansen Test	0.18	0.42	0.11	0,12	0.46	0.23
Instruments	12	18	15	20	18	20

Notes: \* significantly at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2000 and 1960-2008 for sulphur dioxide emissions and carbon dioxide emissions.

## 5.2 Disentangling the indirect effect of democratic institutions

Democratic institutions favour environmental protection by allowing people to choose their political elites and determine environmental policies. Moreover, the characteristic of democracy (the form of government and the age of democracy) can influence the extent of environmental degradation. Our previous results show that a presidential democracy seems to be the best system to protect environmental quality ( $CO_2$  and  $SO_2$ ) and the age of democratic institutions favours the provision of visible environmental goods ( $SO_2$ ).

We now examine the indirect mechanisms by which democracy may influence environmental quality. In section 3, we identify four potential channels: foreign direct investment (FDI), trade openness, income inequality and domestic investments. Tables 6 and 7 show the results of equation (2).

In column (2) of Tables 6 and 7, we include only income inequality in the regression. We believe that there would be endogeneity between environmental quality and income inequality. According to Arrow et al. (1995), economic activity depends on the environmental resource base. High and imprudent use of the environmental resource base may reduce the capacity for generating material production and income in the future. The environmental resource base includes assimilative capacities for waste discharges. Second, the poorest are vulnerable to environmental degradation since they depend heavily on natural resources and have fewer alternative resources. They are also exposed to environmental hazards and are less capable of coping with environmental risks (Dasgupta & Mäler 1995). Furthermore, the rich are more capable of protecting themselves from environmental diseases than the poor. An increase in environment degradation would affect the incomes of the poor more than those of the rich and increase the income inequality. To solve the problem of endogeneity, we use the GMM system, allowing us to instrument income inequality with lagged variables. The results indicate that an increase in income inequality reduces air pollution emissions (carbon dioxide per capita and sulphur dioxide per capita). Income inequality favours environmental protection. These results are also similar to those of scholars (Ravallion et al. 2000) who claim that income inequality may improve environmental protection.

In column (3) of Tables 6 and 7, we include investments in the regression. We find that investments have a positive and significant effect on the carbon dioxide emissions per capita and sulphur dioxide emissions per capita. Indeed, an increase in investments of 1%

contributes to carbon dioxide emissions per capita by 0.351% and sulphur dioxide emissions per capita by 0.161%, respectively. Investments can be considered as an important factor in air pollution. In columns (4) and (5), we include foreign direct investments (FDI) and trade. We find that they have no effect on environmental quality. The inclusion of income inequality and investments in the regression improves the magnitude of the coefficients of democratic institutions (columns (3), (4) and (6)).

The results indicate that democratic institutions have a positive effect on environmental quality. This direct effect (column 6) of democratic institutions is higher than the total effect (column 1). Moreover, the increase in the magnitude and coefficient of democratic institutions (column (1) and column (6)) may indicate that democratic institutions have partial effects through investments and income inequality.

To be sure that they are really channels through which democratic institutions affect environmental quality, we empirically test<sup>16</sup> the effect of democratic institutions on investments and income inequality.

Table<sup>17</sup> (8) shows the results of equation (3). Columns (1) and (2) show that democratic institutions have a positive effect on investments. Our results are similar to those of Feng (2001), Pastor and Hilt (1993) and Pastor and Sung (1995), who conclude that political freedoms (democratic freedoms) attract investments. Columns (3) and (4) show that democratic institutions have a positive effect on income inequality. However, we suspect an inverse relation (endogeneity problem) between income inequality and democratic institutions. First, income inequality increases and exacerbates conflicts in income distribution and political instability. The polarization of resources and incomes causes violence and social trouble. This situation can allow illegal activities, protest movements and coups d'état (Figueroa 1996). Second, Acemoğlu and Robinson (2006) show that income inequality strongly reduces the consolidation of democracies. One argument is that it facilitates and

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<sup>16</sup> Some authors report bivariate regressions (Mo 2001; Pellegrini & Gerlagh 2006) and others include additional determinants (Papyrakis & Gerlagh 2004).

<sup>17</sup> Moreover, we check the robustness of our results by including in the regressions additional independent variables. For the investments equation, we take into account income per capita, inflation, credit available in the private sector and corruption. For the income inequality equation, we include income per capita, lagged income inequality.

allows the redistribution of incomes in favour of the poor and defavours the rich people in power. The burden of democracy on the elites increases in the income gap between them and the citizens. They would have an incitative to destabilize the democracy. Latin America is an example showing that income inequalities do not allow democracy to consolidate. The estimation results are biased. To solve the problem of endogeneity, we use the GMM system, allowing us to instrument democratic institutions with lagged variables. Columns (5) and (6) conclude that democratic institutions reduce income inequality. Thus, democracy allows the poor to obtain more resources through income redistribution. The result is similar to those of previous studies (Boix 2003; Mueller & Stratmann 2003). Indeed, Mueller and Stratmann (2003) show that better participation of citizens in elections reduces income inequality (Gini Index). The reduction of income inequality is explained by income transfers or by government size (expenditure).

Table 6 : Effect of democratic institutions on environmental quality taking into account transmission channels

Dependent variable	Log of carbon dioxide emissions per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged carbon dioxide per capita (log)	0.972*** (0.0352)	0.984*** (0.0687)	0.810*** (0.0711)	1.064*** (0.0317)	1.033*** (0.0684)	0.862*** (0.0491)
Democratic Institutions	-0.00995* (0.00592)	-0.0276*** (0.00762)	-0.0275*** (0.0101)	-0.0179* (0.00994)	-0.0128** (0.00601)	-0.0481* (0.0257)
Population growth	0.0111 (0.00908)	0.0209*** (0.00731)	0.111** (0.0430)	0.0272*** (0.00910)	0.0114 (0.0116)	-0.0545 (0.0370)
Education	0.00563 (0.00849)	-0.00378 (0.00892)	-0.0133 (0.0132)	-0.0143* (0.00778)	0.00751 (0.0148)	-0.0383 (0.0294)
Income Inequality		-0.0230*** (0.00800)				-0.0275*** (0.0101)
Investments (log)			0.351* (0.205)			0.406** (0.162)
FDI (log)				0.0170 (0.0328)		-0.0153 (0.0835)
Trade (log)					0.0473 (0.165)	0.0501 (0.111)
Intercept	0.0987*** (0.0268)	1.075*** (0.338)	-0.564 (0.639)	0.0778*** (0.0279)	-0.0825 (0.644)	-0.513 (0.686)
Observations	867	627	733	634	788	577
Countries	121	111	119	120	120	117
AR (1)	0.01	0.00	0.01	0.004	0.01	0.01
AR (2)	0.464	0.87	0.30	0.550	0.869	0.92
Hansen Test	0.18	0.13	0.53	0.42	0.11	0.44
Instruments	12	14	17	18	15	15

Notes: \* significant at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2008.

Table 7: Effect of democratic institutions on environmental quality taking into account transmission channels

Dependent variable	Log of sulphur dioxide emissions per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged sulphur dioxide per capita (log)	1.086*** (0.0700)	0.856*** (0.0260)	1.027*** (0.0978)	1.157*** (0.0714)	1.027*** (0.165)	0.931*** (0.0626)
Democratic Institutions	-0.0243*** (0.00905)	-0.0664** (0.0323)	-0.0840* (0.0458)	-0.0296*** (0.0106)	-0.0264* (0.0140)	-0.133*** (0.0354)
Population growth	0.0608** (0.0286)	-0.0152 (0.0246)	0.0666** (0.0269)	0.0641** (0.0311)	0.0670** (0.0270)	0.0758*** (0.0229)
Education	-0.0156 (0.0119)		-0.00584 (0.0147)	-0.0219* (0.0120)	0.00175 (0.0175)	-0.00161 (0.00543)
Income Inequality		-0.00662** (0.00319)				-0.0327*** (0.00924)
Investments (log)			0.161** (0.0762)			0.303*** (0.0774)
Trade (log)				-0.0306 (0.0628)		-0.0618 (0.0489)
FDI (log)					-0.0265 (0.0903)	-0.00578 (0.0173)
Intercept	1.276 (0.855)	-1.236*** (0.274)	0.0173 (1.359)	2.266** (0.979)	0.446 (2.042)	-0.970 (0.900)
Observations	800	577	692	744	590	423
Countries	104	104	102	103	104	90
AR (1)	0.02	0.03	0.07	0.03	0.001	0,01
AR (2)	0.24	0.30	0.42	0.308	0.316	0,15
Hansen Test	0.12	0.26	0.57	0.46	0.23	0,24
Instruments	20	21	12	18	20	19

Notes: \* significant at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2000.



Table 8: The effect of Democratic institutions on potential transmission channels

	Investments (log)			Income inequality		
	(1)	(2)	(3)	(4)	(5)	(6)
Democratic Institutions	0.0310*	0.0394**	0.123***	0.0661*	-0.549**	-0.315***
	(0.0186)	(0.0189)	(0.0341)	(0.0348)	(0.233)	(0.0738)
Education		0.0969**		-2.556***		-0.300**
		(0.0412)		(0.582)		(0.151)
Population growth		0.0434**		-0.103		-0.119
		(0.0186)		(0.198)		(0.526)
Constant	2.900***	2.012***	41.33***	65.79***	41.34***	45.45***
	(0.0448)	(0.407)	(0.424)	(5.433)	(0.640)	(1.781)
Observations	674	671	735	683	735	683
R-squared	0.045	0.067	0.234	0.252		
Countries	122	122	125	122	125	122
AR (1)					0.041	0.001
AR (2)					0.482	0.152
Hansen test					0.41	0.102
Instruments						9

Notes: \* significant at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2008.

### 5.3 Robustness checks

How robust are these results to alternative tests? First, we take into account the importance of economic development. Second, we include more control variables (legal structure and security of property rights, corruption) to check the pertinence of the transmission channels (income inequality and investments). Third, alternative measures of democratic institutions are added to the equations. Fourth, an alternative econometric method (two-step GMM system) is applied.

#### 5.3.1 The importance of economic development

Our results conclude that democratic institutions have a positive direct effect on environmental quality. However, an important characteristic of democratic institutions is that their levels differ according to economic development. These results may be biased and explained by the quality of democratic institutions in developed countries. Table (9) indicates that democratic institutions in both groups have a direct positive effect on environmental quality. More interestingly, the direct effect of democratic institutions on environmental quality in developed countries is higher than that in developing countries. This can be

explained by the fact that the quality of democratic institutions is better in developed countries than in developing countries. Another result is that the direct positive effect of democratic institutions is higher for sulphur dioxide per capita than for carbon dioxide per capita in developed countries and in developing countries. These results can be explained by the fact that sulphur dioxide emissions are a local pollutant, contrary to carbon dioxide, which is a global pollutant.

### *5.3.2 Adding more control variables*

A common characteristic of democratic institutions is that they can promote (generally) economic freedom. Aixalá and Fabro (2009) and Lawson and Clark (2010) provide evidence that economic institutions are related to a country's level of political institutions, because on one hand the institutions that affect environmental performance (through economic growth) are distinct from the institutions of representative democracy and on the other hand economic institutions can be affected by democratic institutions.

Moreover, some authors, such as Pellegrini and Gerlagh (2006) show that studies analysing the relationship between democratic institutions and environmental quality may be biased when they do not take into account the level of corruption. Because these two variables are highly correlated, the individual estimation of the effects of democratic institutions overemphasizes its importance (coefficient). They conclude that democratic countries do not protect environmental quality when they are corrupt. We control for property rights, law and order and corruption in table 10. The results are not affected by the inclusion of these variables.

Table 9: Effect of democratic institutions on environmental quality according to economic development

Dependent variable	Log of carbon dioxide		Log of sulphur dioxide	
	Developing	Per capita Developed	Developing	Developed
	(1)	Countries (2)	(3)	(4)
Lag emissions per capita (log)	0.872*** (0.0460)	0.983*** (0.200)	0.697*** (0.111)	0.697*** (0.114)
Democratic Institutions	-0.0348** (0.0143)	-0.0659*** (0.02487)	-0.107** (0.0478)	-0.187** (0.0798)
Population growth	0.00811 (0.0515)	-0.0604 (0.0445)	0.114* (0.0614)	-0.0900 (0.0564)
Education	0.0272 (0.0365)	0.3895** (0.1891)	0.0256 (0.0197)	0.4083** (0.2048)
Income Inequality	-0.0318*** (0.0091)	-0.0215* (.01257)	-0.05796* (0.03329)	-0.02108* (0.01239)
Investments (log)	0.527*** (0.184)	0.514*** (0.192)	0.691*** (0.1084)	0.191* (0.110)
Trade (log)	-0.158 (0.170)	-0.266 (0.221)	0.0769 (0.0882)	0.0710 (0.0814)
FDI (log)	-0.00493 (0.0405)	-0.0392 (0.0383)	0.0233 (0.0318)	0.0144 (0.0285)
Intercept	-0.132 (1.226)	0.129 (0.972)	-3.196* (1.751)	-2.920 (1.757)
Observations	378	171	280	143
Countries	78	27	66	24
AR (1)	0.001	0.09	0.03	0.22
AR (2)	0.13	0.32	0.47	0.26
Hansen Test	0.44	0.70	0.60	0.31
Instruments	17	17	18	17

Notes: \* significantly at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2000 and 1960-2008 for sulphur dioxide emissions and carbon dioxide emissions.

Table 10: Effect on democratic institutions on environmental quality: more control

Dependent variable	Log of carbon dioxide emissions per capita				Log of sulphur dioxide emissions per capita			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged emissions per capita (log)	0.862*** (0.0491)	1.042*** (0.0786)	0.906*** (0.127)	1.150*** (0.0862)	0.931*** (0.0626)	1.075*** (0.108)	0.986*** (0.266)	1.096*** (0.157)
Democratic Institutions	-0.0481* (0.0257)	-0.0342* (0.0198)	-0.0445* (0.0231)	-0.0327*** (0.00924)	-0.133*** (0.0354)	-0.127** (0.0576)	-0.138** (0.0617)	-0.125* (0.0703)
Population growth	-0.0545 (0.0370)	0.0864* (0.0466)	0.0109 (0.0653)	-0.00161 (0.0314)	0.0758*** (0.0229)	0.130 (0.111)	-0.0180 (0.0340)	0.0101 (0.0356)
Education	-0.0383 (0.0294)	0.0358 (0.0568)	0.0285 (0.0420)	-0.0644 (0.0438)	-0.00161 (0.00543)	-0.0498 (0.0303)	-0.00151 (0.0147)	0.00392 (0.00743)
Income Inequality	-0.0275*** (0.0101)	-0.0186** (0.00922)	-0.0120* (0.00699)	-0.0187** (0.00926)	0.0153* (0.00919)	-0.0196** (0.00852)	-0.0234* (0.0129)	-0.0274** (0.0119)
Investment (log)	0.406** (0.162)	0.656*** (0.178)	0.675*** (0.197)	0.558** (0.241)	0.303*** (0.0774)	0.641*** (0.141)	0.404** (0.177)	0.366*** (0.124)
FDI (log)	-0.0153 (0.0835)	0.00247 (0.0417)	0.0515 (0.0570)	-0.00313 (0.0979)	-0.00578 (0.0173)	0.00763 (0.0205)	0.00852 (0.0278)	-0.00945 (0.0197)
Trade (log)	0.0501 (0.111)	-0.136 (0.142)	0.0913 (0.190)	-0.232 (0.209)	-0.0618 (0.0489)	-0.0385 (0.0744)	-0.127 (0.193)	-0.0334 (0.0761)
Law and order		0.00771 (0.0795)				0.00175 (0.0175)		
prights			-2.535 (9.743)				2.374 (19.84)	
Corruption				-0.0306 (0.0628)				-0.232 (0.183)
Intercept	-0.513 (0.686)	-1.563** (0.613)	-1.287 (1.002)	0.0722 (1.268)	-0.970 (0.900)	0.0161 (1.496)	-0.809 (0.883)	2.413 (3.055)
Observations	577	373	506	373	423	309	390	309
Countries	117	105	95	105	90	83	82	83
AR(1)	0.01	0.00	0.00	0.003	0.01	0.001	0.036	0.022
AR(2)	0.92	0.75	0.20	0.119	0.15	0.868	0.405	0.857
Hansen test	0.44	0.27	0.13	0.258	0.24	0.664	0.679	0.115
Instruments	15	18	26	16	19	24	27	26

Notes: \* significantly at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2000 and 1960-2008 for sulphur dioxide emissions and carbon dioxide emissions.

### 5.3.3 *Alternative measures of democratic institutions*

In the literature, many measures of democratic institutions have been used. They can be divided into two categories: dichotomous and continuous indicators. We use two alternative measures of democratic institutions from Cheibub et al. (2010) and Vanhanen (2003). The index of democratic institutions (Cheibub et al. 2010) is a dichotomous indicator (chga) that is coded 1 if a democracy and 0 otherwise. A regime is considered a democracy if the executive and the legislature are directly or indirectly elected by popular vote, multiple parties are allowed, there is de facto existence of multiple parties outside the regime front, there are multiple parties within the legislature and there has been no consolidation of incumbent advantage (e.g. unconstitutional closing of the lower house or extension of the incumbent's term by postponing subsequent elections). Transition years are coded as the regime that emerges in that year. The second measure of democracy, developed by Vanhanen (2003), is a composite (continuous) indicator. It combines two basic dimensions of democracy – competition and participation – measured as the percentage of votes not cast for the largest party (competition) times the percentage of the population that actually voted in the election (participation). It varies from 0 (no democracy) to 100 (full democracy). Tables 11, 12, 13 and 14 show that democratic institutions always have positive (direct) and indirect impacts on environmental quality (SO<sub>2</sub> and CO<sub>2</sub>).

Table 11: Democratic institutions and environmental quality (carbon dioxide per capita): Alternative measures of democracy

Dependent variable	Log of carbon dioxide per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged carbon dioxide per capita (log)	0.963*** (0.0587)	0.824*** (0.0725)	0.911*** (0.0520)	0.938*** (0.0857)	0.862*** (0.180)	0.895*** (0.0404)
Democracy (chga)	-0.0185** (0.00740)	-0.127*** (0.0266)	-0.121** (0.0469)	-0.0190** (0.00883)	-0.0277** (0.0112)	-0.251** (0.0988)
Population growth	0.00120 (0.00400)	-0.0397 (0.0495)	-0.00840 (0.0157)	-0.0130 (0.0317)	0.0125 (0.0177)	-0.0196 (0.0337)
Education	0.0141 (0.0135)	-0.0177 (0.0247)	-0.0264 (0.0295)	0.00906 (0.0201)	0.0265 (0.0394)	0.0662 (0.0754)
Income Inequality		-0.0239** (0.0100)				-0.0173** (0.00838)
Investments (log)			0.457*** (0.113)			0.585*** (0.153)
Trade (log)		0.188 (0.163)		-0.133 (0.164)		0.129 (0.113)
FDI (log)					-0.0609 (0.0807)	-0.0274 (0.0253)
Intercept	0.0635 (0.0441)	0.636 (0.460)	-1.158*** (0.346)	0.611 (0.616)	-0.0406 (0.117)	-1.027* (0.614)
Observations	848	600	725	780	633	569
Countries	120	119	118	119	119	116
AR (1)	0.001	0.01	0.22	0.00	0.00	0.00
AR (2)	0.13	0.10	0.42	0.98	0.20	0.45
Hansen Test	0.11	0.29	0.31	0.12	0.59	0.20
Instruments	19	17	14	22	19	12

Notes: \* significant at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2008.

Table 12: Democratic institutions and environmental quality (sulphur dioxide per capita): Alternative measures of democracy

Dependent variable	Log of Sulphur dioxide per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged Sulphur dioxide per capita (log)	1.200*** (0.0735)	0.890*** (0.0447)	0.842*** (0.0729)	0.700*** (0.118)	0.756*** (0.121)	1.074*** (0.0982)
Democracy (chga)	-0.0452*** (0.0156)	-0.133* (0.0738)	-0.189** (0.0908)	-0.0541*** (0.0141)	-0.0579*** (0.0126)	-0.295*** (0.111)
Population growth	-0.0923 (0.0580)	-0.0145 (0.0412)	0.0224 (0.0543)	-0.0581 (0.0401)	-0.0222 (0.0344)	0.0148 (0.0325)
Education	-0.0736 (0.0499)	-0.0326 (0.0404)	-0.0260 (0.0312)	-0.0543 (0.0418)	-0.0375 (0.0545)	-0.0626 (0.0526)
Income Inequality		-0.0335** (0.0156)				-0.0215** (0.00918)
Investments (log)			0.327** (0.161)			1.176*** (0.359)
Trade (log)				0.188 (0.127)		0.00140 (0.0372)
FDI (log)					0.0485 (0.0570)	-0.0107 (0.0356)
Intercept	2.844*** (0.936)	-0.466 (0.402)	-2.347** (0.917)	-3.634** (1.625)	-2.296* (1.350)	-2.034* (1.035)
Observations	793	584	681	736	576	540
Countries	103	99	101	102	102	100
AR(1)	0.014	0.061	0.018	0.008	0.034	0.017
AR(2)	0.456	0.439	0.905	0.466	0.246	0.805
Hansen Test	0.358	0.338	0.423	0.312	0.783	0.634
Instruments	15	24	24	24	13	12

Notes: \* significant at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2000.

Table 13: Democratic institutions and environmental quality (carbon dioxide per capita): Alternative measures of democracy

Dependent variable	Log of carbon dioxide per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged carbon dioxide per capita (log)	1.008*** (0.0297)	0.912*** (0.0698)	0.811*** (0.0712)	0.717*** (0.0969)	0.749*** (0.114)	0.985*** (0.102)
Democracy (van_index)	-0.0105* (0.00567)	-0.0273*** (0.00887)	-0.0279*** (0.00953)	-0.0138*** (0.00486)	-0.00728 (0.00584)	-0.0561** (0.0269)
Population growth	0.0162** (0.00751)	-0.0937 (0.0632)	-0.00707 (0.0195)	-0.00921 (0.0246)	-0.0331 (0.0393)	0.0333 (0.0890)
Education	-0.00395 (0.00724)	0.0137 (0.0138)	-0.0382 (0.0275)	-0.0188 (0.0272)	0.0130 (0.0285)	0.0634 (0.0424)
Income Inequality		-0.0315*** (0.0114)				-0.0343*** (0.0124)
Investments (log)			0.414*** (0.154)			0.517*** (0.158)
Trade (log)				0.440 (0.276)		-0.542 (0.504)
FDI (log)					-0.0301 (0.0766)	0.162 (0.133)
Intercept	0.150*** (0.0376)	1.987*** (0.443)	-1.086** (0.461)	-1.607 (1.049)	0.281 (0.184)	1.761 (2.384)
Observations	847	580	724	779	632	460
Countries	120	107	118	119	119	110
AR (1)	0.00	0.00	0.01	0.22	0.003	0.001
AR (2)	0.92	0.53	0.12	0.42	0.86	0.53
Hansen Test	0.44	0.14	0.29	0.31	0.329	0.400
Instruments	15	19	17	14	15	17

Notes: \* significant at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2008.



Table 14: Democratic institutions and environmental quality (sulphur dioxide per capita): Alternative measures of democracy

Dependent variable	Log of Sulphur dioxide per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged sulphur dioxide per capita (log)	1.034*** (0.0773)	1.070*** (0.0685)	1.083*** (0.0501)	0.912*** (0.0628)	1.084*** (0.0972)	0.717*** (0.0709)
Democracy (van_index)	-0.00867* (0.00495)	-0.0646** (0.0303)	-0.0566** (0.0277)	-0.0166*** (0.00458)	-0.0147** (0.00601)	-0.116* (0.0591)
Population growth	-0.0620 (0.0388)	-0.0419 (0.0460)	-0.0408 (0.0665)	-0.0290 (0.0448)	-0.0153 (0.0595)	-0.0163 (0.0327)
Education	-0.0127 (0.0110)	-0.0418 (0.0451)	-0.0102 (0.0133)	0.0646*** (0.0213)	-0.00269 (0.00916)	0.0391* (0.0219)
Income Inequality		-0.0217** (0.00988)				-0.0181** (0.00872)
Investments (log)			0.542*** (0.183)			0.527*** (0.164)
Trade (log)				0.0105 (0.0677)		0.137 (0.259)
FDI (log)					-0.0131 (0.0466)	-0.0482 (0.0364)
Intercept	0.736 (0.889)	1.133 (0.773)	-0.293 (0.893)	-0.730 (0.847)	1.227 (1.214)	-4.488*** (1.386)
Observations	792	583	683	551	588	420
Countries	103	99	101	97	103	89
AR (1)	0.000	0.003	0.026	0.006	0.024	0.005
AR (2)	0.181	0.118	0.129	0.518	0.473	0.992
Hansen Test	0.195	0.723	0.228	0.149	0.66	0.212
Instruments	64	27	14	22	23	38

Notes: \* significant at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2000.

#### 5.3.4 *Alternative econometric methods*<sup>18</sup>

We re-estimate our equations using the two step GMM system because the two-step GMM-system estimator is more efficient than the one-step GMM-system estimator even if the standards errors can be severely downward biased in a small sample. This potential bias is solved by the method of correction (Windmeijer 2005) of a covariance matrix in a finite sample. The results are displayed in Tables 15 and 16. We note that the results are similar to those obtained by the one-step GMM estimator and are robust. Indeed, democratic institutions have opposite effects on environmental quality: a positive direct effect on environmental quality and negative indirect effects through domestic investments and income inequality. In other words, on one hand, democratic institutions improve environmental quality and on the other, they damage it through income inequality and investments.

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<sup>18</sup>Two additional robustness checks have been applied. First, we use another empirical strategy to analyse the transmission channels of democratic institutions on environmental quality. We apply the approach of the residuals generated regressors (Gomanee et al. 2005). Second we include income per capita. We find similar results.

Table 15: Effect of Democratic institutions on environment quality with two step GMM-System

Dependent variable GMM System Two Step	Log of carbon dioxide emissions per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged carbon dioxide per capita (log)	0.712*** (0.217)	0.847*** (0.0760)	0.837*** (0.0761)	1.055*** (0.0288)	1.106*** (0.0729)	0.898*** (0.0567)
Democratic Institutions	-0.0186* (0.0107)	-0.0463** (0.0232)	-0.0322** (0.0133)	-0.0192* (0.0105)	-0.0148* (0.00858)	-0.0746** (0.0302)
Population Growth	-0.0521 (0.0499)	-0.0146 (0.104)	-0.0115 (0.0222)	-0.0259 (0.0240)	-0.0485 (0.0301)	-0.0219 (0.0348)
Education	-0.0186 (0.0180)	0.0166 (0.0234)	0.000465 (0.00838)	0.0132 (0.0326)	-0.0118 (0.0144)	-0.0468 (0.0376)
Income inequality		-0.0126* (0.00751)				-0.0181* (0.0102)
Investments (log)			0.380*** (0.133)			0.414** (0.165)
FDI (log)				0.0108 (0.0307)		0.0313 (0.0394)
Trade (log)					0.108 (0.202)	0.127 (0.135)
Intercept	0.0794 (0.0563)	1.669*** (0.594)	-0.945** (0.402)	0.0733** (0.0289)	-0.334 (0.795)	-0.752 (0.742)
Observations	867	589	742	634	788	577
Countries	121	108	119	120	120	117
AR(1)	0.003	0.01	0.003	0.008	0.008	0.032
AR(2)	0.73	0.96	0.13	0.11	0.234	0.114
Hansen Test	0.13	0.21	0.35	0.29	0.400	0.615
Instruments	23	23	19	17	19	12

Notes: \* significant at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2008.

Table 16: Effect of Democratic institutions on environment quality with two step GMM-System

Dependent variable GMM System Two Step	Log of Sulphur dioxide emissions per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged sulphur dioxide per capita (log)	1.073*** (0.0696)	0.871*** (0.0263)	1.060*** (0.0693)	1.100*** (0.0705)	0.950*** (0.160)	0.941*** (0.0717)
Democratic Institutions	-0.0273*** (0.00761)	-0.0566* (0.0330)	-0.0825* (0.0462)	-0.0340*** (0.00937)	-0.0270*** (0.00720)	-0.143*** (0.0452)
Population Growth	-0.0633 (0.0405)	-0.0608 (0.0467)	-0.0434 (0.0341)	-0.0567 (0.0437)	-0.0266 (0.0421)	0.0596 (0.0581)
Education	-0.0116 (0.0145)	-0.0839 (0.0728)	-0.00887 (0.0121)	-0.0132 (0.0142)	0.00781 (0.0189)	-0.00211 (0.00789)
Income inequality		-0.00576* (0.00327)				-0.0250** (0.00977)
Investments (log)			0.128* (0.0768)			0.356*** (0.106)
FDI (log)				-0.0384 (0.0636)		-0.0163 (0.0250)
Trade (log)					-0.0542 (0.0838)	-0.0776 (0.0701)
Intercept	1.109 (0.865)	-1.122*** (0.276)	0.533 (1.002)	1.628* (0.950)	-0.447 (2.014)	-1.022 (1.008)
Observations	800	577	692	744	590	423
Countries	104	104	102	103	104	90
AR(1)	0.007	0.040	0.011	0.009	0.015	0.049
AR(2)	0.288	0.218	0.239	0.285	0.181	0.157
Hansen Test	0.153	0.212	0.197	0.772	0.259	0.719
Instruments	19	11	18	20	19	27

Notes: \* significant at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1960-2000.

## 6 Conclusion

This paper analyses the effect of democratic institutions on environmental quality and identifies transmission channels. The main contribution of this paper is to identify and test some channels, which are income inequality, investments, foreign direct investments (FDI) and trade. We use panel data from 1960 to 2008 for 122 countries and apply alternative econometric methods (one-step GMM system, two-step GMM system, fixed-effect estimators). The results are as follows. Firstly, we show that democratic institutions have opposite effects on environmental quality: a positive direct effect on environmental quality and a negative indirect effect through investments and income inequality. Indeed, democratic institutions attract investments that harm environmental quality. Similarly, democratic institutions damage environmental quality because they reduce income inequality.

Secondly, we find that the negative effect of democratic institutions is higher for local pollutants ( $SO_2$ ) than for global pollutants ( $CO_2$ ). Thirdly, the nature of democratic institutions (presidential, parliamentary) is conducive to environmental quality. In an older democracy, political leaders favour the provision of visible environmental goods ( $SO_2$ ). Fourthly, the results suggest that the direct positive effect of democratic institutions on environmental quality is higher in developed countries than in developing countries. Thus, the democratic process in the first group of countries has increased their awareness of the environmental protection.

The results are robust to an alternative econometric method (two-step GMM system) and the inclusion of more control variables (legal structure and security of property rights, corruption). Moreover, other measures (dichotomous (Cheibub, Gandhi & Vreeland 2010) and continuous indicators (Vanhanen 2003) of democratic institutions are used.

The positive effect of democratic institutions shows that they allow people to be more conscious of environmental problems. Democratic institutions are also responsive to the demands of people by reducing income inequality and increasing investments that favour economic growth. The negative effect on environmental quality through income inequality and investments highlights some important factors explaining the free-riding behaviour of some democratic countries.

Our results suggest policy implications. They suggest that an improvement of the democratization process in countries (especially developing countries) allows a high level of awareness of people. Countries should also find ways to reduce the indirect negative impact of democratic institutions on environmental quality (for example, the implementation of ecologically appropriate investments).

## 7 Appendices

### Appendix 4 : Descriptive statistics

	Average	Standard Dev	Min	Max
Carbon dioxide per capita	4.04	6.69	0	76.16
Sulfur dioxide per capita	0.000018	.0000384	2.94e-08	0.000647
Democratic institutions (Polity 2)	0.32	7.33	-10	10
Income inequality	41.58	6.67	21.82	62.32
Investment rate	21.37	7.486702	2.53	86.79
Foreign Direct Investments	2.627364	4.507913	-13.26511	62.26394
Trade openness	67.83	41.55648	2.35	466.31
Education	5.584886	3.124505	0.0376983	12.91048
Population rate	1.87	1.54	-20.36	11.80
Duration of democracy	21.62517	27.24188	0	197.25
Property rights	12.34949	4.311884	1.94496	20.83041
Corruption	2.929675	1.394834	0	6
Law and Order	3.501834	1.510063	0	6
Democracy (Van index)	10.95214	12.80848	0	45.42
Democracy (chga)	0.4108145	0.478568	0	1

## Appendix 5: Variables definitions and sources

<b>Variables</b>	<b>Definitions</b>	<b>Sources</b>
Sulfur dioxide per capita	Sulphur dioxide emission per GDP	David Stern (2005)
Carbon dioxide per capita	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	WDI (2010)
Democratic institutions	Combined score of democracy and autocracy on a scale going from -10 to 10. (- 10) large represents a big autocracy and 10, large democracy	Polity IV (2008)
Democracy (van)	This index combines two basic dimensions of democracy – competition and participation – measured as the percentage of votes not cast for the largest party (Competition) times the percentage of the population who actually voted in the election (Participation). This product is divided by 100 to form an index that in principle could vary from 0 (no democracy) to 100 (full democracy).	Vanhanen (2011)
Democracy (chga)	Coded 1 if democracy, 0 otherwise. A regime is considered a democracy if the executive and the legislature is directly or indirectly elected by popular vote, multiple parties are allowed, there is de facto existence of multiple parties outside of regime front, there are multiple parties within the legislature, and there has been no consolidation of incumbent advantage (e.g. unconstitutional closing of the lower house or extension of incumbent's term by postponing of subsequent elections). Transition years are coded as the regime that emerges in that year.	Cheibub, Gandhi and Vreeland (2009)
Form of democratic government	It is a trichotomous variable that takes the value of 0 for presidential democracies; 1 for assembly-elected president democracies and 2 for parliamentary democracies.	The logic of Political Survival Data Source
Age of democratic institutions	It's the number of years since the most recent regime change (defined by a three point change in	Polity IV (2008)

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	the p_polity score over a period of three years or less) or the end of transition period defined by the lack of stable political institutions (denoted by a standardized authority score).	
Foreign Direct Investments	FDI is the net inflows in current US\$ (% of Foreign Direct investments )	WDI (2010)
Investments	Gross capital formation (formerly gross domestic investment) consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories.	
Trade openness	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	
Population growth	Annual population growth rate (%). Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of the country of origin.	
Income Inequality	EHII (Estimated Household Income Inequality) variable is an index ranging from 0 (no inequality) to 1 (perfect inequality).	
		University of Texas Inequality Project (UTIP) (2008)
Property rights	Legal structure and security of property rights	Fraser (2008)
Education	Average schooling years in the total population	Barro & Lee 2012
Corruption	Indicator of corruption as reported by international consultants. Scaled from 0 to 6, higher values denote less corruption	ICRG
Law & order	Law and Order are assessed separately, with each sub-component comprising zero to three points. The Law sub-component is an assessment of the strength and impartiality of the legal system, while the Order sub-component is an assessment of popular observance of the law. Thus, a country can enjoy a high rating – 3 – in terms of its judicial system, but a low rating – 1 – if it suffers from a very high crime rate or if the law is routinely ignored without effective sanction (for example, widespread illegal strikes).	ICRG



## Appendix 6 : list of countries in the sample

Country name	Country name	Country name
Albania	Greece	Niger
Algeria	Guatemala	Norway
Argentina	Honduras	Nepal
Armenia	Haiti	New Zealand
Australia	Hungary	Oman
Austria	Indonesia	Pakistan
Azerbaijan	India	Panama
Belgium	Ireland	Peru
Burundi	Iran, Islamic Rep	Guinea
Benin	Israel	Qatar
Bangladesh	Italy Kuwait	Philippines
Bulgaria	Jamaica	P New Guinea
Bahrain	Jordan	Poland
Burkina-Faso	Japan	Portugal
Bolivia	Kenya	Paraguay
Brazil	Kyrgyz Republic	Romania
Botswana	Korea, Rep.	Russian
Central African Republic	Kuwait,	Rwanda
Canada	Sri Lanka	Saudi Arabia
Chile	Lithuania	Senegal
China	Luxembourg	Singapore
Cote d'Ivoire	Mali	El Salvador
Cameroon	Morocco	Suriname
Congo, Rep.	Mauritania	Slovak Republic
Colombia	Moldova	Slovenia
Cape Verde	Madagascar	Sweden
Costa Rica	Mexico	Swaziland
Croatia	Macedonia, FYR	Syria
Cyprus Czech Republic	Malta	Tanzania
Germany	Myanmar	Thailand
Denmark	Mongolia	Tonga

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Togo	Mozambique	Trinidad and Tobago
Ecuador	Mauritius	Tunisia Tunisia,
Egypt, Arab Rep. Eritrea,	Malawi	Turkey
Spain	Malaysia	Uganda
Ethiopia	Namibia	Ukraine
Finland	Nigeria	Uruguay
Fiji	Netherlands	United States
France	Liberia	Sweden
Gabon	Libya	Venezuela, RB
United Kingdom	Lesotho	South Africa
Ghana	Sudan	Zambia
	Switzerland	Zimbabwe



**PART 2. EFFECTS OF ENVIRONMENTAL  
POLICIES AND CLIMATE CHANGE ON  
DEVELOPMENT**



## **Chapter 3: Climatic Variability and Food Security in Developing Countries<sup>19</sup>**

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<sup>19</sup> This chapter was written in collaboration with Badolo Felix. We would like to thank comments from participants from African Economic Conference (Kigali, 30 Oct-02 Nov 2011); 2nd International Conference: Environment and Natural Resources Management in Developing and Transition Economies (Clermont-Fd, 17-19, Oct 2012); UNU-WIDER Conference on Climate Change and Development Policy (Helsinki, Finland, 28-29 sept 2012) and 52nd Congress of the Canadian Society of Economics Sciences (Mont-Tremblant, Canada, 09-11 May 2012).



*Abstract*

This paper contributes to the existing literature on climatic variability and food security. It analyses the impact of climatic variability on food security for 71 developing countries, from 1960 to 2008. Using two complementary indicators of food security (food supply and proportion of undernourished people), we find that climatic variability reduces the food supply and increases the proportion of undernourished people in developing countries. The adverse effect is higher for African Sub-Saharan countries than for other developing countries. We also find that the negative effects of climatic variability are exacerbated in the presence of civil conflicts and are high for the countries that are vulnerable to food price shocks.

Keywords: *Food Prices Vulnerability; Food security; Climatic variability; Civil conflicts*

JEL Codes : *D74; Q17; Q18 ; Q54*





## 1 Introduction

According to the United Nations Development Programme (2011), the number of people living under the international poverty line<sup>20</sup> has reduced from 1.8 billion to 1.4 billion between 1990 and 2005. These results validate several previous studies (Chen & Ravallion 2010; Milanovic 2012) that report a continued decline in global poverty during the last three decades. These authors show that the proportion of the world's people living below the international poverty line varied from 52% in 1980 to 25% in 2005. However, progress is currently not fast enough and is different across regions. From 1980 to 2005, the poverty rate in East Asia fell from 80% to 20% and stayed at around 50% in Sub-Saharan Africa. Despite national and international efforts to reduce poverty, the number of people suffering from chronic hunger has risen from 815 million in 1990 to 1,023 million in 2009 (FAO 2009), and a significant proportion of households depend on agriculture. They are more exposed to the risks of food shortages and hunger that could be caused or increased by climatic change (St.Clair & Lynch 2010).

In the recent years, the debate on climatic variability has led to a renewed interest in the effects of climatic variability on agriculture. Many authors have analysed the relationship between climatic variability and the indicators of food security. We can distinguish two strands in the literature. First, several authors develop theoretical arguments or prospective studies which evidence that climatic variability has a negative impact on agricultural production and decreases food availability. Christensen et al. (2007) show that food production is highly vulnerable to the influence of adverse weather. Furthermore, Haile (2005) and Dilley et al. (2005) confirm that recent food crises in Africa which required large-scale external food aid have been attributed either fully or partially to extreme weather events. Ringler et al. (2010) and St.Clair and Lynch (2010) conclude that climatic variability is a factor of childhood malnutrition in Sub-Saharan Africa. Based on Intergovernmental Panel on Climate Change (IPCC)' climatic projection models, many authors (among others, see Schmidhuber & Tubiello 2007) show that climatic change will negatively affect food security. While the majority of studies are based on theoretical or prospective analyses, the second strand of literature concerns empirical analyses. Using panel data for Asian countries from 1998 to 2007, Lee et al. (2012) show that high temperature and more precipitations in summer increase agricultural production. In the case of Ethiopia, von Braun (1991) concludes that a 10% decrease in the amount of rainfall below the long run average leads to

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<sup>20</sup> The international poverty line of \$1.25 a day.

a 4.4% reduction in the food production. There are some reasons that could explain the difficulties of studying the effect of climatic variability on food security at the macroeconomic level. First, the absence of suitable climatic data for many developing countries over a long period may justify the fact that there are few empirical papers. Second, food security is a complex concept that includes several dimensions.

The objective of this paper is to analyse the causal relationship between climatic variability and food security. It differs from the existing literature on climatic variability and food security in two ways. First, while most of the literature is mainly theoretical, we perform an empirical and macroeconomic analysis for 71 developing countries from 1960 to 2008. Second, we identify two mechanisms by which climatic variability may influence food security.

The plan of the paper is as follows. Section 2 contains a discussion of the literature review on the relationship between climatic variability and food security. Section 3 discusses the econometric method used to evaluate the effect of climatic variability on the indicators of food security. Section 4 presents empirical results. The last section is devoted to concluding remarks and implications.

## **2 Relationship between Climatic Variability and Food Security**

The economic literature on the relationship between climatic variability and food security can be presented according to three different approaches: production-based approach, market approach and institutional failures. Before discussing these approaches, we propose to survey the concepts of food security and climatic variability in order to identify accurate indicators.

### **2.1 Concepts of Food Security and Climatic Variability**

#### *2.1.1 Measuring Food Security*

Food security is a multidimensional and flexible concept that gained prominence since the World Food Conference in 1974. Many definitions have been put forward (Maxwell 1996). They have shifted from food production and importing capabilities at the macro-level towards a focus on individuals and their ability to avoid hunger and undernutrition (Foster Phillips 1992). Reutlinger (1986) suggests that food security is defined as “access by all people at all times to enough food for an active healthy life”. Among them, the definition by the United Nations

Development Programme (UNDP 1994) is widely accepted by the World Bank and nongovernmental organizations. Food security is “a situation that exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life”. This requires not just enough food to go around but necessitates that people have ready access to food, that they have an “entitlement” to food by growing it for themselves, by buying it or by taking advantage of a public food distribution system.

This definition highlights the importance of food security as a basic human right (Dreze & Sen 1991; Sen 1983). Tweeten Luther G. (1997) emphasizes that the concept of food security has three essential dimensions. The first dimension is food availability, which refers to the supply of foodstuffs in a country from production or imports. A “bread basket” of food should be made available for consumption, but nothing is said about how the basket is distributed. The second dimension is food access, which refers to the ability to acquire food for consumption through purchase, production or public assistance. Indeed, food may be available but not necessarily accessible. Contrary to availability that reflects the supply-side, food access focuses on the demand side (Barrett 2010). It takes into account the loss of livelihood producing assets, the incomes of households, the prices of goods and the preferences of households. The third dimension is food utilization, which concerns the physical use of food derived from human distribution. Food may be available to individuals who have access, but health problems may result from the imbalanced diet of food that is consumed.

Because it reflects a multidimensional concept, several indicators of food security have been used in the economic literature. We may distinguish input and outcome indicators (Table 17). The input indicators describe “the structural conditions likely to worsen food insecurity whereas outcome indicators describe food consumption i.e. inadequate food consumption or anthropometric failures.

In the early 1970s, food security was mostly considered in terms of national and global food production. The economic literature focuses on food production/supply indicators such as the energy balance per capita, which is measured by the Dietary Energy Supply (DES) and food production. The energy balance is a measure of national food availability that indicates how a country’s food supply meets the energy needs of its population under the hypothesis that food supply is distributed among individuals according to needs.

In the mid 1980s, researchers realized that food insecurity may appear in regions where food may be available but not accessible because of the erosion of people's entitlements (Sen 1983b). There are many socio economic factors that may influence households' accessibility to food. Several authors use alternative indicators as such under-five mortality rate, child malnutrition and the proportion of undernourished children. The under-five mortality rate partially reflects the fatal synergy between inadequate dietary intake and unhealthy environments. It gives an idea of the severity of food insecurity. The child malnutrition measures the prevalence of underweight in children under the age of five, indicating the proportion of children suffering from weight loss. The proportion of undernourished, as estimated by the Food and Agriculture Organization (FAO), reflects the share of the population with inadequate dietary energy intake, i.e. the proportion of people who are food energy deficient. However, Wiesmann (2004) shows that the proportion of undernourished and the prevalence of underweight in children are both limited in that they do not reveal premature death, which is the most tragic consequence of hunger and undernutrition. Pelletier et al. (1994) suggest that the same level of child malnutrition in two countries can have quite different effects on the proportion of malnutrition-related deaths among children, depending on the overall level of child mortality. Wiesmann (2004) thinks that this limit of the indicator of child malnutrition is mitigated if they take in account of the under-five mortality rate. Pelletier et al. (1994) conclude that mortality takes into account causes of death other than malnutrition, and that the actual contribution of child malnutrition to mortality is not easy to track because the proximate cause of death is frequently an infectious disease. Furthermore, the indicators of child malnutrition and of infant mortality cover a category of population (children). Recent studies (Wiesmann 2004) refer to the Global Hunger Index (GHI)<sup>21</sup> as a measure food insecurity. The GHI is a statistical tool to measure and monitor hunger in the world by country and by region. It captures three dimensions of hunger: i) insufficient availability of food, ii) shortfalls in the nutritional status of children, and iii) premature mortality caused directly or indirectly by undernutrition. The GHI combines the percentage of people who are food energy deficient, which refers to the entire population, with the two indicators that deal with children under five. This index seems to be the best indicator to measure food security. However, this indicator is not available over a long period of time.

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<sup>21</sup>This indicator has been developed by the International Food Policy Research Institute (IFPRI).

**Table 17:** Classification of food security measures

	<b>Inputs</b>	<b>Outcomes</b>
<i>Availability</i>	<ul style="list-style-type: none"> <li>-Average dietary supply adequacy</li> <li>-Food production index</li> <li>-Share of energy supply derived from cereals, roots and tubers</li> <li>-Average protein supply</li> <li>Average supply of protein of animal origin</li> </ul>	
<i>Accessibility</i>	<ul style="list-style-type: none"> <li>-Percentage of paved roads over total roads</li> <li>-Rail lines density</li> <li>-Road density</li> <li>-Food price level index</li> </ul>	<ul style="list-style-type: none"> <li>-Prevalence of undernourishment</li> <li>-Share of food expenditure of the poor</li> <li>-Depth of the food deficit</li> <li>-Prevalence of food inadequacy</li> </ul>
<i>Utilization</i>	<ul style="list-style-type: none"> <li>-Access to improved water sources, -</li> <li>Access to improved sanitation facilities</li> </ul>	<ul style="list-style-type: none"> <li>Percentage of children under 5 years of age who : <ul style="list-style-type: none"> <li>- are stunted</li> <li>-wasted</li> <li>- underweight</li> </ul> </li> <li>-Percentage of adults who are underweight</li> </ul>

Source: FAO (2013)

Because it is hard to find a single or a global indicator that takes all dimensions of food security into account, we consider two indicators. First, we consider an input measure: food supply. It measures the availability of food in a country through any means (national food production, food imports, etc). To take into account access to food by people, we use the proportion of undernourished people. The proportion of undernourished people is the percentage of people who do not have access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. This indicator takes into account the amount of food available per person nationally and the magnitude of inequality in access to food.

### *2.1.2 Measuring Climatic Variability*

According to the Intergovernmental Panel on Climate Change (IPCC), “climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer”. It refers to any change in climate over time, whether due to natural instability or as a result of human activity. This definition differs from the definition of the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

Climatic variability can be considered as a component of climate change. According to the IPCC, climatic variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Measuring climatic variability involves evaluating the gap between the achievements of the climate variable (rainfall or temperature) and its equilibrium value. This equilibrium value refers to the existence of a permanent state or trend. Generally, we measure climatic variability by the standard deviation or the average deviation in absolute value of the distribution of a variable, relative to its mean or to its long-term trend. The standard deviation weights the extreme events more strongly than the average deviation. Other indicators of climatic variability may be the variation coefficient, the kurtosis coefficient and the asymmetry coefficient. The kurtosis coefficient and the asymmetry coefficient (skewness coefficient) are respectively the three-order and four-order moments and obtain information about climatic variability of countries and particularly the frequency of the extreme events.

## **2.2 What Could Explain Food Insecurity?**

In this section, we discuss three approaches highlighting the explanatory factors of food insecurity.

### *2.2.1 The Production-Based Approach*

The production-based approach is derived from the assumption that food insecurity is the result of a decline in food availability. This approach is based on the relationship between population growth and the ability of humans to confront scarcity of food and natural resources, which has dominated the literature on food security (Malthus 1798). Indeed, when a country makes the transition from agriculture to industry, it faces either the industry's environmental effects as well as problems generated by urbanization and demographic change. Malthus (1798) suggests that population expansion follows a geometric progression whereas food supply follows an arithmetic progression, and concludes that population growth outstrips the earth's ability to provide enough means of subsistence for the population. Neo-Malthusian authors (Ehrlich & Ehrlich 1991; Ophuls & Boyan 1992) conclude that population growth is a threat to food security because it leads to a decrease in food availability. This decrease is intensified by problems of access and utilization of foodstuffs, which are exacerbated by the increasing scarcity. Food availability is at the core of environmentalism and needs to conserve resources. Therefore, sustainable methods of food production and economic development are essential.

On this point, neo-Malthusians argue against "infinite substitutability" of the earth's resources, emphasizing the limits of adaptation to environmental change but demanding that people modify current patterns of consumption. Some developing countries have difficulty feeding their own population. Indeed, contrary to developed countries where demographic transition is achieved, in developing countries (Africa), population growth rate is high and around 2.5% per year. This high population growth rate may be explained by low mortality rate (due to technical transfer in public health and medical care) and high birth rate. High population growth associated with persistent poverty may negatively affect environmental resources, increase food insecurity and delay demographic transition.

Contrary to neo-Malthusians, several authors believe that technology and human ingenuity have always adequately confronted existing scarcities and will continue to do so in the future. Boserup (1965) shows that developing countries address urbanization problems and population growth by adapting new technologies and strategies of land-use intensification. In addition to technology, some authors take into account political and economic actions in the relationship between population growth and food security. Cohen (2008) thinks that rational political and economic actions as well as utilization of science and technology contribute to efficiency in food



production and distribution systems, thus reducing threats to food security. Tweeten (1997) suggests that effective trade policy and improvement in access to markets will help to limit food insecurity. For example, an increase in agricultural production or a better food distribution via a good transport infrastructure may offset negative effects of population growth by increasing food availability and food access. In conclusion, infrastructures and advances in technology must be adapted to meet the challenges of growing populations and diminishing resources.

### 2.2.2 *The Market-Based Approach*

The market-based approach is based on the idea that famine is not due to food supply but due to food access. The concept of entitlements developed by Sen (1983) partly joined this approach. The author suggests that people have an entitlement to food. Entitlement is defined as “the set of all possible combinations of goods and services that a person can obtain using the totality of rights and opportunities”. Entitlements depend mainly on two factors: personal endowments and exchange conditions. The *endowments* are the combination of all resources legally owned by people, which include both tangible assets (such as land, equipment, animals, etc.) and intangible assets such as knowledge and skill, labour power, membership of a particular community, etc. In developing countries, an important part of a household’s resources comes from labour activities. In other words, people’s endowments are based on the revenues of employment and the possible earnings by selling non-labour assets. *Exchange conditions* allow people to use their resources to access the set of commodities through trade and production and the determination of relative prices of products or goods. Sen (1983) concludes later that an unfavourable shift in exchange conditions can be the factors of food insecurity. Otherwise, a general shortfall of employment in the economy reduces people’s ability to acquire an adequate amount of food. In other words, a change in relative prices of products or wage rate vis-à-vis food price can cause food insecurity.

In the market-based approach of food security, we also find studies on the relationship between economic performance and food insecurity. A poor economic performance can be a major cause of poverty. A person is considered to be in absolute poverty when s/he is unable to satisfy adequately his/her basic needs such as food, health, water, shelter, primary education and community participation (Frankenberger 1996). The effects of poverty on hunger and undernutrition are pervasive. Poor households and individuals have inadequate resources for care and are unable to achieve food security and to utilize resources for health on a sustainable basis. In

contrast, a sustained economic growth has a positive direct impact on food security by supporting agricultural production and hence food supply.

Wiesmann (2006) suggests that national incomes are central to food security and nutrition because food security, knowledge and caring capacity as well as health environments require a range of goods and services to be produced by the national economy or to be purchased on international markets. Using the Global Hunger Index (GHI) as measure of food security and Gross National Income (GNI) per capita, the author shows that the availability of economic resources at the national level largely determines the extent of hunger and undernutrition. Poor countries tend to have high GHI values.

Smith and Haddad (2000) believe that national income may enhance countries' health environments and services as well as women's education by increasing government budgets. It may also boost national food availability by improving the resources available for purchasing food on international markets. The authors emphasize that national income reflects the contribution of food production to overall income generated by households for countries with large agricultural sectors. Smith and Haddad (2000) also suggest that national income may improve women's relative status directly by freeing up resources for improving women's lives as well as men's. They conclude that there is a strong negative relationship between national income and poverty, as shown by recent studies (Easterly 2005; Ravallion 2008). These studies show that economic growth is a necessary condition for poverty reduction. By promoting poverty reduction, economic growth may reduce the constraints on food access for households and is therefore a source of food security.

### *2.2.3 Institutional Failures*

Keen (1994) and Sen (2000) have highlighted the importance of institutions as an explanation of food insecurity. According to these authors, the failure to deliver food can be due to the implementation of inappropriate policies or government's failure to intervene and the existence of civil conflicts.

Sen (2000) suggests that democracy and political rights can help to prevent famines and other economic disasters. Indeed, authoritarian rulers tend to lack incentives to take timely preventive measures. In contrast, democratic governments have to win elections and face public criticism, and have strong incentives to undertake measures to avert food insecurity and other

catastrophes. For example, democracy may provide some empowerment through voting by the poor to receive human resource investments in health, education and food transfers from government for broad-based development. In the absence of elections, of opposition parties and of scope for uncensored public criticism, authoritarian governments do not have to suffer the political consequences of their failure to prevent food insecurity. However, democracy would spread the penalty of food insecurity to the ruling groups and political leaders. This gives them the political incentive to try to prevent any threatening food insecurity. Sen (2000) also thinks that a free press and the practice of democracy contribute greatly to bringing out information that can have an enormous impact on policies for food insecurity prevention (for example, information about the nature and impact of new production techniques on food supply). The author concludes that a free press and an active political opposition constitute the best early-warning system for a country threatened by famines.

Smith and Haddad (2000) consider that democracy is hypothesized to play a major role in the reduction of food insecurity. According to these authors, a more democratic government affects large revenues in education, health services and income redistribution. This contributes to reduce the problems of food insecurity in the areas affected. Smith and Haddad (2000) also suggest that a more democratic government may be more likely to respond to the needs of all of its citizens, women's as well as men's. With respect to food security, the analyses of Dreze and Sen (1991), among others, conclude that democracy is very important in averting food insecurity. More democratic governments may be more likely to honour human rights including the rights to food and nutrition (Haddad & Oshaug 1998) and to encourage community participation (Isham, Narayan, & Pritchett 1995), both of which may be important means for reducing child malnutrition.

Otherwise, other studies (Barnett 2003) have established a relationship between civil conflicts and hunger in developing countries. Indeed, in the countries in conflict, population, households and individuals suffer disruptions in livelihoods, assets, nutrition and health. The Combatants frequently use hunger as a weapon by cutting off food supplies and productive capacities, starving opposing populations into submission, and hijacking food aid intended for civilians. Warfare disrupts markets and destroys crops, livestock, roads and land. Deliberate asset-stripping of households in the conflict regions may cause those households to lose other sources of livelihood as the ongoing conflict leads to breakdowns in production, trade and the social

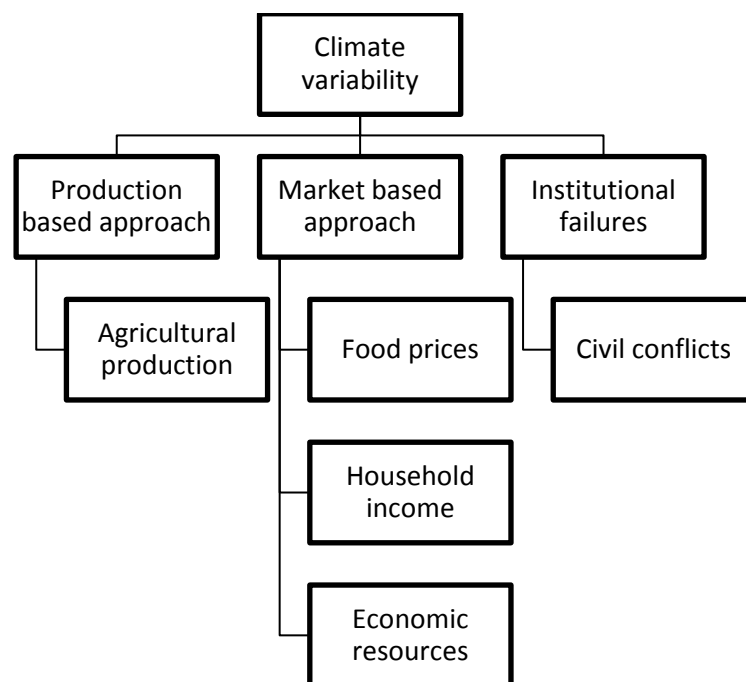
networks. The disruption of markets, schools and infrastructure removes additional resources required for food production, distribution, safety and household livelihoods. These consequences aggravate food insecurity in the countries in conflict.

Messer et al. (1998) have estimated the extent of food production losses due to conflict by examining trends in war-torn countries of Sub-Saharan Africa during 1970 to 1994 and found that food production was lower in the war years by a mean of 12.3%. This decrease in food production has significant impacts on food availability because in these countries, a majority of the workforce earns their livelihood from agriculture. In addition, in eight of the countries, two-thirds or more of the workforce are engaged in agricultural activities (World Bank 1992).

### 2.3 How does Climatic Variability Matter for Food Insecurity?

There are several channels through which climatic variability is likely to affect food security in developing countries. To elucidate these channels, we reflect on the effect of climatic shocks on each approach (Figure 4, diagrammatic presentation).

**Figure 4:** How climatic variability matters for food insecurity – diagrammatic presentation



Source: Authors<sup>22</sup>

<sup>22</sup> We thank Pr Pascale Combes Motel for suggestion.

### 2.3.1 Climatic Variability and Agricultural Production

Several authors (Green & Kirkpatrick 1982) have shown that developing countries with a food deficit are characterized by a large fluctuation in agricultural production. Moreover Barrios, Ouattara, and Strobl (2008) consider that climatic change (change in rainfall and temperature at the country level) is a major determinant of agricultural production in Sub-Saharan African. Therefore, one may wonder whether climatic variability is also worth including in determinants of food security in a production-based approach.

Most developing countries are particularly vulnerable to climatic change (especially climatic variability) because their economies are closely linked to climatic sensitive sectors such as agriculture (Mendelsohn et al. 2006). Millions of people in developing countries depend on agricultural production (Table 18). This vulnerability is particularly high in Africa where agricultural production is the primary source of livelihoods for 66% of the total active population (ILO 2007). The World Development Report (World Bank 2002) has established that 39% of people on fragile (arid and semi-arid) lands live in Africa. They are consequently threatened by climate change and climatic variability. Indeed, climatic variability has a negative effect on crop production. For example, higher average temperatures and changing rainfall patterns negatively impact farm yields, reduce household and national food availability and agricultural income. Poor harvests threaten food security. Moreover, rainfall variability contributes to underinvestment and hence to long-run agricultural stagnation and rural poverty in countries that are dependent on rain-fed agriculture (Kydd et al. 2004). This leads to a decrease in food availability and accessibility.

**Table 18: Rural Population**

<b>Regions</b>	<b>Rural Population</b>	<b>1960-2011</b>
East Asia & Pacific	1.07E+09	66.7
Latin America & Caribbean	1.26E+08	33.5
Middle East & North Africa	1.05E+08	48.8
South Asia	2.85E+08	76.5
Sub-Saharan Africa	8E+08	74.1
OECD	3.49E+08	28.4
World	2.8E+09	58.2

Source: World Development Indicators (2012)

### *2.3.2 Climatic Variability and Households' Income*

Climatic variability has direct and indirect effects on agricultural incomes and thus can harm food security. By reducing households' agricultural incomes, climatic variability also leads to a decrease in demand for goods and services in the affected communities. This threatens the livelihoods of people who indirectly depend on agriculture, such as traders. Nhemachena et al. (2009) show that rainfall variability and higher average temperatures negatively affect households' income that comes from agricultural crops and livestock in Africa. Sen (1983b) considers that beyond the agricultural sector, climatic variability adversely affects the labour market in rural areas, thus leading to a decrease in households' incomes and a decrease in the food basket.

### *2.3.3 Climatic Variability and Food Prices*

Climatic variability impacts food security through its great negative effect on food prices. Because food is a basic necessity good and the demand for food is highly price inelastic, a decrease of food surplus may lead to an important increase in food prices, thus reducing food accessibility. Using a theoretical model, Ringler et al. (2010) find that climatic variability increases childhood malnutrition in Sub-Saharan Africa through higher food prices. Moreover, Aker (2010) considers that climatic variability may have an effect on traders' entry and exit in response to the profitability of food trading. Indeed, climatic variability leading to an increase (decrease) in profits may incite the traders to enter (or exit) the local market. As markets are not well integrated and the dispersion of food (agriculture goods, cattle) prices is high in the least developed countries (Aker 2010; Araujo et al. 2005), climatic shocks may amplify them and harm food security.

### *2.3.4 Climatic Variability and Economic Resources*

Climatic variability can impact food security at the macroeconomic level through its effect on economic growth. Dell et al. (2008) and Mendelsohn et al. (2006) show that climatic variability has large and negative effects on economic growth in the poor countries. Moreover, because developing countries have a disproportionate share of their Gross Domestic Product (GDP) in climatic sensitive sectors, their economic resources are vulnerable to climatic shocks. In other words, climatic shocks may reduce the level of output and the economy's ability for growth (productivity growth) through reduction in agricultural production and exports (Jones & Olken 2010) and investments in research and development. By affecting economic growth, climatic

shocks can reduce the resources available to the governments (low tax revenues, for example). This can be a factor that contributes to food insecurity because climatic shocks affect the ability of countries to (1) purchase food on international markets; (2) invest in technology, services and infrastructure that support food and agricultural production and (3) finance public services and investments in health and education.

### 2.3.5 Climatic Variability and Civil Conflicts

Climatic variability can be a factor of food insecurity by increasing the risk of civil conflicts. Several authors suppose that climatic variability will likely lead to greater scarcity and variability of renewable resources in the long term (Buhaug 2008), as well as increase conflict over limited resources. Moreover, the literature on the determinants of civil war show that economic opportunity is more important than political factors. According to Collier and Hoeffler (1998, 2002, 2006), young men are thought to be more likely to take up arms when income opportunities are worse for them in agriculture or in the formal labour market, relative to their expected income as a fighter. By reducing available natural resources and households' incomes, climatic shocks reduce opportunity cost of fighting and increase the risk of civil conflicts. Hendrix and Glaser (2007) and Burke et al. (2009) find that climatic shocks (inter-annual variability in rainfall, higher temperatures) are associated with more conflicts. The exacerbation of the scarcity of resources and the risk of civil war caused by climatic shocks may increase food insecurity.

## 3 Empirical Analysis

This section presents the method used to analyse the effects of climatic variability on food security. Firstly, we specify the econometric model and then we describe the variables and the data sources.

### 3.1 Empirical Model

The objective of our paper is to analyse the relationship between climatic variability and food security over the period 1960 to 2008 for 71 developing countries. For this purpose, the following model is specified:

$$Y_{i,t} = \alpha_i + \beta CV_{i,t} + \omega X_{i,t} + \gamma_t + \varepsilon_{i,t} \quad (1)$$

With  $X$  the matrix of control variables,  $CV_{i,t}$  is the variable of climatic variability (log) in a country  $i$  at the period  $t$  and it represents our interest variable.  $\varepsilon_{i,t}$  is the error term,  $\gamma_t$  represents time fixed effect and  $\alpha_i$  country fixed effects. The data cover the period from 1960 to 2008 and are compiled in five-year averages (1960-1964, 1965-1969...).  $Y_{i,t}$  is the food security indicator. Because it is a multidimensional concept, we consider two alternative measures. We focus on food supply (input) and use proportion of undernourished people (output) for robustness checks.

Conceptually, the equation (1) is based on studies (Hayami & Ruttan 1970; Lau & Yotopoulos 1989; Zhao, Hitzhusen, & Chern 1991) using meta-production function for food. For robustness checks (proportion of undernourished people), our empirical model followed the economic literature on malnutrition (Smith & Haddad 2000). Our control variables are determinants of food security (Table 19) and are related to a production-based approach, a market-based approach and institutional failures.

**Table 19:** Classification of variables related to food security

	<b>Production based approach</b>	<b>Market based approach</b>	<b>Institutional failures</b>
<i>Main variables</i>	Population growth	Income per capita (log), Food price shocks vulnerability	Democratic institutions, conflicts
<i>Complementary control variables</i>	Arable land (log), Cereal production land (log)	Real effective exchange rate (log)	

Source: Authors

We identify the potential heterogeneities in the relationship between climatic variability and food security. We are interested in two types of heterogeneities.

First, we test if the effects of climatic variability can be different depending on whether the country was under conflict (equation 2). Indeed, in countries under conflict (Barnett 2003), the population suffers disruptions in livelihoods, assets, nutrition and health. Warfare disrupts markets and destroys crops, livestock, roads and land. Deliberate asset-stripping of households in the conflict regions may cause those households to lose other sources of livelihood as the ongoing conflict leads to breakdowns in production, trade and the social networks. Climatic shocks may aggravate food insecurity in the countries under conflict. Moreover, climatic variability increases food insecurity through the risk of civil conflicts. By exacerbating the scarcity of resources and the



risk of civil war (Burke et al. 2009; Hendrix & Glaser 2007), climatic shocks may increase food insecurity.

Second, we analyse the impact of climatic variability on food security in the context of food price shock vulnerability (equation 3).

$$Y_{i,t} = \alpha_i + \beta CV_{i,t} + \beta_1 CV_{i,t} * Conflict_{i,t} + \theta Conflict_{i,t} + \omega X_{i,t} + \gamma_t + \varepsilon_{i,t} \quad (2)$$

$$Y_{i,t} = \alpha_i + \beta CV_{i,t} + \beta_2 CV_{i,t} * PSVul_{i,t} + \theta_1 PSVul_{i,t} + \omega X_{i,t} + \gamma_t + \varepsilon_{i,t} \quad (3)$$

$Conflict_{i,t}$  is the conflict variable and  $PSVul_{i,t}$  is the vulnerability of countries to food price shocks. The equations 1 to 3 of our model are estimated with the ordinary least squares method (OLS). This estimator is, however, biased as a consequence of unobserved heterogeneity of countries. We hypothesize that the latter is either addressed by fixed effect (FE) and / or random effect (RE) estimators.

### 3.2 Data Sources and Description of Variables

The data used in this study cover the period from 1960 to 2008 for 71 developing countries. The data on population growth, income per capita and proportion of undernourished people are from World Development Indicators (2011). Those on democratic institutions, civil conflicts, rainfall and food supply come respectively from Polity IV (2010), Center for Systemic Peace (2010), Guillaumont and Simonet (2011) and Food and Agriculture Organization (2011).

Income per capita is measured by GDP per capita, which is in constant US dollars. Population growth is the annual growth rate of the population. We use the index of polity 2 to appreciate the degree of democracy in a country. The indicator of democracy is characterized by the effective existence of institutional rules and the presence of institutions enabling citizens to express their expectations and choose political elites. The autocracy is characterized by the absence or the restriction of political competition, economic planning and control. The exercise of the power is slightly constrained by institutions and the leaders are only selected within a “political elite”. Civil conflicts are defined as the magnitude score of episodes of civil warfare involving the country.

### *3.2.1 Food Security*

Regarding the food security indicators, we use food supply and proportion of undernourished people because the global hunger index, which is currently considered the best indicator of food security, is not available over the long period of time. The proportion of undernourished people is the percentage of people who do not have access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. This indicator takes into account the amount of food available per person nationally and the magnitude of inequality in access to food. Food supply is from the Food Balance Sheets produced by FAO for every country, which gives the quantity of food available for human consumption. For each primary commodity and a number of processed commodities potentially available for human consumption, food balance sheets show the sources of supply and their utilization. The total quantity of foodstuffs produced in a country added to the total quantity imported and adjusted to any change in stocks that may have occurred since the beginning of the reference period gives the supply available during that period. On the utilization side, a distinction is made between the quantities exported, fed to livestock, used for seed, processed for food use and non-food use, lost during storage and transportation, and food supplies available for human consumption. The per capita food supply of each food item available for human consumption is then obtained by dividing the quantity of the food items concerned by the population actually partaking of it. In other words, food supply is calculated as the difference between, on the one hand, production, the trade balance (imports – exports) and any change in stocks, and on the other hand, all utilizations other than human consumption (seed, livestock feed, etc.). In our paper, we selected the main cereals (maize, rice, sorghum, millet and wheat), soybeans and sugar for the calculation of food supply. These commodities represent an important proportion in the population's food in most of developing countries. Food supply obtained is a simple average of food supplies of selected commodities expressed in kcal/person/year.

### *3.2.2 Climatic Variability*

Climatic variability is measured by rainfall variability. It is the standard deviation of the growth rate of rainfall, which is frequently used in the economic literature. Rainfall variability is defined as the five-year rolling standard deviation of the growth rate of rainfall series. We perform robustness tests using an alternative indicator and measure of climatic variability. First, we use the average deviation in absolute value of the distribution of rainfall relative to its mean or to its long-

term trend (1960-2008). Second, we also perform the impact of asymmetric shocks and extreme variability of rainfall on food security using the four-order moment of rainfall. Third, we check the robustness of estimates by using another database (Mitchell et al. 2004).

### *3.2.3 Food Price Shocks Vulnerability*

We construct the variable of vulnerability to food price shocks using the procedure developed by De Janvry and Sadoulet (2008) and Combes et al. (2012). According to these authors, countries are vulnerable to food price shocks if they meet the following three criteria: (1) high food dependency, (2) a high food import burden and (3) low income.

High food dependency, measured by the share of total food imports in the total household consumption, highlights the importance of food in the basket of goods consumed by the representative household in a given country. A large share of food items in the basket means that the household will be hit by an increase in food prices. High food import burden, measured by the ratio of food imports to total imports, emphasizes the strong dependency of a country on the food imports. Level of income, measured by GDP per capita stresses the capacity of a country to constitute food safety nets for domestic consumers. To calculate the vulnerability index, we use the principal component analysis (PCA) applied to three variables: the ratio of food imports to total household consumption, the ratio of total imports to total imports of goods and services and the inverse of the level of GDP per capita. We use the inverse of the level of GDP per capita to be sure that the level of development is negatively correlated with the degree of vulnerability to food price shocks. We normalize the vulnerability index so that it ranges between 0 and 10, with higher values corresponding to high levels of vulnerability. The variables used to calculate the vulnerability index are from World Development Indicators (2011).

## **4 Results**

### **4.1 Results of Baseline Equation**

Table 20 shows the results of the effects of rainfall variability on food insecurity with different econometric methods: ordinary least squared (OLS), fixed effects (FE) and random effects (RE). The results of the OLS method are in the columns (1) and (2) and they do not take into account the unobserved heterogeneity of countries. This justifies the fact that we apply fixed effects (columns 3 and 4) and random effect (columns 5 and 6) estimators. The Hausman test shows that the fixed effect model is more appropriate than the random effect model.

Income per capita has a positive effect on food supply. Our results are similar to previous studies (Smith and Haddad 2000). Indeed, the economic resource availabilities increase the capacity of countries to meet the food needs through an increase in national production and/or import foods. The population size reduces food supply. This result is similar to Malthus' (1992) intuition that population growth can reduce food supply through a high pressure on agricultural resources and a negative effect on agricultural productivity. Democracy seems to have no effect on food supply. This surprising result may be explained by the fact that democratic institutions may be correlated with economic development that influences food supply. According to Smith and Haddad (2000), the more democratic a country, the greater the part of the resources that may be spent on agricultural investments and food supply.

Rainfall variability has a negative and significant effect on food supply. These results can be explained by several arguments. Firstly, changing rainfall patterns is a source of high uncertainty with regards to food production. This increases fluctuations in agricultural production and reduces households' incomes. For countries that depend on the weather conditions (rain-fed agriculture) for agriculture production, rainfall variability has a negative effect on food production and availability. Second, by reducing agriculture production in developing countries, rainfall variability reduces agricultural incomes and hence negatively affects economic growth (Dell, Jones, & Olken 2008). These countries have a limited ability to purchase food in international markets (food import). In other words, rainfall volatility can reduce the national food supply (food production and import) and increase food insecurity.

**Table 20:** Impacts of rainfall variability on food supply

Dependent variable	Food Supply					
	OLS (1)	(2)	FE (3)	(4)	RE (4)	(6)
Rainfall instability	-0.0176** (-2.110)	-0.0194*** (-2.719)	-0.0168** (-2.365)	-0.0179*** (-2.802)	-0.0176** (-2.468)	-0.0194*** (-2.986)
Rainfall	-0.0165 (-0.322)	0.0209 (0.374)	0.0798 (1.000)	0.148** (2.036)	0.0165 (1.372)	0.0209** (2.403)
Income per capita	0.177*** (5.220)	0.107*** (2.763)	0.149*** (5.457)	0.0557** (2.079)	0.177*** (7.457)	0.107*** (4.533)
Population growth	-0.0102 (-0.835)	-0.0257 (-1.077)	-0.00831 (-0.765)	-0.0300*** (-2.816)	-0.0102 (-0.955)	-0.0257** (-2.414)
Democratic institutions	0.000113 (0.0296)	0.000476 (0.144)	-0.00115 (-0.289)	-0.000663 (-0.185)	0.000113 (0.0297)	0.000476 (0.136)
Intercept	4.789*** (10.48)	4.780*** (9.933)	4.311*** (7.515)	4.238*** (7.994)	4.789*** (13.77)	4.780*** (13.81)
Temporal dummies	No	Yes	No	Yes	No	Yes
Observations	517	517	517	517	517	517
Countries	71	71	71	71	71	71
R-squared			0.079	0.289		

Note: t-statistics are presented in parentheses under the estimated coefficients. \*\*\*, \*\* and \* indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. The study period is 1960-2008

**Table 21:** Impacts of rainfall variability on food supply: adding control variables

Dependent variable	Food Supply				
	(1)	(2)	(3)	(4)	(5)
Rainfall instability	-0.0179*** (-2.802)	-0.0167*** (-2.899)	-0.0140** (-2.308)	-0.0180*** (-2.814)	-0.0196** (-1.976)
Rainfall	0.148** (2.036)	0.122** (2.443)	0.118* (1.702)	0.236 (0.833)	0.110 (0.909)
Income per capita	0.0557** (2.079)	0.0688*** (2.827)	0.0785*** (3.060)	0.0555** (2.069)	0.0233 (0.579)
Population growth	-0.0300*** (-2.816)	-0.0165* (-1.694)	-0.0237** (-2.339)	-0.0299*** (-2.808)	-0.0547** (-2.241)
Democratic institutions	-0.000663 (-0.185)	-0.00200 (-0.617)	-0.000159 (-0.0467)	-0.000665 (-0.185)	0.000497 (0.0940)
Cereal production land		0.259*** (9.772)			
Arable land			0.269*** (6.983)		
Rainfall squared				-0.00755 (-0.321)	
Exchange rate (REER)					-0.0242 (-1.449)
Intercept	4.238*** (7.994)	0.796 (1.335)	3.754*** (7.391)	3.999*** (4.370)	4.826*** (5.606)
Observations	517	517	517	517	517
Countries	71	71	71	71	71
R-squared	0.289	0.417	0.361	0.289	0.299

Note: t-statistics are presented in parentheses under the estimated coefficients. \*\*\*, \*\* and \* indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. The study period is 1960-2008

The next step consists of adding other control variables to check the robustness of results to changes in the baseline model: cereal production land, arable land, squared term of rainfall level and real effective exchange rate. The results of Table 21 show that rainfall variability has a negative effect on food supply. The coefficient associated with rainfall variability is negative and significant. However, the results obtained for cereal production land (column 2) and for arable land (column 3) are positive and significant. Thus, a policy allowing better land use increases food production and supply. The real effective exchange rate has no effect on food supply. We include the squared term of rainfall level to test a non-linear relationship between rainfall level and food supply because we suppose that too much

rainfall may reduce food supply. The results show that rainfall squared has a positive but not a significant effect on food supply.

## **4.2 Heterogeneity on the Impact of Climatic Variability**

In this section, we identify the potential heterogeneities in the relationship between climatic variability and food security. First, we test to determine if the impact of climatic variability can be different depending on whether the country was under conflict. Second, we analyse the impact of climatic variability on food security in the context of food price shock vulnerability.

### *4.2.1 The Importance of Civil Conflicts*

We suppose that the impact of climatic variability on food security is high for countries that are in conflict. We test this hypothesis by adding to our estimations the variable of civil conflicts and an interactive term (rainfall variability\*civil conflicts). The results of Table 22 show that civil conflicts have negative effect on food supply (column 2). Indeed, civil conflicts can negatively affect harvests and reduce active population in the agricultural sector because the armed leaders can recruit farmers by offering them high incomes. This leads to a decrease in food availability through the collapse of agricultural production.

We also find that the impact of rainfall variability on food supply is more important for the countries in conflict (column 3). A characteristic of civil conflicts is its negative effect on market access, political and social networks. First, civil conflicts destroy infrastructure, social services, assets and livelihoods, social cohesion, institutions and norms, and they displace populations and create fear and distrust. In addition, civil conflicts disrupt the farming systems (irrigation schemes) and production (crop production, livestock production and off-farm activities) operated by households. Second, market disruption increases difficulties with regards to households going to market to sell and buy goods, and this leads to a loss of earnings. Third, civil conflicts have negative effects on economic growth by reducing investments and economic infrastructures. This can considerably reduce government's revenues (e.g. tax revenue) and significantly weaken its ability to "invest in people", for instance to provide better nutrition and on-the-job training that would lead to improved living conditions. These effects can be factors of the poverty trap (Kremer & Miguel 2007), increasing vulnerability and food insecurity.

Climatic variability is likely to increase this vulnerability and dampen livelihoods of households affected by civil conflicts. Indeed, the destruction of assets caused by civil conflicts, as well as unstable economic, social and political environments, will significantly impact the ability of countries to confront climatic variability. In other words, the effects of climatic variability on food supply are more severe in the countries under conflict.

**Table 22:** impact of climatic variability on food security: importance of civil conflicts

Dependent variable	Food supply		
	(1)	(2)	(3)
Rainfall instability	-0.0179*** (-2.802)	-0.0177*** (-2.795)	-0.0269** (-2.343)
Rainfall	0.148** (2.036)	0.133* (1.842)	0.149** (2.021)
Rainfall volatility * Civil conflicts			-0.0181** (-2.250)
Civil conflicts		-0.397*** (-2.853)	-0.355** (-2.519)
Income per capita	0.0557** (2.079)	0.0688** (2.549)	0.0563** (2.041)
Population growth	-0.0300*** (-2.816)	-0.0263** (-2.469)	-0.0299*** (-2.789)
Democratic institutions	-0.000663 (-0.185)	-0.00114 (-0.319)	-0.000681 (-0.190)
Intercept	4.238*** (7.994)	4.815*** (8.547)	4.228*** (7.932)
Observations	517	517	517
Countries	71	71	71
R-squared	0.289	0.302	0.307

Note: t-statistics are presented in parentheses under the estimated coefficients. \*\*\*, \*\* and \* indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. The study period is 1960-2008

#### 4.2.2 The Importance of Food Price Shocks Vulnerability

In this section, we test the potential effects of climatic variability on food supply in a context of food price shocks vulnerability. Climatic variability can increase the vulnerability of countries to food price shocks. Indeed, climatic variability can affect agricultural productivity and production and hence households' incomes because income from agriculture represents a large proportion of the total household's income in developing countries. As households' incomes are negatively affected by climatic variability, the part of food expenses



on total consumption (food dependency) increases. Moreover, by affecting economic growth (Dell et al. 2008), climatic variability can lower the resources' capacities and increase the food import burden of countries. Hence the negative effect of climatic variability on food supply can increase the vulnerability of countries to food price shocks.

Table 23 presents the results of the non-linear impact of climatic variability on food supply, depending upon the level of vulnerability of countries to food price shocks. The results indicate that the coefficients associated with the variable of vulnerability to food price shocks and to the interactive term (rainfall variability\*price vulnerability) are negative and significant. This result reveals that the negative impact of climatic variability on food supply increases with the level of vulnerability of countries to food price shocks. Countries that are more vulnerable to food price shocks are less able to maintain food supply. These results can be explained by the fact that vulnerable countries have very little policy space and limited fiscal and administrative capacity to organize safety nets to import food and protect their population from climatic shocks (De Janvry & Sadoulet 2008). Indeed, policy instruments available to facilitate food accessibility by increasing agricultural production or food imports are limited or ineffective.

**Table 23:** impact of climatic variability on food security: vulnerability to food price shocks

Dependent variable	Food supply		
	(1)	(2)	(3)
Rainfall instability	-0.0179*** (-2.802)	-0.0184** (-2.481)	-0.0259** (-2.382)
Rainfall	0.148** (2.036)	0.181*** (2.704)	0.177*** (2.653)
Income per capita	0.0557** (2.079)	-0.241*** (-5.474)	-0.235*** (-5.329)
Population growth	-0.0300*** (-2.816)	-0.0854*** (-5.580)	-0.0808*** (-5.215)
Democratic institutions	-0.000663 (-0.185)	0.00305 (0.909)	0.00260 (0.774)
Food Price vulnerability		-0.0032*** (-6.876)	-0.00300*** (-5.961)
Rainfall volatility * Food Price vulnerability			-0.0018** (-2.371)
Intercept	4.238*** (7.994)	6.179*** (11.27)	6.162*** (11.27)
Observations	517	434	434
Number of countries	71	69	69
R-squared	0.289	0.430	0.435

Note: t-statistics are presented in parentheses under the estimated coefficients. \*\*\*, \*\* and \* indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. The study period is 1960-2008

### 4.3 Robustness Checks

#### 4.3.1 Alternative Indicators of Climatic Variability

In our previous estimations, we use rainfall variability defined as the standard deviation of the growth rate of rainfall. We check the robustness of our results using alternative measures of climatic variability. Rainfall variability may be defined by the average deviation in absolute value of the distribution of rainfall relative to its mean or to its long-term trend. Moreover, we use another data source on climate. It is the database developed by Mitchell et al. (2004). The results presented in Table 24 reveal that the negative effect of rainfall variability on food supply increases with the level of vulnerability of countries to food price shocks, regardless the variability indicator or the database used.

### 4.3.2 Inertia of Food Supply

It is also of interest to discover if food supply in developing countries is characterized by inertia phenomena. In other words, we want to know if the lagged level of food supply is a potential determinant of the current level of food supply. We check this by including the lagged level of food supply in our baseline equation. The dynamic nature of the specified model requires system- Generalized Method of Moments (GMM) estimation from Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998). The results in Table 25 show that the lagged level of food supply has no effect on its current level (columns 2 and 3). There is no inertia for food supply in developing countries.

**Table 24:** Impact of climatic variability on food security: alternative indicator of climatic variability and another database

Dependent variable	Food supply		
		Mitchell Database	Other indicator Mean deviation
	(1)	(2)	(3)
Rainfall instability	-0.0179*** (-2.802)		
Rainfall	0.148** (2.036)	0.0998 (1.418)	
Income per capita	0.0557** (2.079)	0.0743** (2.426)	0.0724*** (2.597)
Population growth	-0.0300*** (-2.816)	-0.0144 (-1.446)	-0.0308** (-2.237)
Democratic institutions	-0.000663 (-0.185)	0.00302 (0.869)	-0.000963 (-0.220)
Rainfall instability		-0.0433*** (-3.379)	
Rainfall instability			-0.0466** (-2.532)
Constant	4.238*** (7.994)	4.600*** (8.613)	5.372*** (24.03)
Observations	517	390	301
Number of countries	71	71	37
R-squared	0.289	0.236	0.412

Note: t-statistics are presented in parentheses under the estimated coefficients. \*\*\*, \*\* and \* indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. The study period is 1960-2008

**Table 25:** Impact of climatic variability on food security: inertia of food supply

Dependent variable	Food Supply		
	Fixed effect	GMM-system One step	GMM-system Two step
	(1)	(2)	(3)
Lagged food supply		0.0260 (1.330)	0.0185 (0.825)
Rainfall instability	-0.0179*** (-2.802)	-0.0152*** (-3.142)	-0.0124** (-2.438)
Rainfall	0.148** (2.036)	0.0133** (2.204)	0.0335* (1.799)
Income per capita	0.0557** (2.079)	0.0706** (2.065)	0.0515** (2.191)
Population growth	-0.0300*** (-2.816)	-0.0151 (-0.840)	-0.0126 (-0.653)
Democratic institutions	-0.000663 (-0.185)	0.00339 (1.344)	0.00362* (1.772)
Intercept	4.238*** (7.994)	0.825** (2.115)	0.962* (1.867)
Observations	511	511	511
R-squared	0.289		
Countries	71	71	71
AR(1)		0.009	0.007
AR(2)		0.16	0.19
Hansen test		0.28	0.28
Instruments		52	52

Note: t-statistics are presented in parentheses under the estimated coefficients. \*\*\*, \*\* and \* indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. The study period is 1960-2008.

### 4.3.3 Complementary Indicator of Food Security

Given that food security is a multidimensional concept, we use another complementary indicator to check the robustness of our results: the proportion of undernourished people. A person is malnourished if his/her average energy intake is less than the minimum necessary to maintain physical and moderate activity. Table 26 presents the results of the impact of climatic variability on the proportion of undernourished people. We find that rainfall variability increases the proportion of undernourished people. The results are strengthened by

adding other control variables (rainfall squared, arable land, cereal production land, food prices and food price volatility).

**Table 26:** Impact of climatic variability on proportion of undernourished people

Dependent Variable	Proportion of undernourished people			
	(1)	(2)	(3)	(4)
Rainfall instability	-0.0205** (-2.586)	-0.0200** (-2.551)	-0.0197** (-2.527)	-0.0191** (-2.451)
Rainfall	0.205*** (3.461)	0.251*** (3.532)	0.211*** (3.654)	0.204*** (3.467)
Income per capita	0.509*** (10.30)	0.499*** (10.00)	0.548*** (11.94)	0.510*** (10.24)
Population growth	0.0219 (0.677)	0.0245 (0.723)	0.0152 (0.693)	0.0209 (0.655)
Democratic institutions	-0.000409 (-0.0382)	-9.80e-05 (-0.00916)	0.00322 (0.315)	0.000251 (0.0232)
Rainfall square		-3.14e-08 (-0.820)		
Arable land			0.0126*** (3.099)	
Cereal production land				0.0277** (2.472)
Intercept	4.685*** (8.022)	4.355*** (6.933)	5.132*** (9.459)	4.717*** (7.985)
Observations	314	314	314	314
Countries	79	79	79	79
R-squared	0.157	0.160	0.231	0.188

Note: t-statistics are presented in parentheses under the estimated coefficients. \*\*\*, \*\* and \* indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. The study period is 1960-2008

#### 4.3.4 Heterogeneity for African Countries

We are interested in the effects of climatic variability on food security in the context of Sub-Saharan African countries. Indeed, these countries have two main characteristics: (i) they are more vulnerable to food price shocks because they are net food importers and they are less resilient, and (ii) they are more vulnerable to climatic variability (Guillaumont & Simonet 2011; Wheeler 2011<sup>23</sup>). The predominance of rain-fed agriculture in most of the Sub-Saharan

<sup>23</sup> Wheeler (2011) shows that, in the top 25 states, 19 are from Sub-Saharan Africa.

African countries means that food systems are highly sensitive to rainfall variability. Table 27 shows the results of the effect of rainfall variability on food supply in developing countries in general and in Sub-Saharan African countries in particular. The results show that the negative effect of rainfall variability on food supply is higher in Sub-Saharan African countries than in other developing countries (columns 1 and 3). In addition, rainfall has a positive and significant effect on food supply in Sub-Saharan African countries. The adverse effect of rainfall variability on food supply is high in the context of food price vulnerability for Sub-Saharan African countries (column 4).

**Table 27:** Impact of climatic variability on food security in African Countries

Dependent Variable	Food Supply			
	Developing Countries		African Countries	
	(1)	(2)	(3)	(4)
Rainfall instability	-0.0179*** (-2.802)	-0.0259** (-2.382)	-0.0276*** (-3.056)	-0.0363*** (-3.463)
Rainfall	0.148** (2.036)	0.177*** (2.653)	0.638*** (2.969)	0.777*** (2.769)
Income per capita	0.0557** (2.079)	0.235*** (5.329)	0.279** (2.208)	0.308** (2.321)
Population growth	-0.0300*** (-2.816)	-0.0808*** (-5.215)	-0.0236** (-2.456)	-0.0525** (-2.417)
Democratic institutions	-0.000663 (-0.185)	0.00260 (0.774)	-0.00826 (-1.027)	-0.00581 (-0.525)
Price vulnerability		-0.00300*** (-5.961)		-0.00527** (-2.437)
Rainfall volatility * Price vulnerability		-0.00018** (-2.371)		-0.00032** (-2.326)
Intercept	4.238*** (7.994)	6.162*** (11.27)	2.857*** (6.568)	3.957*** (10.468)
Observations	517	434	189	140
Countries	71	69	25	24
R-squared	0.289	0.435	0.468	0.236

Note: t-statistics are presented in parentheses under the estimated coefficients. \*\*\*, \*\* and \* indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. Temporal dummies are included. The study period is 1960-2007.

#### *4.3.5 Asymmetric and Extreme Event Effects*

Previous estimates were based on analysis of the impact of rainfall variability on food security but are silent about the asymmetric and extreme events effects. However, there are important differences between the effects of positive and negative rainfall variability on food supply. Table 28 presents the results of negative and positive rainfall variability on food supply. The results suggest that negative rainfall variability is associated with a food supply reduction whereas positive rainfall variability is associated with a food supply improvement (column 2). We also find that rainfall variability is asymmetric because the losses due to negative rainfall variability are not perfectly compensated by the gains due to positive rainfall variability.

We are also interested in the effects of extreme rainfall variability on food supply. We use the skewness coefficient which is the four-order moment of rainfall. This coefficient obtains information about the frequency of the extreme events. The results of Table 28 illustrate that extreme rainfall variability has a negative impact of food supply (column 3). The impact of extreme rainfall variability is largely higher than the impact of normal rainfall variability on food supply.

**Table 28:** Analysis of asymmetric and extreme rainfall variability effects

Dependent Variable	Food Supply		
	(1)	(2)	(3)
Rainfall instability	-0.0179*** (-2.802)		
Positive rainfall instability		0.0540** (2.017)	
Negative rainfall instability		-0.143*** (-4.836)	
Extreme rainfall instability			-0.0534*** (-3.800)
Rainfall	0.148** (2.036)	0.686*** (5.244)	0.125*** (3.854)
Income per capita	0.0557** (2.079)	0.0432* (1.791)	0.0559** (2.009)
Population growth	-0.0300*** (-2.816)	-0.0515*** (-4.732)	-0.0900** (-2.519)
Democratic institutions	-0.000663 (-0.185)	-0.000817 (-0.229)	-0.0568 (-0.0606)
Intercept	4.238*** (7.994)	9.407*** (10.84)	4.516*** (9.214)
Observations	517	626	461
R-squared	0.289	0.426	0.237
Countries	71	71	71

Note: t-statistics are presented in parentheses under the estimated coefficients. \*\*\*, \*\* and \* indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. Temporal dummies are included. The study period is 1960-2008.

## 5 Conclusion

This paper contributes to the existing literature on climatic variability and food security. The main objective of paper is to analyse the effects of climatic variability on food security using panel data during the period from 1960 to 2008 for 71 developing countries. The results of our estimates are as follows: first, we show that climatic variability has a negative effect on food security regardless of the food security indicator used (food supply and proportion of undernourished people). We also find that the adverse effect of climatic variability on food security is higher for Sub-Saharan African countries than for other developing countries. These results correspond with previous authors ( Dilley et al. 2005; Haile 2005) . Second, the



negative effect of climatic variability on food security is exacerbated in countries under conflict. Third, the effects are high for countries that are vulnerable to food price shocks.

Our results are important in terms of recommendations for economic policies. An important intervention to reduce food insecurity would be the implementation of effective mitigation strategies of risks. In line with this, it is imperative to promote measures that enhance the food production systems in the developing countries in order to increase their capacity to withstand the rainfall instability.

One approach would be to invest in agricultural research, extension and methods for reducing food production losses related to climatic variability. Given the large uncertainties about future rainfall patterns in many developing countries, careful consideration should be given to major investments in infrastructure to support irrigation and water resources development in order to limit the effects of a reduction in food production.

Another approach, probably important for international community, is to help developing countries, particularly the least developing countries (LDCs) through aid automatic mechanisms which will be related to the magnitude of effects of climatic variability on food security. For example, the international community may finance stabilization mechanisms (government budget or development projects for the regions adversely affected by climatic variability) with aid (named "*climatic aid*"). When the effect of climatic variability is negative and more important, the level of climatic aid will have to increase. This climatic aid can be given to developing countries that are both more exposed to the effects of climatic variability and vulnerable to food price shocks. The third way to reduce the magnitude of effects of climatic shocks in the developing countries is to diversify the structure of their economy.

## 6 Appendix

### Appendix 7: Variables definition and sources

Variables	Definition	Source
Food supply	Food supply refers to the total amount of the commodity available as human food during the reference period. Food supply are the total of food Production + food import- food exports+ food stocks variation.	FAO (2011)
Percentage of total undernourished population	The percentage of the population whose food intake is insufficient to meet dietary energy requirements continuously.	WDI (2011)
Rainfall volatility	It is the absolute deviation of the yearly average of rainfall from its own trend (long term mean of rainfall 1950-2008).	Calculated by the authors using the data from CERDI (2011)
Rainfall	It is the yearly average of rainfall.	CERDI (2011))
Food Price vulnerability	The FPV index is a weighted <sup>24</sup> average of the following variables: the ratio of food imports to total household consumption; the ratio of total food imports to total imports of goods and services and the inverse of the level of GDP per capita.	Authors from World Development Indicators (2011)
Civil conflicts	Civil conflicts are defined as the magnitude score of episode(s) of civil warfare involving that state in that year.	(Center for Systemic Peace 2010)
Income per capita	Gross Domestic Product per capita	WDI (2011)
Population growth	annual population growth rate	WDI (2011)
Democratic institutions	The Polity Score captures the regime authority spectrum on a 21-point scale ranging from -10 (hereditary monarchy) to +10 (consolidated	Polity IV (2010)

<sup>24</sup> To calculate this index, we use the principal component analysis (PCA) applied to three variables.

	democracy).	
Agricultural land	Agriculture area as percentage of total land area	WDI (2011)
Arable land	Arable area as percentage of total land area	WDI (2011)
Cereal production land	Cereal <sup>25</sup> production area refers to harvested area or Land under cereal production	WDI (2011)
Real effective exchange rate (REER)	REER is the nominal effective exchange rate (a measure of the value of a currency against a weighted average of several foreign currencies) divided by a price deflator or index of costs.	IFS (2011)

**Appendix 8:** Descriptive statistics of variables

Variable	Mean	Std. Dev.	Min	Max
Food supply	389.04	153.74	18.63	1318.99
Rainfall variability	10.37	10.35	0.001	118.69
Rainfall mean deviation	-4.91 10 <sup>5</sup>	812.15	-1183.48	2682.76
Rainfall	1200.57	812.04	16.81	3882.82
Shock price vulnerability	46.15	64.45	0.84	381.48
Civil conflict	0.03	0.33	0	4
Per capita GDP	6396.13	10374.16	84.28	95885.27
Population growth	1.88	1.54	-4.64	16.24
Democratic institutions	-0.52	5.64	-10	10
Land under cereal production	2.22 10 <sup>7</sup>	7.10 10 <sup>7</sup>	0	6.95 10 <sup>8</sup>
Agricultural land	37.67	21.19	0	90.55
Arable land	13.30	12.94	0	71.65
Agricultural irrigated land	10.56	13.73	0	71.58
Undernourished population	15.32	13.71	5	70
Real effective exchange rate	460.20	4391.8	40.85	97285.19

Source: calculations of the authors.

<sup>25</sup> Cereals include wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat and mixed grains.

**Appendix 9:** List of countries

Albania	Honduras	Nicaragua
Argentina	Croatia	Nepal
Azerbaijan	Haiti	Pakistan
Burundi	Indonesia	Panama
Burkina Faso	India	Peru
Bangladesh	Iran	Philippine
Bulgaria	Jamaica	Paraguay
Bolivia	Kenya	Rwanda
Brazil	Kowait	Sudan
Botswana	Liberia	Senegal
Chile	Libya	El Salvador
China	Sri Lanka	Syria
Cote d'Ivoire	Lithuania	Togo
Cameroon	Morocco	Thailand
Colombia	Moldavia	Trinidad and Tobago
Costa Rica	Madagascar	Tanzania
Algeria	Mexica	Uganda
Ecuador	Mali	Ukraine
Egypt	Mongolia	Uruguay
Ethiopia	Mozambique	Venezuela
Fiji	Mauritania	South Africa
Gabon	Malaysia	Zambia
Ghana	Niger	Zimbabwe
Guatemala	Nigeria	



## **Chapter 4: Do Environmental Policies Hurt Trade Performance<sup>26</sup>?**

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<sup>26</sup> This chapter was written in collaboration with Prof Jean Louis Combes and Prof. Pascale Combes Motel.



### **Abstract**

This chapter is a contribution to the controversial literature on the relationship between environmental policies and international trade. It provides new evidence about the effect of a gap in environmental policies between trading partners on trade flow. A sample of 122 countries in the period 1980-2010 is considered. While previous papers have used partial measures of environmental regulations (input-oriented or output-oriented indicators), we compute an index of a country's environmental policy in this chapter. Results suggest that a similarity in environmental policies has no effect on bilateral trade flows. Moreover results do not appear to be conditional on the level of development of the countries trading or on the characteristics of exported goods (manufactured goods and primary commodities).

*Keywords: Trade, Environmental policies, Gravity model*

*JEL Classification: F14, F18, Q56*





## 1 Introduction

In the 1990s, the debate around NAFTA revived the debate on trade and the environment (Grossman & Krueger 1991). Antweiler et al. (2001) addressed theoretically the question the question of whether freer trade hurts the environment, and concluded that it did not. This result was in the spirit of the Doha Round launched in 2001, which objectives comprise specific discussions on trade and the environment. This incantatory affirmation of win-win outcomes for trade, the environment and sustainable development, which has turned into the “Doha blues” (K. A. Jones 2010; Abbas 2011), is at odds with the prevailing idea of increasing ecological scarcities and environmental degradation (E. Barbier 2011; Rockström et al. 2009). Indeed, knowledge and the analysis of global environmental threats improved substantially and has steadily fuelled concerns about environmental degradation. For instance, the Stern Review on the Economics of Climate Change (N. Stern 2007) highlighted the effects of climate change on global welfare, economic growth prospects and development. Climate change certainly entails a differentiated effect on developing countries (Mendelsohn et al. 2006). It may threaten the ability of developing countries to target the Millennium Development Goals set for 2015.

Countries have been encouraged to implement environmental policies particularly since the 1972 meeting of the United Nations *Conference on the Human Environment* in Stockholm. Since then, environmental policies have been enforced in many developed countries. The US Environmental Protection Agency was created in 1970 and accompanied the “command and control era” during which several amendments were introduced to US environmental regulation (Portney 2007). In the same decade, the first EU Environmental Action Plan was decided, in 1973, and initiated the EU environmental policies which had tended to integrate within more global strategies such as the World Conservation Strategy advocated by the IUCN. Countries have committed themselves to international environmental agreements. In the wake of the Rio conference in 1992, a new generation of those agreements came into force and the Kyoto Protocol is the first example of a binding commitment to an environmental issue even though its scope appeared to be limited. The debate about the effect of environmental policies, either domestically rooted or induced by international law on trade and growth, is still lively.

Hallegatte et al. (2012) argue that environmental policies may contribute to economic growth and sustainable development. First, environmental policies that sustain and enhance natural capital assets (fisheries, soils and forests) on which populations rely on for their livelihoods, have the potential to create jobs and therefore increase incomes. For instance green investments may potentially increase employment in the energy sector i.e. wind energy, photovoltaic and biofuels sectors (Zenghelis 2011). Secondly, environmental policies may generate externalities. Economic activities in the tourism sector, which hinges upon natural assets, may increase population income and allow them to increase their resilience. Better air and water quality are crucial for population health and thus labour productivity. Thirdly, environmental policies can change the production frontier through innovation development and dissemination. Several authors believe that strong environmental policies can stimulate competition and exports through innovations (Porter 1991). This is the so-called Porter hypothesis which has been the subject of several theoretical developments within the endogenous growth framework (Acemoglu et al. 2012).

On the other hand, it may be argued that environmental policies entail not only transaction costs (McCann et al. 2005) but potentially impede competitiveness. This is a consequence of the pollution haven hypothesis, according to which a firm's localisation decisions are partly based on weak or poorly enforced environmental rules. Non-stringent environmental policies and a race to the bottom supposedly create comparative advantages. Empirical evidence of the pollution haven hypothesis is mixed (Grether & Melo 2003) although recent results do not invalidate it (Kellenberg 2009; Levinson & Taylor 2008; Millimet & Roy 2011).

This chapter is an attempt to add to the literature on the effect of environmental policies on trade. The contribution is two-fold. First, contrary to most previous studies that analyse the effect of domestic environmental policies on trade (total or bilateral), the effect of a similarity in environmental policies on trade flows between partner countries is highlighted. Indeed, countries either rely on different environmental policy instruments or are engaged in different international agreements. This may result in different policies and results. Secondly we do not focus on the measurement of environmental policies which are usually labelled as either input-oriented or output-oriented indicators. The former derive, for instance, from public research and development expenditure, investment expenditure in pollution abatement technologies, "green" taxes, or multilateral environmental agreements. The latter more simply

measure environmental outputs such as emission intensities, emissions per capita, or soil or water quality. Input oriented indicators are not always available for all countries however, and output oriented indicators may not solely depend on policies with environmental purposes. We therefore propose here to consider a modified output oriented index that is an index of revealed environmental policies. It is hypothesised that environmental degradation is partly determined by a country's structural characteristics and partly by environmental policies i.e. domestic efforts for mitigating environmental degradation. Revealed policies consist of measuring environmental degradation that is solely the result of a country's efforts. We use a methodology developed in other papers which allows an estimation of domestic efforts (Combes & Saadi-Sedik 2006; Combes Motel et al. 2009; Boussichas & Goujon 2010; Guillaumont & Guillaumont 1988) in a manner reminiscent of the Chenery and Syrquin approach to identifying structural change (Chenery & Syrquin 1975).

Our results conclude that a gap in domestic efforts towards environmental protection between trading partners has no effect on exports for the period 1980-2010. We show that this effect is not conditional on the level of development of countries. The results do not depend on the characteristics of exported goods (manufactured and primary commodity goods). These results are robust to the inclusion of additional control variables, other measures of trade and environmental policy and alternative estimators.

The rest of the paper is organized as follows. Section 2 provides a literature review of the theoretical effects of environmental policies on bilateral trade and Section 3 contains a discussion of the methodology to compute domestic efforts for environmental protection. Section 4 presents data and empirical analysis. Section 5 presents results and the last section is devoted to concluding remarks and implications.

## **2 Relationship between environmental policies and trade**

This section reviews the way environmental policies may hamper or spur trade flows.

### **2.1 Environmental policies and trade costs**

Several authors (Kellenberg 2009; Levinson & Taylor 2008; Millimet & Roy 2011) believe that the implementation of environmental policies may reduce the competitiveness of economies. Environmental policies can take several forms, such as command and control or

market-based instruments, and can generate additional costs and burdens on domestic firms. If these costs are high, they may hurt the competitiveness of domestic firms compared to foreign ones operating under weaker environmental policies. Polluting firms may relocate from countries with stringent environmental regulation towards countries with weaker rules. This is known as the pollution haven hypothesis: weak environmental regulations are a source of comparative advantages and modify trade patterns towards dirty goods (Liddle 2001). Moreover, since environmental quality is a normal good, demand for environmental regulations may be higher in developed countries than in developing countries.

Theoretical models and studies suggest a negative link between environmental regulation costs and trade flows. Using a theoretical model where the manufacturing sector differs in primary factors (labour, capital) and pollution intensity, Levinson & M. S. Taylor (2008) show a positive relationship between pollution abatement costs and a country's imports. Peters et al. (2011) provide evidence of carbon leakage. They show that the implementation of environmental policies and agreements in developed countries has increased the imports of polluting intensive goods from developing countries. In addition to compliance costs (for example expenditures on control and new equipment monitoring), Ryan (2012) shows that environmental regulations increase costs and market power. For instance, sunk costs of entry of firms into U.S. markets have significantly increased under the Clean Air Act (CCA). Consequently incumbent firms have benefited from increased market power.

Few studies (Van Beers & Van Den Bergh 1997; Cagatay & Mihci 2006; Keller & Levinson 2002) found a negative effect of environmental regulation on trade patterns. Van Beers & Van Den Bergh (1997) highlight that a divergence between the environmental regulations of developing and developed countries negatively impacts pollution-intensive goods trade (mining, non-ferrous metals, or chemical products). Cagatay & Mihci (2006) found that they had a negative effect on pollution intensive goods. Using the propensity score matching method, Aichele and Felbermayr (2013) analyse the effect of Kyoto Protocol commitments on bilateral exports. They show that Kyoto commitment has cut the exports of Kyoto countries by 13 - 14%. Energy intensive industries such as iron and steel, non-ferrous metals, and organic and inorganic chemicals, are highly affected.

Moreover, according to Dean et al (2009), the attractiveness of environmental regulations to foreign investments in China is conditional on the investor's source country and the industry characteristics. The study concludes that investment from high income countries and non-polluting industries are not attracted by weak environmental regulations.

Tobey (1990) and Cole & Elliott (2003) do not evidence of any relationship between environmental regulations and pollution intensive industries, nor net exports. Trade flows are explained instead by differences in factor endowments (capital, labour, natural resources). A similar result was found by (X. Xu 2000). The lack of evidence in support of the negative effect of environmental regulations on trade may be explained with two reasons. For most industries, environmental costs are smaller than other costs and consequently the effect of environmental policies on international competitiveness are probably minor (Nordström and Vaughan (1999). Further, gains from trade are generally sufficient to pay for additional abatement expenditures and other regulatory costs. Jug & Mirza (2005) consider that the effect of environmental regulations is related to the degree of product differentiation. They show that environmental stringency has less effect on the trade of differentiated goods with a low price elasticity. Albrecht (1998) explains the non-negative impact of environmental regulations through the fact that many developed countries have diversified exports and that most studies do not focus on specific products.

## **2.2 Environmental policies and innovation**

Environmental policies may also have a positive effect on trade flows. Porter (1991) and Porter & Van der Linde (1995) explain that tougher environmental policies stimulate technological innovation, thereby increasing productivity and competitiveness. They dismiss the pollution haven hypothesis as a supposedly static perspective which therefore does not take in account the reactions and behaviours of firms confronted by environmental regulations. When firms face potentially high abatement costs, they will be incited to change production routines, invest in innovative activities and find new ways to achieve environmental objectives and product new marketable goods. They may become more aware of new methods of production that reduce production costs (through increased efficiency, decreased resource inputs) and increase the quality and competitiveness of products. This is

the so-called Porter hypothesis, according to which environmental policies may stimulate innovation opportunities, and improve the productivity and competitiveness of countries.

Three arguments may support the Porter hypothesis. The first one is the strategic effect inside firms. Sinclair-Desgagne & Gabel (1997) assume that firms have myopic behaviours. The implementation of environmental policy can incite them to reconsider existing routines and improve business performance. Xepapadeas & de Zeeuw (1999) for instance, found that environmental regulations such as emission taxes increase a firm's productivity and profits.

The second argument relies on strategic effects between firms. Mohr (2002) developed a theoretical model in which productivity gains are associated with learning by doing. In other words, the productivity of a new green technology is a function of the total accumulated experience in the industry. Because no firm is forced to bear the burden of adopting green technologies (the initial learning costs), governments may promote them with stringent environmental policies. By imposing environmental policies, the government may incite domestic industries to invest in research and development activities (Simpson & Bradford 1996; Greaker 2003). They can acquire strategic advantages and improve their competitiveness in international markets through better access to markets, the possibility of differentiating products or selling pollution-control technology (Lanoie et al. 2011). Using survey data from 78 European firms operating in the building and construction sector, Testa et al. (2011) showed that environmental policies (measured by inspection frequency) have a positive effect on investments in advanced technological equipment, innovative products and business performance. Albrecht (1998) evidences that countries with relatively active environmental regulatory (national ozone policy) have improved their competitiveness of CFC- using manufacturers. Similarly Costantini & Mazzanti (2012) show that, for the EU15 over the period 1996–2007, the high technology sector was positively affected by energy and environmental taxation whereas the more energy intensive medium and low technology sectors were not affected. Some authors (De Santis 2012; Trotignon 2011) believe that the positive effect of environmental regulations on trade flows may be related to multilateral environmental agreements (MEAs) or regional trade agreements which allow trade creation and the diffusion of environmental-related production standards.

The third argument is that the implementation of environmental policies may contribute to increasing environmental awareness and affect the preferences of consumers. Firms are forced to produce new goods in order to survive. Realising a literature review on theoretical foundations and empirical studies on the Porter Hypothesis, Ambec et al. (2013) show that several recent studies support it. These recent results are explained by a heightened social awareness and responsibility for sustainable development. In a world characterised by improving environmental performances, firms and industries are more able to become competitive and produce green goods.<sup>27</sup>

### **3 How to measure environmental policy?**

We review here existing indicators and propose a new measure.

#### **3.1 Existing indicators of environmental policies**

Input-oriented indicators are input efforts devoted to environmental protection. Several authors use public research and development expenditures, current investment expenditures in pollution abatement and control, energy tax, or the number of multilateral environmental agreements signed by countries, as proxies for environmental policies. However there are two limits to this approach: the enforcement of multilateral agreements and the lack of data on wide time and geographical coverage for some inputs.

Van Beers & Van Den Bergh (1997) believe that output oriented indicators are better proxies for environmental policies. Indicators used in the economic literature include emissions intensities (SO<sub>x</sub>, NO<sub>x</sub>, CO<sub>2</sub>, and SO<sub>2</sub>), emissions per capita, or other pollutants related to water or soil quality. The main limitation of these indicators is that output oriented indicators may depend on environmental policies as well as on structural factors. For instance, several determinants of pollution may be out of a government's hands. These are related to long term economic development, business cycles, demographic dynamics or international prices.

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<sup>27</sup> This effect is somehow in the same vein as the "pollution halo" hypothesis according to which better technologies and management, green preferences of consumers in developed countries raise environment friendly technology transfers and know-how. See Zarsky (1999) for a review.



We thus want to disentangle those structural factors from policies and measures dedicated to achieving better environmental quality. From our point of view, comparing observed to “structural” environmental degradation may deliver a proper measure of environmental policies.

### 3.2 An indicator of revealed environmental policies

This approach has been used by other authors. Combes & Saadi-Sedik (2006) built an indicator of a trade policy’s openness or revealed trade policy whereas Combes Motel et al. (2009) estimate an indicator of policies against deforestation. Structural environmental degradation is obtained by calculating the level of pollution a country should have as a result of its structural characteristics. The indicator of revealed environmental policy is the difference between observed pollution levels and structural pollution. It captures revealed environmental policies, based on their results. The main interest in this approach is that it provides a standardised measure of the environmental efforts of countries; it also avoids subjectivity in the choice and weighting in the combination of several environmental policy instruments. Another interest is that the measure of structural environmental degradation may be based on economic theory explaining environmental degradation.

More formally, let us assume that environmental degradation  $ED_{i,t}$  of country  $i$  at period  $t$  depend on a vector  $X_{i,t}$  of structural factors:

$$ED_{i,t} = \beta X_{i,t} + \varepsilon_{i,t} \tag{1}$$

The error term  $\varepsilon_{i,t}$  provides the measure of revealed environmental policies:

$$\varepsilon_{i,t} = ED_{i,t} - \beta X_{i,t} \tag{2}$$

Environmental policies are said to be efficient when the observed environmental degradation is lower than the predicted structural level i.e. when  $\varepsilon_{i,t}$  is significantly negative. This indicates that environmental policies are successful in the mitigation of environmental degradation. On the other hand, environmental policies fail when  $\varepsilon_{i,t}$  is significantly positive. This may be the outcome of policy as well as market failures. It is worth noting that since  $\varepsilon_{i,t}$  is the error term; its average value is zero: this indicator is relative.

### 3.2.1 How to identify structural and mixed determinants of environmental degradation

A measure of revealed environmental policies requires identification of the structural factors of environmental degradation. Table 1 classifies those structural factors: income per capita, population growth, economic growth and lagged level of emissions. Other factors of environmental degradation may be related to specific policies. These policies are of two sorts. First, environmental mitigation can be the result of domestic initiatives. For instance, environmental commitments, as defined by international environmental agreements, contribute to domestic environmental efforts. Secondly, environmental degradation is also influenced by other policies such as education policies, industrial policies or policies targeting more efficient institutions. The classification of other factors between structural determinants, domestic efforts of environmental protection and other policies may be questionable. These factors are trade openness, the real effective exchange rate (REER) and income inequality. Table 29 below summarises our characterisation of the determinants of environmental degradation.

**Table 29: Classification of main variables related to environmental degradation**

<i>Structural factors</i>	<i>Domestic Efforts for Environmental Protection</i>		<i>Mixed variables for structural factors and domestic efforts for environmental protection</i>
	<i>Policies for environment Protection</i>	<i>Policies for various objectives</i>	
Income per capita	International agreements and treaties on environment	Political institutions	Trade openness
Economic growth	National environmental Policies (taxes, etc)	Education Policies	Real Effective Exchange Rate (REER)
Lagged emissions per capita			Income inequality
Population growth			

### **3.2.1.1 *Income per capita***

The relationship between income per capita and environmental quality has been widely studied in literature. According to several authors, environmental quality first deteriorates and then improves as income per capita increases (Grossman & Krueger 1995; Antweiler, Copeland, & Taylor 2001). In other words, environmental quality may be considered a luxury good in the first stage of development. Poor people are more concerned with food and other essential needs and less concerned with environmental protection. At higher income levels, people want higher levels of environmental quality. Moreover, higher incomes enable higher public expenditure on environmental infrastructures, as well as environmental policies that drive private sector expenditure towards abatement technologies. Income per capital is a structural factor of environmental quality: it is often considered in the literature as an “underlying” factor that characterises overall economic conditions. Moreover, a nonlinear effect of income per capita can also be tested in accordance with the Environmental Kuznets Curve.

### **3.2.1.2 *Economic growth***

It is assumed that the economic climate or economic growth may have an ambiguous effect on environmental degradation for two reasons: a positive effect may be explained by structural change in the economy, from the industrialised sectors to the manufacturing and service sectors. A negative effect on environmental quality may be explained by a change of economic structure from agricultural to industrialised sectors. Moreover, when economic growth slows, countries are not incited to implement environmental policies.

### **3.2.1.3 *Population growth***

It is generally assumed that population pressure is a driver of environmental degradation. This idea is popularised by the well-known IPAT identity (Ehrlich & Holdren 1971). Access to food or to energy involves, for instance, emissions of greenhouse gases. Holdren (1991) shows the contribution of population growth to greenhouse gas emissions as being responsible for 40% (36%) of the increase in energy consumption (annual emissions growth) respectively. Shi (2003) finds that the effect of population growth on pollution is higher in developing countries than in developed countries.

#### ***3.2.1.4 Lagged level of emissions per capita***

This variable may be a determinant of current levels of air pollution. The latter may be justified by inertia in environmental degradation. It may be also the result of convergence in environmental degradation, i.e. emissions, as theoretically established by Brock & Taylor (2010) and tested by Kinda (2010). Lagged emissions, as justified by the convergence hypothesis, belong to the set of structural determinants of current environmental degradation.

#### ***3.2.1.5 Trade openness***

Grossman & Krueger (1995) decompose the effects of trade on environmental quality into scale, technical and composition effects. The scale effect of trade measures the negative environmental consequences of scalar increases in economic activity. The technical effect is the positive environmental consequence of increases in income, which call for cleaner production methods. The composition effect can have a positive or negative impact on the environment because it measures the evolution of the economy towards a more or less appropriate productive structure. Thus, Antweiler et al. (2001) conclude that trade reduced the pollution emissions of 43 countries over the period 1971-1996. According to Frankel & Rose (2005), trade is favourable to the reduction of pollution. However, other authors such as Magnani (2000) highlights a negative impact of trade on carbon dioxide emissions.

Discussing the effect of trade openness on the environment illustrates how difficult it is to establish a clear-cut delimitation between structural determinants and domestic policies. Indeed Combes Motel et al. (2009) and Combes & Guillaumont (2002) disentangle the natural openness that is explained by structural factors (size of countries, geographical characteristics) from outward-looking policies implemented by governments which have cut tariffs or withdrawn restrictions or quotas. In Table 1, policies favouring trade openness are considered as a mixed variable: they may partly channel the influence of structural factors on environmental degradation.

#### ***3.2.1.6 Income inequality***

The effect of income inequality on environmental quality has been analysed by many scholars. Magnani (2000) and Koop & Tole (2001) found that inequality of income tends to exacerbate pollution and deforestation respectively. Political economy models provide

theoretical arguments according to which income inequality increases environment degradation through the rate of time preference (Boyce 1994). Indeed, income inequality reduces awareness of environmental quality for both rich and poor: the poor would overexploit natural and environmental resources to ensure survival. Moreover, income inequality and a polarization of resources increase and exacerbate conflicts (violence, social troubles). Rich people seem to prefer a policy of overexploiting the environment and natural resources and investing the returns abroad. Torras & Boyce (1998) assume that political power is highly correlated with income inequality: in unequal societies, those who benefit from environmental degradation (the rich) are more powerful than those who bear the costs (the poor). Therefore, the cost-benefit analysis predicts environmental degradation as a result of income inequality. Borghesi (2006) argues that the implementation of environmental policies is more likely with social consensus. It is easier to get this consensus in an equal society than in an unequal society with conflicts between political agents and social instability.

However other scholars believe that income inequality may have no effect or improved environmental quality. Ravallion et al. (2000) claim that the impact of income inequality on environmental degradation depends on the marginal propensity to emit (MPE). If the poor have a higher (lower) MPE than the rich, a reduction of income inequality will increase (reduce) pollution emissions respectively. One cannot predict *a priori* which of these two effects will happen. Indeed, the poor may consume goods with more (or less) pollution than the rich. Therefore the effect of income inequality is not clear and depends on whether the MPE increases or decreases as income grows. In other words it depends on the second derivative of the pollution-income function.

Similarly to trade openness, we may suppose that inequality of income may be explained simultaneously by structural factors and by policies (social and economic). Indeed, Milanovic (2010) shows that income inequality is determined by income per capita, the ideology (religion), and the quality of democratic institutions that favour redistribution policies.

### **3.2.1.7 Real effective exchange rate (REER)**

The real effective exchange rate may affect environmental degradation. Arcand et al. (2008) show that real exchange rate depreciation may reduce environmental protection in developing countries, and has the opposite effect in developed countries. The REER depends

on international prices, which are structural factors, but also on economic policies. The REER is therefore a mixed variable according to the typology of Table 29.

### 3.2.2 How to measure domestic efforts towards environmental protection?

#### 3.2.2.1 Econometric model and results

The measurement of domestic efforts towards environmental protection is made on a panel of 128 countries over 1980 to 2010. Data are compiled in five-year averages. The panel data regression takes the following form:

$$ED_{i,t} = c_i + \beta X_{i,t} + \gamma_t + \varepsilon_{i,t} \quad (3)$$

$ED_{i,t}$  is the measure of environmental degradation. Two indicators<sup>28</sup> are used: carbon dioxide per capita ( $CO_2$ ) emissions and sulphur dioxide per capita ( $SO_2$ ). Country fixed effects  $c_i$  are taken into account and control for time invariant structural determinants. Period fixed effects  $\gamma_t$  allow controlling for omitted variables that are common to the countries (e.g. international prices). As explained in section 3.2, the residual of this regression is labelled domestic effort for environmental protection (DEEP).

Equation (4) may be estimated with different econometric methods (ordinary least squared (OLS), fixed effects (FE), and random effects (RE)). However these methods are inadequate because the former (OLS) does not take unobserved heterogeneity of countries into account and the latter (FE, RE) are inadequate for dynamic models. Because our model is a dynamic panel, we use the GMM-System (Generalized Method of Moment) from Arellano & Bond (1991), Arellano & Bover (1995) and Blundell & Bond (1998).

The GMM-System (Generalized Method of Moment) is a method that estimates a system of two equations: one equation in level and the other in first differences. In the first estimate,

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<sup>28</sup> In the absence of a single measure of environmental quality, many indicators have been used in the literature as a proxy for environmental quality. The choice of ( $CO_2$ ) as an environmental indicator is based on two reasons. First, data on carbon dioxide emissions is available for longer time-series than any other pollution indicator. Secondly, at the global level, ( $CO_2$ ) is an immediate cause of greenhouse gas, responsible for global warming and climate change. The choice of ( $SO_2$ ) as another environmental variable is also based on two arguments. Contrary to carbon dioxide emissions, sulfure dioxide is a local pollutant. It is widely regarded as one of the most prominent forms of air pollution worldwide, since it has direct and visible effects on human health, ecosystems, and the economy (Konisky 1999). Secondly, data for ( $SO_2$ ) emissions is more reliable than data for other forms of air pollution (so-called criteria pollutants), and it is also available for a large number of countries since the 1970s.

we use lagged variables in levels of at least one period as instruments of the equation in first differences. It removes unobserved time invariant and unobserved individual characteristics. The conditions to be met are that the error terms are uncorrelated and that explanatory variables are weakly exogenous. In the second estimate, we use variables in first differences lagged of at least one period as instruments of the equation in levels.

To check the validity of results we use the standard Hansen test of over-identifying restrictions (where the null hypothesis is that the instrumental variables are not correlated with the residual) and the serial correlation test (AR(2), where the null hypothesis is that the errors exhibit no second-order serial correlation).

Columns (1) and (4) of Table 30 show that the coefficients of most structural variables have the expected signs. The coefficient associated with lagged emissions (carbon dioxide and sulphur dioxide) per capita concludes a divergence on emission per capita for 122 countries. This is not a surprising result: convergence is corroborated only in developed countries (Criado et al. 2011). Income per capita, economic and population growth and trade have an effect on environmental degradation. We find that an increase of (REER)<sup>29</sup> reduces environmental degradation (the coefficient associated with REER is significant for sulphur dioxide per capita). Indeed, an appreciation of the exporting country's currency against its main trading partners may reduce exports and pollution.

In columns (2) and (5) we control for income inequality. Results show that income inequality reduces environmental degradation. When we check for the existence of an Environmental Kuznets Curve by including the squared income per capita (columns (3) and (6) of table 30), this hypothesis is rejected for carbon dioxide emissions.

### ***3.2.2.2 Discussion on Domestic Efforts of Environmental Protection***

To compute the indicator of environmental policy, we use columns (1) of Table 30. Indeed, when we include income inequality (columns 2 & 3), we lose observations. For robustness

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<sup>29</sup> The real exchange effective rate (REER) is computed by taking into account oil exporters in the calculation of the weighting of the main trade partners. When we use the REER without oil exporters and the volatility of real exchange effective rate, we find similar results.

checks in the analysis of the relationship between environmental policies and bilateral trade, we use columns (2) and (3).

Tables 31 and 32 provide a synthesis of the domestic efforts towards environmental protection (DEEP) of different groups of countries over the periods 1980-1989, 1990-1999 and 2000-2010. We may distinguish three groups. The first groups (Eastern Europe and Central Asia (ECA) and South Asia (SA)) are countries in which domestic efforts towards environmental regulation are weak. These domestic efforts do not compensate for structural environmental degradation (carbon dioxide emissions) over the three decades (1980-1989, 1990-1999 and 2000-2010). Similar results are found for the second group (Middle East & North Africa (MENA)) even if these domestic policies have no effect on environmental degradation during the period 2000-2009 and 1990-1999 respectively. The third group (North America (NA), Western Europe (WE)) are countries which have domestic policies that appear to be successful in reducing environmental degradation. Appendix 10 shows that the two indicators (domestic efforts of environmental protection) are correlated to multilateral environmental agreements (such as Annex 1 of Kyoto Protocol) and some environmental measures such as energy taxes (Energy tax revenues as a percentage of total revenues) and environmental tax ratios.



Table 30: Estimation Results (Carbon dioxide emissions and Sulphur dioxide emissions)

Dependent variables	Log of carbon dioxide per capita			Log of sulphur dioxide per capita		
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged carbon dioxide per capita (log)	0.656*** (4.930)	0.894*** (8.955)	0.593*** (5.070)			
Lagged sulphur dioxide per capita (log)				0.970*** (6.907)	1.043*** (8.770)	0.754*** (4.839)
Income capita (log)	0.404*** (3.167)	0.208*** (3.135)	1.649** (2.474)	0.241*** (3.080)	0.173*** (3.613)	2.920*** (2.749)
Population growth	0.0456* (1.692)	-0.00713 (-0.170)	-0.00961 (-0.182)	-0.00581 (-0.0801)	0.0758 (0.833)	0.250** (2.091)
Economic growth	0.0174*** (3.041)	0.0362*** (4.593)	0.0187*** (3.721)	0.0145** (2.054)	0.0371** (2.605)	0.00540** (2.045)
Trade (log)	0.0921** (2.006)	0.0708*** (2.934)	0.0860** (2.283)	-0.599* (-1.731)	-0.588 (-1.423)	-0.0532 (-0.154)
REER				-0.501** (-2.059)		
Income inequality		-0.0456* (-1.692)	-0.0160** (-2.028)		-0.0174*** (-3.041)	-0.0168* (-1.704)
Income cap sq (log)			0.0128 (0.239)			-0.178*** (-2.787)
Intercept	-1.395* (-1.798)	-1.503** (-2.350)	-6.592** (-2.413)	4.145** (2.118)	4.132** (2.179)	-13.34** (-2.316)
Observations	689	486	486	554	389	389
Countries	128	111	111	124	107	107
AR(1)	0.004	0.016	0.01	0.058	0.062	0.001
AR(2)	0.396	0.364	0.443	0.128	0.568	0.384
Hansen Test	0.269	0.432	0.163	0.166	0.176	0.176
Instruments	25	24	25	24	21	22

Notes: \* significantly at 10%; \*\* at 5%; \*\*\* at 1%. The study period is 1980-2010 and 1980-2000 for carbon dioxide and sulphur dioxide emissions. For robustness checks we include other variables (the density of population, natural resources, oil and minerals rents). They do not have an effect on environmental degradation.

**Table 31: Index of Domestic Efforts for environmental protection: CO2 emissions**

Regions	1980- 89	1990- 99	2000- 10
Eastern Europe and Central Asia (ECA)	+*		+***
Middle East & North Africa (MENA)	+*		
South Asia (SA)	+****	+****	+****
Western Europe (WE)	-****	-****	-****
North America (NA)	-****	-****	-****
Sub Saharan Africa (SSA)			
Latin America & Caribbean (LAC)	-*		

The signs are reported here when they are statistically different from zero at the 1% (\*\*\*\*), 5%

(\*\*\*), 10% level (\*\*), and 25% (\*) levels. Negative signs are for successful environmental policies

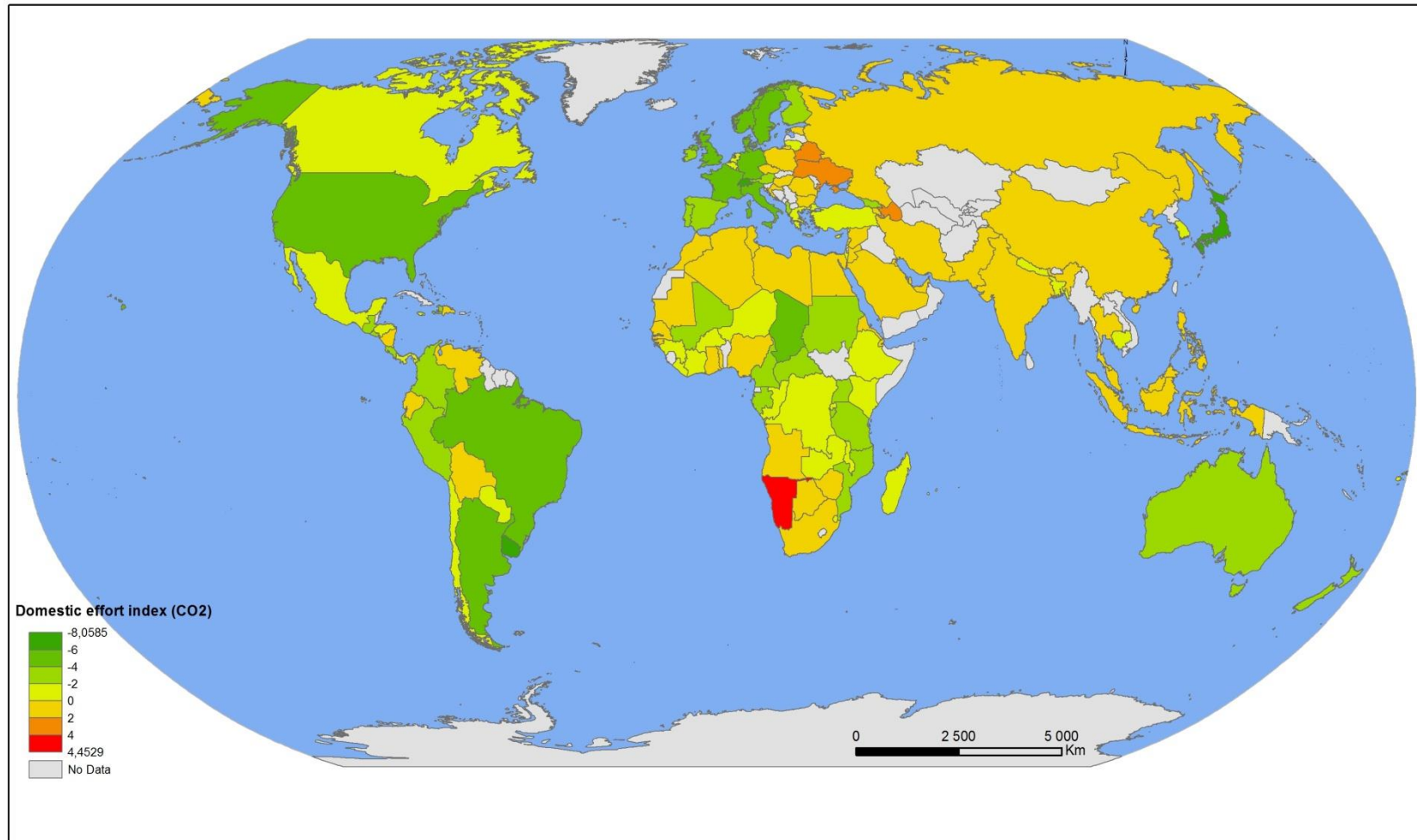
**Table 32: Domestic Efforts for environmental protection: SO2 emissions**

Regions	1980-89	1990-2000
Eastern Europe and Central Asia (ECA)	+*	-****
Middle East & North Africa (MENA)	+****	
South Asia (SA)		-*
Western, Europe (WE)	-*	-****
North America (NA)	-*	-****
Sub Saharan Africa (SS)		-****
Latin America & Caribbean (LAC)	-***	

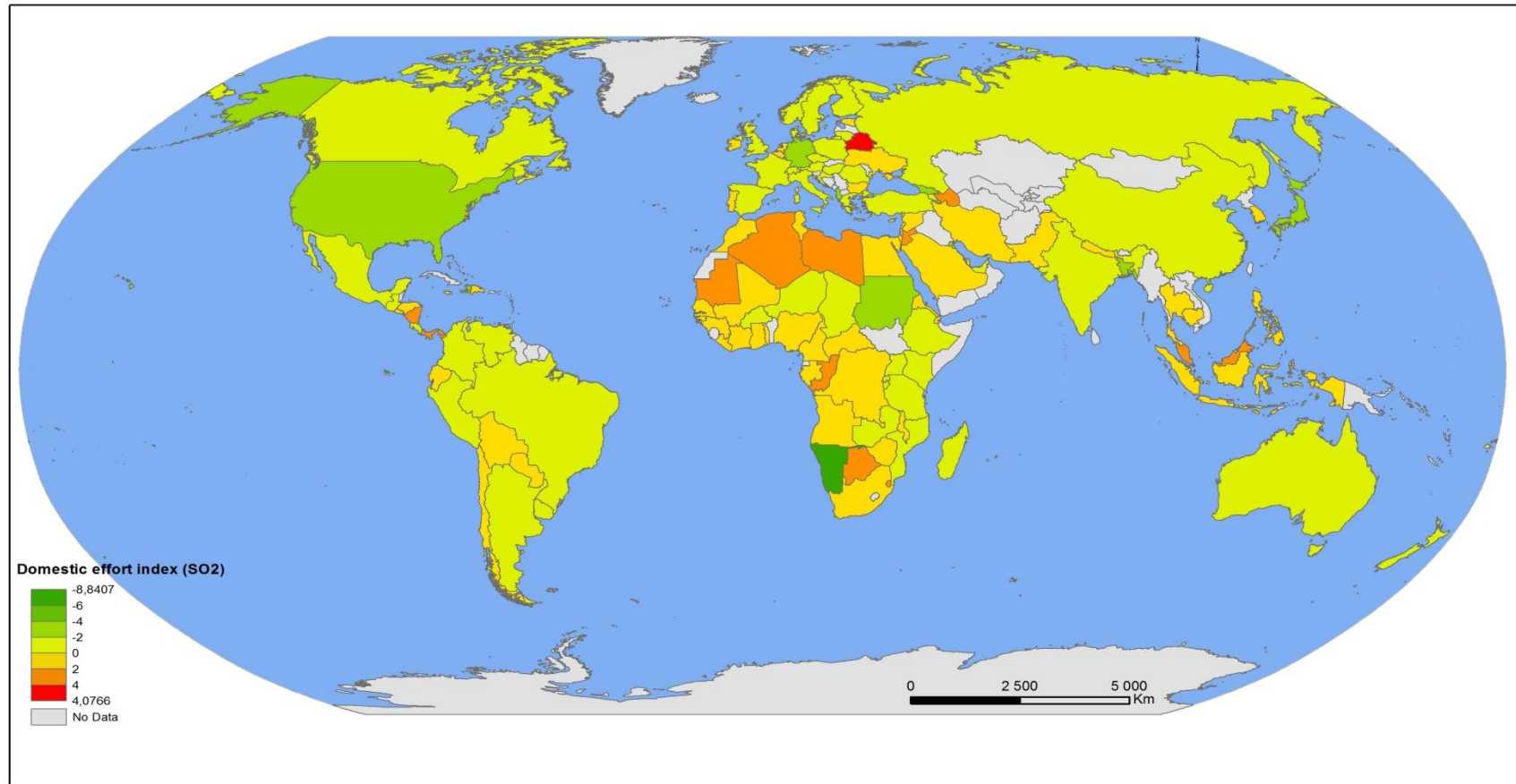
The signs are reported here when they are statistically different from zero at the 1% (\*\*\*\*),

5% (\*\*\*), 10% (\*\*), 25% (\*) levels

**Figure 5: Domestic efforts for environmental protection (C02) for the period 1980-2010**



**Figure 6: Domestic efforts for environmental protection (s02) for the period 1980-2000**



## 4 Empirical analysis: effect of revealed environmental policies on bilateral trade

The objective of the paper is to analyse the effect of gaps in environmental policies between trading partners on bilateral trade flows for the period 1980-2010. For this purpose, we present the econometric model and the empirical method. Moreover, we describe the determinants of bilateral trade flows and the database source.

### 4.1 Empirical Model

#### 4.1.1 Econometric model

In line with previous papers, we use an augmented gravity model of international trade. The gravity model relates bilateral trade flows (exports) between country  $i$  and country  $j$  at time  $t$  to its determinants (such as the economic sizes, trade costs, environmental policies). The equation can be written as:

$$\ln(X_{i,j,t}) = \alpha_0 + \alpha_t + \alpha_{i,j} + \alpha_i + \alpha_j + \beta ER_{i,j,t} + \omega W + \varepsilon_{i,j,t} \quad (4)$$

With  $W$  the matrix of control variables,  $ER_{i,j,t}$  is the gap in environmental policies between trading partners ( $i, j$ ) at period  $t$ . The gap in environmental policies is the absolute difference of domestic efforts for environmental protection (DEEP) of the exporting and importing countries. The data cover the period from 1980 to 2010 and are compiled in five-year averages (1980-1984, 1985-1989...).  $X_{i,j,t}$  is the export flow from country ( $i$ ) to country ( $j$ ) at period ( $t$ ).

Control variables ( $W$ ) are the main determinants of bilateral trade flows. They are the distance between country  $i$  and country  $j$ , the existence of a common border (the variable is equal to one if  $i$  and  $j$  share a common border), the language (an index of language similarity between countries  $i$  and  $j$ )<sup>30</sup>; the economic and population size of partner countries, and the real exchange effective rate of countries. These are from the economic literature. Finally  $\varepsilon_{i,j,t}$  is the error term. The model also includes a complete set of specific effects:

$\alpha_0$ : common effect to all periods and pairs of countries (constant)

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<sup>30</sup> The fixed effect estimates with country-pair takes bilateral distance, colonial linkages, common border into account.

$\alpha_t$ : specific effect to periods  $t$  but common to all the pairs of countries to take into account common shocks .  $\alpha_{i,j}$

$\alpha_{i,j}$ : specific effect to each pair of countries and common to all the periods.

$\alpha_i$ : exporter specific effect and  $\alpha_j$  and importer specific effect

#### 4.1.2 Estimation strategy

The effect of domestic environmental policies on bilateral trade is tested with a panel gravity model framework. Equation (1) can be estimated with three basic approaches: ordinary least square (OLS), fixed effects (FE) or random effects (RE).

The main disadvantage of using OLS estimates is that they do not take into account any unobserved heterogeneity of countries which simultaneously affects the environmental policies and the volume of trade. Indeed, Anderson & van Wincoop (2003) highlighted the existence of multilateral resistance among trading partners. The OLS estimates may be biased if the equation does not specifically take the unobserved heterogeneity of countries into account. To control for multilateral resistance among trading partners, we follow previous studies (Yu 2010; Carrère 2006) and include country-pair specific effects. They control for bilateral distance, colonial linkages, common borders, or any other geographical or time-invariant institutional characteristics. They may be determinants of bilateral flows as evidenced in previous empirical studies (Carrère 2006; Baier & Bergstrand 2007; Baier & Bergstrand 2009). The Hausman test allows a choice of fixed effects (FE) versus random effects (RE).

## 4.2 Data sources and description of variables

Bilateral exports flows are from the UN Comtrade database for the period 1980-2010. The dataset has 72 export and 128 import countries. Income (GDP) and the population of each home and host country are drawn from the World Development Indicators (2012). The data on distance, contiguity and cultural proximity (common language) are from the CEPII distance database. The data on real effective exchange rate (REER)<sup>31</sup> are from CERDI. The index of environmental policy is the residual of regression in which environmental quality (carbon dioxide per capita) is explained by structural and mixed factors (see Table 29). We compute our index, labelled domestic effort for environmental protection (DEEP), by

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<sup>31</sup> An increase means an appreciation and thus a deterioration of competitiveness.

normalizing the residual of regression. We obtain a score ranging from -10 (stringent DEEP) to 10 (laxist DEEP). Appendix 11 presents the definition and source of variables whereas descriptive statistics and correlation of variables are summarized in Appendix 12, 13, 14 and 15.

## 5 Results

### 5.1 Basic results

Table 33 gives the results of the effects of gaps in revealed environmental policies (domestic effort for environmental protection) between partner countries on trade flows, using different econometric methods. Column (1) presents the results with an OLS estimator. It allows traditional determinants of trade flows such as common language, distance, common language and contiguity to be taken into account. It does not, however, take the unobserved heterogeneity of countries into account. We thus run fixed effects (column 2) and random effects (column 3) estimators.

Most determinants are significant and consistent with expectations. The higher the income of both exporting and importing countries, the larger the trade flow. In other words, income captures the increasing capacity of partner countries to trade. Trade flows reduce with the population size of partner countries because bigger countries have relatively lower costs when trading domestically than do smaller ones, and may benefit from increasing returns.

The increase of distance between partner countries has a negative effect on trade flow whereas countries that share a common border and common language trade more. Indeed a common border and language may reduce transaction costs and facilitate trade negotiations. An appreciation of real effective exchange rate increases trade flows. This result does not conform to economic theory. Indeed, an increase of REER reflects an appreciation of the exporting country's currency against its main trading partners, which reduce exports.

Whatever the method used, results show that a gap in environmental policies has no effect on bilateral trade flows. Indeed the coefficient associated with a gap in environmental policies is not significant. It suggests neither pollution havens nor evidence for the Porter hypothesis, which would be reflected, respectively, in significant positive and negative coefficients for environmental policies. Two arguments may partially explain our results. First, we may assume that the costs of domestic environmental policies are low compared to other factors

(economic size, endowments, technology, transports, etc). Secondly, we may consider that the potential effect of environmental policies may depend on the nature or the type or characteristic of the goods. Indeed more stringent environmental regulation may only have an effect on specific goods, such as energy intensive goods.

Table 33: Effect of similarity in environmental policy on bilateral trade flows

	Log of exports		
	(1) OLS	(2) FE	(3) RE
Log GDP (i)	1.315*** (155.1)	1.550*** (28.21)	1.401*** (104.4)
Log GDP (j)	1.089*** (154.4)	1.218*** (25.34)	1.105*** (83.93)
Log Population (i)	-0.157*** (-13.62)	-1.568*** (-14.79)	-0.226*** (-11.85)
Log Population (j)	-0.124*** (-12.69)	0.894*** (9.020)	-0.0990*** (-5.467)
Log reer (i)	0.0314 (1.232)	0.0461** (2.322)	0.117*** (6.443)
Gap ER(i,j)	0.0108** (2.223)	0.00298 (0.472)	0.00359 (0.646)
Common Language	0.771*** (24.26)		0.837*** (13.77)
Log distance	-0.000212*** (-76.82)		-0.000219*** (-42.65)
contiguity	2.219*** (29.32)		2.243*** (15.89)
Intercept	-50.94*** (-191.1)	-54.68*** (-19.69)	-53.28*** (-135.4)
Observations	37,787	38,216	37,787
R-squared	0.782	0.813	
Bilateral countries		8,689	8,332

\*\*\*, \*\* and \* significant at 1%, 5% and 10% levels. T statistics in parentheses

## 5.2 Heterogeneity in the levels of economic development and characteristics of goods

In this section, we identify potential heterogeneities in the relationship between gaps in environmental policies and bilateral trade flows. First, we evaluate whether the effect of a gap in environmental policies on trade flows is conditional on the level of development of countries. Second, we focus our attention on the effect of environmental policies on the characteristics of exported goods.



### *5.2.1 Does economic development matter?*

Given that the incomes of trading partners may vary, is the effect of differences in environmental policies on trade flows sensitive to their level of economic development? Indeed we may assume that the marginal effect of a gap in environmental policies could be stronger in some countries than in others. When the level of economic development of trading partners increases, they may be incited to increase domestic efforts towards environmental protection. We test this hypothesis by adding in our estimations the level of economic development of trading partners (GDP, column 2, table 34), the difference in economic development of trading partners (column 3, table 34) and their interactive term (gap in environmental policies\*GDP of trading partners, gap in environmental policies\*difference in GDP of trading partners). Results show that the impact of a gap in environmental policies on trade flows is not conditional on the level or difference in economic development of trading partners.

### *5.2.2 Do the characteristics of products have an effect?*

By increasing the costs of firms through abatement policies or environmental tax, environmental policies may increase prices and reduce the competitiveness of goods. However the sensitivity of consumers to price variation depends on the nature of goods. They may be more sensitive to differentiated goods than homogeneous goods. To take into account the characteristics of goods, we distinguish manufactured goods (column 3 of table 35) and primary common goods (column 2 of table 35). We find that the marginal impact of a gap in environmental policies does not depend on the characteristics of goods. In other words, it does not favour (or dampen) the export of manufactured and primary commodity products.

Table 34: Effect of similarity in environmental policy on bilateral trade flows: the importance of economic development

Dependent variable	Log of exports		
	(1)	(2)	(3)
Log GDP (i)	1.550*** (28.21)	1.555*** (28.11)	1.549*** (28.05)
Log GDP (j)	1.218*** (25.34)	1.222*** (25.28)	1.217*** (25.23)
Log Population (i)	-1.568*** (-14.79)	-1.575*** (-14.81)	-1.567*** (-14.76)
Log Population (j)	0.894*** (9.020)	0.890*** (8.975)	0.895*** (9.022)
Log reer (i)	0.0461** (2.322)	0.0453** (2.280)	0.0463** (2.329)
Gap ER(i,j)	0.00298 (0.472)	0.0792 (0.871)	-0.0118 (-0.165)
Gap ER(i,j)*Log GDP per capita (i,j)		-0.00306 (-0.840)	
Gap ER(i,j)*Difference in log GDP per capita (i,j)			0.000587 (0.207)
Intercept	-54.68*** (-19.69)	-54.75*** (-19.71)	-54.67*** (-19.68)
Observations	38,216	38,216	38,216
R-squared	0.813	0.813	0.813
Joint signif Gap ER(i,j) coeff (p-value)		0.4007	0.8754
Bilateral countries	8,689	8,689	8,689

\*\*\*, \*\* and \* significant at 1%, 5% and 10% levels. T-statistics in parentheses.

Table 35: Environmental policies and trade flows: characteristics of goods (manufactured and primary commodity)

Dependent variable	Exports (log)	Primary commodity exports (log)	Manufactured exports (log)
	(1)	(2)	(3)
Log GDP (i)	1.550*** (28.21)	0.748** (2.569)	2.001*** (6.323)
Log GDP (j)	1.218*** (25.34)	0.986*** (7.327)	1.044*** (6.534)
Log Population (i)	-1.568*** (-14.79)	-1.802*** (-2.610)	0.821 (1.480)
Log Population (j)	0.894*** (9.020)	-0.925*** (-3.660)	-0.759** (-2.374)
Log reer (i)	0.0461** (2.322)	-0.455 (-1.193)	0.370 (1.282)
Gap ER(i,j)	0.00298 (0.472)	0.00658 (0.323)	0.00137 (0.0576)
Intercept	-54.68*** (-19.69)	11.16 (0.883)	-69.45*** (-5.966)
Observations	38,216	1,777	3,046
R-squared	0.813	0.307	0.188
Bilateral countries	8,689	465	897

\*\*\*, \*\* and \* significant at 1%, 5% and 10% levels. T statistics in parentheses

### 5.3 Robustness Checks

Previous sections show that a similarity in environmental policies between trading partners has no effect on their trade flows. We verify the robustness of previous results in several ways. First, we include more control variables to check the pertinence of results. Second, we apply an alternative econometric approach, the Poisson pseudo-maximum likelihood (PPML) estimation to address the zero trade problem. Third, we use other measures of bilateral trade and environmental policies.

#### 5.3.1 Adding control variables

Previous results have shown that the similarity in environmental policies between trading countries has no effect on bilateral trade flows. However environmental policy could be a reflection of the quality of institutions. In other words, the stricter a country's environmental policy, the better institutions it will have. Indeed some authors (Méon & Sekkat 2008; Yu 2010) suggest that institutions could promote trade flows, particularly for manufactured goods. This may explain the non-significance of the interest variable. In order to capture the

effect of environmental policies only, we control for institutional quality and include the level of corruption, the quality of law and order and democracy in trading partners. The results are not affected (Table 36) when controlling either by corruption, order and law and democracy.

Table 36: Effect of similarity in environmental policy on bilateral trade flows: more control variables

	Log of exports			
	(1)	(2)	(3)	(4)
Log GDP (i)	1.991*** (30.80)	2.001*** (30.34)	1.969*** (30.70)	2.095*** (30.58)
Log GDP (j)	1.256*** (23.23)	1.307*** (23.40)	1.261*** (23.36)	1.354*** (24.03)
Log Population (i)	-1.676*** (-15.23)	-1.549*** (-14.04)	-1.597*** (-14.77)	-1.592*** (-14.33)
Log Population (j)	0.671*** (6.593)	0.798*** (7.793)	0.671*** (6.676)	0.745*** (7.225)
Log reer (i)	0.0451** (2.370)	0.0361* (1.863)	0.0522*** (2.732)	0.0317 (1.621)
Gap ER (i,j)	0.00179 (0.253)	0.00277 (0.390)	0.00102 (0.143)	0.00248 (0.351)
Corruption (i)	0.0565*** (3.588)			0.0727*** (4.329)
Corruption (j)	0.0368** (2.452)			0.0410*** (2.584)
Law & order (i)		0.0432*** (2.682)		0.0743*** (4.330)
Law & order (j)		0.0585*** (3.931)		0.0892*** (5.698)
Democracy (i)			0.0301** (2.484)	0.0298** (2.382)
Democracy (j)			0.0666*** (5.981)	0.0727*** (6.322)
Intercept	-61.45*** (-20.56)	-66.36*** (-21.20)	-62.38*** (-20.87)	-68.74*** (-21.82)
Observations	32,063	32,063	32,063	32,063
R-squared	0.838	0.838	0.838	0.838
Bilateral countries	7,141	7,141	7,141	7,141

\*\*\*, \*\* and \* significant at 1%, 5% and 10% levels. T statistics in parentheses

### 5.3.2 The problem of zero observations

Recent advances in the economic literature on trade gravity models have shown that there may be large part of zero export flows between partner's countries. Our previous results are based on a truncated sample because 10% of country-pairs do not trade. They are dropped

from estimates when we use logarithms of export flows. We therefore run Poisson pseudo-maximum likelihood (PPML) estimators (Silva & Tenreyro 2006) for which results are reported in column (2) of Table 37. We find that the similarity in environmental policies between trading countries again has no effect on bilateral trade flows.

Table 37: Effect of similarity in environmental policy on bilateral trade flows

Dependent variable	Log of exports	Export
	(1)	(2)
	FE	PPML
Log GDP (i)	1.550*** (28.21)	0.765*** (13.02)
Log GDP (j)	1.218*** (25.34)	0.883*** (22.41)
Log Population (i)	-1.568*** (-14.79)	-0.0308 (-0.511)
Log Population (j)	0.894*** (9.020)	-0.206*** (-5.388)
Log reer (i)	0.0461** (2.322)	2.982** (2.244)
Gap ER (i,j)	0.00298 (0.472)	-0.0269 (-1.328)
Intercept	-54.68*** (-19.69)	-39.38*** (-5.599)
Observations	38,216	42,292
R-squared	0.813	0.371
Bilateral countries	8,689	

\*\*\*, \*\* and \* significant at 1%, 5% and 10% levels. T statistics in parentheses

### 5.3.3 *Alternative measure of bilateral trade and environmental policies*

In the baseline model (equation 4), the dependent variable is the bilateral export flow. Because our sample is a set of heterogeneous countries, we normalize the bilateral export flows and use the ratio bilateral exports to GDP (Vijil & Wagner 2012; Melo & Grether 2000).

In accordance with the modification of the dependent variable, the GDP and Population of partner countries are substituted by GDP per capita. Indeed, according to the literature, economic size may be captured either by a country's income (GDP) and population or by a country's income per capita (GDP per capita). We then consider income per capita because the dependent variable (bilateral exports /GDP) is mechanically related to income (GDP).

Other traditional determinants are similar. Table 38 concludes that a similarity in environmental policies has no effect on bilateral exports, primary commodity exports and manufactured exports.

Two alternative measures of environmental policy are also employed. To make sure that our results are robust, environmental policy is computed with additional mixed variables: income inequality and the square of income per capita (Environmental Kuznets Curve). Whatever the indicator<sup>32</sup> (Gap ER (i,j)\_A, Gap ER (i,j)\_B) used, the results (Table 39) are always unchanged.

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<sup>32</sup> To compute Gap ER (i,j)\_A and Gap ER (i,j)\_B, we use columns 2 and 3 of Table 30. We find similar results when we use DEEP for Sulphur dioxide emissions (columns 4, 5 and 6 of table 30). Tables are available for requests.

Table 38: Effect of similarity in environmental policy on bilateral trade (export to GDP ratio)

Dependent variable	Log of export			Primary commodity exports (log)	Manufactured exports (log)
	(1)	(2)	(3)	(4)	(5)
Log GDP per capita (i)	0.731*** (13.98)	1.321*** (19.65)	0.732*** (13.90)	0.771*** (2.656)	1.658*** (5.316)
Log GDP per capita (j)	0.896*** (19.56)	1.339*** (24.07)	0.896*** (19.50)	0.963*** (7.735)	1.001*** (6.593)
Log bilateral trade (i,j)	0.108*** (5.620)	0.113*** (5.891)	0.108*** (5.610)	-0.171 (-0.503)	-0.517** (-2.201)
Gap ER (i,j)	0.00333 (0.524)	-0.0290 (-0.673)	0.00548 (0.184)	0.00574 (0.282)	-0.000185 (-0.00771)
Gap ER(i,j)*Log GDP per capita (i,j)		0.00358 (0.700)			
Log GDP per capita(i,j)		-1.654*** (-14.23)			
Gap ER(i,j)*Difference GDP(log) per capita (i,j)			-0.000256 (-0.0739)		
Gap ER(i,j)*Log GDP per capita (i,j)					
Intercept	-36.67*** (-67.26)	-31.09*** (-45.59)	-36.67*** (-66.73)	-6.145** (-2.423)	-13.27*** (-5.435)
Observations	38,216	38,216	38,216	1,777	3,046
R-squared	0.787	0.788	0.787	0.305	0.177
Bilateral countries	8,689	8,689	8,689	465	897

\*\*\*, \*\* and \* significant at 1%, 5% and 10% levels. T statistics in parentheses

Table 39: Similarity in environmental policy and bilateral trade: alternative measures of environmental policy

Dependent variable	Log of exports		
	(1)	(2)	(3)
Log GDP (i)	1.550*** (28.21)	1.258*** (11.82)	1.261*** (11.76)
Log GDP (j)	1.218*** (25.34)	1.419*** (10.89)	1.426*** (10.91)
Log Population (i)	-1.568*** (-14.79)	-1.415*** (-5.208)	-1.438*** (-5.274)
Log Population (j)	0.894*** (9.020)	1.574*** (6.876)	1.561*** (6.817)
Log bilateral trade (i,j)	0.0461** (2.322)	0.115 (1.305)	0.117 (1.322)
Gap ER (i,j)_A		-0.0112 (-1.013)	
Gap ER (i,j)	0.00298 (0.472)		
Gap ER (i,j)_B			0.00234 (0.226)
Intercept	-54.68*** (-19.69)	-67.13*** (-9.916)	-66.81*** (-9.877)
Observations	38,216	10,861	10,861
R-squared	0.813	0.714	0.714
Bilateral Countries	8,689	3,866	3,866

\*\*\*, \*\* and \* significant at 1%, 5% and 10% Number in parentheses are t-value.

## 6 Conclusion

This paper analyses the effect of a gap in revealed environmental policies between trading partners on bilateral trade flows for 122 countries in the period 1980-2010. Contrary to previous papers in the economic literature, which use either input-oriented indicators or output-oriented indicators, we use an index of environmental policy. Labelled domestic efforts for environmental protection (deep), this index does not depend on other factors (structural or mixed) in that country's policy.

Our results suggest that a gap in environmental policies does not dampen bilateral trade flows. Second, we show that the effect (absence) of a gap in environmental policies on trade flows is not conditional on the level of development of countries. Third the results don't depend on the characteristics (manufactured goods and primary commodity) of exported goods. These results are robust to alternative robustness checks.



Our results are important in terms of recommendations for economic policies. They incite developing and developed countries to increase efforts to protect environmental quality. These climate and environmental policies will not dampen the competitiveness of countries.

## 7 Appendices

### Appendix 10: Correlation between DEEP and environmental measures and agreements

	co2_deep	so2_deep	Annex 1 Kyoto Protocol	Environ mental tax	Energy tax
co2_deep	1				
so2_deep	0.0942	1			
Annex 1 Kyoto P	-0.4564***	-0.0722	1		
Environment tax	-0.5861 ***	-0.8504***	0.2349	1	
Energy tax	-0.2088	-0.0588	0.2831 **	0.0226	1

### Appendix 11: Variable definitions and sources

Variables	Definitions	Sources
Export	Total value of exports of the country i to the country j, Millions of US dollars	COMTRADE
GDP (i), GDP (j)	Gross domestic product of country i or country j, current million US dollars	WDI (2012)
Population (i), Population (j)	Annual population growth rate of country i or country j  Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of the country of origin.	WDI (2012)

DEEP	Domestic effort for environmental protection.	Computed by Authors
Gap ER (i,j)	Similarity in environmental policies (DEEP) between trading partners	Computed by Authors
	GDP per capita, constant 2000 USD	WDI (2012)
Corruption	Indicator of corruption as reported by international consultants. Scaled from 0 to 6, higher values denote less corruption	ICRG
Law & order	Law and Order are assessed separately, with each sub-component comprising zero to three points. The Law sub-component is an assessment of the strength and impartiality of the legal system, while the Order sub-component is an assessment of popular observance of the law. Thus, a country can enjoy a high rating – 3 – in terms of its judicial system, but a low rating – 1 – if it suffers from a very high crime rate or if the law is routinely ignored without effective sanction (for example, widespread illegal strikes).	ICRG
Democracy	This is a measure of how responsive government is to its people, on the basis that the less responsive it is, the more likely it is that the government will fall, peacefully in a democratic society, but possibly violently	ICRG

	in a non-democratic one	
Common Language	1 for countries sharing a common official language	CEPII
Distance	Geographical distance between the largest cities of i and j weighted by the proportion of the city's overall country population, km	CEPII
Contiguity	1 for countries sharing a border	CEPII
Carbon dioxide per capita	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	WDI (2012)
Sulfur dioxide per capita	Sulphur dioxide emission per GDP	David Stern (2005)
Economic growth	GDP average annual growth rate, %	WDI (2012)
Trade	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	WDI (2012)
Income inequality	EHII (Estimated Household Income Inequality) variable is an index ranging from 0 (no inequality) to 1 (perfect inequality).	University of Texas Inequality Project (UTIP) database (2008)
REER	The REER is a CPI-based real effective exchange rate, defined as a weighted geometric mean	International Financial Statistics (IFS) and CERDI calculation

	of the bilateral nominal exchange rate and consumer price indices. It take into account the 10 largest trading partners over the period 200-2008
Energy tax	Energy tax revenues as EUROSTAT percentage of total revenues
Environmental tax	Environmental tax revenues as EUROSTAT percentage of total revenues.

**Appendix 12: Data used to compute the domestic efforts of environmental protection (Summary Statistics)**

Variable	Obs	Mean	Std. Dev.	Min	Max
DEEP (co2)	544	-1.039452	2.524249	-10	10
DEEP (so2)	544	.1045352	1.775024	-10	10
Residu-co2	544	-.004855	.3857367	-.96909	2.904843
Residu-so2	544	.0049914	.5175716	-3.12151	2.716986
co2 per capita	544	4.121948	5.82373	.0149349	55.04334
so2 per capita	544	.000013	.0000197	1.33e-07	.0001649
co2 per capita (log)	544	.3067105	1.754491	-4.204056	4.008121
so2 per capita (log)	544	-12.03178	1.265662	-15.83289	-8.71047
gdp capita (log)	544	7.515326	1.630679	4.445175	10.77187
Population growth	544	1.801467	1.261486	-4.644716	6.160783
Economic growth	544	3.266433	3.962397	-42.45112	33.34696
Trade (log)	544	4.082641	.5392496	2.555366	5.606332
REER (log)	544	4.742542	.4878034	3.589216	10.46013
Income inequality	379	42.07493	6.371779	26.41345	64.2473
Deep co2 (eq6)	380	-.746186	2.454736	-10	10
Deep co2 (eq7)	380	-.2367504	2.634788	-10	10

**Appendix 13: Data used to estimate environmental policies on trade flows (Summary Statistics)**

Variable	Obs	Mean	Std. Dev.	Min	Max
Export	42292	122526.9	1920389	0	1.72e+08
Log of export	38216	3.007629	4.804744	-19.33697	18.96019
Log GDP (i)	42292	24.53953	2.201506	19.10038	30.08547
Log GDP (j)	42292	23.88649	2.19372	18.72202	30.08547
Log Population (i)	42292	16.38086	1.540362	11.94303	21.00186
Log Population (j)	42292	16.2686	1.590785	11.09309	21.00186
Log bilateral reer (i,j)	42292	4.72921	.5776506	2.971653	14.00383
DEEP (i)	42292	-1.392026	2.640095	-8.457233	5.679702
DEEP (j)	42292	-1.039452	2.524249	-10	10
Gap ER (DEEP)	42292	2.917947	2.263038	.0003948	17.77451

**Appendix 14: Data used to compute the domestic efforts of environmental protection (Correlation matrix)**

	DEEP (co2)	DEE P (so2)	co2 per capita (log)	so2 per capita (log)	gdp capita (log)	Pop growth	Economi c growth	Trade (log)	REER (log)
DEEP (co2)	1,00								
DEEP (so2)	0,45	1,00							
co2 per capita (log)	0,01	-0,03	1,00						
so2 per capita (log)	0,06	0,10	0,73	1,00					
gdp capita (log)	-0,32	-0,14	0,90	0,61	1,00				
Pop growth	0,21	0,22	-0,49	-0,29	-0,49	1,00			
Economic growth	0,06	0,03	-0,01	-0,04	-0,05	0,20	1,00		
Trade (log)	0,34	0,46	0,29	0,21	0,24	-0,09	0,07	1,00	
REER (log)	0,21	0,41	-0,20	-0,15	-0,26	0,23	-0,05	-0,16	1,00

**Appendix 15: Data used to estimate environmental policies on trade flows (Correlation matrix)**

	Export (log)	Gap ER (DEEP)	Log GDP (i)	Log GDP (j)	Log Pop (i)	Log Pop (j)	Log bil reer (i,j)
Export (log)	1.0000						
Gap ER (DEEP)	0.1295	1.0000					
Log GDP (i)	0.5058	0.1891	1.0000				
Log GDP (j)	0.4229	0.0860	-0.1108	1.0000			
Log Pop (i)	0.3047	0.0655	0.6688	-0.0701	1.0000		
Log Pop (j)	0.2506	0.0284	-0.0759	0.6781	-0.0484	1.0000	
Log bil reer (i,j)	-0.1279	0.0076	-0.2018	0.0244	-0.0397	0.0142	1.0000

**Appendix 16: List of countries****Origin countries (72)**

Armenia, Australia, Austria, Burundi, Belgium, Bulgaria, Bahrain, Bolivie, Central African Republic, Canada, Switzerland, Chile, China, Ivory-Cost, Cameroon, Colombia, Costa Rica, Cyprus, Czech Republic, Germany, Denmark, Dominican Republic, Algeria, Ecuador, Spain, Finland, Fiji, France, Gabon, United Kingdom, Georgia, Ghana, Gambia, Equatorial Guinea, Greece, Croatia, Hungary, Ireland, Iran, Israel, Italy, Japan, Luxembourg, Morocco, Mexico, Malawi, Malaysia, Nigeria, Nicaragua, Netherlands, Norway, New Zealand, Pakistan, Philippines, Poland, Portugal, Paraguay, Romania, Russian Federation, Sweden, Togo, Tunisia, Uganda, Ukraine, Uruguay, United States of America, Venezuela, South Africa, Congo, Dem. Rep. and Zambia

**Destination countries (128)**

Angola, Albania, United Arab Emirates, Argentina, Armenia, Australia, Austria, Azerbaijan, Burundi, Belgium, Burkina Faso, Bangladesh, Bulgaria, Bahrain, Belarus, Belize, Bolivia, Brazil, Botswana, Central African Republic, Canada, Switzerland, Chile, Chine, Cote d'Ivoire, Cameroon, Congo Rep., Colombia, Costa Rica, Cyprus, Czech Republic, Germany, Djibouti, Denmark, Dominican Republic, Algeria, Ecuador, Egypt, Arab Rep., Eritrea, Spain, Estonia, Ethiopia, Finland, Fiji, France, Gabon, United Kingdom, Georgia, Ghana, Guinea, Gambia, Guinea-Bissau, Equatorial Guinea, Greece, Guatemala, Honduras, Croatia, Haiti, Hungary, Indonesia, India, Ireland, Iran, Israel, Italy, Jamaica, Jordan, Japan, Kenya, Cambodia, Korea Rep, Kuwait, Lebanon, Liberia, Libya, Lithuania, Luxembourg, Morocco, Madagascar, Mexico, Mali, Mozambique, Mauritania, Mauritius, Malawi, Malaysia, Namibia, Niger, Nigeria, Nicaragua, Netherlands, Norway, Nepal, New Zealand, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Paraguay, Qatar, Romania, Russian Federation, Rwanda, Saudi Arabia, Sudan, Senegal, El Salvador, Sweden, Swaziland, Seychelles, Syrian Arab Republic, Chad, Togo, Thailand, Tunisia, Turkey, Tanzania, Uganda, Ukraine, Uruguay, United States, Venezuela, South Africa, Congo, Dem. Rep, Zambia Zimbabwe





# **General Conclusion**



## 1 Main results

This dissertation has explored the relationship between environmental degradation and economic development. Our main objective was to look beyond reduced forms such as the environmental Kuznets curve and investigate several channels.

The first chapter analyses the role of education in environmental quality. No evidence of an effect of education on carbon dioxide emissions is found using a panel of developed and developing countries over the period from 1970 to 2004. This effect, however, is heterogeneous according to the levels of development. Indeed, while the effect of education remains insignificant in developing countries, education does matter for pollution growth in developed ones. More interestingly, when controlling for the quality of democratic institutions, the positive effect of education on air pollution growth is mitigated in developed countries while being insignificant in developing countries. In addition, our results show a divergence in carbon dioxide per capita at the global level and in developing countries during the period 1970–2004.

The second chapter contributes to the controversial link between democratic institutions and environmental protection. It explores the effect of democratic institutions on environmental quality for 122 developed and developing countries from 1960 to 2008. The main contribution of this chapter is that we identify and test four potential transmission channels: income inequality, investments, foreign direct investments and trade openness. Several results are worth noticing. First, democratic institutions have a direct and positive effect on environmental quality. This positive effect is stronger for local pollutants than for global ones. Second, democracy also indirectly affects environmental degradation. Indeed, by increasing people's preferences for redistribution and economic policies, democratic institutions have direct and negative effects on environmental protection through income inequality and investments. Third, the nature of democratic institutions (presidential, parliamentary) is conducive to environmental quality. In older democracies, political leaders favour the provision of visible environmental goods ( $SO_2$ ). Fourth, the results suggest that the effect of democratic institutions on environmental quality is higher in developed countries than in developing countries.

The third chapter investigates the effects of climatic variability on food security for 71 developing countries from 1960 to 2008. Three main results emerge from the analysis. First, we provide evidence that climatic variability reduces the food supply in developing countries. The adverse effect is higher for African sub-Saharan countries than for other developing countries. Second, the negative effect of climatic variability on food security is exacerbated in countries facing conditions of conflict. Indeed, in countries under conflict, the population suffers disruptions in livelihoods, assets, nutrition and health. Warfare disrupts markets and destroys crops, livestock, roads and land. Deliberate asset-stripping of households in the conflict regions may cause those households to lose other sources of livelihood as the ongoing conflict leads to breakdowns in production, trade and social networks. Climatic shocks aggravate food insecurity in countries under conflict. Moreover, climatic variability increases food insecurity through the risk of civil conflicts. By exacerbating the scarcity of resources and the risk of civil war, climatic shocks may increase food insecurity. Third, the effects are high for countries that are vulnerable to food price shocks.

The fourth chapter contributes to the controversial literature on the relationship between environmental regulations and international trade. It provides new evidence on the effect of the gap in environmental policies between trading partners on trade flows for 122 countries during the period 1980–2010. Indeed, according to several authors (Cagatay & Mihci 2006; Keller & Levinson 2002; Van Beers & Van Den Bergh 1997), environmental policies entail additional costs and may erode the competitiveness of firms or countries. However, this paradigm is challenged by the Porter hypothesis (Porter 1991; Porter & Van der Linde 1995), which considers that strong environmental policies can stimulate competitiveness through innovations. Our contribution is twofold. First, contrary to most previous studies that analyse the effect of domestic environmental policies on trade (total or bilateral), we focus on the effect of similarity in environmental policies on trade flows between partners' countries. The second contribution of this paper is that we develop a new approach to computing an index of a country's environmental policy. Indeed, previous studies have used either input-oriented indicators or output-oriented indicators. The main limits of these indicators are that input-oriented indicators are not always available for all countries and output-oriented indicators may depend on other factors than policy. The results suggest that similarity in environmental policies does not dampen bilateral trade flows. Moreover, the results are not conditional on the level of development of trading countries or the characteristic of the exported goods (manufactured goods and primary commodities).

## **2 Policy implications and future research**

A major challenge for governments (especially in developing countries) is to implement policies that protect environmental quality without dampening their economic development. The analysis of the determinants of environmental degradation and their consequences can help define policy recommendations that may be useful to developing countries.

The first chapter, concerning the role of education in environmental quality, concludes that the accumulation of knowledge (education) is a factor in pollution growth. It incites governments and the international community to introduce a change in perception and the role of education in favour of the environment. This is urgent in developing countries because the achievement of the Millennium Development Goals (MDG) regarding education could be followed by environmental pollution. The ongoing debate on sustainable development goals evidences the need to include the environment to a greater extent in education objectives.

The second chapter stresses the importance of democratic institutions in the process of environmental protection. It suggests that even if they favour the environment, these influences should be understood in the light of the priorities of countries that may prefer economic and redistribution priorities. The results suggest an improvement of the democratization process in countries (especially developing countries), which allows a high level of environmental awareness. Governments should implement policies lessening the negative and indirect impact of democratic institutions (for example the implementation of ecologically appropriate investments).

The second part of the thesis highlights the effect of environmental degradation and policies on development. The third chapter shows that climatic variability is a factor in food insecurity in developing countries. This chapter highlights that this effect is exacerbated in countries under conflict and amplified for countries that are vulnerable to food price shocks. These results suggest two policies. First, governments should invest in agricultural research, extension and methods for reducing food production losses related to climate variability. Given the large uncertainties about future rainfall patterns in many developing countries, careful consideration should be given to major investments in infrastructure to support irrigation and water resources development in order to limit the effects of a reduction in food production. Second, the international community may help developing countries, particularly

the least developed countries (LDCs), through automatic aid mechanisms that will be related to the magnitude of the effects of climate variability on food security. They could finance stabilization mechanisms (government budget or development projects for the regions adversely affected by climate variability) with aid (named “climatic aid”). This “climatic aid” can be given to developing countries that are both more exposed to the effects of climate variability and more vulnerable to food price shocks.

Finally, the last chapter shows that environmental policies do not dampen the competitiveness of countries. It incites developing and developed countries to increase their efforts to protect environmental quality. They may implement ecologically appropriate investments.

Future investigations into the relationship between environmental degradation and economic development are still open. The third chapter concludes that climatic variability has a negative impact on food insecurity in developing countries. It motivates the international community to help developing countries through foreign aid. These implications also call for a deepening of the research on the impacts of aid insofar as this will provide more knowledge about how aid may mitigate the effect of climatic shocks.

Democratic institutions are hypothesized to play a major role in the reduction of food insecurity (Smith & Haddad 2000). It may be interesting to analyse the importance of political participation. In other words, we may look at whether a better representation of women in democratic institutions (government, parliamentary) may mitigate the effect of climatic shocks.







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## **Abstract:**

This dissertation is a contribution to the debate on environmental degradation and development. It focuses on the determinants and macroeconomic effects of environmental degradation. It is structured in two parts. The first part analyses the effects of education and democratic institutions on environmental quality. The first chapter analyses the role of education in environmental quality. No evidence of an effect of education on carbon dioxide emissions. However, this effect depends crucially on the sample of countries according to their levels of development. While the effect remains insignificant in developing countries, education does matter for carbon dioxide emissions in developed ones. Moreover, when controlling for the quality of democratic institutions, the positive effect of education on carbon dioxide emissions is mitigated in developed countries while remaining insignificant in developing ones. The second chapter explores the effect of democratic institutions on environmental quality. We evidence that democratic institutions do have a direct and positive effect on environmental quality. This positive effect is stronger for local pollutants than for global ones. More interestingly, it identifies the indirect channels through which democracy affects environmental degradation. Indeed, by increasing people's preferences for redistribution and economic policies, democratic institutions have indirect and negative effects on environmental protection through income inequality and investments. In the second part, the dissertation provides two essays on the effects of environmental policies and climate change on development. The third chapter investigates the effects of climatic variability on food security. The results show that climatic variability reduces food security in developing countries. The adverse effect is higher for African sub-Saharan countries than for other developing countries. Second, the negative effect of climatic variability on food security is exacerbated in countries facing conditions of conflict and is high for the countries that are vulnerable to food price shocks. The fourth chapter provides new evidence about the effect of a gap in environmental policies between trading partners on trade flow. While previous papers have used partial measures of environmental regulations (input-oriented or output-oriented indicators), we compute an index of a country's environmental policy. Results suggest that a similarity in environmental policies has no effect on bilateral trade flows. Moreover results do not appear to be conditional on the level of development of the countries trading or on the characteristics of exported goods (manufactured goods and primary commodities).

## **Résumé:**

Cette thèse apporte un nouvel éclairage au débat sur la dégradation de l'environnement et le développement. Elle analyse les déterminants et les effets macroéconomiques de la dégradation de l'environnement. Elle est subdivisée en deux parties. La première partie analyse les effets de l'éducation et des institutions démocratiques sur la qualité de l'environnement. Le premier chapitre analyse le rôle de l'éducation dans la protection de l'environnement. Les résultats empiriques indiquent que l'effet dépend du niveau de développement. Contrairement à l'échantillon des pays en développement où elle n'a pas effet, l'éducation est source de pollution dans les pays développés. Cependant, cet effet est atténué en présence de bonnes institutions démocratiques. Le deuxième chapitre étudie l'impact des institutions démocratiques sur la qualité de l'environnement. Nous montrons qu'elles ont un effet direct et positif sur la qualité de l'environnement. Celui-ci est plus élevé pour les polluants locaux que pour les polluants globaux. De plus, ce chapitre identifie des canaux indirects par lesquels l'amélioration de la démocratie dégrade l'environnement. En effet, en favorisant l'adoption de politiques de redistribution des revenus et de politiques économiques, la démocratie a un effet indirect et négatif sur la protection de l'environnement. La deuxième partie propose deux essais sur les effets du changement climatique et des politiques environnementales sur le développement. Le troisième chapitre met en évidence un effet négatif et significatif de la variabilité climatique sur la sécurité alimentaire dans les pays en développement. Cet effet apparaît plus élevé dans les pays africains. Par ailleurs, cet effet est exacerbée dans les pays à conflit et ceux vulnérables aux chocs des prix des biens alimentaires. Le quatrième chapitre analyse l'effet de la similitude des politiques environnementales sur le commerce bilatéral. Contrairement aux études précédentes qui utilisent des indicateurs partiels de réglementation environnementale (indicateurs axés sur les moyens ou sur les résultats), nous construisons un indicateur de politique environnementale révélé. Les résultats suggèrent que la similitude dans les politiques environnementales n'a pas d'effet sur les flux commerciaux bilatéraux. En outre les résultats ne dépendent ni du niveau de développement de pays partenaires ni des caractéristiques des biens exportés (biens manufacturés et biens primaires).

*Keywords:* Democratic institutions; Education; Income inequality; Investments; Food Prices Vulnerability; Food security; Panel data; Gravity model; Trade, Environmental policies; Climatic variability; Civil conflicts; Air pollution



