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Thore Kockerols

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**Essays on**  
**Macro-Financial Linkages**

Thore Kockerols

*Thèse pour l'obtention du grade de  
Docteur de l'Université Paris 1 Panthéon-Sorbonne  
en Sciences Economiques*

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# Glossary

<b>AIC</b>	Akaike Information Criterion
<b>CES</b>	constant elasticity of substitution
<b>CPI</b>	consumer price index
<b>DSGE</b>	dynamic stochastic general equilibrium
<b>EBA</b>	European Banking Authority
<b>EC</b>	European Commission
<b>ECB</b>	European Central Bank
<b>F-IRB</b>	Foundation-Internal Ratings Based
<b>FCE</b>	final consumption expenditure
<b>GAMLSS</b>	Generalized Additive Models for Location, Scale and Shape
<b>GDP</b>	gross domestic product
<b>GFC</b>	Global Financial Crisis
<b>IFRS</b>	International Financial Reporting Standards
<b>IMF</b>	International Monetary Fund
<b>IRF</b>	impulse response function
<b>LME</b>	London Metal Exchange
<b>NPL</b>	non-performing loan
<b>OECD</b>	Organisation for Economic Co-operation and Development
<b>OMT</b>	Outright Monetary Transactions
<b>SME</b>	Small and Medium Enterprise

**TFP** total factor productivity

**VAR** vector autoregression

# Résumé

La crise financière mondiale a mis en évidence l'importance du secteur financier pour l'économie. Au-delà de la tourmente économique qu'elle a provoquée, la crise financière mondiale a donné lieu à un débat scientifique animé sur les liens entre le secteur financier et la macroéconomie. Il est devenu évident que ces liens n'étaient pas suffisamment représentés dans les modèles utilisés pour la prévision et l'analyse des politiques avant la crise. Mais il ne suffit pas d'essayer de comprendre comment se déroulent les crises. Il est tout aussi important de comprendre les remèdes efficaces et de développer des *les leçons apprises* pour le secteur financier et la macroéconomie sont après la crise. Ma thèse de doctorat m'éclaire sur trois questions liées à ce thème.

Le chapitre 1 est un effort théorique et empirique pour comprendre l'émergence des crises financières, en étudiant les liens entre la macroéconomie et le secteur financier. Gaël Giraud et moi-même développons un modèle de système macro-financier dynamique de la zone euro, qui saisit les caractéristiques importantes de la crise financière. La classe des modèles dynamiques non linéaires permet d'inclure la crise financière en tant que résultat *endogène* de la dynamique, plutôt qu'en raison de chocs exogènes anormalement importants. De plus, des écarts importants par rapport à l'équilibre peuvent être obtenus tout en maintenant la stabilité des paramètres. Ces caractéristiques nous ont conduit à choisir cette classe de modèles et à l'étendre à un secteur financier. L'une des applications du modèle est un test de résistance du secteur bancaire dans différents scénarios possibles liés à l'Union bancaire européenne (Giraud and



Kockerols, 2015). Nous estimons que le cadre de renflouement proposé et la taille du Fonds à résolution unique ne sont probablement pas suffisants pour briser la boucle diabolique entre les États souverains et les banques. Les forces de notre modèle résident dans ses caractéristiques et dans l'adéquation démontrée aux données, qui seront mises en évidence plus en détail dans le chapitre 1. Ces caractéristiques en font une contribution pertinente à la classe des modèles de politiques.

Dans les chapitres suivants de ma thèse, je me penche sur les phénomènes après la crise. Le chapitre 2 examine le comportement des banques au lendemain de la crise. Prenant l'exemple d'un pays gravement touché par la crise financière mondiale, l'Irlande, Katharina Bergant et moi-même examinons les déterminants, l'efficacité et les implications de "forbearance".<sup>1</sup> En utilisant des données très détaillées sur les prêts aux entreprises, nous montrons que les banques confrontées à des niveaux élevés de prêts non productifs par rapport à leur capital et à leurs provisions étaient plus susceptibles d'accorder des mesures d'abstention au groupe d'emprunteurs le plus risqué. Dans un deuxième temps, nous analysons l'efficacité de cette pratique pour réduire la probabilité de défaut. Nous montrons que la mesure la plus courante de l'abstention, soit l'extension de la limite, est efficace à court terme, tandis que l'absence d'abstention réduit considérablement la probabilité de défaut à long terme. Nos données empiriques suggèrent en outre que l'abstention et les nouveaux prêts sont des substituts pour les banques, car les parts élevées de l'abstention sont corrélées négativement avec les nouveaux prêts au même groupe d'emprunteurs. Ce lien entre l'abstention et les nouveaux prêts nous ramène au thème des liens macrofinanciers.

Le chapitre 3 se concentre sur un cas d'implication des banques dans les matières premières. L'analyse du comportement des banques est menée dans un contexte de faible rentabilité bancaire et de faibles coûts de financement, à la suite d'une

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<sup>1</sup>"Forbearance" est la pratique consistant à accorder des concessions à un emprunteur.

politique monétaire expansionniste après la crise financière mondiale. Il met en lumière les implications des activités bancaires, du secteur financier à la macroéconomie, et met en lumière un autre aspect des liens macrofinanciers. Plus précisément, entre 2010 et 2014, un certain nombre de banques ont été - prétendument - impliquées dans la manipulation des marchés des matières premières. Cette évolution fait suite à une période d'intensification des échanges de produits financiers liés aux matières premières. Les banques sont devenues plus intégrées dans les marchés des produits de base, certaines d'entre elles ayant même étendu leurs activités au commerce physique et à l'entreposage. Au lendemain de la crise financière mondiale, il y a eu une offre excédentaire importante de produits de base en raison de l'effondrement de la demande et la manipulation présumée a commencé peu de temps après. Il a été dit que les banques détenaient des stocks, possédaient des entrepôts et négociaient des dérivés sur marchandises et des marchandises physiques à leur propre avantage. Cela aurait pu à son tour influencer sur l'élasticité des prix en rendant plus difficile la récupération des marchandises dans les entrepôts. Pour trouver des preuves de cette prétendue manipulation sur le marché de l'aluminium, j'utilise un modèle macroéconomique structurel et je conclus que les activités des banques ont effectivement eu un impact majeur sur les prix. Cet effet prix a eu des conséquences macroéconomiques négatives.

Dans ce qui suit, je résume brièvement les résultats de chacun des trois chapitres de cette thèse de doctorat et je les incorpore dans leur littérature respective.

## **Un modèle de système macrofinancier dynamique non linéaire de la zone euro**

*“Policy models, aimed at analyzing actual macroeconomic policy issues. Models in this class should fit the main characteristics of the data, including dynamics, and allow for policy analysis and*

*counterfactuals.”*

Cette citation d'un billet de blog écrit par Olivier Blanchard (Blanchard, 2017, cf.) sur la distinction entre la théorie et les modèles de politiques prépare le terrain pour notre contribution à la classe des modèles de politiques. Nous considérons le texte comme les principales caractéristiques des données. Cette caractéristique des données découle du fait que l'économie peut être considérée comme un système complexe, tel qu'il est décrit en évidence dans Arthur (1999). L'approche systémique dynamique est un moyen de saisir les phénomènes émergents et des progrès considérables ont été réalisés dans la modélisation de l'économie en tant que système dynamique (Keen, 1995, cf.). Ici, nous voulons élargir le côté financier de ces modèles et évaluer les prévisions pour les agrégats économiques tels que la croissance du PIB, le chômage, l'inflation ou la dette publique.

Nous construisons notre modèle comme une démonstration de la faisabilité de la simulation et de la prévision de ce type de modèles et nous proposons une méthode de calibration et d'estimation. Compte tenu de l'histoire économique récente de la zone euro, nous estimons qu'il est essentiel d'inclure la monnaie endogène et la dette publique et privée comme moteurs de la dynamique de notre système dynamique non linéaire. Benes et al. (2014) souligne cet argument en montrant que la création endogène de monnaie par le secteur bancaire entraîne une volatilité nettement plus élevée des variables réelles. En outre, les versions linéarisées de leur modèle ne rendent pas compte de ces mouvements brusques et importants, qui se sont produits pendant la crise financière, par rapport aux versions non linéaires. Nous adoptons donc une approche de modélisation non linéaire et incluons la création monétaire endogène qui n'est pas neutre à court et à long terme. Une autre caractéristique que nous jugeons essentielle dans cette analyse est le rôle de la dette publique et de la dette privée. Le rôle de la dette publique a été suffisamment souligné pendant la crise de la dette grecque (Reinhart and Rogoff, 2009, cf.). La dette privée était moins au centre

de l'attention, mais joue certainement un rôle tout aussi important dans le cycle financier (Vague, 2014, cf.). Enfin, on peut dire que l'économie pendant la crise financière était loin d'être à l'équilibre et que le comportement d'un agent représentatif avait du mal à décrire son comportement. Cette notion de comportement n'émergeant qu'à un niveau agrégé et qui ne pouvait pas être déduite des microfondations a été décrite de manière évidente par le théorème Sonnenschein-Mantel-Debreu (Debreu (1974); Mantel (1974); Sonnenschein (1972, 1973)) pour le côté de la demande et par Mas-Colell (1989) pour le côté de l'offre. En conséquence, nous adoptons une approche phénoménologique de la consommation, de l'investissement et de la fixation des salaires et nous les estimons en fonction des variables d'état. Afin de saisir les dynamiques hors équilibre, nous adoptons une approche systémique dynamique avec une dynamique Lotka-Volterra entre les salaires et le chômage.

Le modèle de base auquel nous ajoutons nos extensions a été introduit par Goodwin (1967). Il a mis en place un modèle de systèmes dynamiques non linéaires présentant des cycles économiques endogènes. Diverses extensions ont été ajoutées au fil du temps au modèle. L'utilisation variable des capacités, une caractéristique cruciale pour capter les pénuries de demande, a été introduite pour la première fois par Desai (1973). Keen (1995, 2000) a ajouté de la dette au modèle et a montré son effet déstabilisateur. Ce phénomène a été décrit pour la première fois par l'hypothèse d'instabilité de Hyman Minsky et la théorie de la déflation de la dette d'Irving Fisher.<sup>2</sup> Des contributions plus récentes se concentrent sur la façon dont les extensions du modèle standard affectent leurs équilibres à long terme et la stabilité de ceux-ci (cf. analyse de Giraud and Grasselli (2016); Giraud and Nguyen-Huu (2016); Grasselli and Costal-Lima (2012); Grasselli and Nguyen-Huu (2015)). Un autre volet de la documentation porte sur la capacité de ces modèles à reproduire les données observées. Une première contribution à la méthodologie d'estimation de cette

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<sup>2</sup>(Fisher, 1933; Minsky, 1957, 1970, 1982, cf.)

classe de modèles a été faite par Desai (1984). Harvie (2000) a conclu qu'ils ont une mauvaise concordance avec les données réelles, mais récemment Grasselli and Maheshwari (2016) a prouvé que l'enquête originale de Harvie était erronée et a conclu que le modèle correspondait bien aux données. De plus, Mc Isaac (2016) utilise la méthode du maximum de vraisemblance simulé pour estimer un modèle standard légèrement modifié et constate qu'il surpasse un modèle vector autoregression (VAR) dans la prévision de la part des salaires sur un horizon temporel allant jusqu'à deux ans.

La dynamique fondamentale sous-jacente peut être décrite comme suit : Supposons que le secteur de production augmente sa production. Si la demande peut absorber cette augmentation, le secteur de la production continuera d'augmenter la production et l'emploi. À un certain moment, cela facilitera les négociations salariales en cours sur le marché du travail et la part des salaires augmentera. Ces dernières réduisent la part des bénéfices des entreprises, de sorte qu'elles inversent leur comportement et réduisent la production et l'emploi. La part des bénéfices se redressera en réaction à la réduction de la production et de l'emploi et le cycle économique recommencera. Dans le présent document, la dynamique susmentionnée est enrichie par deux facteurs supplémentaires. Premièrement, nous n'imposons pas la loi de Say de sorte que la demande pourrait ne pas être en mesure d'absorber une production supplémentaire dans la phase ascendante du cycle économique réel. Deuxièmement, si le secteur de la production veut investir, il devra peut-être emprunter au secteur bancaire, qui acceptera de fournir le soutien financier nécessaire à un coût qui dépend de l'état général de l'économie et des niveaux d'endettement. Ces frictions supplémentaires nous permettent d'étudier une variété de trajectoires hors équilibre aux propriétés riches.

A la lumière de la littérature en plein essor mentionnée ci-dessus, nos contributions méthodologiques consistent à introduire un secteur public interagissant avec toutes les parties de l'économie, les taux d'intérêt et la dynamique de

la dette pour tous les secteurs et un secteur bancaire dirigé par les besoins réglementaires et avec un taux d'intérêt déterminé de manière endogène. De plus, nous apportons une procédure d'étalonnage et d'estimation. Les équations déterminant la consommation, l'investissement et les salaires sont estimées à partir des données des comptes nationaux de la zone euro, en utilisant des techniques d'estimation non linéaires et non gaussiennes d'abord introduites par Voudouris et al. (2012). Enfin, l'ensemble des paramètres dynamiques du système sont estimés en utilisant le maximum de vraisemblance.

## **Modèles de “forbearance” dans la période d’après-crise**

Lors de la récente crise financière, le secteur bancaire a été à la fois le déclencheur et l'un des secteurs les plus touchés dans de nombreux pays. Les défaillances d'entreprises, un effondrement des prix des maisons et un taux de chômage élevé ont menacé la santé des bilans des banques. Dans ces circonstances, les prêteurs et les emprunteurs ont jugé qu'il était dans leur intérêt de maintenir en vie les prêts non productifs en empêchant la défaillance d'un emprunteur risqué. Des termes tels que “evergreening”, “prêts zombie” ou “gambling for resurrection” sont apparus dans la littérature économique pour décrire la pratique consistant à accorder des concessions aux emprunteurs en difficulté. Bien que cela puisse être économiquement utile dans certaines circonstances, les banques peuvent s'en servir pour dissimuler des pertes potentielles. Cela peut entraîner un risque systémique, accroître l'incertitude quant à la qualité des actifs des banques et miner la confiance dans la solvabilité du secteur bancaire, ce qui exige des régulateurs qu'ils surveillent et empêchent la mise en place de cette pratique.

À l'aide de données sur les prêts commerciaux de toutes les banques irlandaises, nous étudions les déterminants et l'efficacité de l'abstention après la récente crise financière mondiale et fournissons des preuves de plusieurs tendances

observées dans les banques en difficulté. Dans notre cadre empirique, nous distinguons entre les extensions de la limite globale de crédit ou de l'échéance du prêt, un arrêt de l'amortissement, une baisse relative du taux d'intérêt et un refinancement de l'exposition. En utilisant un modèle logit standard saturé de divers effets fixes, nous constatons que les emprunteurs les plus risqués sont plus susceptibles de se voir accorder une mesure d'abstention si le prêteur est confronté à des niveaux élevés de prêts non productifs par rapport à son capital et à ses provisions. En ce qui concerne la relation positive entre les niveaux de stress des banques - mesurés par le ratio Texas - et une plus grande probabilité d'accorder l'abstention de réglementation, nous offrons une explication dans le cadre réglementaire actuel. Lorsque la défaillance est perçue comme une décision consciente de la banque et de l'entreprise, les banques sont incitées à ne pas considérer les prêts comme non productifs, mais à accorder l'abstention en raison de l'impact sur leur rentabilité et, en fin de compte, sur leurs ratios de fonds propres (Eisfeldt and Rampini, 2008). De plus, comme les banques ne connaissent pas la persistance du choc qui frappe les entreprises, il est rationnel de pratiquer l'abstention en supposant qu'elle pourrait aider l'entreprise à survivre. Outre les incitations, l'abstention peut être un moyen de soulager les emprunteurs et les banques si elle permet de réduire la probabilité de défaut et d'aider ainsi l'économie dans son ensemble.

Dans un deuxième temps, nous examinons l'efficacité de l'abstention comme moyen de prévenir le défaut de paiement. Nous montrons qu'une prolongation de la limite est efficace pour réduire la probabilité de défaut jusqu'à un an à l'avance. Pour un horizon de temps plus long et d'autres mesures d'abstention, nous constatons que les emprunteurs traités sont en fait plus susceptibles d'être en défaut que leurs pairs dans la même catégorie de risque. Bien que cela puisse être dû à plusieurs mécanismes (p. ex. biais de sélection au sein d'une catégorie de risque), nous montrons que l'abstention n'a pas empêché la défaillance à long terme après la crise financière mondiale. Enfin, la question se pose de savoir

si les nouveaux prêts sont modérés ou non parce que le capital et les autres ressources au sein de la banque sont affectés aux prêts faisant l'objet d'une abstention. Nous présentons des preuves que les prêts et l'abstention pourraient être traités comme des substituts par les banques. Dans des groupes de prêts similaires, nous constatons que la part de l'abstention est négativement liée à l'émission de nouveaux crédits.

Par conséquent, nous contribuons à un courant de littérature axée sur les techniques d'abstention des banques qui a émergé au cours des deux dernières décennies. Pour le Japon, les données empiriques montrent que les banques en difficulté ont alloué des crédits à des emprunteurs gravement dépréciés pour éviter la réalisation de pertes sur leurs propres bilans (par exemple, Peek and Rosengren (2005), Sekine et al. (2003), et Watanabe (2010)). En analysant le mécanisme moteur de l'abstention pendant la "décennie perdue" du pays, Caballero et al. (2008) utilise le terme "prêts zombie" pour le crédit aux entreprises non rentables à des taux d'intérêt inférieurs aux valeurs du marché. Outre le danger pour les banques elles-mêmes, les auteurs montrent que cette mauvaise allocation du crédit vers des emprunteurs insolubles a eu des effets négatifs significatifs sur l'économie réelle. Il a été constaté que la présence d'entreprises zombies freine la création d'emplois, décourage l'entrée d'entreprises saines et réduit l'emploi et l'investissement dans des entreprises saines. En utilisant les effets des injections de capital pour les institutions financières japonaises, Giannetti and Simonov (2013) montrent que les banques en difficulté qui restaient sous-capitalisées étaient plus susceptibles de s'engager dans le "evergreening" en maintenant des relations avec des emprunteurs faibles.

Plus récemment, il est devenu plus clair que le Japon n'était pas une exception (Acharya et al., 2016a). Homar et al. (2015) regardez les banques européennes et découvrez que les banques faibles sont plus susceptibles d'accorder des concessions aux emprunteurs faibles. Les auteurs réclament davantage de travaux empiriques sur les modèles d'abstention comme facteur important de la lente



reprise après la crise financière mondiale. En utilisant le registre de crédit italien, Schivardi et al. (2017) montrent que les banques italiennes avec des niveaux de capital relativement bas étaient moins susceptibles de réduire le crédit aux entreprises non viables après la crise financière mondiale. Cette mauvaise répartition du crédit a entraîné une augmentation du taux de faillite d'entreprises saines, tout en réduisant le taux de faillite d'entreprises non viables. Acharya et al. (2016b) utilisent l'annonce du Outright Monetary Transactions (OMT) comme un événement sur lequel identifier les modèles de "prêts zombie" pour les banques européennes. Les institutions qui n'ont pas été suffisamment recapitalisées à la suite de l'annonce de l'OMT étaient plus susceptibles d'accorder des prêts à des entreprises faibles au lieu de leurs pairs plus solvables qui auraient été en mesure d'investir le crédit de manière plus rentable. Il en a résulté des effets réels significatifs, notamment un ralentissement de la reprise économique dans la période d'après-crise.

Notre analyse est également motivée par les travaux existants axés sur les incitations des banques à s'engager dans l'abstention et donc dans des prêts relativement risqués. Keuschnigg and Kogler (2017) présente un modèle théorique montrant que les banques faibles tentent d'éviter de radier les prêts non productifs afin de prévenir une violation des exigences réglementaires ou même l'insolvabilité. Cette littérature souligne également les conséquences négatives possibles de ces modèles pour la stabilité financière lorsque les banques ne "nettoient pas leurs bilans" (Diamond and Rajan, 2011). En analysant le cas de la Chine, Zhang et al. (2016) montre que des ratios élevés de prêts non productifs sont associés à des prêts plus risqués, ce qui augmente potentiellement le risque de crédit des institutions individuelles et menace la stabilité financière. Huizinga and Laeven (2009) montrent que les banques en difficulté aux États-Unis ont utilisé leur pouvoir discrétionnaire en matière de comptabilité pendant la crise financière mondiale afin de gonfler la valeur comptable de leurs actifs, ce qui fausse la vision de la santé financière de ces institutions. En outre, Bonac-

corsi di Patti and Kashyap (2017) montrent que les banques sont en mesure de se remettre beaucoup plus rapidement des chocs défavorables importants si elles gèrent les clients à risque de manière plus agressive et réduisent ainsi le risque de crédit.

Nos conclusions révèlent plusieurs nouveautés. D’abord, nous soutenons que la capitalisation n’est pas le seul facteur déterminant de l’abstention pour les banques. Comme on peut le voir dans les récents stress tests (EBA, 2016b), certaines banques de notre échantillon ont été suffisamment recapitalisées depuis la crise par un sauvetage public, de sorte qu’elles dépassent désormais largement les exigences réglementaires. Cependant, les prêts non performants se situent à des niveaux très élevés par rapport à toutes les normes, ce qui peut constituer une menace pour les niveaux de capitalisation, même en cas de stress économique modéré (IMF, 2016). Par conséquent, nous soutenons que la qualité du portefeuille de prêts d’un prêteur doit être prise en compte dans l’analyse des déterminants du “prêt zombie”. Deuxièmement, nous exploitons la qualité des données sur le niveau des prêts pour mesurer les techniques d’abstention en utilisant plus de définitions que ce qui est courant dans la littérature. Nous suggérons que la pression financière en temps de crise crée des incitations pour différents types d’abstention autres que les prêts subventionnés par le biais d’un taux d’intérêt plus bas. Plus précisément, nous analysons si les banques étendent les limites de crédit ou les échéances, ou choisissent d’accorder d’autres mesures telles que l’arrêt de l’amortissement ou le refinancement d’un produit de prêt. De plus, les données granulaires sur les prêts nous permettent de suggérer qu’une prolongation de la limite a permis de réduire la probabilité de défaut jusqu’à un an, mais qu’aucune mesure d’abstention n’a été efficace à long terme pour le système bancaire. En utilisant un modèle logit-hazard, nous montrons la relation entre les différentes mesures d’abstention et la probabilité de défaut sur divers horizons temporels. Enfin, les faits suggèrent que l’abstention immobilise les ressources des banques qui auraient pu être utilisées pour de nouveaux prêts.

Nous concluons notre analyse empirique par une analyse de corrélation qui révèle la relation négative entre l'abstention et les nouveaux prêts.

## **Conséquences économiques de la manipulation sur les marchés des produits de base – Données issues d'un modèle DSGE**

En 2014, le Sénat américain a publié un rapport sur l'implication des banques de Wall Street dans les marchés des matières premières (US Senate Permanent Subcommittee on Investigations, 2014). Ces banques ont été accusées de manipuler divers marchés de matières premières et, dans le cas de l'aluminium, elles sont actuellement en litige. Le marché de l'aluminium était censé être manipulé par l'augmentation des files d'attente des entrepôts, limitant ainsi l'aluminium disponible sur le marché. Il y a un débat animé sur l'effet sur les prix, une question que j'aborderai dans ce document. Pour leur défense, les accusés soutiennent que leur but était d'augmenter leurs revenus locatifs dans les entrepôts qu'ils possédaient, et non d'influencer les prix.

La manipulation alléguée sur le marché de l'aluminium est pertinente en raison de l'importance globale de l'aluminium en tant que métal industriel. D'autant plus que d'autres produits similaires auraient également été touchés ou pourraient l'être en abusant du même mécanisme de file d'attente. L'aluminium est un métal industriel important et largement utilisé dans tous les secteurs de l'économie. Il représente environ 0,38 % de la valeur ajoutée en 2007 des États-Unis<sup>3</sup>, ce qui représente environ un dixième de l'importance sur le pétrole.<sup>4</sup> Les stocks dans les entrepôts sous licence de London Metal Exchange (LME) ont augmenté en raison de la baisse de la demande après la crise financière mondiale. A partir de 2010, ces stocks ont continuellement diminué dans tous les

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<sup>3</sup>Les auteurs font leurs propres calculs en utilisant les données du Bureau of Economic Analysis Input Output tables.

<sup>4</sup>Voir Bodenstein et al. (2011).

entrepôts à l'exception de ceux de Vlissingen, aux Pays-Bas et de Detroit, aux Etats-Unis. Ces deux entrepôts appartenaient à des banques de Wall Street ou à des maisons de commerce de marchandises et étaient utilisés pour la prétendue manipulation. En 2011, les stocks totaux de LME et les stocks hors Vlissingen et Detroit ont considérablement divergé. Cela s'explique par l'accumulation de stocks dans ces endroits et, en même temps, le nombre de mandats annulés a grimpé en flèche dans ces entrepôts. Cela a conduit à des temps d'attente (files d'attente) pour la livraison des bâtiments en aluminium jusqu'à environ deux ans à la pointe, et parce que le stockage de l'aluminium est relativement moins cher que son transport, la file d'attente à Detroit a joué un rôle majeur pour les prix de l'aluminium aux États-Unis. Les mandats annulés dans ces deux endroits sont devenus moins importants à partir de 2014. Cela coïncide avec un changement de règle pour les ruptures de stock par le LME et l'enquête du Sénat américain sur cette pratique. L'importance de la disponibilité artificiellement limitée de l'aluminium provenant des entrepôts LME est diminuée par le fait que le marché de l'aluminium n'utilise le système LME qu'en dernier recours pour équilibrer le marché. En outre, une partie non négligeable de l'aluminium est stockée dans des entrepôts sous licence non LME, mais le système LME est le stockage préféré en raison de la facilité d'échange des warrants. Enfin, la grande majorité de la production d'aluminium est directement vendue aux consommateurs dans le cadre de contrats à long terme.

Il y a eu deux périodes de stocks élevés au cours des trois dernières décennies. La première, à l'époque de la surproduction par les anciens États soviétiques au début des années 1990 et la deuxième période suivant l'effondrement de la demande après la crise financière mondiale. L'effondrement de la demande a eu un impact négatif tout aussi important sur les prix de l'aluminium. Néanmoins, ils ont rebondi peu de temps après et, à partir de 2010, ils ont connu une légère tendance à la baisse avec des pics sporadiques. La question est de savoir si le nombre anormalement élevé de mandats annulés a fait grimper les prix entre

2010 et 2014.

J'aborde cette question en élaborant d'abord un modèle structurel, que j'utilise ensuite pour vérifier si l'impact de la manipulation sur les prix est empiriquement étayé par les résultats de l'estimation. Dans une deuxième étape, j'analyse ensuite l'importance et les conséquences/coûts économiques de ce phénomène pour l'économie américaine. Un impact économique négatif en ferait une question pertinente pour les décideurs et justifierait leur examen. D'autant plus que d'autres marchés de matières premières comparables au marché de l'aluminium (par exemple le cuivre) auraient été également affectés.

Cet article contribue à un courant de littérature sur la manipulation et la spéculation sur les marchés des matières premières. Pirrong (2017) présente les différents types de manipulation et constate que la manipulation du pouvoir de marché (comme c'est prétendument le cas pour l'aluminium) entraîne des pertes de poids mort dans l'économie. En outre, Pirrong (1993) et Fackler (1993) soulignent que les prix et les stocks sur le marché de la livraison (US Midwest Premium pour les entrepôts de Detroit) augmentent à la suite de la manipulation. Cette augmentation devrait être temporaire et, à la fin de la manipulation, le prix et le niveau des stocks diminuent. À la suite de l'argument des banques accusées, on pourrait soutenir que d'autres spéculateurs étaient à l'œuvre sur ce marché. Knittel and Pindyck (2016) présentent un modèle avec des stocks et soutiennent que la spéculation a un faible impact à moins que l'élasticité des prix ne soit supposée proche de zéro. Ils analysent le marché pétrolier, où la financiarisation aurait conduit à une augmentation de la spéculation sur les matières premières, et trouvent peu de preuves de l'influence de la spéculation. La différence entre la manipulation et la spéculation réside précisément dans le fait que l'élasticité des prix change avec le temps et peut être influencée par le manipulateur. Dans les deux cas, il faut faire la distinction entre la demande réelle (demande de flux) et la demande spéculative ou manipulatrice.

Il existe une littérature de plus en plus abondante qui utilise des modèles

structurels pour identifier les deux sources de la demande.

Kilian (2009) enquête sur le marché du pétrole avant la crise financière mondiale avec un modèle VAR incluant le stockage. Il accorde peu d'importance aux chocs spécifiques au marché pétrolier pour être un moteur du prix du pétrole. Du côté de la demande, il utilise les taux de fret maritime comme approximation de la demande liée aux produits de base, ce qui est un instrument faible pour la demande de pétrole. Les taux de fret sont fortement influencés par le marché du transport maritime et la construction navale cyclique. Par conséquent, ils ne représentent pas seulement les facteurs de la demande mondiale (Papapostolou et al., 2016). Pour combler ces lacunes dans la modélisation du côté de la demande, je plaide en faveur des modèles dynamic stochastic general equilibrium (DSGE). Ils permettent une modélisation plus détaillée de l'offre et de la demande et constituent un outil approprié pour estimer la demande manipulatrice d'aluminium. Le modèle DSGE utilisé ici s'appuie sur Unalmis et al. (2012) et Tumen et al. (2015). Ils modélisent l'économie américaine avec le pétrole utilisé dans la consommation et la production. Plus important encore, ils incluent le stockage dans leur modèle et identifient un choc de demande de stockage, qui est orthogonal aux autres chocs du côté de la demande. J'adapte ce modèle à mes besoins en implémentant le mécanisme de mise en file d'attente en tant que fonctionnalité du modèle. En outre, le marché de l'aluminium ne livre pas aux consommateurs comme c'est le cas pour le mazout (p. ex. chauffage ou essence).

La contribution de ce document est que j'estime l'effet et l'étendue d'un exemple concret de manipulation (présumée) d'un marché de produits de base avec un modèle macroéconomique structurel. L'estimation du modèle fournit des preuves de l'influence du mécanisme de file d'attente sur la dynamique du marché de l'aluminium après 2010. Le paramètre de friction correspondant s'avère plus élevé qu'avant la crise financière mondiale. En outre, les chocs manipulateurs de la demande (de stockage) s'avèrent être le choc le plus

important pour expliquer les variations du prix de l'aluminium. En outre, je trouve que les États-Unis ont un impact relativement faible sur le marché de l'aluminium. L'impact du marché de l'aluminium sur l'économie américaine est négligeable, ce qui n'est pas surprenant étant donné sa taille relative. Néanmoins, les chocs manipulateurs de la demande (de stockage) ont un impact négatif sur la production et entraînent une hausse des prix de l'aluminium, ainsi qu'une hausse de l'inflation et des taux d'intérêt nominaux.

Ces conclusions confirment que la manipulation alléguée a eu un impact sur le marché de l'aluminium. De plus, l'impact sur l'économie est faible mais négatif. Par conséquent, je soutiens que les décideurs politiques devraient s'inspirer de l'exemple du marché de l'aluminium et mettre en œuvre des changements de règles similaires, qui ont essentiellement conduit à des limites de rupture de stock plus élevées sur d'autres marchés de matières premières.

Cette thèse de doctorat est structurée comme suit. Le chapitre 1 traite d'un modèle de système dynamique de l'économie de la zone euro que Gaël Giraud et moi développons. Dans le chapitre 2, Katharina Bergant et moi analysons les modèles de tolérance dans la période post-crise. Enfin, dans le chapitre 3. Je cherche des preuves de manipulation sur les marchés des produits de base et j'en évalue les conséquences économiques.

# Introduction

The Global Financial Crisis (GFC) highlighted the importance of the financial sector for the economy. Beyond the economic turmoil it caused, the GFC led to a lively scientific debate about the linkages between the financial sector and the macroeconomy. It became apparent that these linkages were not sufficiently represented in the models used for forecasting and policy analysis before the crisis. Yet it is not sufficient to only try to understand how crises unfold. It is equally important to understand effective remedies and develop *lessons learned* for the financial sector and the macroeconomy after the crisis. My doctoral thesis sheds light on three questions related to this theme.

Chapter 1 is a theoretical and empirical effort to understand the emergence of financial crises, by studying the links between the macroeconomy and the financial sector. Gaël Giraud and I develop a macro-financial dynamical system model of the Euro Area, which captures important features of the financial crisis. The class of non-linear dynamic models allows to include financial crisis as an *endogenous* result of the dynamics, rather than because of abnormally large exogenous shocks. Moreover, large deviations from equilibrium can be obtained while maintaining parameter stability. These features led us to choose this class of models and extend it with a financial sector. One application of the model is a stress test of the banking sector under different possible scenarios related to the European Banking Union (Giraud and Kockerols, 2015). We find that the proposed bail-in framework and the size of the Single Resolution Fund are most likely not sufficient to break the diabolic loop between sovereigns and



banks. The strengths of our model lie in its features and in the demonstrated fit to the data, which will be highlighted more in detail in chapter 1. These characteristics make it a relevant contribution to the class of policy models.

In the subsequent chapters of my thesis I look at phenomena after the crisis. Chapter 2 investigates bank behaviour in the aftermath of the crisis. Taking the example of a country severely hit by the GFC, Ireland, Katharina Bergant and I look at the determinants, effectiveness and implications of forbearance.<sup>5</sup> Using highly detailed supervisory loan-level data on corporate loans, we show that banks facing high levels of non-performing loans (NPLs) relative to their capital and provisions were more likely to grant forbearance measures to the riskiest group of borrowers. As a second step, we analyse the effectiveness of this practice in reducing the probability of default. We show that the most common measure of forbearance, a limit extension, is effective in the short run, while no forbearance measure significantly reduces probability of default in the long run. Our empirical evidence further suggests that forbearance and new lending are substitutes for banks, as high shares of forbearance are negatively correlated with new lending to the same group of borrowers. This connection between forbearance and new lending brings us back to the theme of macro-financial linkages.

Chapter 3 focuses on a case of banks' involvement in commodities. The analysis of bank behaviour is conducted in a context of low bank profitability and low funding costs, following expansionary monetary policy after the GFC. It highlights the implications of bank activities from the financial sector to the macroeconomy, and sheds light on another aspect of macro-financial linkages. More specifically, between 2010 and 2014 a number of banks were –allegedly– involved in manipulating commodity markets. This development followed a period of heightened trading of financial products linked to commodities. Banks became more integrated in commodity markets, with some of them

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<sup>5</sup>Forbearance is the practice of granting concessions to a borrower.

even expanding their activities to physical trading and warehousing. In the aftermath of the GFC, there had been a substantial over-supply of commodities due to the collapsed demand and the alleged manipulation began soon after. Banks were said to hold inventories, owning warehouses and trading commodity derivatives and physical commodities to their own advantage. This in turn could have influenced price elasticities by making it more difficult to retrieve commodities from warehouses. To find evidence for this alleged manipulation in the aluminium market, I use a structural macroeconomic model and conclude that the banks' activities indeed had a major impact on prices. This price effect resulted in negative macroeconomic consequences.

In the following, I provide a short summary of the findings of each of the three chapters of this doctoral thesis and embed them into their respective literatures.

## **A macro-financial non-linear dynamical system model of the Euro Area**

*“Policy models, aimed at analyzing actual macroeconomic policy issues. Models in this class should fit the main characteristics of the data, including dynamics, and allow for policy analysis and counterfactuals.”*

This quote from a blog post written by Olivier Blanchard (Blanchard, 2017, cf.) about the distinction between theory and policy models sets the scene for our contribution to the class of policy models. We deem *emergent phenomena* as the main characteristics of the data. This feature of the data arises from the fact that the economy can be thought of as a complex system, as prominently described in Arthur (1999). The dynamical systems approach is one way to capture emergent phenomena and considerable progress has been done in modelling the economy as a dynamical system (cf. Keen (1995)). Here, we want to expand the financial side of these models and evaluate forecasts for economic

aggregates such as gross domestic product (GDP) growth, unemployment, inflation or public debt.

We build our model as a demonstration of the feasibility for simulating and forecasting these kind of models and propose a method for calibration and estimation. Given the recent economic history of the Euro area we deem it essential to include endogenous money and public and private debt to be drivers of the dynamics in our non-linear dynamical system. Benes et al. (2014) underlines this argument by showing that endogenous money creation by the banking sector leads to significantly higher volatility in real variables. Furthermore, linearised versions of their model fail to capture those abrupt and large moves, which occurred during the financial crisis, compared to non-linear versions. Therefore, we adopt a non-linear modelling approach and include endogenous money creation which is non-neutral in the short and long run. Another characteristic we deem critical in this analysis is the role of public as well as private debt. The role of public debt was arguably sufficiently highlighted during the Greek debt crisis (Reinhart and Rogoff, 2009, cf.). Private debt was less in focus, yet certainly plays an equally important role in the financial cycle (Vague, 2014, cf.). Finally, it is safe to say that the economy during the financial crisis was far from equilibrium and that the behaviour of a representative agent was at pains to describe its behaviour. This notion of behaviour emerging only at an aggregate level and which could not be deduced from microfoundations was prominently described by the Sonnenschein-Mantel-Debreu theorem (Debreu (1974); Mantel (1974); Sonnenschein (1972, 1973)) for the demand side and by Mas-Colell (1989) for the supply side. As a consequence we adopt a phenomenological approach to consumption, investment and wage setting and estimate them as functions of state variables. In order to capture out-of-equilibrium dynamics we adopt a dynamical systems approach with Lotka-Volterra dynamics between wages and unemployment.

The base model to which we add our extensions was introduced by Goodwin

(1967). He set up a non-linear dynamical systems model exhibiting endogenous business cycles. Various extensions were added over time to the model. Variable capacity utilisation, a crucial feature to capture demand shortages, was first introduced by Desai (1973). Keen (1995, 2000) added debt to the model and showed its destabilising effect. This phenomenon was first described by Hyman Minsky's "instability hypothesis" and Irving Fisher's debt-deflation theory.<sup>6</sup> More recent contributions focus on how extensions to the standard model affect their long term equilibria and stability of these (cf. Giraud and Grasselli (2016); Giraud and Nguyen-Huu (2016); Grasselli and Costal-Lima (2012); Grasselli and Nguyen-Huu (2015)). Another strand of the literature focuses on the ability of these kind of models to replicate the observed data. A first contribution to the methodology of estimating this class of models was made by Desai (1984). Harvie (2000) concluded that they have a poor fit to the actual data but recently Grasselli and Maheshwari (2016) proved the original investigation by Harvie to be erroneous and conclude a good fit of the model to the data. Furthermore, Mc Isaac (2016) uses the simulated maximum likelihood method to estimate a slightly modified standard model and finds that it outperforms a vector autoregression (VAR) model in forecasting the wage share over a time horizon of up to two years.

The core underlying dynamics can be described as follows: Suppose that the production sector increases its output. If the demand can absorb this increase, the production sector will continue to increase production and employment. At a certain point, this will ease the ongoing wage bargaining on the labour market, and the wage share will increase. The latter reduces the profit share of firms, so that they will reverse their behaviour and reduce production, and employment. The profit share will recover as a reaction to the reduction in production and employment and the business cycle starts anew. In this paper, the aforementioned dynamic is enriched by two additional factors. First, we

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<sup>6</sup>cf. Fisher (1933); Minsky (1957, 1970, 1982)

do not impose Say's law so that the demand may not be able to absorb an additional output in the ascending phase of the real business cycle. Second, if the production sector wants to invest, it might need to borrow from the banking sector, which will agree to provide the needed financial support at a cost which depends on the overall state of the economy and debt levels. These additional frictions enable us to study a variety of out-of-equilibrium trajectories with rich properties.

In light of the above mentioned burgeoning literature, our methodological contributions consist in introducing a public sector interacting with all parts of the economy, interest rate and debt dynamics for all sectors and a banking sector driven by regulatory needs and with an endogenously determined interest rate. Furthermore, we contribute a calibration and estimation procedure. The equations determining consumption, investment and wages are estimated on the national accounts data of the Euro Area, using non-linear and non-Gaussian estimation techniques first introduced by Voudouris et al. (2012). Finally, the whole dynamical system parameters are estimated using maximum likelihood.

## **Forbearance Patterns in the Post-Crisis Period**

In the recent financial crisis, the banking sector was simultaneously both the trigger as well as one of the most affected sectors in many countries. Corporate defaults, a crash in house prices, and high unemployment threatened the health of banks' balance sheets. Under these circumstances, lenders and borrowers found it in their interest to keep otherwise NPLs alive by preventing a risky borrower's default. Terms such as "evergreening", "zombie lending", or banks "gambling for resurrection" emerged in the economic literature to describe the practice of granting concessions to troubled borrowers. Whilst this can be economically useful under some circumstances, it can be used by banks to conceal potential losses. This can cause systemic risk, increase uncertainty

about the quality of banks' assets, and undermine trust in the banking sector's solvency, which calls for regulators to monitor and prevent the establishment of this practice.

Using loan-level data on the commercial loans of all Irish banks, we study the determinants and the effectiveness of forbearance after the recent GFC and provide evidence for several patterns observed in banks under stress. In our empirical setting, we distinguish between extensions in the overall credit limit or the maturity of the loan, a stop in amortisation, a relative decrease in the interest rate, and a rollover of the exposure. Using a standard logit model saturated with various fixed effects, we find that the riskiest borrowers are more likely to be granted a forbearance measure if the lender is facing high levels of NPLs relative to its capital and provisions. For the positive relationship between banks' stress levels - measured by the Texas Ratio - and a higher probability of granting forbearance, we offer an explanation through the current regulatory framework. When default is seen as a conscious decision of the bank and the firm, banks face an incentive not to flag loans as non-performing but to grant forbearance because of the impact on their profitability and ultimately their capital ratios (Eisfeldt and Rampini, 2008). Furthermore, since banks do not know the persistence of the shock hitting firms it is rational to practice forbearance under the assumption that it might help the firm survive. Besides the incentives, forbearance can be one way of releasing stress on borrowers and banks if it is effective in bringing down the probability of default and thereby helping the overall economy.

As a second step, we look at the effectiveness of forbearance as a mean of preventing default. We show that a limit extension is effective in reducing the probability of default up to one year ahead. For a longer time horizon and other forbearance measures we find that treated borrowers are in fact more likely to default compared to their peers within the same risk category. While this can be due to several mechanisms (e.g. selection bias within a risk category),

we show that forbearance did not prevent default in the long run after the GFC. Finally, the question arises over whether or not new lending is subdued because capital and other resources within the bank are allocated to forbore loans. We present evidence that lending and forbearance might be treated as substitutes by banks. Within buckets of similar loans, we find that the share of forbearance is negatively related with the issuance of new credit.

Therefore, we contribute to a strand of literature focused on forbearance techniques of banks which has emerged in the last two decades. For Japan, empirical evidence shows that troubled banks allocated credit to severely impaired borrowers to avoid the realisation of losses on their own balance sheets (e.g. Peek and Rosengren (2005), Sekine et al. (2003), and Watanabe (2010)). Analysing the driving mechanism of forbearance during the country's "lost decade", Caballero et al. (2008) use the term "zombie lending" for credit to unprofitable firms at interest rates below market values. Besides the hazard for banks themselves, the authors show that this misallocation of credit towards otherwise insolvent borrowers had significant negative effects on the real economy. The presence of zombie firms was found to depress job creation, deter the entry of healthy firms, and to decrease employment and investment of healthy firms. Using the effects following capital injections for Japanese financial institutions, Giannetti and Simonov (2013) show that troubled banks that remained under-capitalized were more likely to engage in "evergreening" by maintaining relationships with weak borrowers.

More recently, it became clearer that Japan was not an exception (Acharya et al., 2016a). Homar et al. (2015) look at European banks and find that weak banks are more likely to grant concessions to weak borrowers. The authors call for more empirical work regarding patterns of forbearance as an important factor in the slow recovery after the GFC. Using the Italian credit registry, Schivardi et al. (2017) show that Italian banks with relatively low capital levels were less likely to cut credit to non-viable firms after the GFC. This credit

misallocation led to an increase in the failure rate of healthy firms while it reduced the failure rate of non viable firms. Acharya et al. (2016b) use the announcement of the Outright Monetary Transactions (OMT) as an event on which to identify “zombie lending” patterns for European banks. Institutions which were not sufficiently recapitalised in the wake of the OMT announcement were more likely to extend loans to weak firms instead of their more creditworthy peers who would have been able to invest credit more profitably. This resulted in significant real effects, most notably a slow down of the economic recovery in the post-crisis period.

Our analysis is also motivated by existing work focused on the incentives for banks to engage in forbearance and therefore relatively risky lending. Keuschnigg and Kogler (2017) present a theoretical model showing that weak banks try to avoid writing off NPLs in order to prevent a violation of regulatory requirements or even insolvency. This literature also emphasizes possible negative consequences of these patterns for the financial stability when banks do not “clean up their balance sheets” (Diamond and Rajan, 2011). Analysing the case of China, Zhang et al. (2016) show that high NPL ratios are associated with riskier lending, potentially increasing individual institutions credit risk and threatening financial stability. Huizinga and Laeven (2009) show that distressed banks in the US used discretion in accounting during the GFC in order to inflate the book value of their assets which results in a distorted view of the financial health of these institutions. In addition, Bonaccorsi di Patti and Kashyap (2017) show that banks are able to recover significantly faster from large adverse shocks if they manage risky clients more aggressively and thereby reduce credit risk.

Our findings reveal several novelties. First, we argue that capitalisation is not the only determinant factor of forbearance for banks. As can be seen in recent stress tests (EBA, 2016b), some of the banks in our sample have been sufficiently re-capitalised since the crisis through a public bailout, so that



they now comfortably exceed regulatory requirements. However, NPLs are at very high levels by any standards, which can pose a threat to capitalisation levels under even moderate economic stress (IMF, 2016). Therefore, we argue that the quality of a lender's loan book must be considered when analysing the determinants of "zombie lending". Secondly, we exploit the quality of the loan level data to measure forbearance techniques using more definitions than are common in the literature. We suggest that financial pressure in times of crises creates incentives for different types of forbearance other than subsidised lending through a lower interest rate. More specifically, we analyse whether banks extend credit limits or maturities, or opt to grant other measures such as a stop in amortisation or a rollover of a loan product. Furthermore, the granular loan-level data allow us to suggest that a limit extension has been effective in bringing down the probability of default up to one year but no forbearance measure has been effective in the long run for the banking system. Using a standard logit-hazard model, we show the relationship between the different forbearance measures and the probability of default across various time horizons. Finally, the evidence suggests that forbearance ties up banks' resources that might have been used for new lending. We conclude our empirical analysis with a correlation analysis that reveals the negative relationship between forbearance and new lending.

## **Economic consequences of manipulation in commodity markets – Evidence from a DSGE model**

In 2014 the US Senate published a report about Wall Street banks involvement in commodity markets (US Senate Permanent Subcommittee on Investigations, 2014). Said banks were accused of manipulating various commodity markets, and, in the case of aluminium, they are currently in litigation. The aluminium market was supposedly manipulated by increasing stock out queues from

warehouses, and thereby limiting the available aluminium to the market. There is a lively debate about the effect on prices, a question I will address in this paper. To their defence, the accused argue that their goal was to increase their rental income in the warehouses they owned, and not to influence prices.

The alleged manipulation in the aluminium market is relevant because of the overall importance of aluminium as an industrial metal. Even more so, because other similar commodities were also allegedly affected or could be affected by abusing the same queuing mechanism. Aluminium is an important industrial metal widely used in all sectors of the economy. It accounts for about 0.38% of value added in 2007 in the US<sup>7</sup> which is about a tenth of the importance of oil.<sup>8</sup> Inventories in London Metal Exchange (LME) licensed warehouses increased as a consequence of falling demand after the GFC. From 2010 on these inventories did continuously fall in all warehouses except those based in Vlissingen, Netherlands and Detroit, USA. These two warehouses were owned by Wall Street banks or commodity trading houses, and used for the alleged manipulation. In 2011 total LME inventories and the inventories excluding Vlissingen and Detroit significantly diverged. This was due to an accumulation of inventories in said locations and at the same time the amount of cancelled warrants jumped in those warehouse locations. This led to waiting times (queues) for the delivery of aluminium building up to around two years at the peak, and because storing aluminium is relatively cheaper than transporting it, the queue in Detroit played a major role for aluminium prices in the US. The cancelled warrants in these two locations became less important from 2014 on. This coincides with a rule change for stock outs by the LME and the US Senate investigation into the practice. The importance of the artificially limited availability of aluminium from LME warehouses is diminished by the fact that the aluminium market uses the LME system only as a last resort to balance the

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<sup>7</sup>Authors own calculation using data from the Bureau of Economic Analysis Input Output tables.

<sup>8</sup>See Bodenstein et al. (2011).

market. Furthermore, a non-negligible part of aluminium is stored in non-LME licensed warehouses, but the LME system is the preferred storage because of the ease of trading the warrants. Lastly, the vast majority of the aluminium production is directly sold to consumers on long term contracts.

There were two periods of high inventories in the last three decades. The first one, around the time of overproduction by the ex-Soviet states in the early 1990's and the second period following the collapse in demand after the GFC. The collapse in demand had an equally important negative impact on aluminium prices. Nonetheless, they rebounded shortly after and from 2010 on they were on a slight downward trend with sporadic peaks. The question is, did the unusually high amount of cancelled warrants push up prices between 2010 and 2014?

I address this question by first developing a structural model, which I then use to test if the impact of manipulation on prices is empirically supported by the estimation results. In a second step I then analyse the importance and economic consequences/costs of this phenomenon for the US economy. A negative economic impact would make it a relevant issue for policy makers and warrant their scrutiny. Even more so, given that other commodity markets which are comparable to the aluminium market (e.g. copper) were allegedly equally affected.

This paper contributes to a strand of literature about manipulation and speculation in commodity markets. Pirrong (2017) lays out the different kinds of manipulation and finds that market power manipulation (as is allegedly the case for aluminium) causes deadweight losses in the economy. Furthermore, Pirrong (1993) and Fackler (1993) highlight that prices and inventories in the delivery market (US Midwest Premium for the case of the Detroit warehouses) rise as a consequence of the manipulation. This increase is expected to be temporary and at the end of the manipulation the price and inventory levels decrease. Following the argument of the accused banks, one could argue that, if

anything, other speculators were at work in this market. Knittel and Pindyck (2016) lay out a model with inventories and argue that speculation has a small impact unless price elasticities are assumed to be close to zero. They analyse the oil market, where financialisation supposedly led to an increase in commodity speculation, and find little evidence for speculation having an influence. The difference between manipulation and speculation is precisely that price elasticities do change over time and can be influenced by the manipulator. In both cases one needs to distinguish between real demand (flow demand) and speculative or manipulative demand.

There is a growing literature using structural models to identify the two sources of demand.

Kilian (2009) investigates the oil market before the GFC with a VAR model including storage. He assigns little importance to oil market specific shocks to be a driver of the oil price. For the demand side he uses ocean freight rates as a proxy for commodity related demand, which is a weak instrument for oil demand. Freight rates are strongly influenced by the shipping market and the cyclical shipbuilding. Therefore, they do not only represent global demand factors (Papapostolou et al., 2016). To overcome these shortcomings in modelling the demand side, I argue in favour of dynamic stochastic general equilibrium (DSGE) models. They allow for a more detailed modelling of demand and supply and are a suitable tool to estimate the manipulative demand for aluminium. The DSGE model used here builds on Unalmis et al. (2012) and Tumen et al. (2015). They model the US economy with oil used in consumption and production. Most importantly, they include storage in their model and identify a storage demand shock, which is orthogonal to the other demand side shocks. I adapt this model for my purposes by implementing the queueing mechanism as a feature in the model. Furthermore, the aluminium market does not deliver to consumers as is the case for oil (e.g. heating or gasoline).

The contribution of this paper is that I estimate the effect and extend of a concrete example of (alleged) manipulation of a commodity market with a structural macroeconomic model. The model estimation provides evidence for the influence of the queue mechanism on dynamics in the aluminium market after 2010. The corresponding friction parameter turns out to be higher than before the GFC. Furthermore, manipulative (storage) demand shocks are found to be the most important shock in explaining variations in the price of aluminium. Furthermore, I find that the US has a relatively small impact on the aluminium market. The impact on the US economy from the aluminium market is found to be negligible, which is not surprising given its relative size. Nonetheless, manipulative (storage) demand shocks are found to have a negative impact on output and lead to higher aluminium prices, along with higher inflation and nominal interest rates.

These findings confirm that the alleged manipulation had an impact on the aluminium market. Furthermore, the impact on the economy is small but negative. Therefore, I argue that policy makers should learn from the example of the aluminium market and implement similar rule changes, which essentially led to higher stock out limits, in other commodity markets.

This doctoral thesis is structured as follows. Chapter 1 is about a dynamical system model of the euro area economy Gaël Giraud and I develop. In chapter 2, Katharina Bergant and I analyse forbearance patterns in the post-crisis period. Finally, in chapter 3 I look for evidence of manipulation in commodity markets and evaluate the economic consequences.

# 1

## A macro-financial non-linear dynamical system model of the Euro Area<sup>1</sup>

### 1.1 Introduction

*“Policy models, aimed at analyzing actual macroeconomic policy issues. Models in this class should fit the main characteristics of the data, including dynamics, and allow for policy analysis and counterfactuals.”*

This quote from a blog written by Olivier Blanchard (cf. Blanchard (2017)) about the distinction between theory and policy models is to set the scene for our contribution to the class of policy models. As for the main characteristics of the data we deem essential emergent phenomena. This feature of the data arises from the fact that the economy can be thought of as a complex systems, as prominently described in Arthur (1999). The dynamical systems approach is one

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<sup>1</sup>Joint work with Gaël Giraud (Université Paris 1 Panthéon-Sorbonne; E-mail: gael.giraud@univ-paris1.fr). The authors are grateful for comments and suggestions by Antoine Monserand, Farshad Ranjbar Ravasan, Julian Hinz and Adrien Nguyen-Huu. The authors gratefully acknowledge the support of the Laboratory of Excellence on Financial Regulation (Labex ReFi), and PRES heSam under the reference ANR-10-LABX-0095 and the support of the Chair “Energy and Prosperity”. The usual *caveat* applies.

way to capture emergent phenomena and considerable progress has been done in modelling the economy as a dynamical system (cf. Keen (1995)). Here, we want to expand the financial side of these models and evaluate forecasts for economic aggregates such as gross domestic product (GDP) growth, unemployment, inflation or public debt.

We build our model as a demonstration of feasibility for simulating and forecasting these kind of models and propose a method for calibration and estimation. Given the recent economic history of the Euro area we deem it essential to include endogenous money and for public and private debt to be drivers of the dynamics in our non-linear dynamical system. Benes et al. (2014) underlines this argument by showing that endogenous money creation by the banking sector leads to significantly higher volatility in real variables. Furthermore, linearised versions of their model fail to capture those abrupt and large moves, which occurred during the financial crisis, compared to non-linear versions. Therefore, we adopt a non-linear modelling approach and include endogenous money creation which is non-neutral in the short and long run. Another characteristic we deem critical in this analysis is the role of public as well as private debt. The role of public debt was sufficiently highlighted during e.g. the Greek debt crisis (cf. Reinhart and Rogoff (2009)). Private debt was less in focus and certainly plays an equally important role in the financial cycle (cf. Vague (2014)). Finally, it is safe to say that the economy during the financial crisis was far from equilibrium and that the behaviour of a representative agent was at pains to describe its behaviour. This notion of behaviour emerging only at an aggregate level and which could not be deduced from microfoundations was prominently described by the Sonnenschein-Mantel-Debreu theorem (Debreu (1974); Mantel (1974); Sonnenschein (1972, 1973)) for the demand side and by Mas-Colell (1989) for the supply side. As a consequence we adopt a phenomenological approach to consumption, investment and wage setting and estimate them as functions of state variables. In order to capture out-of-equilibrium

dynamics we adopt a dynamical systems approach with Lotka-Volterra dynamics between wages and unemployment.

The base model to which we add our extensions was introduced by Goodwin (1967). He set up a non-linear dynamical systems model exhibiting endogenous business cycles. Various extensions were added over time to the model. Variable capacity utilisation, a crucial feature to capture demand shortages, was first introduced by Desai (1973). Keen (1995, 2000) added debt to the model and showed its destabilising effect. This phenomenon was first described by Hyman Minsky's "instability hypothesis" and Irving Fisher's debt-deflation theory.<sup>2</sup> More recent contributions focus on how extensions to the standard model affect their long term equilibria and stability of these (cf. Giraud and Grasselli (2016); Giraud and Nguyen-Huu (2016); Grasselli and Costal-Lima (2012); Grasselli and Nguyen-Huu (2015)). Another strand of the literature focuses on the ability of these kind of models to replicate the observed data. A first contribution to the methodology of estimating this class of models was made by Desai (1984). Harvie (2000) concluded that they have a poor fit to the actual data but recently Grasselli and Maheshwari (2016) proved the original investigation by Harvie to be erroneous and conclude a good fit of the model to the data. Furthermore, Mc Isaac (2016) uses the simulated maximum likelihood method to estimate a slightly modified standard model and finds that it outperforms a vector autoregression (VAR) model in forecasting the wage share over a time horizon of up to two years.

The core underlying dynamics can be described as follows: suppose that the production sector increases its output; if the demand can absorb this increase, the production sector will continue to increase production and employment. At a certain point, this will ease the ongoing wage bargaining on the labour market, and the wage share will increase. The latter reduces the profit share of firms, so that they will reverse their behaviour and reduce production, and

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<sup>2</sup>cf. Fisher (1933); Minsky (1957, 1970, 1982)



employment. The profit share will recover as a reaction to the reduction in production and employment and the business cycle starts anew. In this paper, the aforementioned dynamic is enriched by two additional factors. First, we do not impose Say's law so that the demand may not be able to absorb an additional output in the ascending phase of the real business cycle. Second, if the production sector wants to invest, it might need to borrow from the banking sector, which will agree to provide the needed financial support at a cost which depends on the overall state of the economy and debt levels. These additional frictions enable us to study a variety of out-of-equilibrium trajectories with rich properties.

In light of the above mentioned burgeoning literature, our methodological contributions consist in introducing a public sector interacting with all parts of the economy, interest rate and debt dynamics for all sectors and a banking sector driven by regulatory needs and with an endogenously determined interest rate. Furthermore, we contribute a calibration and estimation procedure. The equations determining consumption, investment and wages are estimated on the national accounts data of the Euro Area, using non-linear and non-Gaussian estimation techniques first introduced by Voudouris et al. (2012). Finally, the whole dynamical system parameters are estimated using maximum likelihood.

We develop our argument as follows. In Section 1.2, we formally describe our model for the Euro Area, while highlighting the extensions previously alluded to. Section 1.3 and 1.4 describes the calibration and estimation of the model to the Euro Area economy (more details on data and estimation can be found in the Appendix: A.1, A.2). Section 1.5 is devoted to analysing our simulations and presenting the results. Finally, Section 1.6 concludes. In the Appendix, Section A.3 highlights endogenous money creation in our model and Section A.4 explores the long term characteristics of the model. Section A.5, A.6 and A.7 highlight some modelling choices of our model.

## 1.2 Model

### 1.2.1 General structure of the economy

We consider a five-sector open economy consisting of corporate firms,<sup>3</sup> commercial banks, households, a public sector and the rest of the world. The latter is a synthetic entity comprising the European Central Bank (ECB), foreign commercial banks that interact with the domestic ones on the interbank market, foreign investors, etc. Firms produce one homogeneous good used for consumption, investment and trade, using capital and labour as inputs. Firms hold the stock of capital,  $K$ , which follows the standard accumulation rule:

$$\dot{K} = I_k - \delta K, \quad (1.1)$$

where  $I_k$  denotes real capital investment and  $\delta \in (0, 1)$  is a constant depreciation rate. We assume that the capital stock determines maximum output,  $Y_{max}$ , according to the relationship

$$Y_{max} := \frac{K}{\nu}, \quad (1.2)$$

where  $\nu > 0$  is a constant capital-to-output ratio. In order to capture the effect of a demand shortfall on production, we follow Desai (1973) by introducing a variable capacity utilisation rate,  $u \in (0, 1)$ , which enables us to define the real GDP,  $Y$ :

$$Y := uY_{max}.$$

Let us denote real aggregate consumption by  $C$ , which together with capital investment,  $I_k$ , government spending,  $\widehat{G}$ , exports,  $X$ , and imports,  $IM$ , determine total real sales demand faced by the domestic production sector:

$$Y_d := C + I_k + \widehat{G} + (X - IM) \quad (1.3)$$

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<sup>3</sup>Throughout, “corporates”, “production sector” and “firms” mean non-financial companies.

The difference between supply and demand determines changes in the real level of inventory held by firms.<sup>4</sup> In other words,

$$\dot{V} = Y - Y_d, \quad (1.4)$$

where  $V$  stands for the stock of inventories and  $\dot{V}$  denotes investment in inventory. Let the real wage bill be denoted by  $W$ , the active population by  $N$  and the number of employed workers by  $L$ . We then obtain the productivity per worker,  $a$ , the employment rate,  $\lambda$ , and the nominal wage per capita,  $w$ , as

$$a := \frac{Y}{L}, \quad \lambda := \frac{L}{N}, \quad w := \frac{W}{L}. \quad (1.5)$$

For simplicity, labour productivity and the active population (cf. (1.5)) are assumed to grow exogenously:

$$\frac{\dot{a}}{a} := \alpha > 0, \quad \frac{\dot{N}}{N} := \beta > 0.$$

The unit cost of production, defined as the nominal wage bill divided by the quantity produced, is

$$c = \frac{W}{Y}. \quad (1.6)$$

Nominal output  $Y_n$  is given by:

$$Y_n = p \left( C + I_k + \widehat{G} + X - IM \right) + c\dot{V} = pY_d + c\dot{V},$$

with  $p$  being the price index (cf. (1.11)).

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<sup>4</sup>Inventories in the Goodwin dynamics have been introduced by Grasselli and Nguyen-Huu (2016).

### 1.2.2 The production sector

Firms have their own expectations,  $Y_e$ , of the demand they will meet. These expected sales follow a standard adaptive expectations process:

$$\dot{Y}_e = \mu_e (Y_d - Y_e) \quad \text{with } Y_e(0) = Y_{max}(0), \quad (1.7)$$

where  $\mu_e$  measures the speed at which firms adjust their expectations. These expectations drive the capacity utilisation in the following way:

$$u = \vartheta + (1 - \vartheta) \frac{Y_e}{Y_{max}},$$

where  $\vartheta \in (0, 1)$  captures the viscosity of the aggregate production sector in adjusting its usage rate of capital to its expected aggregate demand. Therefore, real output can be rewritten as:

$$Y = \vartheta Y_{max} + (1 - \vartheta) Y_e. \quad (1.8)$$

Given (1.4) and (1.8) changes in inventories can be divided into an expected part,  $I_p$ , and an unexpected part,  $I_u$ :

$$\dot{V} = Y - Y_d = \underbrace{\vartheta(Y_{max} - Y_e)}_{I_p} + \underbrace{(Y_e - Y_d)}_{I_u}$$

Real investment is given by:

$$I = Y - C - \hat{G} - (X - IM) = Y - Y_d + I_k = \dot{V} + I_k = I_p + I_u + I_k,$$

that is, the sum of capital investment and changes in inventory.

### 1.2.3 Price, wage and employment dynamics

The employment rate dynamics is given by:

$$\frac{\dot{\lambda}}{\lambda} = \frac{\dot{Y}}{Y} - \alpha - \beta. \quad (1.9)$$

We assume the participation rate to be constant and the labour market dynamics to be reflected in the employment rate:  $\lambda = \frac{L}{N}$ , with  $L$  being the number of employed persons and  $N$  being the active population.

Unemployment determines the dynamics of wage per capita through a short-run Philips curve with no money illusion (see Mankiw (2001, 2014)):

$$\frac{\dot{w}}{w} = \Phi(\lambda) + \gamma \frac{\dot{p}}{p}, \quad (1.10)$$

with  $\gamma = 1$  representing no money illusion. In words, workers bargain for real wages based on the current state of the labour market (cf. Keen (1995)). The function,  $\Phi(\cdot)$ , will be empirically estimated. The total wage bill in the economy is given by:

$$W := w\lambda N.$$

Building partially on Grasselli and Nguyen-Huu (2016), we assume that prices are driven by the following dynamic:

$$\frac{\dot{p}}{p} = \beta_1 \left[ m \frac{c}{p} - 1 \right] - \beta_2 \frac{I_p}{Y}, \quad (1.11)$$

for constants  $\beta_1, \beta_2 > 0$  and  $m \geq 1$ . Equation (1.11) assumes that, absent any real growth, the long-run equilibrium price is given by a mark up,  $m$ , over the unit production cost,  $c$  (cf. (1.6)). Prices converge towards this value with a relaxation time,  $1/\beta_1$ . A value of  $m > \frac{p}{c}$  implies an asymptotically inflationary dynamic and vice versa for  $m < \frac{p}{c}$ . This is the ‘‘Classical’’ part of our price dynamics.<sup>5</sup> Because prices are viscous (consistently with the neo-keynesian

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<sup>5</sup>cf. Blinder et al. (1998)

perspective), the market for goods does not clear at all times, so that inventories play the role of an accommodating variable instead. The second part,  $\beta_2 \frac{I}{Y}$ , reflects the fact that prices do not need to clear markets in our model, but are influenced by the possible disequilibrium of the good market. The latter is the “neo-classical” part of our price dynamics.

	Households	Firms		Banks	Government	Rest of the world	Sum
<b>Balance sheet</b>							
Capital stock	$+E_b$	$+pK$		$-E_b$			$+pK$
Inventory		$+cV$					$+cV$
Deposits	$+M_h$	$+M_f$		$-M$			0
Loans	$-L_h$	$-L_f$		$+L_h + L_f - L_b$		$+L_b$	0
Bills	$+\tau_h B$	$+\tau_f B$		$+\tau_b B$	$-B$	$+\tau_R B$	0
Sum (Net worth)	$X_h$	$X_f$		$X_b$	$X_g$	$X_R$	$X$
<b>Transactions</b>		Current	Capital				
Consumption	$-pC$	$+pC + pX - pIM$				$+pIM - pX$	0
Capital investment		$+pI_k$	$-pI_k$				0
Change in inventory		$+c\dot{V}$	$-c\dot{V}$				0
Government spending	$+pG_h$	$+pG_f$		$+pG_b$	$-pG$		0
Wages	$+pW$	$-pW$					0
Interest on loans	$-r_L^h L_h$	$-r_L^f L_f$		$+r_L^h L_h + r_L^f L_f - r_b L_b$		$+r_b L_b$	0
Interest on bills	$+r_B \tau_h B$	$+r_B \tau_f B$		$+r_B \tau_b B$	$-r_B B$	$+r_B \tau_R B$	0
Interest on deposits	$+r_d M_h = 0$	$+r_d M_f = 0$		$-r_d (M_h + M_f) = 0$			0
Taxes	$-pT_h$	$-pT_f$		$-pT_b$	$+pT$		0
Dividends	$+pDiv_f + pDiv_b$	$-pDiv_f$		$-pDiv_b$			0
Financial balances	$S_h$	$S_f$	$-pI_k - c\dot{V}$	$S_b$	$S_g$	$S_R$	$S = pI_k + c\dot{V}$
<b>Flows of funds</b>							
Change in capital stock		$+pI_k$					$+pI_k$
Change in inventory		$+c\dot{V}$					$+c\dot{V}$
Change in deposits	$+\dot{M}_h$	$+\dot{M}_f$		$-\dot{M}$			0
Change in loans	$-\dot{L}_h$	$-\dot{L}_f$		$\dot{L}_h + \dot{L}_f - \dot{L}_b$		$+\dot{L}_b$	0
Change in bills				$+B$	$-\dot{B}$		0
Column sum	$S_h$	$S_f$		$S_b$	$S_g$	$S_R$	$pI_k + c\dot{V}$
Change in net worth	$\dot{X}_h = S_h$	$\dot{X}_f = \Pi + (\dot{p} - p\delta)K + c\dot{V}$		$\dot{X}_b = S_b$	$\dot{X}_g = S_g$	$\dot{X}_R = S_R$	$\dot{X}$

Table 1.1 – Stock-Flow consistent model of the economy

### 1.2.4 A stock-flow consistent open economy

Let us consider the closed system of accounts shown in Table 1.1 on page 40, where each entry represents a time-dependent quantity and a dot corresponds to differentiation with respect to time. Balance sheet items are stocks measured in Euro, whereas transactions are measured in Euro per unit of time. Households hold  $\tau_h B$ , banks' equity,  $E_b$ , and bank deposits,  $M_h$  and a share of government debt.<sup>6</sup> On the liabilities side, they hold bank loans  $L_h$ . The assets of firms are bank deposits  $M_f$ , capital goods,  $pK$ , a share of government debt  $\tau_f B$ , and inventories,  $cV$ .<sup>7</sup> They have liabilities as well, in the form of bank loans  $L_f$ . The domestic banking sector has total deposits  $M = M_h + M_f$  and equity  $E_b$  as their domestic liabilities. Banks also have loans to the rest of the world  $L_b$  as their international liability (partly due to the ECB, partly to foreign investors). On the asset side, they hold loans of households and firms  $L = L_f + L_h$  plus a fraction of sovereign debt,  $\tau_b B$ .<sup>8</sup> Public debt,  $B$ , is the only liability of the government sector. A fraction,  $\tau_R = (1 - \tau_h - \tau_f - \tau_b)$ , of this sovereign debt is owned by the ECB or foreign investors. Together with bank loans  $L_b$  they make up the assets of the rest of the world.

$G$  and  $T$  denote government subsidies and taxes and  $Div_b$  and  $Div_f$  are dividends from banks and firms paid to households. Because within the Euro area, the interest rate on deposits,  $r_d = 0$ , we can ignore income on bank deposits for the financial balances. Ultimately, investment:  $pI = pI_k + c\dot{V}$  adds to the net worth of the overall economy.

<sup>6</sup>For instance, in Italy,  $\tau \simeq 60\%$ , while in France,  $\tau \simeq 30\%$ . For simplicity, we assume  $\tau$  to be constant throughout.

<sup>7</sup>Capital goods and inventories are denoted in real terms.

<sup>8</sup>In recent years, the fact that  $\tau_b$  significantly increased (partly because of the capital adequacy requirements related to sovereign debt in Basel III) contributed to the infamous "Bank-State conundrum".



### 1.2.5 Deposits, loans and debts

The capital stock and inventories change, not only because of new investment, but as well due to the change in unit prices, unit cost and depreciation:

$$\frac{d(pK)}{dt} = pI_k + (\dot{p} - p\delta)K$$

$$\frac{d(cV)}{dt} = c\dot{V} + \dot{c}V$$

Crucial to our monetary model is the fact that firms finance investment using both their financial balance and net borrowing from the banking sector according to the accounting identity

$$\dot{D}_f = \dot{L}_f - \dot{M}_f = c\dot{V} + pI_k - \Pi_{nf} + Div_f \quad (1.12)$$

where,  $\Pi_{nf}$ , stands for nominal corporate profits:

$$\begin{aligned} \Pi_{nf} &= pY_d + c\dot{V} - pW + pG_f - pT_f + r_B\tau_f B - rD_f \\ &= (p - c)(C + I_k + (X - IM)) + cY + p(G_f - T_f - W) + r_B\tau_f B - rD_f. \end{aligned}$$

The gap between nominal capital investment  $pI_k$ , change in inventories  $c\dot{V}$ , dividends  $Div_f$ , and corporate profits  $\Pi_{nf}$ , results in the change of corporate debt  $\dot{D}_f$  (cf. (1.12)). This net borrowing omits an underlying dynamic for loans and deposits, which we will disentangle in the following.

For simplicity, we assume that a constant fraction,  $\mu \in (0, 1)$ , of nominal expected profit,  $\Pi_{nef}$  (cf. (1.14)), is redistributed as dividends to the shareholders (households),  $Div_f = \mu\Pi_{nef}$ , while a fraction,  $1 - \mu$ , is saved to finance investment.<sup>9</sup> Thus, the change in net worth of the corporate sector (after dividends have been distributed) is:

$$S_f = \Pi_{nf} - \mu\Pi_{nef}.$$

---

<sup>9</sup>An alternative modelling option would have consisted in assuming that dividends are distributed out of actual profits, i.e.,  $Div_f = \mu\Pi_{nf}$ .

As for deposits, loans and debt, the dynamics of the real economy leaves us with one degree of freedom. In equation (1.12), the increase of private net debt can equally arise from an additional loan or a reduction in deposits. Intuition suggests, firms' loans should increase only in order to finance investment and neither to pay wages, nor to pay back that debt.<sup>10</sup> As a consequence, we define the change in deposits as:

$$\dot{M}_f = \Pi_{nf} - Div_f$$

and

$$\dot{L}_f = c\dot{V} + pI_k$$

Thereby, investment is reflected in the loan account.

REMARK 1. We depart from Grasselli and Costal-Lima (2012) in an aspect that is worth mentioning. They stipulate that households do not borrow from the banking sector (only firms do) and that banks have zero net worth. This implies that  $\dot{D}_f = \dot{L}_f - \dot{M}_f = \dot{M}_h$ . Here, we drop these two restrictions, and allow households to borrow for consumption purposes, while the net worth of banks is endogenously determined.

Thus, household deposits,  $M_h$ , depend on their net revenues,  $R_h$ :

$$\dot{M}_h = R_h,$$

with

$$R_h := p(W + G_h - T_h) + Div_f + Div_b + r_B\tau_h B - rD_h.$$

Therefore, consumption is financed via the loan account  $\dot{L}_h = pC$  and the household debt changes according to:

$$\dot{D}_h = \dot{L}_h - \dot{M}_h = pC - R_h.$$

---

<sup>10</sup>Borrowing to pay back anterior debt is known as a Ponzi scheme, and would be forbidden by law.

Changes in deposits held by banks reflect the level of change in debt of households and firms:

$$\dot{M} = \dot{L}_h - \dot{D}_h + \dot{L}_f - \dot{D}_f.$$

REMARK 2. Another departure from the literature is that we do not postulate that the interest rate charged on firms' debt,  $r$ , the interest rate on deposits,  $r_d$ , and the interest rate on loans of firms,  $r_L^f$ , be all equal:  $r = r_d = r_L^f$ . Imposing this equality (cf. Grasselli and Nguyen-Huu (2015)) has the advantage of inducing the following simplifying equation:  $rD_f = r_L^f L_f - r_d M_f$ . While this makes sense in countries where banks pay a significant interest rate on deposits, it is more questionable in the Euro Area, where  $r_d$  is essentially zero. We therefore adopt a slightly different convention. Net firms' debt is still defined by  $D_f = L_f - M_f$ , while  $r_d = 0$  and interest payments are given by

$$rD_f = r_L^f L_f. \quad (1.13)$$

We shall assume that  $r$  is endogenously fixed by the banking sector (cf. (1.22)) and that  $r_L^f$  adjusts so that (1.13) be always satisfied. Similarly,  $D_h = L_h - M_h$  and  $rD_h = r_L^h L_h$ .<sup>11</sup>

### 1.2.6 Investment and Consumption

Driving the demand side are firms and households, which decide on their respective levels of investment and consumption based on income proxies. For firms, the variable influencing investment is the expected profit share,  $\pi_{ef}$ :

$$\Pi_{nef} := Y_{ne} - pW + pG_f - pT_f + r_B \tau_f B - rD_f, \quad (1.14)$$

with  $Y_{ne} = pY_e + c\vartheta(Y_{max} - Y_e)$  being the nominal expected output.

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<sup>11</sup>In the following, we can therefore neglect  $r_L^*$ , which becomes a residual parameter.

Real capital investment is driven by the expected profit share,  $\pi_{ef} = \frac{\Pi_{nef}}{Y_{ne}}$ :

$$I_k = \kappa(\pi_{ef}, d_f, u)Y_{max} \quad (1.15)$$

with  $d_f = \frac{D_f}{pY}$  and where  $\kappa(\cdot)$  is a phenomenological, aggregate behavioural function of the expected profit share,  $\pi_{ef}$ . In the same way as we refrain from striving for a micro-founded derivation of the Phillips curve and aggregate consumption demand, the investment function will be empirically estimated.<sup>12</sup>

REMARK 3. The interest payments on nominal debt provide the link between the monetary sphere and the real economy. Here, the causality runs from the interest payment through expected profits (1.14) to the preferred investment (1.15). Hence, the money supply has an explicit influence on aggregate demand. Furthermore, high debt levels have an impact on the investment behaviour via the interest payments.

We assume that aggregate real consumption depends on the wage share which is equivalent to the unit cost of production,  $c$ , in the following way:

$$C = \varphi(\omega, d_h)Y, \quad (1.16)$$

with  $\omega = \frac{W}{pY}$  and  $d_h = \frac{D_h}{pY}$  where the phenomenological function  $\varphi(\cdot)$  will be empirically estimated.

Modelling these functions for growth rates is a departure from the literature we are drawing from. Were we to model the functions on absolute consumption and investment, we would potentially have a problem where the functions impose an upper or lower limit on the economy. Furthermore, there is no data supporting values of investment and consumption values way above current levels. Nonetheless, we would expect to see significantly higher levels in the far future. By estimating these functions on growth rates and making sure they are defined for negative and positive growth rates we can address this issue

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<sup>12</sup>cf. Sections 1.4 and A.2

and rely on the available data.

### 1.2.7 Government

Public intervention is captured through government spending,  $\widehat{G}$ , real subsidies,  $G_f$ , and real taxes,  $T_f$  (resp.  $G_h$  and  $T_h$ ) directed towards the production sector (resp. households). Their real dynamics are given by:

$$T = \begin{cases} T_h = \Theta_1 W \\ T_f = \Theta_2 (Y - W) \end{cases} \quad \text{and} \quad G = \begin{cases} G_h = \Gamma_1 W, & \text{Households} \\ G_f = \Gamma_2 Y, & \text{Firms.} \end{cases} \quad (1.17)$$

Parameters  $\Theta$  are calibrated and using the tax time series as a point of orientation, whereas the subsidy parameters  $\Gamma$  are estimated. This modelling approach is inspired by Costa Lima et al. (2014), who model taxes and subsidies as a function of the employment rate and firms' profits. Here, we model taxes and subsidies for firms, households and banks as opposed to only firms. The influence of firm profits is reflected by the fact that firm taxes depend on  $Y - W$ , which is a proxy for firm profits. The employment rate plays a role because household taxes and subsidies are a function of the total wage bill  $W$ .

Government spending,  $\widehat{G}$ , is modelled as a function of state variables in the economy:

$$\widehat{G} = \widehat{\Gamma}(Y, W) \quad (1.18)$$

The difference  $T - G - \widehat{G}$  describes the primary balance and, by adding interest payment on government debt  $r_B B$ , we get to the overall fiscal balance, which drives the government debt level:

$$\dot{B} = p(\widehat{G} + G - T) + r_B B. \quad (1.19)$$

Thereby, we assume for simplicity, that any fiscal imbalance is bond financed (cf. Takeuchi and Yamamura (2004)). We further postulate that any new issuance of government debt is absorbed by the banking sector. Consequently,

a reduction in government debt is subtracted from the banking sector holdings until the initial amount of holdings is reached. Beyond that point they are subtracted according to the relative shares  $(\tau_f, \tau_h, \tau_b)$ .

In order to determine the government debt yield,  $r_B$ , we first need to compute the nominal debt to expected GDP ratio:  $b = \frac{B}{Y_{ne}}$ . A change in the debt to expected GDP ratio determines a change in yield, alongside a change in the interest rate set by the central bank,  $r_b$  (following a Taylor Rule cf. (1.21)):

$$r_B = \dot{b}/40 + r_b. \quad (1.20)$$

In words, a 1% point increase in the debt to GDP ratio leads to a 0.025% point yield increase.<sup>13</sup>

## 1.2.8 The banking sector

The basic idea underlying the way we introduce the commercial banking sector is the following: each time commercial banks issue new loans on the request of the endogenous demand from the real economy, they face two additional costs. On the one hand, the reserve requirement forces banks to borrow an additional amount of central bank money from the ECB. On the other hand, the Basel III capital adequacy ratio implies an increase in bank equity. Here, for simplicity, we assume that banks increase their equity by setting a higher interest rate and thereby accumulate retained earnings in order to reach the leverage ratio target.

These two operations (additional borrowing from the ECB and additional capital) have a cost: the interest payments on bank debt and the dividends to be paid increase. On the side of shareholders, we make the simplifying assumption that the average Return on Equity,  $r_{e,b}$ , of the banking system as a whole remains constant over time. Bearing in mind the strong competitiveness

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<sup>13</sup>We draw on the results of Dell’Erba et al. (2013) for this calibration.

of international capital markets, such a restriction does not seem unrealistic (banks offering a lower  $r_{e,b}$  would be crowded out of the capital market). These choices enable us to define the control variable of the banking sector as being the interest rate,  $r$ , charged by commercial banks on their loans to the real economy. By assuming that the banking sector chooses  $r$ , so that they reach their leverage ratio target, it is defined in an unambiguous way. The endogenous dynamics of  $r$  will impact the financing of investment and consumption.

Banks essentially make their profit on financing and refinancing at different interest rates. The interest rates on which banks earn their net profit in our model economy are on the debt and deposits of the government, households, firms and their own bank debt. Various interest rates are therefore relevant:  $r_b$  is the leading short-run interest rate set by the ECB following a Taylor rule with a 2% inflation target,  $\bar{\pi}$ , and an interest rate floor at 0.025%:

$$r_b = \frac{3\dot{p}}{2p} - \bar{\pi} \text{ and } r_b \geq 0.025\%, \quad (1.21)$$

The sovereign 10-year bill pays an interest rate,  $r_B$ , which is endogenously defined as a function of the governments' debt to GDP ratio and the central bank's interest rate (cf. (1.20)). Finally, the interest rate on deposits is  $r_d = 0$ .<sup>14</sup>

The banks income statement, absent subsidies and taxes, takes the form:

$$r(D_h + D_f) + \tau_b r_B B = E_b r_{e,b} + r_b L_b.$$

If banks were to set the interest rate,  $r$ , so as to satisfy the above equation, they would have no income adding to their equity, disregarding government transfers. Here we introduce the influence of the leverage ratio target as follows.

The leverage ratio target has two ways of influencing the banks' behaviour: via

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<sup>14</sup>None of the interest rates just alluded to coincides with the rental rate of capital,  $\rho$ . There are two ways to define the dividends that are distributed by firms to their shareholders. When put together, they provide the endogenous value of  $\rho$ :  $Div_f = \rho K = \frac{\mu}{p} \Pi_{nef}$ . Hence  $\rho = \frac{\mu}{p} \Pi_{nef} / K$ .

the effective return on equity,  $r_{e,b}^e$ , and the effective equity on which the return is calculated,  $E_b^e$ . The effective return on equity:

$$r_{e,b}^e = \frac{\bar{e}}{e} r_{e,b},$$

is a function of the predetermined return on equity,  $r_{e,b}$ . The function reacts to the relative capitalisation of the banking sector. The leverage ratio,  $e = \frac{E_b}{E_b + L_b + M}$ , and the leverage ratio target,  $\bar{e}$ , determine the mark-up on the return on equity. Thereby, we implement a pricing mechanism dependent on the level of capitalisation of the banks.

The effective return on equity  $r_{e,b}^e$  is paid on the effective equity:

$$E_b^e = \max [E_b, \bar{e}(E_b + L_b + M)],$$

which is at least the hypothetical equity required by the leverage ratio target,  $\bar{e}$ , or, if higher, the actual equity. By modelling the cost of equity in this way banks set the interest rate relatively high, if they are below their target and relatively low if they are above the target.

To complete this dynamic we introduce effective return on equity and effective equity to the equation. This gives us:

$$r(D_h + D_f) + \tau_b r_B B = \left( \frac{\bar{e}}{e} r_{e,b} \right) \max [E_b, \bar{e}(E_b + L_b + M)] + r_b L_b.$$

Solved for  $r$  banks set the interest rate according to:

$$r = \frac{\left( \frac{\bar{e}}{e} r_{e,b} \right) \max [E_b, \bar{e}(E_b + L_b + M)] + r_b L_b - \tau_b r_B B}{D_h + D_f}. \quad (1.22)$$

Coming back to the financial balances we can define the net profit of the banking sector as given by:

$$\Pi_b = r_B \tau_b B + r(D_h + D_f) - r_b L_b$$



The dividends distributed by the banks to their shareholders are given by

$$Div_b = E_b r_{e,b}$$

The equity of the banking sector evolves according to

$$\begin{aligned} \dot{E}_b &= \Pi_b - Div_b \\ &= r_B \tau_b B + r(D_h + D_f) - r_b L_b - r_{e,b} E_b \\ &= r_{e,b}^e E_b^e - r_{e,b} E_b \\ &= \left( \frac{\bar{e}}{e} r_{e,b} \right) \max [E_b, \bar{e}(E_b + L_b + M)] - r_{e,b} E_b. \end{aligned}$$

Turning to the second mechanism which has an influence on bank balance sheets, we can define reserve requirements as:

$$\zeta = \frac{1}{f + v(1 - f)} \simeq 12.6$$

where  $f$  is the fraction of money that is converted into fiduciary money (7%, on average) and  $v$ , the reserve requirement (1% in the Euro Area since January, 18, 2012). Therefore any change in loans to the real economy requires a deposit with the central bank according to the following dynamics:

$$\dot{L}_b = \frac{\dot{L}_h + \dot{L}_f + \dot{B}}{\zeta} + \dot{B} - p(X - IM)$$

### 1.3 Calibration

The models state variables are initialised and certain ratios calculated from historical data. The model uses starting values for the following nominal variables: capital stock,  $K$ , nominal GDP,  $Y_n$ , capital investment,  $I_k$ , consumption,  $C$ , wages,  $W$ , exports,  $X$ , imports,  $IM$ , firm debt,  $D_f$ , households debt,  $D_h$ , government debt,  $B$ , banking sector debt,  $D_b$ , banking sector equity,  $E_b$ , and

banking sector deposits  $M$ . Furthermore, starting values are used for: the employment rate,  $\lambda$ , total population,  $N$ , GDP deflator,  $p$ , long term government debt yield,  $r_B$  and the ECB key interest rate,  $r_b$ .

The constant ratios comprise of the inflation target,  $\bar{\pi}$ , the households' share of government debt,  $\tau_h$ , the firms' share of government deb,  $\tau_f$ , the banking sectors' share of government debt,  $\tau_b$ , the capital to output ratio,  $\nu$  and the adaptation parameter of the production sector,  $\vartheta$ , is set to  $\omega/p$ . Regarding capital depreciation,  $\delta$ , we use the standard, 2.5% per quarter.

## 1.4 Estimation

The estimation of the model consists of two steps. First, We estimate the characteristic equations (cf. Grasselli and Maheshwari (2016); Harvie (2000)) for the three functions determining wage per capita growth,  $\Phi(\cdot)$ , consumption,  $\varphi(\cdot)$ , and investment,  $\kappa(\cdot)$ . After testing for co-integration of the respective time series, which we can reject in all three cases, we can proceed to estimate the characteristic functions of the model. We introduce the Generalized Additive Models for Location, Scale and Shape (GAMLSS) estimation procedure for the use with this kind of models. It has the advantage of modelling the four first moments of the relationship and estimating them with not necessarily Gaussian residuals. This approach originates in the work by Rigby and Stasinopoulos (2005, 2013); Voudouris et al. (2012).

We use polynomials up to the power of 4 to determine the behaviour of the moments:

$$y = \alpha_0 + \alpha_1 x + \alpha_2 x^2 + \alpha_3 x^3 + \alpha_4 x^4 + \epsilon.$$

The error distributions can follow one of the following: normal, t family, skew t type, Johnson's SU ( $\mu$  the mean), Box-Cox power exponential, Box-Cox t, Box-Cox Cole and Green. We estimate different specifications for the

polynomials and error distributions and select the candidates based on their Akaike Information Criterion, significance of parameter estimates and visual inspection of their Q-Q plots. The selection process is described in further detail in the Appendix A.2. The results for the first moment are used in our model to describe the behaviour of investment, consumption and wages.

In the second step of model estimation we estimate the free parameters in the whole system by minimising the distance of the model and the data. Since we fit it on the European Commission (EC) forecast we do not need to take into account a measurement error. Due to the high dimensionality, non-linearity and non-differentiability of the cost function we use a heuristic to find the best parametrisation of the model over the whole set of free parameters and over all combinations of candidate functions for investment, consumption and wages.

## 1.5 Results

The goal with our proposed model is to estimate a model which can produce a realistic forecast such as the EC economic forecast. After calibrating and estimating the model with the historical data and EC forecast we compare GDP growth, unemployment, and government debt to GDP ratios for the Euro Area.

Figure 1.1 shows the historical development of real GDP growth since the inception of the Euro Area, the EC forecast and the simulations from our model. The model simulation and EC forecast are close in level and direction and forecast an increasing growth up to 2016.

In our model, growth is the dynamic determinant of unemployment. Therefore, the model simulation in figure 1.2 exhibits the same features as GDP growth. The model unemployment ratio, using quarterly data from Eurostat, starts off higher than the EC forecast yearly data and peaks in 2013. Afterwards it falls,

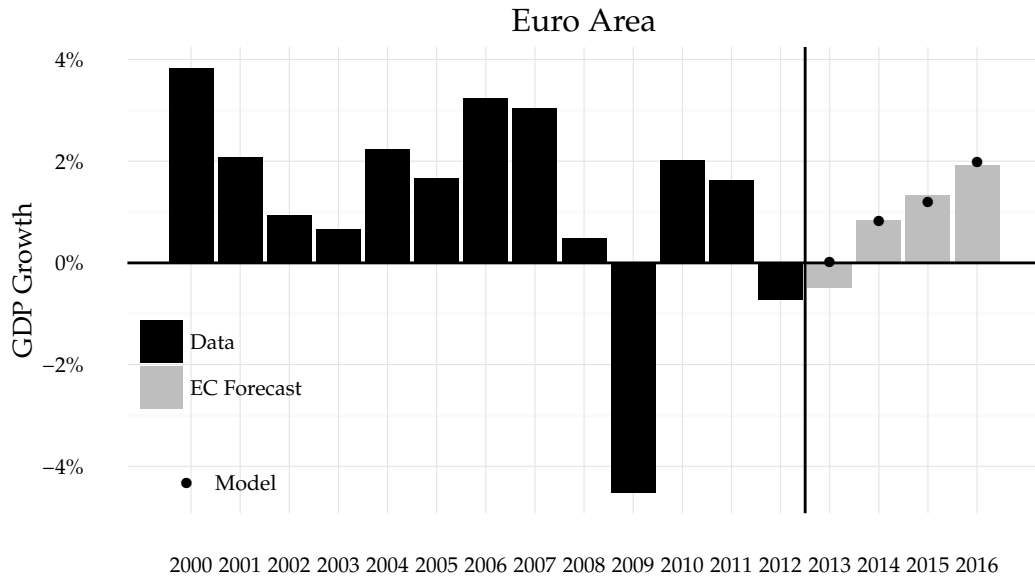


Figure 1.1 – GDP growth in the Euro Area and model forecasts

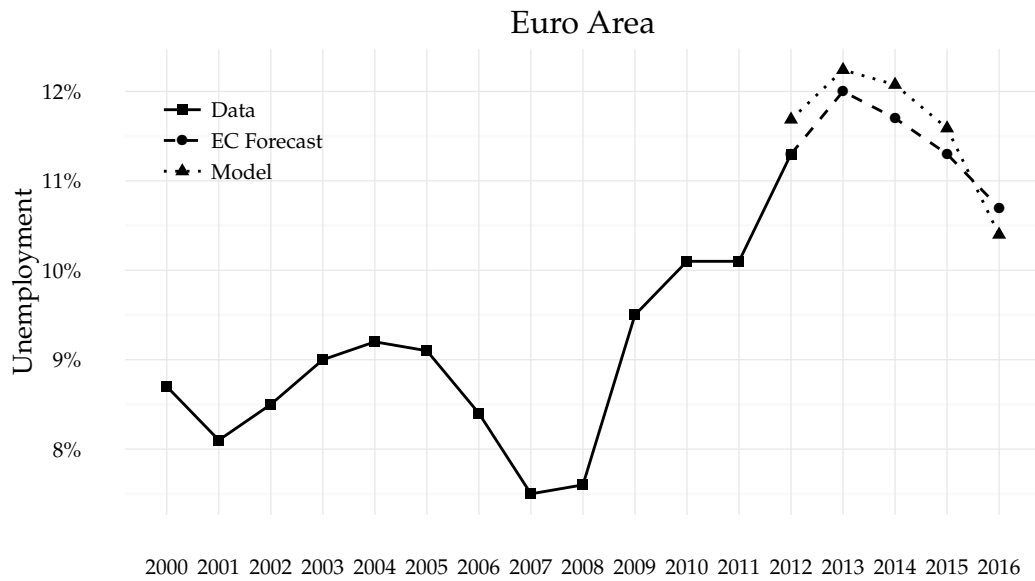


Figure 1.2 – Unemployment in the Euro Area and model forecasts

in line with the EC forecast.

Figure 1.3 shows inflation is forecast to be around 1% with a rebound in 2016. The model forecasts rising inflation over this time horizon. In the estimation process, inflation matching got a smaller penalty and matches only loosely the forecast. Nonetheless, the model yields a realistic forecast.

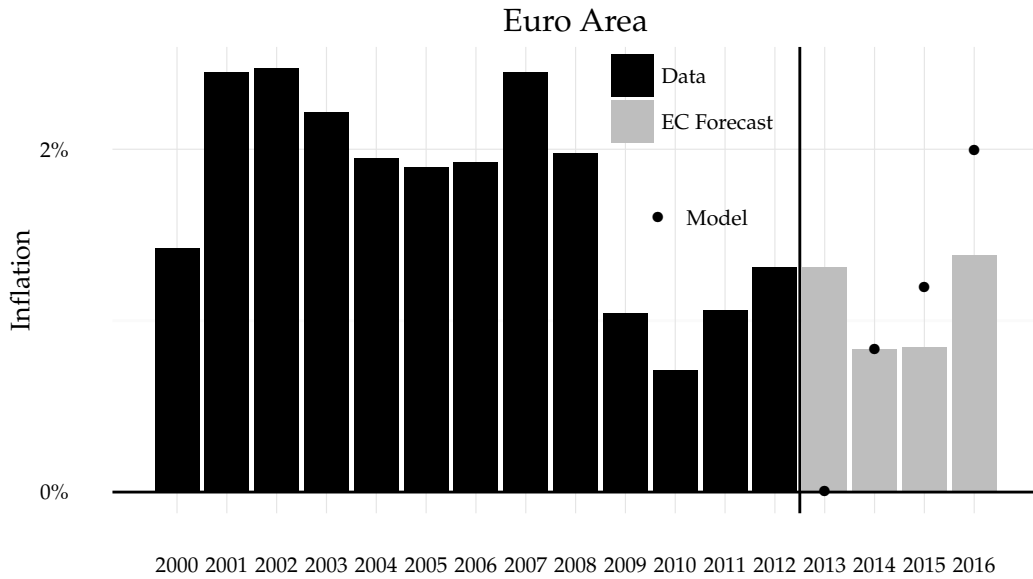


Figure 1.3 – Inflation in the Euro Area and model forecasts

Since private and public debt play a key role in our model figure 1.4 shows them here in their historical context. Debt to GDP ratios rise over the 2000’s and especially public debt to GDP increases strongly in the post crisis period. The model simulation predicts constant but rising firm debt levels and a turning point for household debt in 2015. Government debt to GDP levels are forecast to slightly grow by our model. This is broadly in line with the EC forecast.

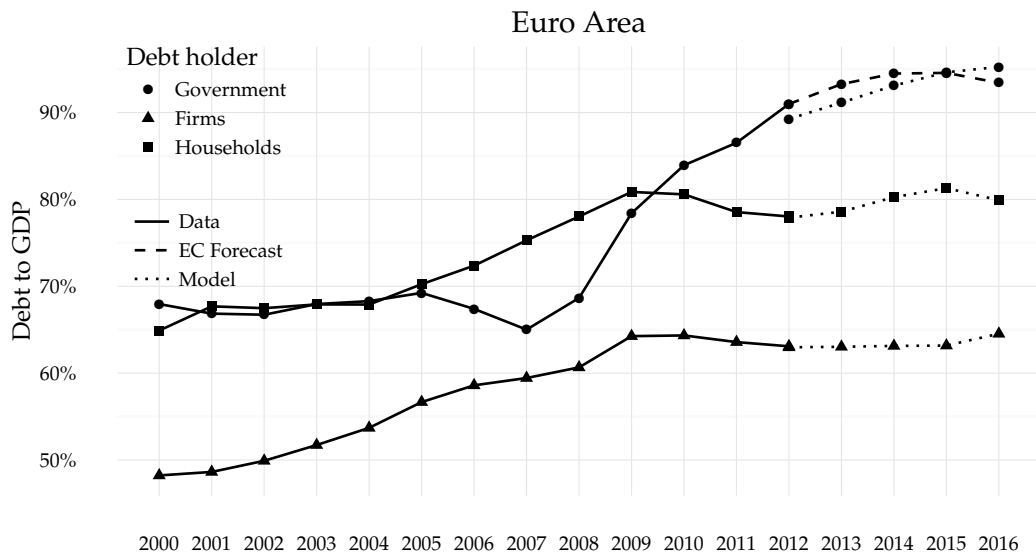
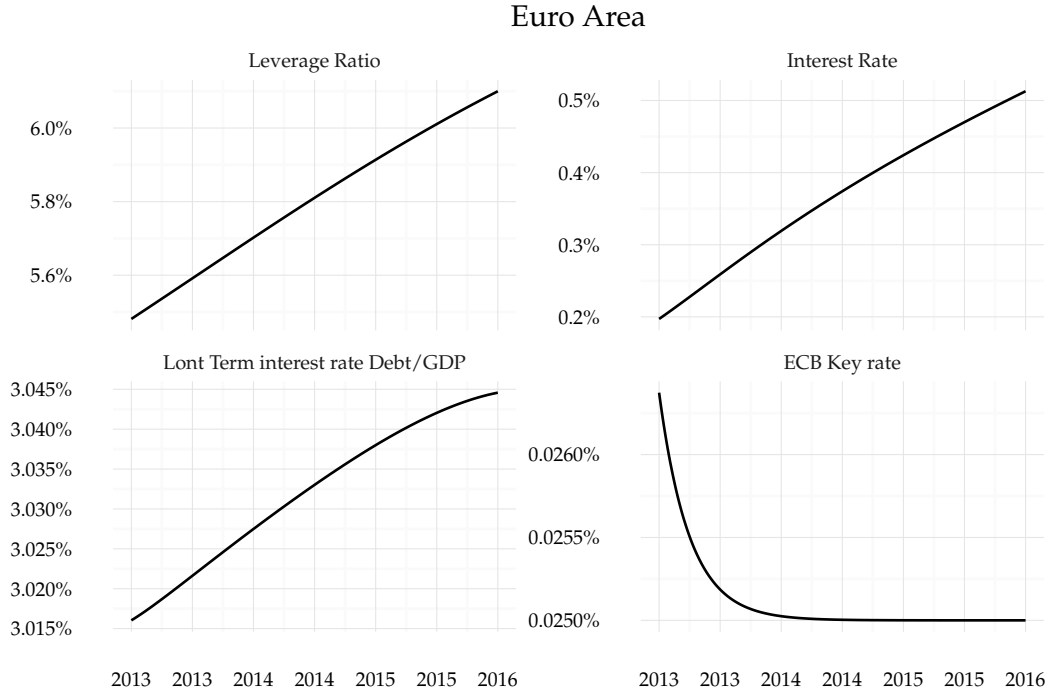


Figure 1.4 – Private and public debt in the Euro Area and model forecast

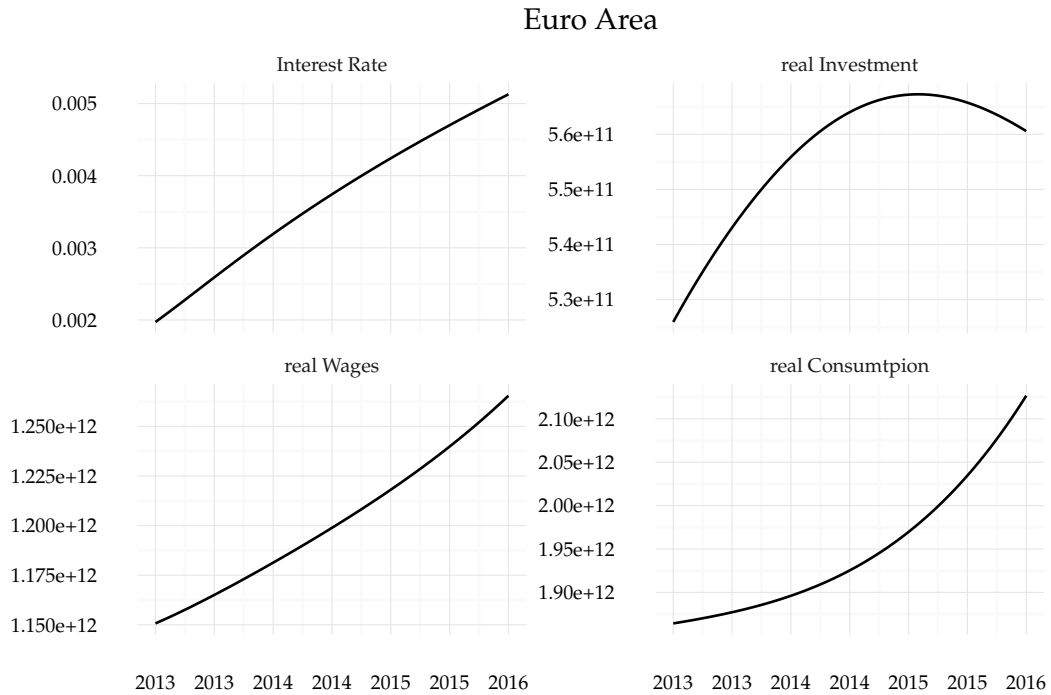
Apart from comparing our model to the EC forecast, it yields realistic behaviour for interest rates and other macro aggregates.



**Figure 1.5** – Interest rates and leverage ratio for the Euro Area: model forecast

Figure 1.5 gives insight into the workings of the model regarding the banking sector. The leverage ratio increases towards the estimated leverage ratio target of about 9%. This increase in equity is mainly driven by setting a higher interest rate, which can be seen in the top right panel. Due to the diminishing distance to the leverage ratio target the slope in the interest rate faces downward. The long term interest rate reacts to the public debt to GDP ratio and rises but stagnates towards the end of the simulation, as does the public debt to GDP ratio. The ECB key rate is initialised at the rate prevailing at the end of 2012 and quickly approaches the lower bound.

GDP in our model is driven by the supply and demand side. The demand side consists of consumption and investment which we can see in figure 1.6. Consumption is steadily increasing, backed by rising wages. Investment peaks in 2015 due to a higher cost of wages and the rising interest rates. Through



**Figure 1.6** – Investment, Consumption and its determining factors: model forecast

the estimated characteristic function the lower profit share translates into decreasing investment.

## 1.6 Conclusion

We propose a non-linear dynamical systems model including endogenous money, variable usage rate of capital, inventories, non-neutral money, a crucial role for public and private debt and an extended banking sector for the Euro Area. After laying out the calibration and estimation procedures we go on to simulate the model and compare them with the EC forecast. The model simulations of the Euro Area yield realistic results in light of the EC forecasts and are a point of departure for scenario analysis. Furthermore, the banking sector and real economy variables such as consumption, wages or investment behave in a realistic way over the medium term.

This paper is a first tentative pass for a large scale macro-financial model. It

will need improvements in various directions. For simplicity, the public sector has been formalised in a rather simplistic way. A more detailed understanding of the dynamics of taxes and public spending would help provide refined recommendations in terms of economic policy. Similarly, we have used the simplest possible way to extend our framework to an open economy. Further research will be needed in order to provide a realistic model of the exchange dynamics in the spirit of the present model. Finally, since we were mostly interested in the financial and monetary issues at stake, we kept the Leontief approach of the production sector. One consequence is that the capital to output ratio is assumed to be constant. Dropping this restriction also opens a new area of research.



## 2

# Forbearance Patterns in the Post-Crisis Period<sup>1</sup>

## 2.1 Introduction

In the recent financial crisis, the banking sector was simultaneously both the trigger as well as one of the most affected sectors in many countries. Corporate defaults, a crash in house prices, and high unemployment threatened the health of banks' balance sheets. Under these circumstances, lenders and borrowers found it in their interest to keep otherwise non-performing loans (NPLs) alive by preventing a risky borrower's default. Terms such as "evergreening", "zombie lending", or banks "gambling for resurrection" emerged in the economic literature to describe the practice of granting concessions to troubled borrowers. Whilst this can be economically useful under some circumstances, it can be

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used by banks to conceal potential losses. This can cause systemic risk, increase uncertainty about the quality of banks' assets, and undermine trust in the banking sector's solvency, which calls for regulators to monitor and prevent the establishment of this practice.

Using loan-level data on the commercial loans of all Irish banks, we study the determinants and the effectiveness of forbearance after the recent Global Financial Crisis (GFC) and provide evidence for several patterns observed in banks under stress. In our empirical setting, we distinguish between extensions in the overall credit limit or the maturity of the loan, a stop in amortisation, a relative decrease in the interest rate, and a rollover of the exposure. Using a standard logit model saturated with various fixed effects, we find that the riskiest borrowers are more likely to be granted a forbearance measure if the lender is facing high levels of NPLs relative to its capital and provisions. For the positive relationship between banks' stress levels - measured by the Texas Ratio - and a higher probability of granting forbearance, we offer an explanation through the current regulatory framework. When default is seen as a conscious decision of the bank and the firm, banks face an incentive not to flag loans as non-performing but to grant forbearance because of the impact on their profitability and ultimately their capital ratios (Eisfeldt and Rampini, 2008). Furthermore, since banks do not know the persistence of the shock hitting firms it is rational to practice forbearance under the assumption that it might help the firm survive. Besides the incentives, forbearance can be one way of releasing stress on borrowers and banks if it is effective in bringing down the probability of default and thereby helping the overall economy.

As a second step, we look at the effectiveness of forbearance as a mean of preventing default. We show that a limit extension is effective in reducing the probability of default up to one year ahead. For a longer time horizon and other forbearance measures we find that treated borrowers are in fact more likely to default compared to their peers within the same risk category. While this

can be due to several mechanisms (e.g. selection bias within a risk category), we show that forbearance did not prevent default in the long run after the GFC. Finally, the question arises over whether or not new lending is subdued because capital and other resources within the bank are allocated to forbore loans. We present evidence that lending and forbearance might be treated as substitutes by banks. Within buckets of similar loans, we find that the share of forbearance is negatively related with the issuance of new credit.

Therefore, we contribute to a strand of literature focused on forbearance techniques of banks which has emerged in the last two decades. For Japan, empirical evidence shows that troubled banks allocated credit to severely impaired borrowers to avoid the realisation of losses on their own balance sheets (e.g. Peek and Rosengren (2005), Sekine et al. (2003), and Watanabe (2010)). Analysing the driving mechanism of forbearance during the country's "lost decade", Caballero et al. (2008) use the term "zombie lending" for credit to unprofitable firms at interest rates below market values. Besides the hazard for banks themselves, the authors show that this misallocation of credit towards otherwise insolvent borrowers had significant negative effects on the real economy. The presence of zombie firms was found to depress job creation, deter the entry of healthy firms, and to decrease employment and investment of healthy firms. Using the effects following capital injections for Japanese financial institutions, Giannetti and Simonov (2013) show that troubled banks that remained under-capitalized were more likely to engage in "evergreening" by maintaining relationships with weak borrowers.

More recently, it became clearer that Japan was not an exception (Acharya et al., 2016a). Homar et al. (2015) look at European banks and find that weak banks are more likely to grant concessions to weak borrowers. The authors call for more empirical work regarding patterns of forbearance as an important factor in the slow recovery after the GFC. Using the Italian credit registry, Schivardi et al. (2017) show that Italian banks with relatively low capital levels

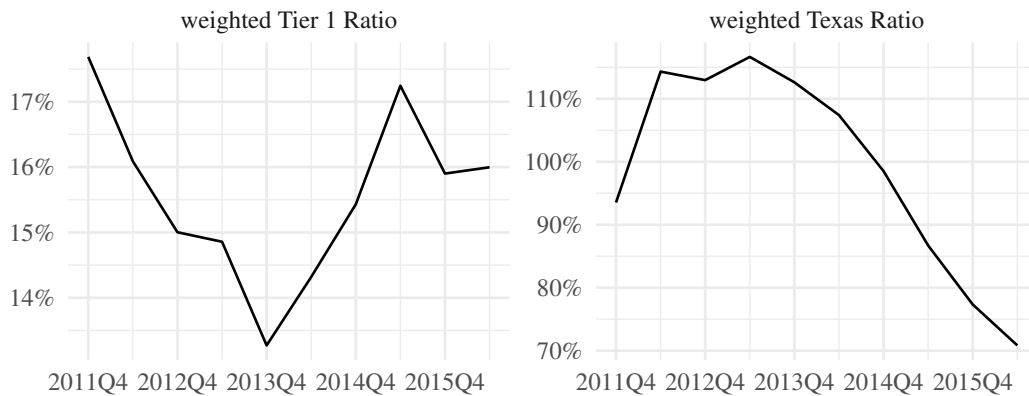
were less likely to cut credit to non-viable firms after the GFC. This credit misallocation led to an increase in the failure rate of healthy firms while it reduced the failure rate of non viable firms. Acharya et al. (2016b) use the announcement of the Outright Monetary Transactions (OMT) as an event on which to identify “zombie lending” patterns for European banks. Institutions which were not sufficiently recapitalised in the wake of the OMT announcement were more likely to extend loans to weak firms instead of their more creditworthy peers who would have been able to invest credit more profitably. This resulted in significant real effects, most notably a slow down of the economic recovery in the post-crisis period.

Our analysis is also motivated by existing work focused on the incentives for banks to engage in forbearance and therefore relatively risky lending. Keuschnigg and Kogler (2017) present a theoretical model showing that weak banks try to avoid writing off NPLs in order to prevent a violation of regulatory requirements or even insolvency. This literature also emphasizes possible negative consequences of these patterns for the financial stability when banks do not “clean up their balance sheets” (Diamond and Rajan, 2011). Analysing the case of China, Zhang et al. (2016) show that high NPL ratios are associated with riskier lending, potentially increasing individual institutions credit risk and threatening financial stability. Huizinga and Laeven (2009) show that distressed banks in the US used discretion in accounting during the GFC in order to inflate the book value of their assets which results in a distorted view of the financial health of these institutions. In addition, Bonaccorsi di Patti and Kashyap (2017) show that banks are able to recover significantly faster from large adverse shocks if they manage risky clients more aggressively and thereby reduce credit risk.

Our findings reveal several novelties. First, we argue that capitalisation is not the only determinant factor of forbearance for banks. As can be seen in recent stress tests (EBA, 2016b), some of the banks in our sample have

been sufficiently re-capitalised since the crisis through a public bailout, so that they now comfortably exceed regulatory requirements. However, NPLs are at very high levels by any standards, which can pose a threat to capitalisation levels under even moderate economic stress (IMF, 2016). Therefore, we argue that the quality of a lender's loan book must be considered when analysing the determinants of "zombie lending". Secondly, we exploit the quality of the loan level data to measure forbearance techniques using more definitions than are common in the literature. We suggest that financial pressure in times of crises creates incentives for different types of forbearance other than subsidised lending through a lower interest rate. More specifically, we analyse whether banks extend credit limits or maturities, or opt to grant other measures such as a stop in amortisation or a rollover of a loan product. Furthermore, the granular loan-level data allow us to suggest that a limit extension has been effective in bringing down the probability of default up to one year but no forbearance measure has been effective in the long run for the banking system. Using a standard logit-hazard model, we show the relationship between the different forbearance measures and the probability of default across various time horizons. Finally, the evidence suggests that forbearance ties up banks' resources that might have been used for new lending. We conclude our empirical analysis with a correlation analysis that reveals the negative relationship between forbearance and new lending.

In Section 2.2, we explain the conceptual framework, the different forbearance measures and offer an explanation as to why banks face an incentive to engage in forbearance within the current regulatory framework. Section 2.3 introduces the data and lays out our analysis of the determinants of forbearance. Section 2.4 elaborates on the effectiveness of the different forbearance measures in avoiding default, and Section 2.5 looks at possible correlations between forbearance and new lending. Finally, Section 2.6 concludes.



**Figure 2.1** – Weighted Tier 1 Capital Ratio and Texas Ratio of Irish banks. Weighted by Total Assets of respective bank.

*Source: Author's calculations; Data: SnL*

## 2.2 Conceptual Framework

### 2.2.1 The Crisis and the Irish Case

Ireland experienced one of the worst banking crises in the aftermath of the recent GFC. It originated from a devastating boom-bust cycle in the domestic property market which was financed by bank loans. While the economic growth in the years leading up to 2000 can be interpreted as a healthy convergence of the “Celtic Tiger” with the rest of the European Union, the surge in output in 2003-2007 turned out to be of a different kind: a construction boom (Honohan, 2010). Banks became highly exposed to the housing market through the extremely rapid credit expansion to home owners and property developers. As a consequence of the shift in international financial markets in 2007/2008, Irish banks faced difficulties to maintain funding while domestic investors pulled back from the property market. After prices declined sharply and construction activities collapsed, banks faced an unprecedented increase in NPLs. Finally, public funds had to be used in order to recapitalise the most significant credit institutions in Ireland (Lane, 2011).

The banks' recovery was then shaped by two stylised facts: (i) a fast recapitali-

sation of banks due to the public bail-out but (ii) threatening levels of NPLs on their balance sheets. We show these two developments for Irish banks in Figure 2.1. On the left side, we look at Tier 1 capital as an indicator of the health of an institution's balance sheet.<sup>2</sup> We can see that after the public bailouts of banks in response to the crisis, the ratio of Tier 1 capital to risk weighted assets (Tier 1 Capital Ratio) has levelled off well above the regulatory requirement of 8% and the European average of 14.1%.<sup>3</sup> On the right side, we analyse the Texas Ratio, which indicates how close the bank is to the regulatory constraints due to credit risk.<sup>4</sup> The measure is defined as:

$$\text{Texas Ratio} = \frac{\text{Impaired Loans} + \text{Loans 90 days past due \& not impaired}}{\text{Tangible Equity} + \text{Loan Loss Provisions}}.$$

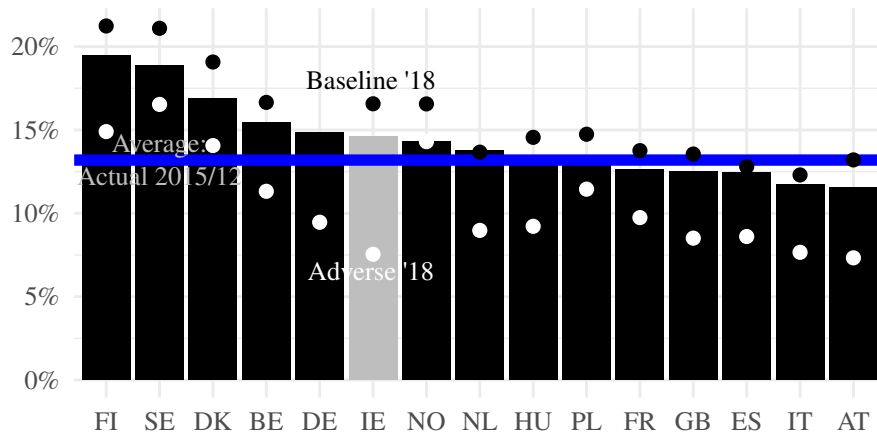
Intuitively, a value above 100% is widely considered to be critical and we can see that the Irish banking sector only recovered to below this threshold in 2014. Evidently, Ireland continues to suffer from high levels of impaired loans as a legacy from the GFC. Besides the decline in house prices and resulting wealth effects, unemployment and contractionary fiscal policy have made it impossible for some borrowers to pay back their loans. Hence, NPL ratios have risen to approximately four times the European average, driving the Texas Ratio to critical levels throughout our period of observation.

The high levels of the Texas Ratio suggest a threatening sensitivity to credit risk, which has been confirmed by recent stress tests, such as the latest Financial Sector Assessment Program of the International Monetary Fund (IMF) and European Banking Authority (EBA)'s stress tests (EBA (2016a); IMF (2016)). In Figure 2.2, we use data from EBA (2016a) to illustrate this risk: although Irish banks seem well capitalised in normal economic conditions, the stress test

<sup>2</sup>Tier 1 capital is composed of Common Equity Tier 1 and Additional Tier 1 capital, which is available to the institution for unrestricted and immediate use to cover risks or losses as soon as these occur.

<sup>3</sup>Through the public bank bailouts, 99.9% of Allied Irish Banks and 15% of Bank of Ireland became state-owned.

<sup>4</sup>Developed by Gerard Cassidy and others at RBC Capital Markets, the Texas Ratio got its name from its use to analyse weak banks in Texas during the 1980s.



**Figure 2.2** – The y-axis measures the Tier 1 Ratios for banks residing in the respective countries under different scenarios. The black (white) dot represents the Tier 1 Ratio under the baseline (adverse) scenario in 2018. The blue line shows the European average. *Source: Author’s calculations; Data: EBA (2016a)*

points out that regulatory requirements may not be reached under the adverse scenario. In addition, compared to other Euro Area countries, the difference of Tier 1 capital levels between the baseline and adverse scenario turns out to be the largest for Ireland.

A breakdown of the drivers behind this large gap, shown in Figure 2.3, reveals that credit risk is the main contributor and accounts for a 6 percentage point difference in the Tier 1 capital ratio between the two scenarios.<sup>5</sup>

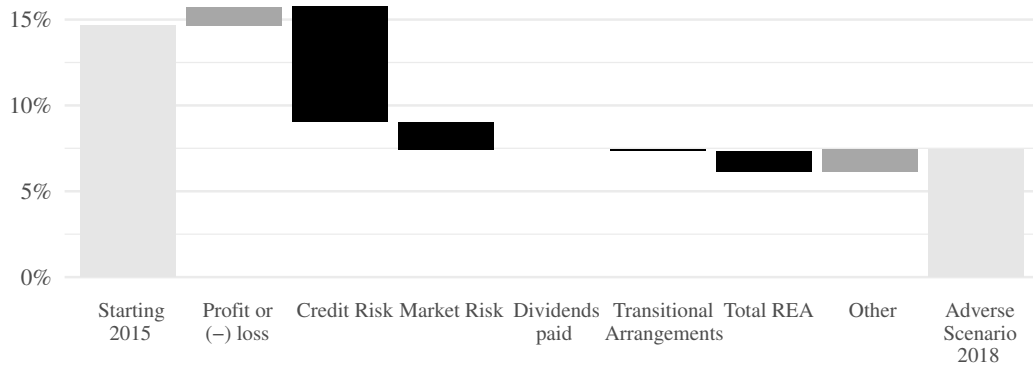
### 2.2.2 Forbearance

#### Types of Forbearance

In this section, we define and explain the different forbearance measures that we construct from our data. We exploit the quality and granularity of the Irish commercial loan level data to measure forbearance techniques along several definitions. The first definition of forbearance we consider is when banks (temporarily) suspend instalments and allow borrowers to only make interest

<sup>5</sup>In comparison, Italy is less affected by credit risk and is projected to have higher profits under the adverse scenario.





**Figure 2.3** – Drivers of changes in the Tier 1 capital ratio from Actual 12/2015 to Adverse 12/2018. Credit Risk refers to: Impairment or (-) reversal of impairment on financial assets. Profit or (-) loss refers to: profit or (-) loss before tax from continuing operations before credit risk and market risk losses.

*Source: Author’s calculations; Data: EBA (2016a)*

payments. This measure, referred to as an “amortisation stop”, ensures that the outstanding amount on the loan remains constant until further agreement or maturity. This is straight-forward to detect since banks report any changes in the amortisation status of each loan.<sup>6</sup> Furthermore, a bank can grant two types of loan extensions. First, loans can be extended by increasing the total limit that can be drawn down by the borrower. This measure is especially common for overdrafts. In the framework of forbearance, the idea is that a borrower needs more credit, e.g. to cover current expenses or even to fulfil payments that are outstanding on another existing loan product. We define this measure as a positive change in the total limit that can be drawn by a borrower. Second, the loan’s maturity can be extended by pushing back the due date of the loan. Non-amortising loans therefore become due at a later date. For loans with constant repayments, this can result in smaller instalments and therefore a lighter financial burden for the company over time. In a similar manner, the bank can “rollover” a loan. This measure is less straight forward to extract from loan-level data. We consider a loan “rolled-over” if for a given borrower one of its significant loans disappears from the sample (expired or

<sup>6</sup>Under Capital Requirements Regulation Article 178 (3) a) non-accrual status amounts to a default of a loan. Here, we rely on banks internal indicators of an amortisation stop which does not correlate with default, both before and after CRR/CRD IV took effect.

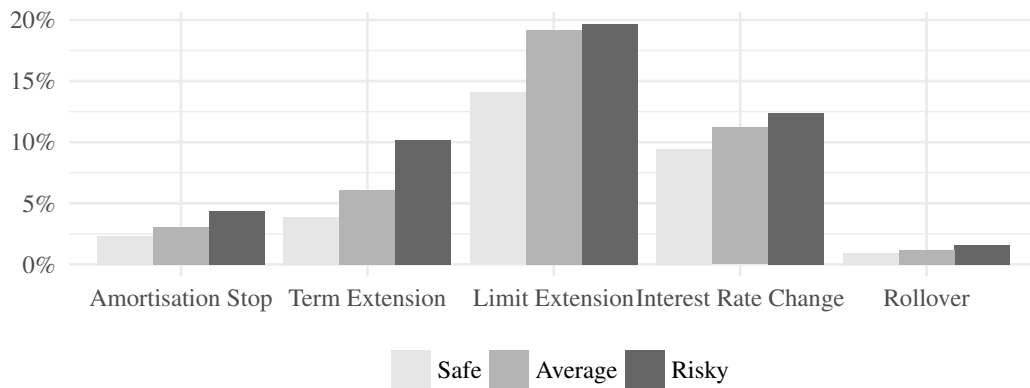
concordantly ended) but the borrower limit does not decrease by more than half of the discontinued loan's amount. This implies that limits on other products were increased or new products were issued. Finally, we follow Caballero et al. (2008) and look at subsidised lending via a comparably lower interest rate. We extend this idea to account for the environment of decreasing interest rates for our sample period. Therefore, we analyse whether banks grant specific borrowers significantly greater interest rate decreases compared to their peers. We define an advantageous change in the interest rate if the decrease in a borrower's interest rate is greater than the decrease for the safest borrowers within the same sector, segment, and product type.<sup>7</sup>

These measures are very heterogeneous. A limit extension can be requested for very different purposes by very diverse borrowers. Safe borrowers might apply for more credit in order to finance projects with net positive returns. In contrast, a stressed borrower might apply for further credit when he is unable to cover due payments and expenses. However, other measures, such as an amortisation stop, might be the most necessary, but also the most risky, when a borrower is in distress. In order to account for this, we split borrowers in three risk categories: safe, average, and risky.<sup>8</sup> Figure 2.4 shows the share per borrower rating of the different treatments across time. We find that the share of treated loans is the highest for the riskiest borrowers for every forbearance measure. The most commonly applied measure within the group of risky borrowers is a limit extension, followed by an interest rate change. A rollover and an amortisation stop are the least commonly applied measures. The fact that risky borrowers have higher shares of forborne loans goes against banks' risk aversion, but this phenomenon is intuitive when considering that borrowers in distress are most in need of additional financial support. In the following sections we will focus the banks' incentives to prevent default and

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<sup>7</sup>An extensive description of how we measure forbearance can be found in the Appendix.

<sup>8</sup>The borrower classification used here is based on similar observed default rates for the different ratings which are unified across banks.



**Figure 2.4** – Forbearance measures taken by borrower classification [% of loans per risk class and forbearance measure].

test this hypothesis empirically.

### The Banks' Incentives and Constraints

In the context of our research question it is important to understand how the constraints and incentives of banks influence their credit supply to the economy. Banks maximise their profits while staying solvent and holding enough liquid assets to meet their obligations. At the same time, they are subject to the capital and liquidity regulation set out in the Basel II and III framework.

Let us consider the case of a commercial loan close to default (low rating). The bank has an incentive to prevent default because of the impact on its capital ratio. NPLs have a negative impact on capital both now and in the future. First, a provisioning shortfall is deducted from Tier 1 capital<sup>9</sup> in case of default under the Foundation-Internal Ratings Based (F-IRB) approach.<sup>10</sup> This shortfall might occur because of the discretionary nature of provisions. Banks have an incentive to “underprovision” and only realise the loss at default. Second, a default leads to higher future provisions since these are based on

<sup>9</sup>Excess provisions are added to Tier 2 capital.

<sup>10</sup>The majority of corporate, Small and Medium Enterprise (SME) and micro SME portfolios are held under the F-IRB approach. Minor parts are accounted for using the Standardised Approach and one bank has a small part of their portfolio with the Retail Internal Ratings Based approach.

historical observed default rates. International Financial Reporting Standards (IFRS) 9, in place from January 2018 on, will lead to an earlier recognition of expected losses and thereby mitigate the issue of underprovisioning.

Intuitively, banks have a strong incentive to prevent this potential decrease of capital and adopt forbearance measures in order to support the borrower in difficulty. Nonetheless, forbearance measures themselves might also impact regulatory capital ratios. First, a maturity extension mechanically increases the risk weight as maturity is part of the risk weight formula.<sup>11</sup> Second, an increase of the overall borrower limit translates directly into an increase of the exposure at default and thereby risk weighted assets. Third, reducing the interest rate will lead to lower capital because of the lower future interest earnings but risk weights are unaffected. Fourth, an amortisation stop is a temporary stop/reduction of the regular payments. The effect on capital depends on whether missed payments are repaid in full once the loan becomes amortising again. Lastly, a rollover can be seen as a maturity extension with regards to risk weights, because a considerable amount of the exposure stays on the book of the bank.

Having laid out the motivation for using forbearance measures, the question that arises is whether or not new lending is subdued because capital and other resources within the bank are allocated to forborne loans. New lending mechanically increases risk weighted assets with risk weights being dependent on observed default rates of comparable loans. This explains why, after the GFC, commercial lending had very high risk weights.

One could argue that these considerations only hold once the constraints become binding (low capital ratios). Thus, high risk weighted capital ratios should allow the bank to focus on profitability. We argue that capital ratios alone are not sufficient to capture the pressure for banks to optimise their risk weighted assets. Credit risk poses a significant risk to capital levels as

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<sup>11</sup>See Capital Requirements Regulation Article 153 (1) for the F-IRB approach.

could be seen in the stress test results (see Figure 2.3). As the risk of a bank's loan portfolio changes over the economic cycle, seemingly prudent provisioning levels can turn out to be insufficient during an economic downturn. This uncertainty around the credit risk and its provisions casts doubt on capital levels. This effect is even more relevant if the overall quality of a bank's book is inferior.<sup>12</sup> A deterioration of the economic environment can potentially lead to a significant average downgrade and would increase risk weighted assets and decrease capital. Therefore, the Texas Ratio defined in Section 2.2.1 is a more informative measure taking into account the uncertainty surrounding capital levels and credit risk.

## **2.3 The Determinants of Forbearance**

### **2.3.1 Data**

We use the commercial loan level data from the Central Bank of Ireland provided by Irish banks in biannual frequency from 2011 Q4 up to 2016 Q2. This covers all loans to large corporates, SMEs, and Micro SMEs including loan-specific as well as borrower-specific characteristics. Therefore, while most of the previous literature considered only listed firms, we are able to analyse lending to any type of firm that borrows from Irish Banks in Ireland. The loan-specific characteristics contain information on product type, maturity, interest rate, the repayment schedule, a mapped rating of the risk of the loan, and whether the loan is securitised. The borrower-specific characteristics include information about the firm's sector and segment.

We have 1,686,325 observations (loan  $\times$  time) and 244,908 borrowers in our sample. Once a loan defaults, the borrower and all of the related loans are no longer included in the sample. The data covers the 26 Irish counties, 8

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<sup>12</sup>One bank in our sample has around 50% of its commercial loans in default throughout the sample. Accordingly, another 25% of this bank's commercial loan book is close to default.

sectors, 3 segments (Corporate, SME and micro SME), and 4 product types (leasing/hire purchase, overdraft, term loan and other).

Table 2.1 shows a split of the sample by rating, segment, and product type. Starting with rating, we observe not just a high share of defaulted loans (32.3% weighted by outstanding balance) but also a significant share of loans in the riskiest category (26.1% weighted by outstanding balance). This supports the hypothesis that a high number of NPLs indicates an overall stressed loan portfolio. Furthermore, only 6.4% of loans weighted by outstanding balance are in the safe category. Comparing these shares by volume and number of loans, we can see that loans in the safe category are relatively smaller whereas defaulted loans are considerably larger on average. This difference is even more evident turning to the split by segment. We can see that the largest amount outstanding is towards the SME segment but the majority of loans go to micro SMEs. Even more extreme, corporate lending makes up for 18.9% of outstanding balance but only 0.3% of loans. Finally, we look at different product types where term loans represent the largest share by volume as well as number of loans. Furthermore, we see a larger amount outstanding for this product type (120,000 € on average) which is only surpassed by the “Other” category with an average loan size of 265,000 €. <sup>13</sup>

Table 2.2 shows how many borrowers are affected by different forbearance measures across the whole sample. 89,255 borrowers receive any kind of measure, with the most frequent being a limit extension, followed by an interest rate change. This means that more than a third of all borrowers in our sample were granted forbearance measures. This split by the individual measures confirms what we show in Figure 2.4: limit extension is the most popular measure, followed by interest rate changes, term extensions, an amortisation stop and finally a rollover. As even the latter has been applied to 11,353

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<sup>13</sup>The significantly higher average in the “Other” category is due to large loans to corporates, such as syndicated loans.

borrowers in our sample, we argue that none of the measures are negligible.

A caveat of this confidential data is that we do not obtain the firms' names. This has two consequences: first, we cannot enrich the data with balance sheet information in order to control for firm characteristics. Secondly, we cannot identify the same firm across banks. While the data allows us to identify a borrower having several loan products within a bank, we cannot control for the fact that the firm might have a relationship to another bank. However, Albertazzi and Marchetti (2010) use the Italian credit registry to show that the ability of borrowers to compensate through substitution across banks appears to have been limited after Lehman's collapse.

### 2.3.2 Empirical Approach

In a first step, we want to estimate the probability of forbearance measure  $i$  being applied for a given borrower  $j$  in the next six months with the following logit model:

$$Pr(F_{i,j,t+1}) = \alpha + \beta_1 X_{l,t} + \beta_2 T_{k,t} + \beta_3 R_{l,t} * T_{k,t} + F_{j,t}^{u < t} + \text{fixed effects} + \epsilon \quad (2.1)$$

where  $X_{l,t}$  contains the time varying characteristics per loan  $l$ : rating,  $R_{l,t}$ , and  $\ln(\text{Outstanding Balance})$ ,  $T_{k,t}$  corresponds to the time varying Texas Ratio of bank  $k$ , and  $F_{j,t}^{u < t}$  is a dummy if borrower  $j$  received any forbearance measure before. Finally, we include various fixed effects: *loan age* fixed effects control for the influence of the loan age on the estimated probability of forbearance, *sector*  $\times$  *time* fixed effects attempt to control for the macroeconomic environment, *bank*  $\times$  *segment*  $\times$  *product type* fixed effects control for the variation between different loan products of different sizes at a given bank, and *county* fixed effects consider geographical variation. In order to control for other bank and time varying characteristics that might correlate with the Texas Ratio, we also include *bank*  $\times$  *time* fixed effects. Once we do include *bank*  $\times$  *time*

fixed effects the Texas Ratio drops out of the regression and we consider the differential impact of the Texas Ratio combined with borrower riskiness. Given that borrowers do not leave the sample once they received a treatment, the dummy whether any loan by borrower  $j$  was modified before  $t$ ,  $forb. before_{j,t}$ , tests if it is more likely for a loan to be forborne if another measure has already been granted. Contrary to forborne loans which stay in the sample, non performing loans are excluded from the sample once default occurs. Thus, our specification does not suffer from endogeneity problems which would arise if we had NPLs on the left hand side and the Texas Ratio - including NPLs - on the right. Regarding the dependent variable, we start by testing the probability of receiving any of the five different forbearance measures: an extension in the overall credit limit or the maturity of the loan, a stop in amortisation, a change in the interest rate, or a rollover of the loan product. As a second step, we then test the specification for each measure individually in order to identify the patterns driving our results.

### 2.3.3 Results

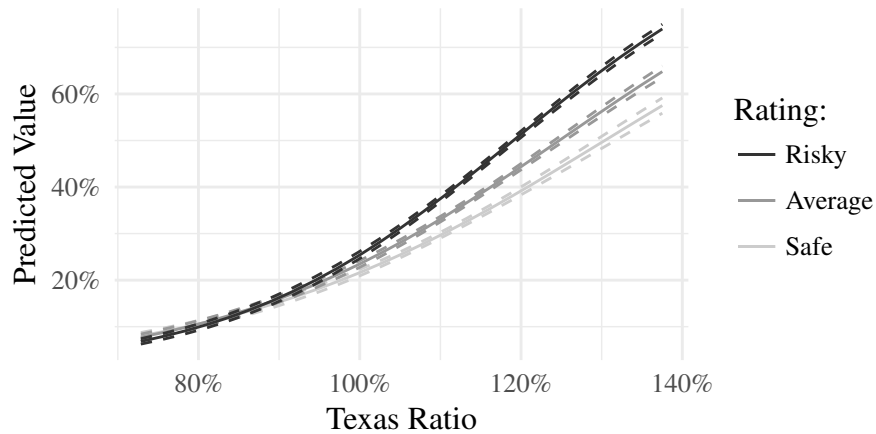
#### Overall Forbearance

In Table 2.3, we show the results of our logit model regressions. From column (1) to (7) we include fixed effects and lastly the forbearance before dummy up to the full specification of equation (2.1). The interpretation of the results only becomes relevant once we load in at least fixed effects controlling for the demand side ( $sector \times time$ ). On the other hand, the supply side fixed effects ( $bank \times time$ ) are important because the Texas Ratio of a bank is likely to be correlated with other time varying bank characteristics. Nonetheless,  $bank \times time$  fixed effects do not allow us to make a statement about the influence of the Texas Ratio on the probability of forbearance in absolute terms but only in relative terms. Therefore, we add fixed effects in the following order in columns



(2-6): *loan age*, *sector*  $\times$  *time*, *bank*  $\times$  *time*, *bank*  $\times$  *segment*  $\times$  *product type*, and *county*. In order to gauge whether risky borrowers are more or less likely to receive forbearance we have to add up the difference in probabilities for the different ratings and the differential slopes with respect to the Texas Ratio and ratings. When controlling for *loan age* and *sector*  $\times$  *time* we find that for the average Texas Ratio of 105%, the probability of receiving forbearance is higher for risky borrowers than for safe borrowers. The coefficient for risky loans (having safe borrowers as the reference group) is significantly negative in column (3) but the effect is outweighed by the significantly positive interaction term for risky borrowers with the Texas Ratio (again with safe borrowers as the reference group). Therefore, we can say that a stressed borrower paired with a stressed bank has a higher probability of agreeing on forbearance than a risky borrower with a less stressed bank and a safe borrower with a stressed bank.

We present this main result in a more intuitive way in Figure 2.5, which is based on the regression in column (7) without *bank*  $\times$  *time* fixed effects. In order to calculate the actual probabilities of receiving forbearance, we vary the Texas Ratio and keep all other values (e.g. *segment*, *bank*,  $\ln(\text{Outstanding Balance})$ ) at mean or mode. We can see that for the average Texas Ratio of 105%, the probability of a risky loan receiving forbearance is 5 percentage points higher than for a safe loan and at an absolute value of about 52%. For a risky loan, the difference in predicted probability is around 60 percentage points between a bank with a Texas Ratio at the 95th percentile (134%) and a bank at the 5th percentile (70%). Given the higher Texas Ratio a representative borrower of a risky loan has a 70% probability of receiving any forbearance measure within the next six months. Therefore, we show two main results. Our first result, increasing probability of receiving a forbearance measure with decreasing borrower rating, is driven by two mechanisms: first, only borrowers in need will ask for forbearance. Secondly, borrowers have an informational advantage



**Figure 2.5** – Predicted probability of any measure taken by borrower rating class and Texas Ratio. All other variables at mean or mode.

over their lenders which they might exploit in a situation where default is unavoidable. This strategic motive can play a role if the borrower knows that the bank believes forbearance is effective and that the bank has an incentive to help because it cannot afford to let the borrower default. Our second result is the increasing probability of receiving a forbearance measure with the increasing Texas Ratio of the lender. This is in line with the incentives for constrained banks to preserve their capital ratios by forbearing loans, outlined in Section 2.2.2. Furthermore, we find that larger loans are more likely to receive a forbearance measure.

Turning back to Table 2.3, in column (4) we add  $bank \times time$  fixed effects which are crucial to control for anything correlated with the bank's Texas Ratio. We find the interaction effect of the safe borrower's rating (with the safe rating as the reference category) and the bank's Texas Ratio to be significantly positive. In other words, for a risky borrower, the probability of receiving forbearance increases more with respect to bank level stress than for a safe borrower. One has to bear in mind that the base probability of receiving forbearance is lower but insignificant for risky borrowers as can be seen in column (4). The coefficient is significant and negative once we control for  $bank \times segment \times product\ type$  and  $county$  fixed effects. For the average value of

the Texas Ratio, 105%, the coefficient on the interaction term outweighs the difference in the baseline probability. Therefore, for the average value of the Texas Ratio and above, the probability of receiving forbearance is higher for risky borrowers compared to safe borrowers. This result is robust throughout columns (4-6).

Another way of interpreting the results is to look at odds-ratios.<sup>14</sup> Summing up the coefficients of interest in column (7), we can say that at an average Texas Ratio of 105%, the odds of a risky loan receiving forbearance are 28.5% higher than for a safe loan, *ceteris paribus*. With regards to the second result we compare the odds of receiving forbearance for a risky loan with a bank at times of very low and very high values of the Texas Ratio. At the 95th percentile (Texas Ratio of 134%), the odds of receiving forbearance for a risky loan are 67% higher than at the 5th percentile (Texas Ratio of 70%), *ceteris paribus*. The other important factor in explaining the probability of receiving forbearance is if the loan already received another forbearance measure. The odds are 224% higher to receive forbearance if the borrower already received forbearance.

The previously presented results are robust given the saturation with fixed effects. Furthermore, we cluster standard errors at *bank*  $\times$  *time* level to tackle the problem of heteroskedasticity. Another concern could be that at high levels of the Texas Ratios, banks have an additional incentive to forbear the most important borrowers by loan size as they are concerned about the exposure at default. Although we already control for the loan size in our regression, we conduct another robustness test, shown in Table B.1 in the Appendix, where we add a double interaction effect:  $\ln(\text{Outstanding Balance}_{l,t}) : \text{Texas Ratio}_{k,t}$ . We can see that the additional effect of the loan size at high Texas Ratios is not significant and that our main results hold.

We argue for the use of the Texas Ratio in Section 2.2.1 and use it for our

<sup>14</sup>As we run a logit model we look at  $e^\beta$  to get the odds-ratio.

regressions. Nonetheless, we have not yet analysed which of the components of the Texas Ratio, namely NPLs and the Tier 1 Ratio, are driving these results. Table B.3 shows the same regression we previously interpreted for the NPL Ratio<sup>15</sup> instead of the Texas Ratio. We find that the results for the Texas Ratio can be confirmed for the NPL Ratio. In column (8), we add the Tier 1 ratio interacted with the borrower rating and it turns out to be insignificant. Once we include both, the interaction of the NPL Ratio and the Tier 1 Ratio with the borrower rating in column (9), it is only the NPL Ratio interaction term that remains significant. Therefore, we conclude that the level of NPLs is driving our results when we use the Texas Ratio as a measure for bank stress in determining the granting of forbearance.

### Different Measures of Forbearance

In Table 2.4, we look at the different forbearance measures<sup>16</sup> individually so that the dependent variable is equal to one if a specific forbearance measure was granted within the following 6 months. For policy makers, it is indispensable to know which measure exactly the mechanism found in our previous results.

Column (1) shows the results for any forbearance measure which can be found in column (7) of Table 2.3 in order to contrast the individual forbearance measures results. The two main results laid out in the previous section can be confirmed for Term and Limit extensions. For these two measures, the interaction term of the borrower's rating and the bank's Texas Ratio is significantly positive (with the safe rating as the base category). The baseline probability of receiving a limit extension is significantly lower for a risky borrower than for a safe borrower. This effect is outweighed by the interaction for values of the Texas Ratio of greater than 120%. One has to bear in mind that we define limit extension as a forbearance measure only for borrowers in distress (risky). A

<sup>15</sup>The NPL Ratio is defined as:  $\frac{\text{Non-Performing Loans (Impaired or 90 days past due)}}{\text{Total Loans}}$ .

<sup>16</sup>See Section 2.2.2 for the definitions of each forbearance measure.

limit extension for a safe borrower is not necessarily forbearance but more likely growth financing. Therefore, the probability of receiving a limit extension, in the sense of growth financing, is naturally higher for a safe borrower paired with a not stressed bank, than receiving a limit extension as a forbearance measure for a risky borrower paired with a similar bank. The significantly positive coefficient on the interaction term in column (5) confirms that the probability of agreeing a limit extension increases more strongly with the Texas Ratio of the bank for risky borrowers than for safe borrowers. For term extensions the argument is the same, whereas in this case the baseline coefficient in column (3) is negative but insignificant.

Turning to the other three forbearance measures, the results differ. For an amortisation stop - column (2), an interest rate change - column (4) or a rollover - column (5) we do not find a significant influence of neither the bank's nor the borrower's risk. The interaction term for rollover and amortisation stop is positive but insignificant given our very conservative standard error clustering at *bank*  $\times$  *time* level. The size of the loan is the only variable with a significant coefficient. This is to say that an amortisation stop and an interest rate change is more likely for larger loans and the contrary holds for a rollover. For all the individual forbearance measures the probability of receiving it is higher if the borrower received a forbearance before.

### Sequencing of forbearance measures

Forbearance is not necessarily a one off treatment and we observe that banks and borrowers often agree to more than just one measure over time. The question arises if there is an observable pattern in the sequencing of measures. We want to check if certain types of forbearance are typically applied first while others might be predominantly used as a “measure of last resort”, after other measures were deemed insufficient. A simple descriptive analysis can be found in Table 2.5. Among all borrowers who received more than one measure, we

measure how many times each forbearance type has been applied as a first, second, or third measure. The first column describes what measures were taken first, given that two or more measures were taken for a given borrower. Because a borrower can have multiple loan products, there can be more than one forbearance measure per borrower. The distribution of measures taken first resembles that of the overall distribution presented in Figure 2.4 and Table 2.2. Limit extensions are the most common, followed by an interest change, whereas a rollover is the least common measure. Furthermore, out of the 244,908 borrowers in our sample, 52,255 receive two or more forbearance measures and 33,342 receive three or more. For the distribution of the measures applied second, for all cases where there were at least two measures applied, we find that limit extensions are less often applied as a second measure compared to being employed as the first measure. All other forbearance measures are employed more frequently as a second measure than as a first measure. As for the third measure we find that the relative shares differ from those of the first and second measure. A limit extension is much less likely to be taken as a third measure compared to a first and amortisation stop and interest rate changes are more likely. To conclude, a limit extension seems to be a measure more often applied at first, whereas interest rate changes and an amortisation stop become more important as a second and third measure.

## **2.4 Effectiveness of Forbearance**

### **2.4.1 Empirical Approach**

Having shown that banks under stress are more likely to forbear risky borrowers we now turn to the effectiveness of forbearance. This question is important for the overall economy as effective forbearance means lower default rates of firms and higher bank capital. Therefore, we estimate the probability of default for

a given borrower with the following logit hazard model:

$$Pr(Def_{j,t}) = \alpha + \beta_1 X_{l,t} + \beta_2 F_{j,t} + \beta_3 R_{l,t} * F_{j,t} + \beta_4 F_{j,t}^{u < t} + \text{fixed effects} + \epsilon \quad (2.2)$$

where  $Pr(Def_{j,t})$  is the probability of default on any loan held by borrower  $j$  in different periods in the future,  $X_{l,t}$  consists of the time varying characteristics of loan  $l$ : rating,  $R_{l,t}$ , and  $\ln(\text{Outstanding Balance})$ ,  $F_{j,t}$  is a dummy for (any) forbearance measure for any loan held by borrower  $j$  within the last six months, and  $F_{j,t}^{u < t}$  is the dummy for any previous forbearance measure towards borrower  $j$ . Again, we include *loan age*, *bank*  $\times$  *time*, *bank*  $\times$  *segment*  $\times$  *product type*, and *county* fixed effects and we cluster standard errors at *bank*  $\times$  *time* level. *Sector*  $\times$  *time* fixed effects control for the macroeconomic environment in a given sector at a given point in time.

We let  $Pr(Def_j)$  vary over periods in order to analyse the timing of default. Given that only forbearance measures to risky borrowers should be of concern, we look at  $\beta_3$  where the  $Rating_{l,t}$  is *Risky*. If forbearance was effective, this should lead to a lower probability of default of the borrower, hence  $\beta_3$  would be negative for any time period. However, if forbearance is just used to conceal “short-term” threats to a bank’s balance sheet,  $\beta_3$  might be significant only in the short term, i.e. lowering the probability of default for short periods.

## 2.4.2 Results

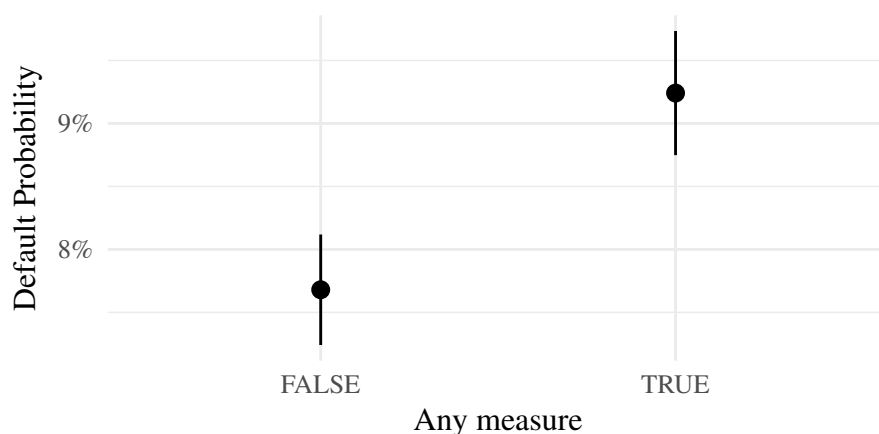
The regression results of the logit model can be found in Table 2.6. We first analyse if the granting of any forbearance measure is associated with a lower probability of default in the future (infinite horizon). As the ratings are defined by the ex-ante probability of default, the increasing coefficients with riskiness across all columns are reassuring. However, even controlling for the rating, the interaction of the dummy for any forbearance with the rating is positive for all ratings when controlling at least for *loan age* and *sector*  $\times$  *time*. In other

words, a risky borrower who received forbearance is more likely to default than a risky borrower who did not receive forbearance. This result is robust when loading in more fixed effects.

We suggest that these results could be driven by two different mechanisms. First, a selection bias might cause a bank to choose to give forbearance to the “worst” borrowers (closest to default) within the group of risky borrowers in an attempt to prevent default where it is most likely. Secondly, borrowers might act strategically and demand forbearance knowing that they are going to default even with forbearance. The intuition is that it might be profitable for firms to keep business alive even just for a limited period of time. We cannot disentangle these two effects. However, we can conclude that they outweigh the positive impact of forbearance as a financial support for struggling borrowers in order to prevent default. Using the regression results in column (6), with all fixed effects loaded in, we find that the odds of default for a borrower having received any forbearance measure in the last six months are 20% higher than if the borrower was not treated. In column (7), we add the forbearance before dummy but we find no significant effect for this variable. Outstanding balance has a significantly positive coefficient, which means that larger loans are more likely to default.

In Figure 2.6, we show our result graphically. The graph shows the probability of default for risky borrowers who received a forbearance measure and those who did not receive a measure in time  $t$ . In order to calculate the actual probabilities, we keep all variables at mean or mode and change only the dummy for any measure. If no measure was taken during the last six months, the probability of default is around 8.7%. The probability for a risky borrower who received forbearance in the last six months is significantly higher at around 9.25%. The default probabilities are significantly lower if we do not condition the results on the riskiness of the borrower. Figure B.1 in the appendix shows the probabilities ranging from 1.4% to 1.8% for the average borrower.





**Figure 2.6** – Predicted probability of default for a risky loan, depending on any measure being taken. All other variables at mean or mode.

*Source: Author's Calculations; Data: CBI*

Again, it is crucial for policy makers to know which measures of forbearance are associated with a higher probability of default. In Table 2.7, we can see the results for the different measures. In column (1), we see the result for any measure as a benchmark for the results of the individual measures. All regressions control for the full set of fixed effects. The findings outlined regarding the negative impact of any measure on subsequent default are confirmed for term extensions, interest rate changes, and amortisation stops. The probability of default is higher given that a risky borrower has received these three different forbearance measures. The overall finding cannot be confirmed for limit extensions or rollovers. For these two, the coefficients are negative but insignificant. However, only a negative coefficient could be interpreted as a positive effect of this forbearance measure. Therefore, also for those measures, we cannot show that they effectively lower default rates for stressed borrowers.

In a last step, we want to analyse the timing of default. We just showed that  $\beta_3$  is positive for  $Rating - Risky_{l,t} * F_{j,t}$  which means that risky borrowers who received forbearance were subsequently more likely to default than other risky borrowers. This would be an additional loss (of the forbearance) for the bank and would not be in line with banks' profit optimizing behaviour.

However, if forbearance is just used to conceal (short-term) threats to a bank's balance sheet,  $\beta_3$  might be significant only in the short term, i.e. lowering the probability of default for short periods.

Comparing Table 2.6 and Table 2.8, where the dependent variables are *Probability of default in any period in the future* and *Probability of default in the next six months* we can evaluate the effectiveness in the short and long run. Again, we focus on  $Risky_{i,t} * F_{j,t}$  where we see that overall, the coefficient is significantly positive for both specifications, i.e. forbearance is associated with a higher probability of default both in the short and in the long term.

However, looking at measures individually reveals surprising results. Besides the importance for policy, we argue that the different measures also impose different risks for banks. E.g. if a banks grants a limit extension, it increases its exposure and would therefore suffer a greater loss in the case of default. On the other hand, a bank increases its risk relatively less through a small change in the interest rate or a term extension. In line with this reasoning, we find the coefficient on Limit Extension to be significantly negative in the short term in Table 2.9 while it is insignificant in the long term (Table 2.7). As Limit Extension is the most common measure of forbearance this lets us conclude that the most common form of forbearance decreases the probability of default in the short term but remains uncorrelated to default for longer horizons and is therefore not effective in ultimately preventing default. In a final specification in Table B.2, we show the effectiveness for every period after each forbearance measure was granted for all risky borrowers. We can see that Limit Extensions are significantly negatively related with defaults up to two periods after the measure was taken while borrowers are equally as probably to default as borrowers within the same risk category thereafter. On the other hand, Amortisation Stops are always associated with higher probabilities of default at any point in the future. This could be due to a "selection bias" where this measure is only given to the riskiest borrowers among those with a "risky"

rating. This reasoning is in line with our findings in section 2.3.3 where we highlight that Amortisation Stop is relatively more often applied as a second or third measure and could therefore be interpreted as a “measure of last resort”.

## 2.5 Correlation with new Lending

### 2.5.1 Empirical Approach

Existing literature shows that when stressed banks keep relationships with risky borrowers alive, they issue significantly lower volumes of new lending compared with their peers (e.g. Acharya et al. (2016b); Caballero et al. (2008)). This literature strongly emphasises the negative real effects this behaviour can have for the economy. The presence of zombie firms was found to depress job creation, deter the entry of healthy firms, and to decrease employment and investment levels in healthy firms (Giannetti and Simonov, 2013).

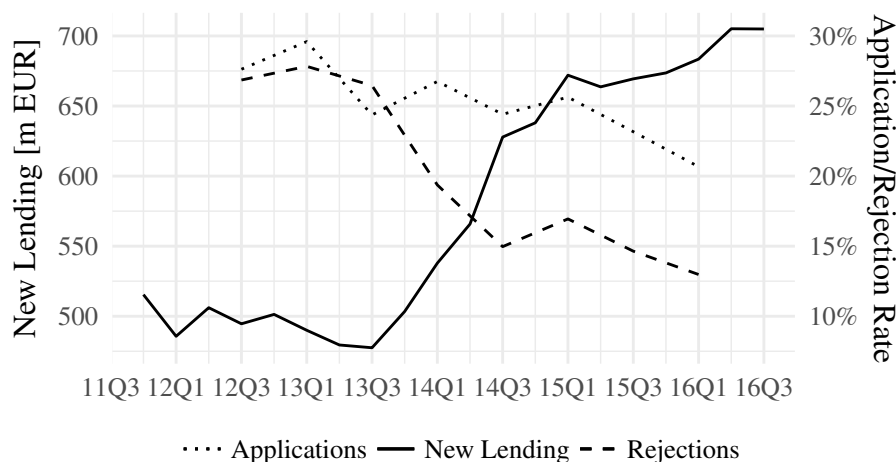
The empirical evidence from this literature suggests a relationship between credit supply and lower volumes of new credit. In Figure 2.7, we analyse seasonally adjusted<sup>17</sup> quarterly new lending to Irish firms. While Irish banks were under stress due to their high NPL levels, their new lending to the SME sector was subdued. In order to exclude the hypothesis that this is due to constrained credit demand after the GFC<sup>18</sup>, we look at survey data on SME credit applications during that time.<sup>19</sup> The dotted (dashed) line in Figure 2.7 shows the application (rejection) rate for Irish SMEs over time. The application rate for new products and thereby demand for new credit was high in 2012 and continuously dropped throughout the sample. The coincidence of the period

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<sup>17</sup>New lending exhibits significant seasonality, which we treat using the X13-ARIMA-SEATS procedure.

<sup>18</sup>Accornero et al. (2017) also find a negative relationship of new lending and NPLs but suggest that this was driven by demand for the case of Italy.

<sup>19</sup>We obtain these data from the RedC Reports on SME lending provided by the Department of Finance of Ireland. As SMEs are by far the largest borrower group, we argue that it is representative to look at this group in order to get an overview of the lending market.



**Figure 2.7** – The left y-axis shows the quarterly new lending to Irish SMEs (seasonally adjusted in m EUR). *Source: Author’s Calculations; Data: CBI*  
 The right y-axis shows application rate for new products (% of firms) and rejection rate for new products (% of applications) for Irish SMEs. *Data: RED-C SME Market Report*

of low new lending volumes and high credit demand suggests that the low volumes were driven by banks credit supply. The dashed line confirms the high rejection rate for new product applications around the time of low new lending volumes. In our empirical analysis, we want to see if this is correlated with forbearance patterns which might tie up capital so that supply for new loans remains suppressed.

In the following, we test this correlation of forbearance and new lending for Ireland. First, we set up buckets of borrowers,  $b$ , by *bank*, *segment*, *time*, and *county* because we suggest that lending decisions are made separately for these groups. Then, we estimate the following OLS regression:

$$Share(New\ Lending)_{b,t} = \alpha + Share(Forbearance)_{b,t-1} + fixed\ effects + \epsilon \quad (2.3)$$

where  $Share(New\ Lending)_{b,t}$  is the sum of lending to new borrowers over the total lending in bucket  $b$  in time  $t$  and  $Share(Forbearance)_{b,t-1}$  is the sum of loans to forborne borrowers over the total lending in  $t - 1$  in bucket  $b$ . Again, we add fixed effects to control for the macroeconomic environment (*county*  $\times$  *time*) and variation between banks (*bank*), and between banks over time (*bank*

× *time*).

## 2.5.2 Results

The results in Table 2.10 confirm a negative correlation between forbearance and new lending in the same bucket and across all specifications. This means that the higher the share of forbearance within a certain segment and county by a specific bank, the lower the share of new loans. This result holds when saturating the regression with fixed effects (see columns 1-4). In terms of magnitude, a 1% higher share of forborne loans is correlated with a 0.076% lower share of new lending, as can be seen in our most conservative specification in column (4).

We test the robustness of this result in two ways: first, we use contemporaneous new lending in column (5). As our unit of time is relatively large (six months) the decision to “substitute” new lending with forbearance could happen within the same time period. Second, instead of using the share of new lending and forbearance, we use the natural logarithm of new lending and forbearance instead of shares in column (6). However, for both robustness checks, results remain highly significant even in our most conservative specification. Combining this with our previous results and the literature we can suggest that forbearance - which occurs mostly for risky borrowers - is a trade-off for new loans, which are potentially safer.

## 2.6 Conclusion

In this paper, we analysed the forbearance patterns of stressed banks in the post-crisis period. More specifically, our analysis presents five measures: an extension in the credit limit or maturity, a pause in amortisation, a comparably lower interest rate change, and a rollover of a loan product. We find that risky

borrowers are more likely to receive a limit or maturity extension when banks are facing high levels of NPLs relative to their capitalisation and provisions. As a second step, we evaluate the effectiveness of this practice. Using a logit-hazard model, we find that a limit extension is effective in reducing the probability of default up to one year. For longer horizons and other forbearance measures we find a higher probability of default of the risky borrower. While we cannot conclude that the forbearance measures themselves caused defaults, we argue that credit might have been misallocated to the weakest borrowers which were subsequently not “rescued” from default. In the last part of our empirical analysis, we show that banks with a high share of forborne loans issue lower volumes of new credit. This could result in tighter financial conditions for new firms who might potentially be more productive.

Our analysis highlights the importance of the health banks’ loan books. While banks can be well-capitalised on paper, they might be under pressure by high levels of NPLs on their balance sheets. We suggest that banks have an incentive not to recognise loans as non-performing and offer an explanation through the regulatory framework. This is crucial for policy makers as uncertainty about the real quality of the loan book, if widespread in the economy, can lead to systemic risk and undermine trust in the banking sector’s solvency.

## **Tables**

**Table 2.1** – Summary statistics by segment, rating, and product type

Split by:	Sample share by outstanding balance	Sample share by number of loans
<b>Rating</b>		
Safe	6.4%	8.7%
Average	35.2%	40.0%
Risky	26.1%	32.5%
Default	32.3%	18.9%
<b>Segment</b>		
Corporate	18.9%	0.3%
SME	61.6%	30.7%
Micro SME	19.4%	69.0%
<b>Product Type</b>		
Term Loan	81.8%	49.6%
Overdraft	6.9%	34.3%
Leasing/Hire Purchase	4.6%	14.3%
Other	6.7%	1.7%

*Note: Ratings are based on underlying ex-ante probabilities of default for individual loans, segments relate to the size of the firm, and product type describes the type of loan held by the borrower. These summary statistics are averages over 1,686,325 observations (loan  $\times$  time) held by 244,908 borrowers in our sample.*

**Table 2.2** – Number of borrowers who received a forbearance measure

	Number of borrowers
Rollover	11,353
Amortisation Stop	14,087
Term Extension	17,377
Interest Rate Change	27,837
Limit Extension	69,209
Any measure	89,255
All borrowers	244,908

*Note: The numbers presented here are across time, which means that borrowers can obtain more than one measure.*

**Table 2.3** – Logit regression: Probability of application of any forbearance measure - Texas Ratio

	<i>Dependent variable:</i>						
	Any measure <sub>j</sub>						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rating - Average <sub>l</sub>	-0.152 (0.296)	-0.136 (0.295)	-0.202 (0.237)	0.029 (0.120)	-0.153 (0.113)	-0.162 (0.112)	-0.094 (0.172)
Rating - Risky <sub>l</sub>	-0.843 (0.585)	-0.856 (0.589)	-0.887*** (0.338)	-0.408 (0.268)	-0.565** (0.263)	-0.578** (0.263)	-0.589** (0.273)
ln(Outstanding Balance <sub>l</sub> )	0.218*** (0.012)	0.213*** (0.012)	0.207*** (0.013)	0.212*** (0.013)	0.132*** (0.009)	0.130*** (0.008)	0.096*** (0.009)
Texas Ratio <sub>k</sub>	-0.011** (0.005)	-0.011* (0.005)	-0.001 (0.018)				
Rating - Average <sub>l</sub> :Texas Ratio <sub>k</sub>	0.003 (0.003)	0.003 (0.003)	0.003 (0.003)	0.001 (0.001)	0.003** (0.001)	0.003** (0.001)	0.002 (0.002)
Rating - Risky <sub>l</sub> :Texas Ratio <sub>k</sub>	0.009 (0.006)	0.009 (0.006)	0.011*** (0.004)	0.006* (0.003)	0.008*** (0.003)	0.008*** (0.003)	0.008** (0.003)
Forbearance Before <sub>j</sub>							1.178*** (0.098)
Fixed Effects:							
Loan age		Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time			Yes	Yes	Yes	Yes	Yes
Bank x Time				Yes	Yes	Yes	Yes
Bank x Segment x Prod. Type					Yes	Yes	Yes
County						Yes	Yes
Observations	1,393,284	1,393,284	1,393,284	1,393,284	1,393,284	1,393,284	1,324,317

*Note: Logit Regression with standard errors clustered at Bank x Time level. The dependent variable is the probability of receiving forbearance in  $t + 1$  whereas the independent variables are measured in  $t$ . We split the borrowers in Safe, Average and Risky based on their ex-ante probability of default. Forbearance Before is a dummy which is one if a borrower has ever received forbearance before  $t + 1$ . Significance levels: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$*



**Table 2.4** – Logit regression: Probabilities of different measures being applied, taking into account prior forbearance

Measure <sub><i>i</i></sub> :	<i>Dependent variable:</i>					
	Any measure <sub><i>j</i></sub>	Amortisation Stop <sub><i>j</i></sub>	Term Extension <sub><i>j</i></sub>	Interest Rate Change <sub><i>j</i></sub>	Limit Extension <sub><i>j</i></sub>	Rollover <sub><i>j</i></sub>
	(1)	(2)	(3)	(4)	(5)	(6)
Rating Average <sub><i>t</i></sub>	-0.094 (0.172)	0.099 (0.665)	-0.614 (0.473)	0.050 (0.193)	-0.184* (0.103)	-0.445 (0.386)
Rating Risky <sub><i>t</i></sub>	-0.589** (0.273)	0.851 (0.592)	-0.512 (0.470)	0.073 (0.331)	-0.483** (0.225)	-0.102 (0.441)
ln(Outstanding Balance <sub><i>t</i></sub> )	0.096*** (0.009)	0.030* (0.015)	0.029 (0.021)	0.240*** (0.025)	0.008 (0.008)	-0.112*** (0.014)
Rating Average <sub><i>t</i></sub> :Texas Ratio <sub><i>k</i></sub>	0.002 (0.002)	0.001 (0.006)	0.009** (0.005)	-0.001 (0.002)	0.003*** (0.001)	0.001 (0.004)
Rating Risky <sub><i>t</i></sub> :Texas Ratio <sub><i>k</i></sub>	0.008** (0.003)	0.0005 (0.006)	0.014*** (0.005)	-0.002 (0.004)	0.004* (0.002)	0.0005 (0.005)
Forbearance Before <sub><i>j</i></sub>	1.178*** (0.098)	1.184*** (0.186)	0.676*** (0.146)	1.667*** (0.226)	0.728*** (0.085)	0.291*** (0.111)
Fixed Effects:						
Loan age	Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Time	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Segment x Prod. Type	Yes	Yes	Yes	Yes	Yes	Yes
County	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,324,317	1,321,654	972,779	1,304,003	1,181,047	1,285,117

*Note: Logit Regression with standard errors clustered at Bank x Time level. The dependent variable is the probability of receiving a specific forbearance measure  $i$  in  $t + 1$  whereas the independent variables are measured in  $t$ . We split the borrowers in Safe, Average and Risky based on their ex-ante probability of default. Forbearance Before is a dummy which is one if a borrower has ever received forbearance before  $t + 1$ . Significance levels: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$*

**Table 2.5** – Number of occurrence of each measure granted in a sequence of measures.

	First Measure of 2 or more		Second Measure of 2 or more		Third Measure of 3 or more	
Term Extension	5,370	8.6%	6,506	10.4%	3,598	8.8%
Limit Extension	34,201	55.1%	32,109	51.1%	19,860	48.6%
Interest Rate Change	14,271	23.0%	15,119	24.1%	11,186	27.4%
Amortisation Stop	5,102	8.2%	5,687	9.0%	4,341	10.6%
Rollover	3,179	5.1%	3,438	5.5%	1,840	4.5%
Total number of borrowers	52,255		52,255		33,342	

*Note: Among all borrowers who received more than one measure, we measure how many times each forbearance type has been applied as a first, second, or a third measure.*

**Table 2.6** – Logit regression: Probability of default for any loan by borrower - Influence of any measure taken by borrower

	<i>Dependent variable:</i>						
	Probability of Default <sub>j</sub>						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rating Average <sub>t</sub>	1.199*** (0.181)	1.204*** (0.185)	1.370*** (0.111)	1.380*** (0.116)	1.280*** (0.118)	1.281*** (0.118)	1.281*** (0.118)
Rating Risky <sub>t</sub>	2.895*** (0.291)	2.898*** (0.286)	3.001*** (0.151)	3.061*** (0.152)	3.010*** (0.155)	3.010*** (0.155)	3.010*** (0.154)
ln(Outstanding Balance) <sub>t</sub>	0.131*** (0.026)	0.132*** (0.026)	0.102*** (0.026)	0.100*** (0.026)	0.127*** (0.019)	0.128*** (0.019)	0.127*** (0.018)
Rating Safe <sub>t</sub> :Any Measure <sub>j</sub>	-0.061 (0.450)	-0.021 (0.450)	0.378** (0.172)	0.409** (0.164)	0.397** (0.189)	0.400** (0.188)	0.387** (0.178)
Rating Average <sub>t</sub> :Any Measure <sub>j</sub>	-0.274 (0.254)	-0.244 (0.254)	0.151* (0.081)	0.176** (0.076)	0.225*** (0.077)	0.231*** (0.076)	0.217*** (0.079)
Rating Risky <sub>t</sub> :Any Measure <sub>j</sub>	-0.234 (0.176)	-0.210 (0.171)	0.190*** (0.054)	0.169*** (0.047)	0.192*** (0.034)	0.197*** (0.033)	0.184*** (0.035)
Forbearance Before <sub>j</sub>							0.019 (0.031)
<b>Fixed Effects:</b>							
Loan age		Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time			Yes	Yes	Yes	Yes	Yes
Bank x Time				Yes	Yes	Yes	Yes
Bank x Segment x Prod. Type					Yes	Yes	Yes
County						Yes	Yes
Observations	1,563,456	1,563,456	1,563,456	1,563,456	1,563,456	1,563,456	1,563,456

*Note: Logit Hazard Regression with standard errors clustered at Bank x Time level. The dependent variable is the probability of default of any loan held by borrower j in any period in the future whereas the independent variables are measured in t. We split the borrowers in Safe, Average, and Risky based on their ex-ante probability of default. Forbearance Before is a dummy which is one if a borrower has ever received forbearance before t. The loan exits the sample once a default occurs. Significance levels: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01*

**Table 2.7** – Logit regression: Probability of default for any loan by borrower - Influence of different measures taken by borrower

Measure <sub>i</sub> :	<i>Dependent variable:</i>					
	Probability of Default <sub>j</sub>					
	Any Measure <sub>j</sub>	Term Extension <sub>j</sub>	Interest Rate Change <sub>j</sub>	Limit Extension <sub>j</sub>	Rollover <sub>j</sub>	Amortisation Stop <sub>j</sub>
	(1)	(2)	(3)	(4)	(5)	(6)
Rating Average <sub>l</sub>	1.281*** (0.118)	1.298*** (0.068)	1.294*** (0.079)	1.312*** (0.063)	1.271*** (0.074)	1.235*** (0.080)
Rating Risky <sub>l</sub>	3.010*** (0.155)	3.195*** (0.072)	3.140*** (0.071)	3.161*** (0.062)	3.067*** (0.064)	2.921*** (0.090)
ln(Outstanding Balance <sub>l</sub> )	0.128*** (0.019)	0.099*** (0.020)	0.144*** (0.020)	0.126*** (0.017)	0.126*** (0.017)	0.131*** (0.020)
Rating Safe <sub>l</sub> :Measure <sub>i</sub>	0.400** (0.188)	0.462*** (0.157)	1.535*** (0.176)	0.400*** (0.102)	0.419*** (0.087)	0.402* (0.229)
Rating Average <sub>l</sub> :Measure <sub>i</sub>	0.231*** (0.076)	0.344*** (0.126)	1.085*** (0.116)	0.231*** (0.086)	0.237** (0.116)	0.517*** (0.109)
Rating Risky <sub>l</sub> :Measure <sub>i</sub>	0.197*** (0.033)	0.744*** (0.062)	0.266*** (0.073)	-0.015 (0.051)	-0.038 (0.034)	0.326*** (0.056)
<b>Fixed Effects:</b>						
Loan age	Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Time	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Segment x Prod. Type	Yes	Yes	Yes	Yes	Yes	Yes
County	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,563,456	956,718	1,326,984	1,304,332	1,304,332	1,561,260

*Note: Logit Hazard Regression with standard errors clustered at Bank x Time level. The dependent variable is the probability of default of any loan held by borrower j in any period in the future whereas the independent variables are measured in t. We split the borrowers in Safe, Average, and Risky based on their ex-ante probability of default. Measure on loan l is specified by the heading of each column. The loan exits the sample once a default occurs. Significance levels: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01*

**Table 2.8** – Logit regression: Probability of default in next period for any loan by borrower - Influence of any measure taken by borrower

	<i>Dependent variable:</i>						
	Probability of Default $_{t+1,j}$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rating Average $_l$	0.926*** (0.208)	0.940*** (0.212)	1.026*** (0.192)	1.033*** (0.198)	0.980*** (0.197)	0.981*** (0.196)	0.980*** (0.196)
Rating Risky $_l$	3.268*** (0.353)	3.267*** (0.353)	3.279*** (0.316)	3.322*** (0.326)	3.295*** (0.325)	3.294*** (0.325)	3.293*** (0.325)
ln(Outstanding Balance) $_l$	0.015 (0.022)	0.018 (0.021)	0.003 (0.022)	0.003 (0.022)	0.011 (0.017)	0.012 (0.017)	0.011 (0.016)
Rating Safe $_l$ :Any Measure $_j$	0.145 (0.419)	0.203 (0.429)	0.333 (0.351)	0.323 (0.355)	0.256 (0.370)	0.261 (0.369)	0.214 (0.352)
Rating Average $_l$ :Any Measure $_j$	-0.219 (0.226)	0.258 (0.231)	0.450*** (0.173)	0.446** (0.176)	0.441*** (0.166)	0.446*** (0.165)	0.401*** (0.149)
Rating Risky $_l$ :Any Measure $_j$	0.091 (0.125)	0.128 (0.124)	0.307*** (0.101)	0.283*** (0.104)	0.274*** (0.077)	0.281*** (0.077)	0.234*** (0.073)
Forbearance Before $_j$							0.069 (0.066)
<b>Fixed Effects:</b>							
Loan age		Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time			Yes	Yes	Yes	Yes	Yes
Bank x Time				Yes	Yes	Yes	Yes
Bank x Segment x Prod. Type					Yes	Yes	Yes
County						Yes	Yes
Observations	1,292,685	1,292,685	1,292,685	1,292,685	1,292,685	1,292,685	1,292,685

Note: Logit Hazard Regression with standard errors clustered at Bank x Time level. The dependent variable is the probability of default of any loan held by borrower  $j$  in any period in the future whereas the independent variables are measured in  $t$ . We split the borrowers in Safe, Average, and Risky based on their ex-ante probability of default. Forbearance Before is a dummy which is one if a borrower has ever received forbearance before  $t$ . The loan exits the sample once a default occurs. Significance levels: \*  $p < 0.1$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$

**Table 2.9** – Logit regression: Probability of default in next period for any loan by borrower - Influence of different measures taken by borrower

Measure <sub><i>i</i></sub> :	<i>Dependent variable:</i>					
	Probability of Default <sub><i>t+1,j</i></sub>					
	Any Measure <sub><i>j</i></sub>	Term Extension <sub><i>j</i></sub>	Interest Rate Change <sub><i>j</i></sub>	Limit Extension <sub><i>j</i></sub>	Rollover <sub><i>j</i></sub>	Amortisation Stop <sub><i>j</i></sub>
	(1)	(2)	(3)	(4)	(5)	(6)
Rating Average <sub><i>l</i></sub>	0.981*** (0.196)	1.209*** (0.130)	1.153*** (0.152)	1.151*** (0.119)	1.157*** (0.142)	1.053*** (0.184)
Rating Risky <sub><i>l</i></sub>	3.294*** (0.325)	3.655*** (0.153)	3.642*** (0.172)	3.638*** (0.133)	3.536*** (0.152)	3.242*** (0.253)
ln(Outstanding Balance <sub><i>l</i></sub> )	0.012 (0.017)	-0.023** (0.011)	0.029* (0.017)	-0.001 (0.009)	-0.001 (0.009)	0.015 (0.018)
Rating Safe <sub><i>l</i></sub> :Measure <sub><i>i</i></sub>	0.261 (0.369)	1.793*** (0.324)	0.414*** (0.099)	0.290 (0.205)	0.250 (0.528)	1.006* (0.539)
Rating Average <sub><i>l</i></sub> :Measure <sub><i>i</i></sub>	0.446*** (0.165)	1.319*** (0.246)	0.444*** (0.161)	0.335* (0.186)	0.708** (0.335)	0.762*** (0.220)
Rating Risky <sub><i>l</i></sub> :Measure <sub><i>i</i></sub>	0.281*** (0.077)	0.114 (0.130)	-0.005 (0.062)	-0.251*** (0.076)	0.077 (0.125)	1.166*** (0.092)
Fixed Effects:						
Loan age	Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Time	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Segment x Prod. Type	Yes	Yes	Yes	Yes	Yes	Yes
County	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,292,685	799,152	1,109,815	1,100,091	1,100,091	1,291,121

*Note: Logit Hazard Regression with standard errors clustered at Bank x Time level. The dependent variable is the probability of default of any loan held by borrower *j* in any period in the future whereas the independent variables are measured in *t*. We split the borrowers in Safe, Average, and Risky based on their ex-ante probability of default. Measure on loan *l* is specified by the heading of each column. The loan exits the sample once a default occurs. Significance levels: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$*

**Table 2.10** – OLS regression: Relationship between forbearance and new lending by buckets:  
County × Time × Bank × Segment

	<i>Dependent variable:</i>					
	Share(New Lending <sub>t</sub> )				ln(New Lending <sub>t</sub> )	
	(1)	(2)	(3)	(4)	(5)	(6)
Share(Forbearance) <sub>t-1</sub>	-0.034*** (0.007)	-0.053*** (0.007)	-0.066*** (0.007)	-0.076*** (0.008)		
Share(Forbearance) <sub>t</sub>					-0.045*** (0.011)	
ln(Forbearance) <sub>t</sub>						-0.160*** (0.042)
Fixed Effects:						
Bank		Yes	Yes			
County x Time			Yes	Yes	Yes	Yes
Bank x Time				Yes	Yes	Yes
Observations	754	754	754	754	873	872
R <sup>2</sup>	0.033	0.136	0.383	0.419	0.290	0.597
Adjusted R <sup>2</sup>	0.032	0.134	0.144	0.185	0.011	0.438

*Note: OLS Regressions saturated with fixed effects. The dependent variable is the volume-weighted share of new lending (1)-(5) or the ln of new lending (6) per bucket of borrowers within a bank, segment, and county. The independent variable is the volume-weighted share of forborne loans in t – 1 or t (first two lines) or the ln of the sum of forborne loans in t (last line). Significance levels: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01*

# 3

## Economic consequences of manipulation in commodity markets – Evidence from a DSGE model<sup>1</sup>

### 3.1 Introduction

In 2014 the US Senate published a report about Wall Street banks involvement in commodity markets (US Senate Permanent Subcommittee on Investigations, 2014). Said banks were accused of manipulating various commodity markets, and, in the case of aluminium, they are currently in litigation. The aluminium market was supposedly manipulated by increasing stock out queues from warehouses, and thereby limiting the available aluminium to the market. There is a lively debate about the effect on prices, a question I will address in this

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<sup>1</sup>The author is grateful for comments and suggestions by Craig Pirrong, Nikos Nomikos, Steffen Hitzemann, Nuno Coimbra, Farshad Ranjbar Ravasan, Michael Stemmer, Ansgar Rannenberg, Matija Lozej, Ezgi Özsögüt, Julian Hinz and participants of the 2017 Commodity Markets Winter Workshop, the Commodity and Energy Markets Association Annual Meeting 2017, the AFSE Meeting 2017 and the Paris School of Economics Macro Workshop for valuable comments and discussions. The author gratefully acknowledges the support of the Laboratory of Excellence on Financial Regulation (Labex ReFi), and PRES heSam under the reference ANR-10-LABX-0095. The usual *caveat* applies.



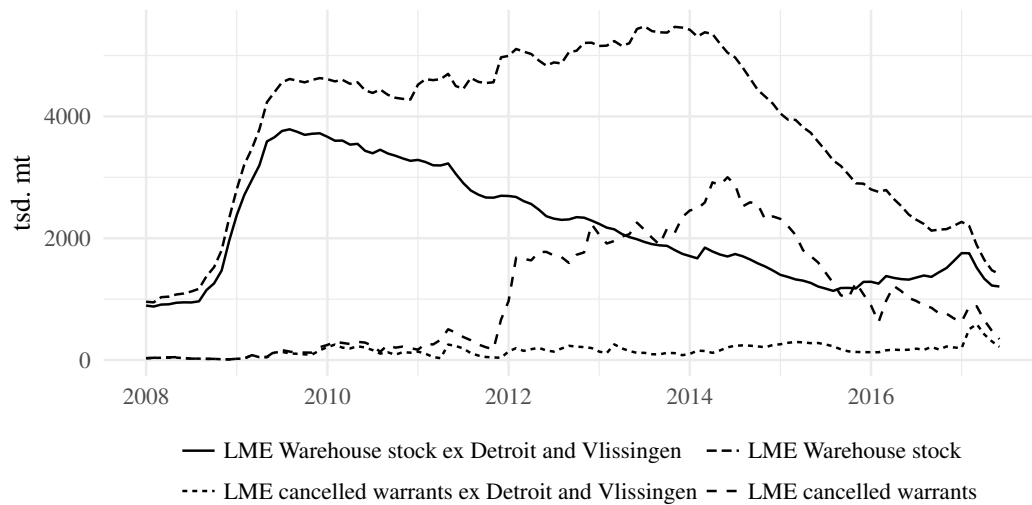
paper. To their defence, the accused argue that their goal was to increase their rental income in the warehouses they owned, and not to influence prices.

The alleged manipulation in the aluminium market is relevant because of the overall importance of aluminium as an industrial metal. Even more so, because other similar commodities were also allegedly affected or could be affected by abusing the same queuing mechanism. Aluminium is an important industrial metal widely used in all sectors of the economy. It accounts for about 0.38% of value added in 2007 in the US<sup>2</sup> which is about a tenth of the importance of oil<sup>3</sup>. Given the importance of aluminium for the economy, Figure 3.1 shows the extent of the manipulation. Inventories in London Metal Exchange (LME) licensed warehouses increased as a consequence of falling demand after the Global Financial Crisis (GFC). From 2010 on these inventories did continuously fall in all warehouses except those based in Vlissingen, Netherlands and Detroit, USA (see solid black line in Figure 3.1). These two warehouses were owned by Wall Street banks or commodity trading houses, and used for the alleged manipulation. In 2011 we see that the total LME inventories (line above solid black line) and the inventories excluding Vlissingen and Detroit significantly diverge. This is due to an accumulation of inventories in said locations and at the same time the amount of cancelled warrants jumped (compare the two lower dotted lines) in those warehouse locations. This led to waiting times (queues) for the delivery of aluminium building up to around two years at the peak, and because storing aluminium is relatively cheaper than transporting it, the queue in Detroit played a major role for aluminium prices in the US. The cancelled warrants in these two locations became less important from 2014 on. This coincides with a rule change for stock outs by the LME and the US Senate investigation into the practice. The importance of the artificially limited availability of aluminium from LME warehouses is diminished by the fact that

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<sup>2</sup>Authors own calculation using data from the Bureau of Economic Analysis Input Output tables.

<sup>3</sup>See Bodenstein et al. (2011).

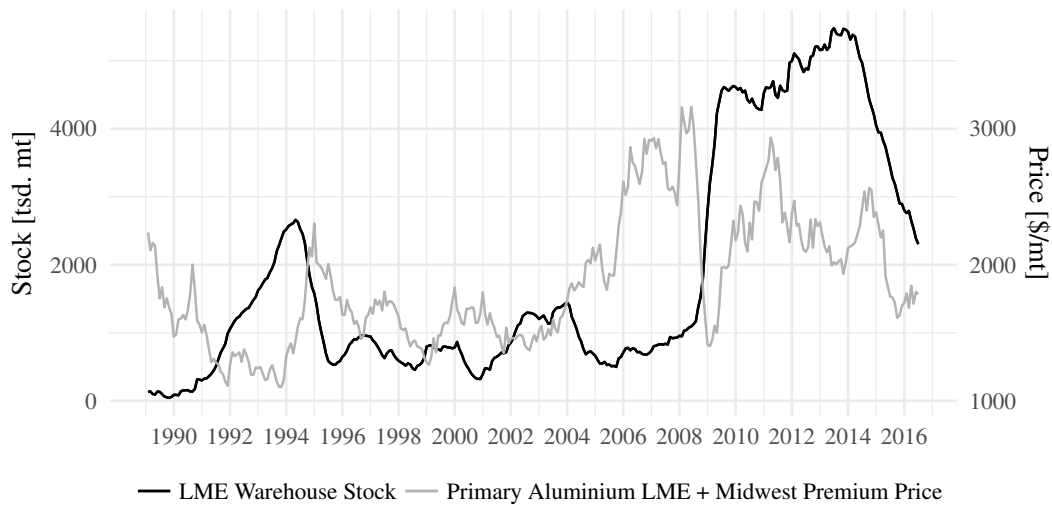


**Figure 3.1** – Inventory levels and cancelled warrants in LME Warehouses

the aluminium market uses the LME system only as a last resort to balance the market. Furthermore, a non-negligible part of aluminium is stored in non-LME licensed warehouses, but the LME system is the preferred storage because of the ease of trading the warrants. Lastly, the vast majority of the aluminium production is directly sold to consumers on long term contracts.

Figure 3.2 shows two periods of high inventories. The first one, around the time of overproduction by the ex-Soviet states in the early 1990's and the second period following the collapse in demand after the GFC. The collapse in demand had an equally important negative impact on aluminium prices. Nonetheless, they rebounded shortly after and from 2010 on they were on a slight downward trend with sporadic peaks. The question is, did the cancelled warrants we saw in Figure 3.1 push up prices between 2010 and 2014?

I address this question by first developing a structural model, which I then use to test if the impact of manipulation on prices is empirically supported by the estimation results. In a second step I then analyse the importance and economic consequences/costs of this phenomenon for the US economy. A negative economic impact would make it a relevant issue for policy makers and warrant their scrutiny. Even more so, given that other commodity markets



**Figure 3.2** – LHS: LME Warehouse Stock [tsd. mt]; RHS: Primary Aluminium LME Spot + Midwest Premium [\$/mt]

which are comparable to the aluminium market (e.g. copper) were allegedly equally affected.

This paper contributes to a strand of literature about manipulation and speculation in commodity markets. Pirrong (2017) lays out the different kinds of manipulation and finds that market power manipulation (as is allegedly the case for aluminium) causes deadweight losses in the economy. Furthermore, Pirrong (1993) and Fackler (1993) highlight that prices and inventories in the delivery market (US Midwest Premium for the case of the Detroit warehouses) rise as a consequence of the manipulation. This increase is expected to be temporary and at the end of the manipulation the price and inventory levels decrease. Figure 3.1 shows how Detroit and Vlissingen became increasingly important after the alleged manipulation started in 2010. The effect on prices is less clear, since the overall price levels declined over this period (see Figure 3.2).

Following the argument of the accused banks, one could argue that, if anything, other speculators were at work in this market. Knittel and Pindyck (2016) lay out a model with inventories and argue that speculation has a small impact

unless price elasticities are assumed to be close to zero. They analyse the oil market, where financialisation supposedly led to an increase in commodity speculation, and find little evidence for speculation having an influence. The difference between manipulation and speculation is precisely that price elasticities do change over time and can be influenced by the manipulator. In both cases one needs to distinguish between real demand (flow demand) and speculative or manipulative demand.

There is a growing literature using structural models to identify the two sources of demand. Kilian (2009) investigates the oil market before the GFC with a vector autoregression (VAR) model including storage. He assigns little importance to oil market specific shocks to be a driver of the oil price. For the demand side he uses ocean freight rates as a proxy for commodity related demand, which is a weak instrument for oil demand. Freight rates are strongly influenced by the shipping market and the cyclical shipbuilding. Therefore, they do not only represent global demand factors (Papapostolou et al., 2016). To overcome these shortcomings in modelling the demand side, I argue in favour of dynamic stochastic general equilibrium (DSGE) models. They allow for a more detailed modelling of demand and supply and are a suitable tool to estimate the manipulative demand for aluminium. The DSGE model used here builds on Unalmis et al. (2012) and Tumen et al. (2015). They model the US economy with oil used in consumption and production. Most importantly, they include storage in their model and identify a storage demand shock, which is orthogonal to the other demand side shocks. I adapt this model for my purposes by implementing the queueing mechanism as a feature in the model. Furthermore, the aluminium market does not deliver to consumers as is the case for oil (e.g. heating or gasoline).

The contribution of this paper is that I estimate the effect and extend of a concrete example of (alleged) manipulation of a commodity market with a structural macroeconomic model. The model estimation provides evidence for

the influence of the queue mechanism on dynamics in the aluminium market after 2010. The corresponding friction parameter turns out to be higher than before the GFC. Furthermore, manipulative (storage) demand shocks are found to be the most important shock in explaining variations in the price of aluminium. Furthermore, I find that the US has a relatively small impact on the aluminium market. The impact on the US economy from the aluminium market is found to be negligible, which is not surprising given its relative size. Nonetheless, manipulative (storage) demand shocks are found to have a negative impact on output and lead to higher aluminium prices, along with higher inflation and nominal interest rates.

These findings confirm that the alleged manipulation had an impact on the aluminium market. Furthermore, the impact on the economy is small but negative. Therefore, I argue that policy makers should learn from the example of the aluminium market and implement similar rule changes, which essentially led to higher stock out limits, in other commodity markets.

The paper develops the argument in the following way. Section 3.2 describes the model which is then estimated on the data described in Section 3.3. This Section describes as well the estimation of the model and the results can be found in Section 3.4. Section 3.5 concludes.

## **3.2 Model**

The model builds on a standard DSGE framework with households, firms, a government and a monetary authority (see Clarida et al. (2001); Galí (2002)). Following Unalmis et al. (2012) and Tumen et al. (2015) works on oil storage, I implement a competitive storer of aluminium, exogenous aluminium supply and aluminium which is used in production, but not in consumption. These modelling choices are made in order to have the most parsimonious model with the essential ingredients for the analysis of the issue at hand. Aluminium is a

commodity which is primarily used as an intermediate good and not consumed directly, unlike oil. The model of Unalmis et al. (2012) is extended by taking into account storage rigidities reflecting queues in aluminium warehouses. The price of aluminium is endogenously determined.

Households maximise their utility out of consumption and provide labour to firms against a wage. They own the firms they are working for and receive their dividends and they hold a capital stock and rent it out to firms in a perfectly competitive market. Firms produce a differentiated good using labour, capital and aluminium as input and are price setters in a sticky price framework. The competitive, risk-neutral and profit maximising storer buys and stores aluminium in one period and sells it in the next depending on the arbitrage conditions and cost of storage adjustment.

In the following, small letters denote percentage deviations from steady-state.

### 3.2.1 Households

The infinitely lived households, indexed by  $j$ , maximise their lifetime utility by choosing the level of consumption,  $C_t(j)$ , and labour supply,  $N_t(j)$ , according to:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{(C_t(j) - H_t)^{1-\sigma}}{1-\sigma} - \frac{N_t(j)^{1+\varphi}}{1+\varphi} \right].$$

$H_t$  defines habit consumption:  $H_t = hC_{t-1}$  with  $h \in [0, 1]$  being the habit formation parameter.  $\sigma > 0$  defines the inverse constant elasticity of substitution (CES) of consumption,  $\varphi > 0$  is the inverse of the intertemporal elasticity of hours, and  $\beta \in [0, 1]$  represents the discount factor in the model. Aggregation of the households consumption follows a CES aggregator:

$$C_t = \left( \int_0^1 C_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}},$$

with  $\epsilon$  being the constant elasticity of substitution between varieties.

The households optimise their utility subject to the nominal budget restriction:

$$P_t C_t(j) + P_t I_t(j) + \mathbb{E}_t [Q_{t,t+1} D_{t+1}(j)] \leq D_t(j) + W_t N_t(j) + R_t^K K_t(j) + \Pi_t(j) + T_t(j).$$

The budget constraint implies, on the income side, that households have a portfolio  $D_t(j)$  which pays out one unit of currency in a particular state, that they earn a wage,  $W_n$ , from their labour,  $N_t(j)$ , receive the rate of return on capital,  $R_t^K$ , on their invested capital stock,  $K_t(j)$ , receive the profits of monopolistic firms  $\Pi_t(j)$  and the lump-sum transfer<sup>4</sup> from government,  $T_t(j)$ . On the expenditure side, households consume  $P_t C_t(j)$  and invest  $P_t I_t(j)$ . Furthermore,  $D_{t+1}(j)$  is the expected nominal pay off in the next period of the portfolio held at the end of the period and  $Q_{t,t+1}$  is the stochastic discount factor for the one period ahead nominal pay off.

Inherent in the budget constraint is the decision of capital allocation. Households own firms and rent capital to them by deciding their investment level given capital adjustment cost. Capital accumulation follows the following dynamics:

$$K_{t+1}(j) = (1 - \delta)K_t(j) + \Phi\left(\frac{I_t(j)}{K_t(j)}\right) K_t(j), \quad (3.1)$$

with  $\delta \in [0, 1]$  being the depreciation rate of the capital stock,  $K_t(j)$ , and  $I_t(j)$  being the households investment. The model features capital adjustment cost,  $\Phi\left(\frac{I_t(j)}{K_t(j)}\right)$ , with their steady state values being  $\Phi_{ss} = \delta$  and for their first and second derivatives,  $\Phi'_{ss} = 1$ ,  $\Phi''_{ss} = \xi < 0$  and  $\delta\xi = -1$ .

Assuming complete asset markets implies perfect risk-sharing among households. Therefore, we can drop the index  $j$  of households. The above described

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<sup>4</sup>The lump sum transfer is set to balance the government budget.

optimisation problem leads to the following optimality conditions:

$$(C_t - H_t)^\sigma N_t^\varphi = \frac{W_t}{P_t}, \quad (3.2)$$

$$\frac{1}{R_{t-1}} = \beta \frac{P_{t-1}}{P_t} \left( \frac{C_t - H_t}{C_{t-1} - H_{t-1}} \right)^{-\sigma}, \quad (3.3)$$

$$P_{t-1} \Lambda_{t-1} = \beta \frac{P_{t-1}}{P_t} \left( \frac{C_t - H_t}{C_{t-1} - H_{t-1}} \right)^{-\sigma} (R_t^K + P_t \Lambda_t \tilde{\Phi}), \quad (3.4)$$

with  $R_t$  being the risk free nominal interest rate. The shadow price of capital is denoted by:  $\Lambda_t = [\Phi'(\frac{I_t}{K_t})]^{-1}$  and  $\tilde{\Phi} = [(1 - \delta) + \Phi(\frac{I_t}{K_t}) - \frac{I_t}{K_t} \Phi'(\frac{I_t}{K_t})]$ .

### 3.2.2 Firms

The good is produced under monopolistic competition and used for consumption and investment. A continuum of firms produces a differentiated good indexed by  $i$  and given the CES production function:

$$Y_t(i) = A_{y,t} \left[ (1 - w_{ly})^{\frac{1}{\rho_y}} V_t(i)^{\frac{\rho_y - 1}{\rho_y}} + w_{ly}^{\frac{1}{\rho_y}} L_{y,t}(i)^{\frac{\rho_y - 1}{\rho_y}} \right]^{\frac{\rho_y}{\rho_y - 1}}, \quad (3.5)$$

with  $L_{y,t}(i)$  being the amount of aluminium used in the production of the core good and  $V_t(i)$  being the value added input.  $w_{ly} \in [0, 1]$  is the share of aluminium used in production and  $\rho_y$  is the elasticity of substitution between the two inputs. Furthermore, there is a total factor productivity (TFP) shock,  $A_{y,t}$ , which equally affects all firms.

The value added input is produced by the firms using capital and labour and the CES production function:

$$V_t(i) = \left[ (1 - w_{ny})^{\frac{1}{\rho_v}} K_t(i)^{\frac{\rho_v - 1}{\rho_v}} + w_{ny}^{\frac{1}{\rho_v}} (A_{n,t} N_t(i))^{\frac{\rho_v - 1}{\rho_v}} \right]^{\frac{\rho_v}{\rho_v - 1}}, \quad (3.6)$$

with  $\rho_v$  being the elasticity of substitution and  $w_{ny} \in [0, 1]$  is the share of labour in production. Here,  $A_{n,t}$  stands for a labour productivity shock. Firms take prices (including the endogenously determined price of aluminium,  $P_{l,t}$ ) as



given and minimise their costs:

$$\min_{L_{y,t}(i), K_t(i), N_t(i)} P_{l,t} L_{y,t}(i) + R_t^K K_t(i) + W_t N_t(i).$$

This leads to the following optimality conditions:

$$\frac{P_{l,t} L_{y,t}(i)^{\frac{1}{\rho_y}}}{w_{ly}^{\frac{1}{\rho_y}}} = \frac{R_t^K K_t(i)^{\frac{1}{\rho_v}}}{(1 - w_{ny})^{\frac{1}{\rho_v}} (1 - w_{ly})^{\frac{1}{\rho_y}}} = \frac{W_t N_t(i)^{\frac{1}{\rho_v}}}{A_{n,t}^{\frac{\rho_v - 1}{\rho_v}} w_{ny}^{\frac{1}{\rho_v}} (1 - w_{ly})^{\frac{1}{\rho_y}}}. \quad (3.7)$$

Given optimal allocation, the nominal marginal cost are:

$$MC_t^n = \frac{1}{A_{y,t}} \left[ (1 - w_{ly}) V_{c,t}^{1 - \rho_y} + w_{ly} P_{l,t}^{1 - \rho_y} \right]^{\frac{1}{1 - \rho_y}}, \quad (3.8)$$

with  $V_{c,t}$  being the cost of the value added input, defined as:

$$V_{c,t} = \left[ (1 - w_{ny}) R_t^K^{1 - \rho_v} + w_{ny} \left( \frac{W_t}{A_{n,t}} \right)^{1 - \rho_v} \right]^{\frac{1}{1 - \rho_v}}. \quad (3.9)$$

Firms have price setting power but only a random fraction,  $\theta$ , can reset their prices each period as laid out in the Calvo (1983) staggered price setting framework. Here, a partial indexation to past inflation is included. This leads to the following (log-linearised) Philipps curve:

$$\pi_t = \frac{\beta}{1 + \beta\varsigma} \mathbb{E}_t [\pi_{t+1}] + \frac{\varsigma}{1 + \beta\varsigma} \pi_{t-1} + \frac{(1 - \theta)(1 - \beta\theta)}{\theta(1 + \beta\varsigma)} mc_t, \quad (3.10)$$

with  $\varsigma$  being the inflation indexation parameter and  $\theta \in [0, 1]$  denoting the share of randomly selected firms which cannot adjust their prices optimally in each period.  $\pi_t$  is the consumer price index (CPI) inflation and  $mc_t$  denotes the marginal cost.

### 3.2.3 Aluminium Storage

Aluminium storage refers to the physical storage of finished aluminium products, which can be used for production. Warehouses compete for inventories and have

an incentive to keep them in stock as long as possible. The LME regulates the stock-out rules, which limit the inventory which can leave a warehouse per day. Another way of increasing the queue is to attract large amounts of aluminium to a warehouse and incentivise warrant holders to cancel and re-warrant in another location. This causes demand not being satisfied because the ordered aluminium has to enter the queue before becoming available for physical delivery. I model this mechanism as a friction for storage level adjustments. The mechanism is embedded in the problem of a continuum of competitive storers<sup>5</sup> that maximise their profit<sup>6</sup> from buying, storing and eventually selling aluminium:

$$\max_{S_t} \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left[ \frac{\alpha \mathbb{E}_t(P_{l,t+1}) S_t}{R_t} - P_{l,t} S_t \left( 1 + \Upsilon(S_t) + \frac{\phi_s}{2} \left( \frac{S_t}{S_{t-1}} - A_{s,t} \right)^2 \right) \right],$$

with  $S_t$  being the inventory level, and  $\Upsilon(S_t) = \kappa + \frac{\Psi}{2} S_t$  representing the physical cost of storing one unit of aluminium.  $\kappa < 0$  denotes the convenience yield<sup>7</sup> or relative benefit of holding the physical asset over time and  $\Psi > 0$  represents the increasing costs with the quantity stored. Furthermore, there is a loss of inventory  $(1 - \alpha) \in [0, 1]$  over time. Inventories can only be positive and here this constraint is implemented by having a sufficiently high steady state inventory level compared to the deviations. Another approach would be to incorporate non-linearities but for simplicity this approach is not chosen here.<sup>8</sup>

This modelling approach draws on the work by Unalmis et al. (2012) and here I extend it by adding quadratic adjustment cost, reflecting the stickiness of inventory levels. The parameter,  $\phi_s$ , denotes the quadratic adjustment cost of inventory levels (cf. Rotemberg (1982)). The higher the adjustment parameter, the more costly it is to adjust inventories and the stickier will inventory levels be.

<sup>5</sup>The competitive storers have the same rational expectations. Therefore, no indexation is needed.

<sup>6</sup>The profits of the competitive storers is distributed to the households via the lump sum transfer,  $T_t$ .

<sup>7</sup>The convenience yield is a commonly assumed feature of commodities markets and Figuerola-Ferretti and Gonzalo (2010) estimate it for the aluminium market.

<sup>8</sup>For a discussion on modelling non-linearities in DSGE models see e.g. Fernández-Villaverde et al. (2015) for the case of the zero lower bound on interest rates.

This shall represent directly the manipulation of queues, which equally caused sticky inventory levels. The storage demand shock,  $A_{s,t}$ , represents a cost for the competitive storer if the growth in storage is not equal to the shock, which follows a stationary AR(1) process. This shock can be interpreted as being a manipulative (storage) demand shock as well as a precautionary demand shock (see Alquist and Kilian (2010)). Uncertainty about future aluminium supply, would lead to higher inventory levels because of precautionary demand and this would be captured in the storage demand shock. Nonetheless, the supply of aluminium is stable and predictable over the long term. Another possible explanation is that financialisation is behind a movement in storage levels. Basak and Pavlova (2016) show that financialisation had a positive impact on prices and inventory levels of storable commodities.

Storers are price takers in the aluminium market and their first order condition with respect to  $S_t$  is:

$$\frac{\alpha}{R_t} = \frac{P_{l,t}}{\mathbb{E}_t [P_{l,t+1}]} \left( 1 + \kappa + \Psi S_t + \frac{\phi_s}{2} \left( \frac{S_t}{S_{t-1}} - A_{s,t} \right)^2 + \frac{S_t}{S_{t-1}} \phi_s \left( \frac{S_t}{S_{t-1}} - A_{s,t} \right) \right) - \left( \frac{\mathbb{E}_t [S_{t+1}]}{S_t} \right)^2 \beta \phi_s \left( \frac{\mathbb{E}_t [S_{t+1}]}{S_t} - \mathbb{E}_t [A_{s,t+1}] \right)$$

In log-linearised form this becomes:

$$s_t = \Theta \left[ \mathbb{E}_t [\widehat{p}_{l,t+1} + \pi_{t+1}] - r_t - \widehat{p}_{l,t} - \frac{\phi_s}{\alpha\beta} (s_t - s_{t-1} - a_{s,t}) + \frac{\phi_s}{\alpha} (\mathbb{E}_t [s_{t+1} - a_{s,t+1}] - s_t) \right], \quad (3.11)$$

with  $\Theta = \frac{\alpha\beta}{\alpha\beta-1-\kappa}$ , and  $\widehat{p}_l = p_l - p$  denoting the real price of aluminium. Therefore, the decision on storage levels depends on past and future expected storage levels as well as current and expected aluminium price levels, the interest rate and the exogenous shock. The friction representing the queueing mechanism does not influence equilibrium storage levels but effects the dynamics.

### 3.2.4 Goods markets equilibrium

The goods markets always clear in equilibrium and satisfy the condition:

$$Y_t(i) = G_t(i) + I_t(i) + C_t(i), \quad (3.12)$$

with  $G_t(i)$  being the government demand.

Furthermore, the market for aluminium is always in equilibrium. That implies that the world endowment of aluminium,  $L_{s,t}$ , plus old inventories less depreciation, equals the use in production and new inventories:

$$L_{y,t} + S_t = L_{s,t} + \alpha S_{t-1}, \quad (3.13)$$

with,  $L_{s,t}$ , being subject to an exogenous shock defined by a stationary AR(1) process.

### 3.2.5 Monetary Policy

Monetary policy follows a Taylor rule:

$$r_t = \phi_r r_{t-1} + (1 - \phi_r) \phi_\pi \pi_t + (1 - \phi_r) \phi_y y_t + a_{r,t}, \quad (3.14)$$

with  $\phi_r \in [0, 1]$  denoting the interest rate smoothing,  $\phi_\pi$  being the monetary policy response to inflation and  $\phi_y$  to output.  $a_{r,t}$  represents a monetary policy shock, following a stationary AR(1) process.

### 3.2.6 Fiscal Policy

Government demand is directed towards the core good only:

$$G_t = \left( \int_0^1 G_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}.$$

The public sector does not have a deficit in our model and therefore the demand

equals a lump-sum tax:

$$P_t T_t = G_t.$$

Under optimal allocation this yields the government demand function:

$$G_t(i) = \left( \frac{P_t}{P_t(i)} \right)^\epsilon G_t,$$

with the process for government spending,  $G_t$ , being a stationary AR(1) process.

### 3.3 Estimation

I estimate the model on two subsamples. The first sample from 2009Q4 until 2016Q2 covers the period where the alleged manipulation of storage queues took place. If storage adjustment cost are estimated to be significantly above zero, this would confirm the importance of the queuing mechanism. In order to gauge the significance of that finding we contrast the estimated storage adjustment cost parameter of that period with the one for the period 1989Q1 until 2008Q2.

A log-linearised approximation of the model is estimated, which is described in the Appendix. In a subsequent step the model is transformed into a state-space representation and the likelihood is evaluated with a Kalman filter. Given the prior distributions of the parameters, as described in Section 3.4.1, and the likelihood we obtain the posterior densities of the parameters. Ultimately, a Markov Chain Monte Carlo simulation is used to maximise the posterior density.<sup>9</sup>

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<sup>9</sup>The Dynare 4.4.3 software is used for the estimation. The Metropolis-Hastings algorithm finds the posterior density based on 250.000 draws.

### 3.3.1 Data

The model is estimated using quarterly US data of output, investment, CPI inflation, interest rate, aluminium price and aluminium storage levels from 1989Q1 until 2016Q2. I split the sample into pre GFC (before 2008Q2) and post GFC period (after 2009Q4), following the findings of Galí et al. (2012) and Lubik and Schorfheide (2004). The latter show that DSGE models are indeterminate before 1982 due to a shift in monetary policy and the former argues that the zero lower bound leads to non-linearities, which cannot be captured with a linear model. The aluminium price used in the estimation consists of the LME spot primary aluminium price and the Metal Bulletin Midwest Premium.<sup>10</sup> Storage levels correspond to LME warehouse inventories. Both aluminium prices and storage levels are first deseasonalised using the X13-ARIMA-SEATS procedure and then converted to a quarterly frequency. Aluminium prices are deflated using the CPI index. Aluminium storage levels are converted to a per capita basis using the civilian non-institutional population time series. The same per capita transformation is undertaken for investment (Gross Fixed Capital Formation), with investment being deflated by the GDP deflator. The federal funds rate and real GDP per capita are taken directly from the Federal Reserve Bank of St. Louis' database, as are all other time series not related to aluminium. Finally, the time series for real GDP per capita, real investment per capita, CPI inflation, federal funds rate, real price of aluminium and aluminium storage per capita are then transformed into the log-difference from the Hodrick-Prescott filtered trend ( $\lambda = 1600$ ).

### 3.3.2 Calibrated Parameters

Since the model is based on a standard DSGE framework we can draw on a large literature regarding parameter calibration. As usual for this type of

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<sup>10</sup>The Midwest Premium reflects the market conditions in the US.

models we set capital depreciation,  $\delta = 0.025$ ,  $\beta = 0.99$ , implying a riskless rate of return of 4% and the investment and government share of output are set to  $I_y^{ss} = 0.2$  and  $G_y^{ss} = 0.18$ . The labour share in the production of the value added input,  $V_t$ , is set to  $w_{ny} = 0.66$  following the results of Rios-Rull and Santaaulalia-Llopis (2010) and Raurich et al. (2012). For the inventory loss  $\alpha = 0.01$  we follow Unalmis et al. (2012). Regarding the aluminium parameters we calculate the share of aluminium in output<sup>11</sup> to be  $w_{ly} = 0.0038$  and the ratio of storage to supply in steady state to be  $L_s^{ss} = 0.34$ . The ratio varies quite significantly over time. For the period after the GFC I use  $L_s^{ss} = 2.14$ . The steady state share of aluminium supply over storage is a result of other variables:  $L_y^{ss} = w_{ly} (1 - (1 - \alpha) L_s^{ss})$ .

## 3.4 Results

### 3.4.1 Prior and Posterior Distributions

The model is taken to the data (output, investment, CPI inflation, interest rate, aluminium price and aluminium storage levels) to estimate 12 structural parameters, and the AR(1) coefficients and shock standard deviations for the six shocks (aluminium supply, labour productivity, TFP, government spending, monetary policy, and storage demand shock).

Table 3.1 shows the results of the parameter estimation for two subsamples. The first sample period covers the time of alleged manipulation (2009Q4:2016Q2) and the period before is used to contrast the results. I will begin by interpreting the results for the more recent subsample.

The priors of the staggered price parameters, consumer preferences and the monetary policy block are taken from Sahuc and Smets (2008) and Nakov and Pescatori (2010). The Calvo probability,  $\theta$ , and the price indexation parameter,

<sup>11</sup>The share is calculated using the Bureau of Economic Analysis input output tables for the US economy in 2007. For comparison, the share of oil in output is about ten times larger.

$\varsigma$ , have a beta prior with mean 0.5 and standard deviation 0.15.  $\theta$  is estimated to be 0.733, in combination with an estimated inflation indexation parameter of 0.626, this leads to relatively sticky prices. Regarding consumer preferences, the consumption utility parameter,  $\sigma$ , has a normal prior with mean 1 and standard deviation 0.1 and the inverse Frisch labour supply elasticity,  $\varphi$ , has a gamma distribution prior with mean 1 and standard deviation 0.25.  $\sigma$  and  $\varphi$  are estimated at 0.925 and 0.901 respectively which would mean almost log-utility. The prior of the habit formation parameter,  $h$ , follows a beta distribution with mean 0.6 and standard deviation 0.1. The posterior has its mean at 0.437 which is slightly higher than in the literature and signifies more sticky consumption. Turning to the monetary policy block, the interest rate smoothing parameter,  $\phi_r$ , has a beta prior with mean 0.6 and standard deviation 0.1 and is estimated at 0.587. The inflation and output gap parameters,  $\phi_\pi$  and  $\phi_y$  have a gamma prior with mean 1.5 and 0.5 and standard deviations 0.5 and 0.15 respectively and have a posterior mean of 3.393 and 0.492. This means that monetary policy reacts strongly to inflation. Since we are using a CES production function we need to define priors for the elasticity of substitution between capital and labour,  $\rho_v$ . Here, we rely on the literature and set a gamma prior with mean 0.5 and standard deviation 0.1 (Chirinko, 2008). The posterior mean comes in at 0.457.

The priors for all standard deviations of the exogenous shocks follow an inverse gamma distribution with mean 2 and standard deviation 2. The persistence parameters of the exogenous shocks follow a beta distribution with mean 0.5 and standard deviation 0.2. Labour, TFP and storage demand shocks have the highest volatility, whereas storage demand shocks turn out to be the most persistent. A more in depth discussion about the exogenous shocks follows in Section 3.4.2.

Finally, the parameters specific to the model with aluminium are defined. For the priors we draw on Unalmis et al. (2012). The convenience yield,  $\kappa$ , is



Parameters		Prior Distribution			Posterior Distribution					
		Distr.	$\mu$	$\sigma$	Sample: 2009Q4:2016Q2			Sample: 1987Q4:2008Q2		
					$\mu$	5%	95%	$\mu$	5%	95%
Structural Parameters										
$\rho_y$	Elasticity: Aluminium/VA	gamma	1.00	0.50	0.899	0.213	1.551	1.262	0.323	2.164
$\rho_v$	Elasticity: Capital/Labour	gamma	0.50	0.10	0.457	0.311	0.602	0.659	0.496	0.824
$\phi_s$	Inventory level adj. cost	gamma	1.00	0.50	0.622	0.311	0.930	0.116	0.057	0.174
$\kappa$	Convenience yield	norm	-0.03	0.05	-0.021	-0.022	-0.020	-0.020	-0.021	-0.020
$\theta$	Calvo Parameter	beta	0.50	0.15	0.733	0.675	0.795	0.743	0.696	0.792
$\varsigma$	Price indexation	beta	0.50	0.15	0.626	0.418	0.841	0.342	0.165	0.516
$h$	Habit persistence	beta	0.60	0.10	0.437	0.274	0.599	0.281	0.153	0.404
$\sigma$	inv. el. of int.subst. cons.	norm	1.00	0.10	0.925	0.746	1.109	0.771	0.624	0.916
$\varphi$	inv. el. of labor supply	gamma	1.00	0.25	0.901	0.504	1.266	0.893	0.513	1.268
$\phi_\pi$	Int. rate: inf. response	gamma	1.50	0.50	3.393	2.465	4.327	4.660	3.611	5.666
$\phi_y$	Int. rate: output response	gamma	0.50	0.05	0.492	0.411	0.572	0.491	0.411	0.570
$\phi_r$	Int. rate: persistence	beta	0.60	0.10	0.587	0.454	0.719	0.554	0.457	0.651
Persistence of exogenous processes										
$\rho_g$	Government Spending	beta	0.5	0.2	0.368	0.152	0.573	0.801	0.731	0.872
$\rho_{ay}$	Total Factor Prod.	beta	0.5	0.2	0.712	0.425	0.929	0.780	0.715	0.844
$\rho_{an}$	Labour Productivity	beta	0.5	0.2	0.715	0.600	0.826	0.950	0.928	0.972
$\rho_{mp}$	Monetary Policy	beta	0.5	0.2	0.465	0.302	0.635	0.599	0.494	0.704
$\rho_l$	Aluminium Supply	beta	0.5	0.2	0.293	0.089	0.483	0.315	0.167	0.461
$\rho_{as}$	Storage Demand	beta	0.5	0.2	0.583	0.452	0.717	0.686	0.592	0.781
Standard Deviation of Shocks										
$\varepsilon_g$	Government Spending	invg	2	2	1.357	0.965	1.742	2.702	2.111	3.290
$\varepsilon_{ay}$	Total Factor Prod.	invg	2	2	0.666	0.466	0.854	0.600	0.487	0.709
$\varepsilon_{an}$	Labour Productivity	invg	2	2	0.912	0.539	1.280	0.473	0.374	0.569
$\varepsilon_r$	Monetary Policy	invg	2	2	0.458	0.353	0.558	0.389	0.316	0.449
$\varepsilon_l$	Aluminium Supply	invg	2	2	6.674	5.223	8.048	5.312	4.606	5.990
$\varepsilon_{as}$	Storage Demand	invg	2	2	8.299	4.210	12.206	60.061	30.934	87.329

**Table 3.1** – Prior distributions and posterior estimates - model with storage and storage adjustment cost

suspected to be negative but we allow the data to tell us otherwise by setting a normal prior with mean -0.03 and standard deviation 0.05. The convenience yield turns out to take a mean value of -0.021 and thereby confirming the presence of a convenience premium to holding the physical commodity. The degree of storage level stickiness,  $\phi_s$ , has a gamma prior with mean 1 and standard deviation 0.5. This choice reflects the fact that we don't know much about this parameter. It turns out that the posterior mean lies at 0.622. A value greater than 0 means a lower short run price elasticity of storage and leads to stickier storage levels. Furthermore, the estimation confirms the importance of this friction in the second subsample where the alleged manipulation occurred. Thereby, this result confirms that the model estimates are consistent with what

we would expect given that the queueing mechanism was abused in this period. Finally, the elasticity of substitution for the value added good and aluminium,  $\rho_y$ , has a gamma distribution prior with mean 1 and standard deviation 0.5, reflecting the little knowledge we have about this parameter. It is estimated at 0.899, suggesting almost a Cobb-Douglas production function like relationship between the value added input and aluminium.

When we compare these results with the estimation of the model for the period before the GFC a number of differences stand out. The storage adjustment cost is estimated to be much less important before the crisis compared to the time when the suspected manipulation of warehouse queues took place. This lends empirical evidence to the fact that this manipulation took place from 2010 on. The estimation results suggest that the structure of the market changed between the two subsamples and storage levels are more sticky in the latter sample, because of the higher storage adjustment costs, which resemble the queueing mechanism in our model. The data does not lend clear evidence to the identification of the storage demand shock. Here, I find a very high standard deviation compared to the estimation results of the other sample. The importance of this shock is diminished by the relatively (compared to the shocks in the same sample period) low persistence compared to the other shocks.

### **3.4.2 Variance Decomposition**

Table 3.2 shows the relative importance of the structural shocks in explaining the variance of model variables. The aluminium price volatility is mainly explained by the storage demand shock and partially by aluminium supply and TFP shocks. This outcome can be interpreted in the following way. The US economy has a limited impact on the aluminium market in the period of 2009 until 2016. This importance is small compared to the influence of storage demand shocks, which is by far the most important in explaining variance in

the price of aluminium. This underlines the importance of storage and possibly manipulation via storage queues (storage adjustment cost) for the aluminium market. The third most important shock is aluminium supply which explains more of the variance than the US economy but far less than manipulative (storage) demand shocks. When interpreting these results, one has to bear in mind that China was the most important producer and consumer of aluminium at the time. A factor which is omitted here. This certainly is picked up by other shocks in the estimation and diminishes the strength of this finding. Furthermore, the model attributes all the variance in storage levels to supply. This is possibly a further symptom of the models difficulties in identifying the shocks, given missing relevant data.

	$\varepsilon_r$	$\varepsilon_g$	$\varepsilon_l$	$\varepsilon_{ay}$	$\varepsilon_{an}$	$\varepsilon_{as}$
$y$	10.91	1.07	0.00	70.05	17.97	0.01
$c$	5.96	0.35	0.00	81.12	12.57	0.01
$i$	23.77	0.39	0.00	35.94	39.89	0.01
$r$	8.17	2.07	0.00	74.42	15.33	0.01
$\pi$	43.08	0.14	0.00	45.41	11.36	0.01
$\hat{p}_l$	0.72	0.04	11.53	6.20	0.99	80.52
$s$	0.00	0.00	100.00	0.00	0.00	0.00

**Table 3.2** – Variance Decomposition (%) - model with storage and storage adjustment cost  
- 2009Q4:2016Q2

Variation in the US economy is mostly explained by TFP, interest rate, and labour productivity shocks. The aluminium market has almost no influence on the macroeconomic dynamics. This outcome is not surprising given that aluminium makes up only 0.38% of US output. Overall the most important shock for output, inflation, interest rate, and consumption is TFP. Inflation is driven as well by monetary policy shocks and investment reacts most strongly to labour productivity shocks.

Tables 3.3 shows the conditional variance decomposition over different time horizons. manipulative (storage) demand explains more of the short term

(4 quarters) rather than the long term (40 quarter) variation in the price of aluminium. Furthermore, TFP shocks become more important in the long run for the price of aluminium. This suggests that the US economy plays a more important role for the aluminium market in the long run, compared to the short term (still small in comparison to storage demand shocks). Regarding output, we can confirm that storage demand and aluminium supply do not, even in the short run, play a role in explaining variation in output. Here as well, TFP shocks become more important over time.

	Quarter	$\varepsilon_r$	$\varepsilon_g$	$\varepsilon_l$	$\varepsilon_{ay}$	$\varepsilon_{an}$	$\varepsilon_{as}$
$y$	2	24.46	2.41	0.00	47.19	25.93	0.01
	4	15.48	1.52	0.00	59.78	23.22	0.01
	12	11.21	1.10	0.00	69.21	18.48	0.01
	40	10.91	1.07	0.00	70.05	17.97	0.01
$\hat{p}_t$	2	0.83	0.04	13.43	2.00	0.44	83.26
	4	0.75	0.04	12.04	3.38	0.72	83.06
	12	0.73	0.04	11.57	5.78	0.99	80.90
	40	0.72	0.04	11.52	6.20	0.99	80.52

**Table 3.3** – Conditional Variance Decomposition (%) - model with storage and storage adjustment cost - 2009Q4:2016Q2

### 3.4.3 Impulse Response Functions

Impulse response functions (IRFs) allow the analysis of the impact of structural shocks to variables in the model. The shock is always a one standard deviation from steady state and the response is shown in percent deviations from steady state on the y-axis. The x-axis shows the number of quarters after the shock. Here, I show the results for the model estimated on the sample of alleged manipulation.

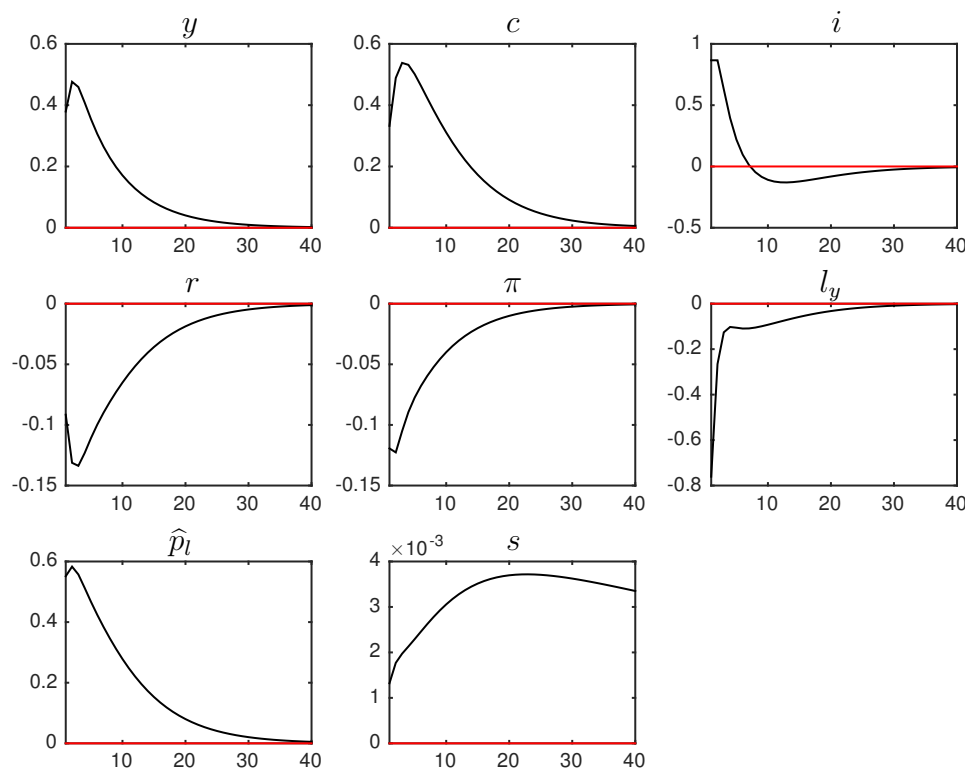
**Total factor productivity shock**

Figure 3.3 shows the response over 40 quarters to a one standard deviation TFP shock. Demand for all factors increases and the supply of aluminium is fixed, which leads to a price increase for aluminium. The increased factor productivity leads to lower prices, to which monetary policy reacts by lowering nominal interest rates. The fall in prices is smaller than the fall in the nominal interest rate, leading to a decrease in the real interest rate. The negative real interest lowers the cost of storage leads to an increase in storage. The price of aluminium falls over time but this downward slope is not enough of a negative incentive to outweigh the lower cost of storage. Eventually storage levels increase and diminish slowly over time, as well because of the storage adjustment cost (resembling queues) making it costly to change inventories. The use of aluminium in production drops because of the higher demand for storage and the higher price of aluminium.

A one standard deviation positive TFP shock leads to higher aluminium prices, output and storage levels. Inflation and real interest rates decrease as a response to the shock.

**Labour productivity shock**

For a one standard deviation positive shock to labour productivity, Figure 3.4 shows the IRFs. Given a one standard deviation labour productivity shock, output, consumption and investment increase. The increased demand leads to higher prices for aluminium but overall inflation drops due to the productivity gains. Monetary policy reacts by lowering the nominal interest rate, further supporting demand. The real interest rate is negative leading to an increase in storage levels, and putting further upward pressure on the price of aluminium. With the relatively low estimate for the elasticity of substitution, aluminium decreases in production. The reactions of the variables are broadly the same as



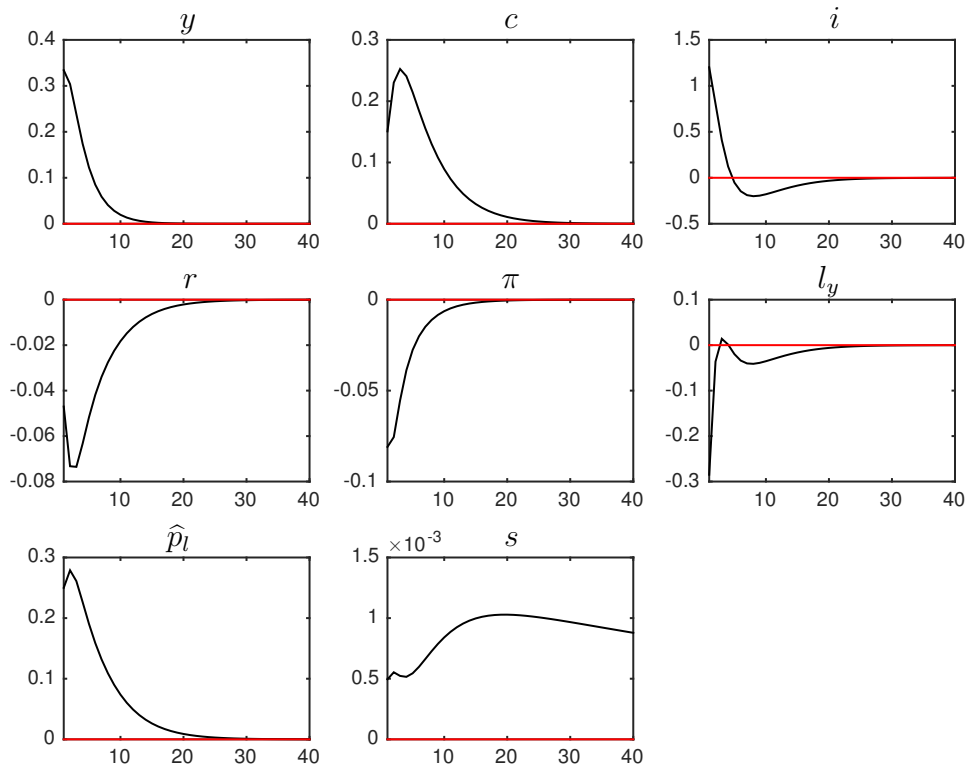
**Figure 3.3** – IRF - model with storage and storage adjustment cost (orthogonalized shock to  $\varepsilon_{ay}$ ).

for a TFP shock and differ mainly in magnitudes.

### Monetary Policy shock

A one standard deviation positive shock to interest rates leads to a steep fall in demand, driven mainly by investment. The lack of demand leads to lower inflation and aluminium prices. The negative real interest rate leads to an increase in storage levels but this demand for aluminium cannot offset the diminished demand for aluminium used in production. Storage levels stay high and gradually return to steady state due to the storage adjustment cost.

Thereby, a monetary policy shock has an additional channel of influencing inflation through the price of aluminium. This finding confirms the results of Blanchard and Gali (2009) and Blanchard and Riggi (2013), which highlight the importance of oil price shocks for monetary policy and inflation dynamics.

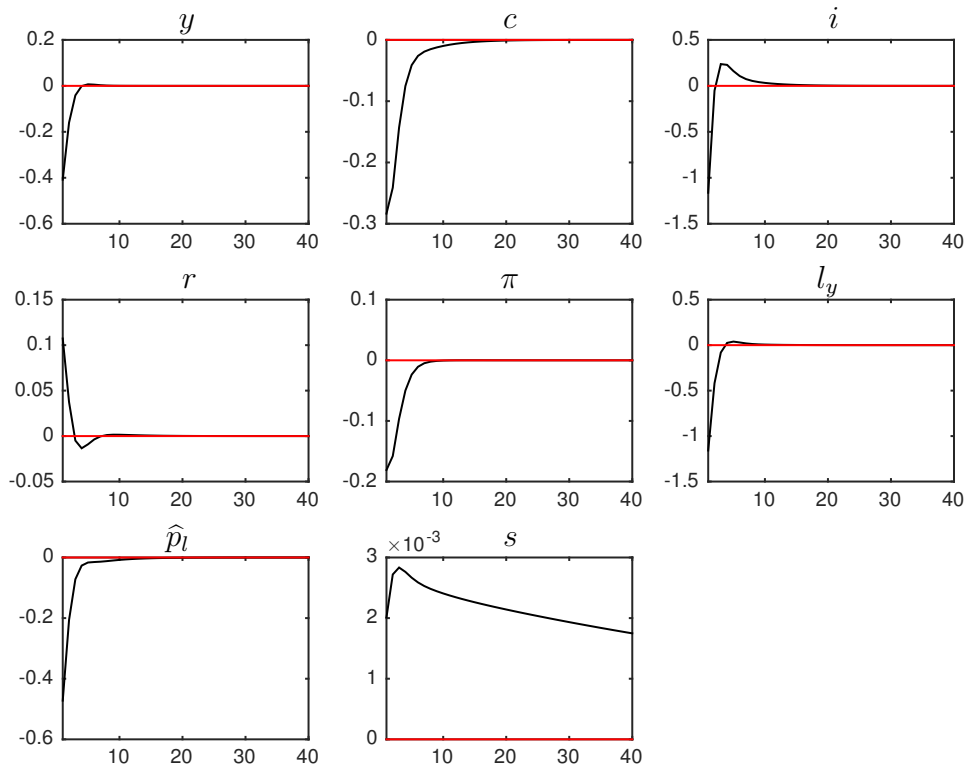


**Figure 3.4** – IRF - model with storage and storage adjustment cost (orthogonalized shock to  $\varepsilon_{an}$ ).

An interest rate shock leads to lower output, inflation and aluminium prices but increased storage levels.

### Public expenditure shock

A public expenditure shock immediately leads to higher output and crowds out investment and consumption. Figure 3.6 shows that the increase in demand leads to inflation, to which the monetary authority reacts by increasing the nominal interest rate. The negative real interest rate leads to a decrease in storage levels but overall demand is stronger for aluminium due to the increased overall demand. This leads to an increase in aluminium in production but overall the price of aluminium decreases.



**Figure 3.5** – IRF - model with storage and storage adjustment cost (orthogonalized shock to  $\varepsilon_r$ ).

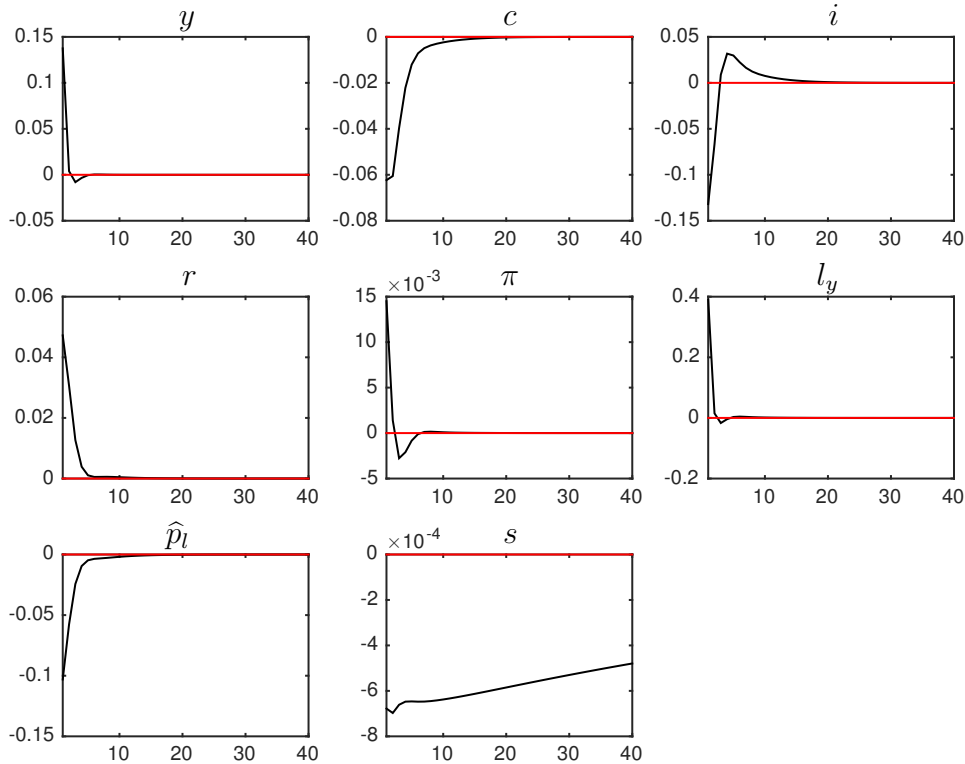
### Aluminium supply shock

An aluminium supply shock can occur because of increased production or more imports of aluminium. Either way, Figure 3.7 shows that this shock leads to a decrease in the price of aluminium. Inflation equally goes down, as does the nominal interest rate as a reaction to the subdued inflation. This puts upward pressure on output and investment specifically. The negative real interest rate together with the upward sloping price curve leads to an increase in storage and a slow levelling off afterwards. This means that part of the supply increase is absorbed in storage.

### Storage demand shock

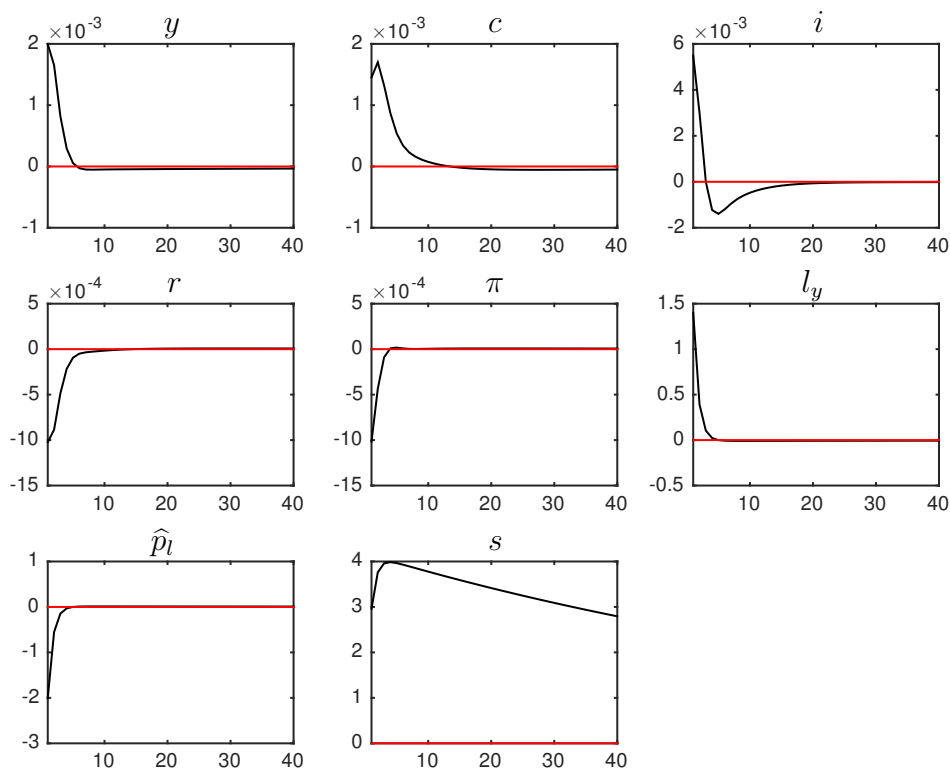
Coming to the most important shock in our investigation Figure 3.8 shows the impulse responses to a one standard deviation positive storage demand





**Figure 3.6** – IRF - model with storage and storage adjustment cost (orthogonalized shock to  $\varepsilon_g$ ).

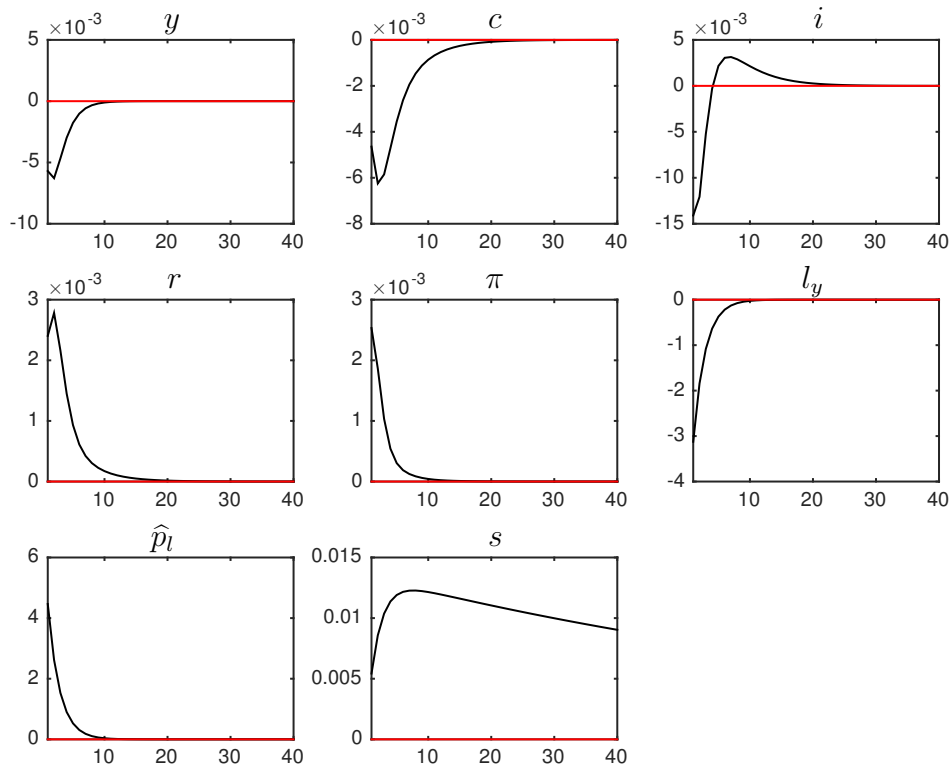
shock. This shock has the strongest effect on aluminium prices, because significant amounts of aluminium are tied up in warehouses. Furthermore, the storage adjustment cost leads to these quantities being withheld for an extended period from the market. The price increase has a positive impact on overall inflation and the nominal interest rate goes up as a reaction to the higher inflation. Especially investment reacts strongly negative to the shock, as well as consumption. Overall, economic output goes down in response to a storage demand shock. This finding is crucial in assessing the consequences of warehouse queue manipulation. The negative reaction of economic output to storage demand and the importance of this shock for variation in the price of aluminium warrants a policy reaction.



**Figure 3.7** – IRF - model with storage and storage adjustment cost (orthogonalized shock to  $\varepsilon_l$ ).

### 3.5 Conclusion

This paper investigates the influence of manipulation of warehouse queues in the market for aluminium. Given the importance of the US for the aluminium market and the importance of aluminium and comparable storable metals for the US economy, I investigate whether there is evidence for the alleged manipulation, and what the economic consequences are. I argue in favour of using a DSGE model to better capture the demand side. The evidence presented here suggests that the structure of the aluminium market is what would be expected, had the manipulation taken place. In other words, during the time of the alleged manipulation (2010-2014) storage levels were much more sticky compared to the time before the GFC. The parameter determining the stickiness of storage levels is estimated to be positive in the alleged manipulation period and much smaller in the other.



**Figure 3.8** – IRF - model with storage and storage adjustment cost (orthogonalized shock to  $\varepsilon_{as}$ ).

Using a rational expectations framework it is not possible to model manipulation explicitly inside the model. The manipulation can only be inferred by looking at price elasticities and shocks over time. In reality manipulation would mean: 1) taking a position in aluminium, 2) using the market power to influence price elasticities, and 3) unwind the position. The price elasticity of aluminium changes as a consequence of the storage level frictions. Turning to the shocks, I identify the storage demand shock as the residual shock which most closely captures speculative or manipulative storage demand. The variance decomposition suggests that this shock is very important in driving the price of aluminium before and after the GFC. Last but not least, storage demand has a negative impact on the economy and therefore calls for policy makers to increase scrutiny of the queueing mechanism and inventory level transparency.

# Conclusion

The uniting theme of this doctoral thesis are macro-financial linkages. The thesis covers three different questions related to this topic, with each chapter contributing to the literature by adding novel datasets, and empirical and theoretical modelling approaches. In chapter 1, Gaël Giraud and I develop a model for the Euro Area answering to many of the critiques of policy models before the GFC, with a focus on the interaction between the financial sector and the macroeconomy. Chapters 2 and 3 focus on the behaviour of the financial sector in the aftermath of the GFC and its implications for the macroeconomy. Chapter 2 investigates the practice of forbearance towards stressed borrowers. The ultimately relevant question in this chapter is to what extent there is a feedback to the real economy due to this behaviour. Finally, chapter 3 sheds light on an episode of manipulation in commodity markets. This alleged manipulation was only possible due to the dominant market position banks took in the run up to the crisis and thereafter. I quantify the effects of such behaviour and provide evidence of a structural change of the manipulated market during the period of alleged manipulation. Chapter 2 exploits a bank level dataset, whereas in chapters 1 and 3 I develop structural macroeconomic models. Furthermore, the dynamical system model in chapter 1 is the first given its size and the class of models to be estimated and subsequently used for policy analysis.

In chapter 1 of this doctoral thesis, Gaël Giraud and I propose a non-linear dynamical systems model including endogenous money, variable usage rate of

capital, inventories, non-neutral money, a crucial role for public and private debt and an extended banking sector for the Euro Area. After laying out the calibration and estimation procedures, we go on to simulate the model and compare them with the EC forecast. The model simulations of the Euro Area yield realistic results in light of the EC forecasts and serve as a point of departure for scenario analysis. Furthermore, the banking sector and real economy variables such as consumption, wages or investment behave realistically over the medium term.

In chapter 2, Katharina Bergant and I analyse the forbearance patterns of stressed banks in the post-crisis period. More specifically, our analysis presents five forbearance measures: an extension in the credit limit or maturity, a pause in amortisation, a comparably lower interest rate change, and a rollover of a loan product. We find that risky borrowers are more likely to receive a limit or maturity extension when banks are facing high levels of NPLs relative to their capitalisation and provisions. As a second step, we evaluate the effectiveness of this practice. Using a logit-hazard model, we find that a limit extension is effective in reducing the probability of default up to one year. For longer horizons and other forbearance measures we find a higher probability of default of the risky borrower. While we cannot conclude that the forbearance measures themselves caused defaults, we argue that credit might have been misallocated to the weakest borrowers which were subsequently not “rescued” from default. In the last part of our empirical analysis, we show that banks with a high share of forborne loans issue lower volumes of new credit. This could result in tighter financial conditions for new firms who might potentially be more productive. Our analysis highlights the importance of the health banks’ loan books. While banks can be well-capitalised on paper, they might be under pressure by high levels of NPLs on their balance sheets. We suggest that banks have an incentive not to recognise loans as non-performing and offer an explanation through the regulatory framework.

Chapter 3 of my doctoral thesis investigates the influence of manipulation of warehouse queues in the market for aluminium. This paper investigates the influence of manipulation of warehouse queues in the market for aluminium. Given the importance of the US for the aluminium market and the importance of aluminium and comparable storable metals for the US economy, I investigate whether there is evidence for the alleged manipulation, and what the economic consequences are. I argue in favour of using a DSGE model to better capture the demand side. The evidence presented here suggests that the structure of the aluminium market is what would be expected, had the manipulation taken place. In other words, during the time of the alleged manipulation (2010-2014) storage levels were much more sticky compared to the time before the GFC. The parameter determining the stickiness of storage levels is estimated to be positive in the alleged manipulation period and much smaller in the other.

Using a rational expectations framework it is not possible to model manipulation explicitly inside the model. The manipulation can only be inferred by looking at price elasticities and shocks over time. In reality manipulation would mean: 1) taking a position in aluminium, 2) using the market power to influence price elasticities, and 3) unwind the position. The price elasticity of aluminium changes as a consequence of the storage level frictions. Turning to the shocks, I identify the storage demand shock as the residual shock which most closely captures speculative or manipulative storage demand. The variance decomposition suggests that this shock is very important in driving the price of aluminium before and after the GFC. Last but not least, storage demand has a negative impact on the economy and therefore calls for policy makers to increase scrutiny of the queueing mechanism and inventory level transparency.

The three chapters of my thesis aim to improve the understanding of the economy in the run up to and the aftermath of the crisis. The dynamical system policy model of chapter 1 helps understanding the modelling aspect of financial crisis. Furthermore, I investigate banks behaviour after the crisis

and its implications for the macroeconomy. First, I empirically investigate the drivers, effectiveness and ultimately the consequences for new lending of the practice of forbearance. Finally, using a DSGE model I quantify the consequences of commodity market manipulation, of which certain banks were accused of. Each of these research questions added insights but asks for more research to be done.

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## Appendix A

### A macro-financial non-linear dynamical system model of the Euro Area

## A.1 Data

We use the ECB, OECD and Eurostat as sources. The quarterly data covers the time frame from 1999 Q4 until 2013 Q4. For the empirical estimation of the functions determining wage per capita growth,  $\Phi(\cdot)$  (cf. (1.10)), investment,  $\kappa(\cdot)$  (cf. (1.15)), and consumption,  $\varphi(\cdot)$  (cf. (1.16)), we use the whole time series (from Eurostat) of GDP, salaries, GDP and FCE deflator, investment, consumption, employment and firm profits. The datasets of total population,  $N$ , employment,  $L$ , interest,  $rD_f$ , subsidies,  $G_f$  and taxes,  $T_f$  are manually deseasonalised using the X-13ARIMA-SEATS procedure detailed in U.S. Census Bureau (2015). All data is publicly available and for further details on the exact specifications see appendix A.1.

Table A.1 provides detailed information about the source and exact specification of the data used for the calibration of the model to the Euro Area economy. Table A.2 provides the descriptive statistics of the data input used in the model. Furthermore, there are a few calculations to be done in order to obtain all the necessary variables:

The FCE Deflator is used to calculate real salaries:

$$W = \text{Compensation of Employees} \times \text{FCE Deflator}$$

We calculate the shares of government debt holdings:  $\tau_h, \tau_f, \tau_b$  using:

Total gov. debt = Gov. Debt ex gov. holdings + Foreign holdings of gov. debt

$$\tau_b = \frac{\text{Gov. Debt ex gov. holdings} - \text{Dom. sector ex fin. corp. and gov.} - \text{CB}}{\text{Total gov. debt}}$$

$$\tau_f = 0.1 \times \frac{\text{Domestic sector ex fin. corp. and gov.}}{\text{Total gov. debt}}$$

$$\tau_h = 0.9 \times \frac{\text{Domestic sector ex fin. corp. and gov.}}{\text{Total gov. debt}}$$

Since, there is a lack of data on the partition among households and firms we make the simplifying assumption, that households hold 9 times as much government debt as firms.

Bank debt,  $L_b$ , can be calculated as:

$$\text{Consolidated Domestic Banking sector - Total Liabilities} - E_b - M$$

The capital-to-output ratio,  $\nu$ , is calculated using:

$$\nu = \frac{K}{Y_n}$$

Dataset	Variable	Series Key	Source	Start	End	Frequency	Unit	SA	WDA	Accessed
Government debt yield	$r_B$	irt_lt_mcby_m - EA	Eurostat	2000 M1	2013 M12	Monthly	Percent	-	-	27.06.14
Gross government debt	$B$	gov_10q_ggdebt - EA18	Eurostat	2006 Q1	2013 Q4	Quarterly	nominal Euro	no	no	09.03.15
Total Population	$N$	lfsi_act_q - EA18	Eurostat	2000 Q1	2013 Q4	Quarterly	thousands	man.	no	08.03.15
Employment	$L$	lfsi_emp_q - EA18	Eurostat	2000 Q1	2013 Q4	Quarterly	thousands	man.	no	08.03.15
Real labour productivity	$\alpha$	namq_10_lp_ulc - EA18	Eurostat	2001 Q1	2013 Q4	Quarterly	Percent change	no	no	08.03.15
Gross fixed capital formation	$pI$	namq_10_gdp - EA18	Eurostat	2000 Q1	2013 Q4	Quarterly	nominal Euro	yes	yes	08.03.15
Compensation of employees	$p_{FCEW}$	namq_10_gdp - EA18	Eurostat	2000 Q1	2013 Q4	Quarterly	nominal Euro	yes	yes	08.03.15
GDP	$Y_n$	namq_10_gdp - EA18	Eurostat	2000 Q1	2013 Q4	Quarterly	nominal Euro	yes	yes	08.03.15
FCE	$pC$	namq_10_gdp - EA18	Eurostat	2000 Q1	2013 Q4	Quarterly	nominal Euro	yes	yes	08.03.15
Exports	$pX$	namq_10_gdp - EA18	Eurostat	2000 Q1	2013 Q4	Quarterly	nominal Euro	yes	yes	08.03.15
Imports	$pIM$	namq_10_gdp - EA18	Eurostat	2000 Q1	2013 Q4	Quarterly	nominal Euro	yes	yes	08.03.15
GDP Deflator	$p$	namq_10_gdp - EA18	Eurostat	2000 Q1	2013 Q4	Quarterly	Index 2010=100	yes	yes	08.03.15
FCE Deflator	$p_{FCE}$	namq_10_gdp - EA18	Eurostat	2000 Q1	2013 Q4	Quarterly	Index 2010=100	yes	yes	08.03.15
Interest	$rD_f$	nasq_10_nf_tr - EA18 - non-fin. corp.	Eurostat	2000 Q1	2013 Q4	Quarterly	nominal Euro	man.	no	08.03.15
Current taxes on income, wealth, etc.	$T_f$	nasq_10_nf_tr - EA18 - non-fin. corp.	Eurostat	2000 Q1	2013 Q4	Quarterly	nominal Euro	man.	no	08.03.15
Subsidies	$G_f$	nasq_10_nf_tr - EA18 - non-fin. corp.	Eurostat	2000 Q1	2013 Q4	Quarterly	nominal Euro	man.	no	08.03.15
Consumption of fixed capital	$p\delta K$	nasq_10_nf_tr - EA18	Eurostat	2002 Q1	2013 Q4	Quarterly	nominal Euro	no	no	08.03.15
Productive capital stock	$K$	Economic Outlook No. 95 - sum of EA	OECD	2000	2013	Annual	nominal Euro	-	-	29.08.14
ECB key interest rate	$r_b$	FM.B.U2.EUR.4F.KR.MRR_FR.LEV	ECB	2000 Q1	2013 Q4	Quarterly	Percent	-	-	26.11.14
Central Bank holdings of gov. debt		GST.A.I7.N.B1210.MAL.B1300.SA.E	ECB	2000	2013	Annual	nominal Euro	-	-	15.01.15
Foreign holdings of gov. debt		GST.A.I7.N.B2000.MAL.B1300.SA.E	ECB	2000	2013	Annual	nominal Euro	-	-	15.01.15
Gov. Debt ex gov. holdings		GST.A.I7.N.B1X13.MAL.B1300.SA.E	ECB	2000	2013	Annual	nominal Euro	-	-	15.01.15
Gov. Debt holdings of domestic sectors ex fin. corp. and gov.		GST.A.I7.N.B1XGF.MAL.B1300.SA.E	ECB	2000	2013	Annual	nominal Euro	-	-	15.01.15
Non - fin. corp. partially consolidated debt	$L_f$	IEAQ.Q.I7.N.V.LE.FP.S11.A1.S.2.P.E.Z	ECB	2000 Q1	2013 Q4	Quarterly	nominal Euro	no	no	11.03.15
Households partially consolidated debt	$L_h$	IEAQ.Q.I7.N.V.LE.F4.S1M.A1.S.2.X.E.Z	ECB	2000 Q1	2013 Q4	Quarterly	nominal Euro	no	no	11.03.15
Consolidated Domestic Banking sector - Total Liabilities		CBD.A.I7.67.A.32000.X.1.Z5.0000.Z01.E	ECB	2007	2013	Annual	nominal Euro	-	-	15.01.15
Consolidated Domestic Banking sector - Equity	$E_b$	CBD.A.I7.67.A.33000.X.1.Z5.0000.Z01.E	ECB	2007	2013	Annual	nominal Euro	-	-	15.01.15
Consolidated Domestic Banking sector - Deposits	$M$	CBD.A.I7.67.A.32700.X.1.Z5.0000.Z01.E	ECB	2007	2013	Annual	nominal Euro	-	-	15.01.15

Table A.1 – Data description

Name	Variable	Starting Value	Min.	Median	Mean	Max.
Government debt yield	$r_B$	0.03090	0.03090	0.04090	0.04188	0.05470
Gross government debt	$B$	8.900e+12	5.939e+12	7.186e+1	7.229e+12	8.900e+12
Total Population	$N$	310.0e+6	310.0e+6	323.4e+6	322.1e+6	329.1e+6
Employment	$L$	129.1e+6	129.1e+6	139.5e+6	138.6e+6	145.6e+6
Real labour productivity	$\alpha$	-0.003	-0.044	0.007	0.005521	0.031
Gross fixed capital formation	$pI$	4.907e+11	3.968e+11	4.824e+11	4.720e+11	5.591e+11
Compensation of employees	$p_{FCE}W$	1.178e+12	8.336e+11	1.035e+12	1.029e+12	1.179e+12
GDP	$Y_n$	2.457e+12	1.747e+12	2.232e+12	2.172e+12	2.457e+12
FCE	$pC$	1.894e+12	1.323e+12	1.685e+12	1.659e+12	1.895e+12
Exports	$pX$	1.068e+12	6.039e+11	8.069e+11	8.174e+11	1.076e+12
Imports	$pIM$	9.920e+11	5.885e+11	7.779e+11	7.831e+11	1.001e+12
GDP Deflator	$p$	1.0300	0.8260	0.9430	0.9390	1.0300
FCE Deflator	$p_{FCE}$	1.0390	0.8190	0.9430	0.9371	1.0390
Interest	$rD_f$	5.22e+10	5.199e+10	6.292e+10	6.709e+10	1.042e+11
Current taxes on income, wealth, etc.	$T_f$	4.088e+10	3.383e+10	4.387e+10	4.608e+10	6.534e+10
Subsidies	$G_f$	1.388e+10	1.296e+10	1.604e+10	1.630e+10	2.552e+10
Consumption of fixed capital	$p\delta K$	4.418e+11	2.963e+11	3.789e+11	3.737e+11	4.418e+11
Productive capital stock	$K$	2.770e+13	2.131e+13	2.441e+13	2.461e+13	2.770e+13
ECB key interest rate	$r_b$	0.00750	0.00750	0.04250	0.03211	0.04250
Central Bank holdings of gov. debt		2.145e+11	8.363e+10	1.095e+11	1.234e+11	2.145e+11
Foreign holdings of gov. debt		4.228e+12	1.691e+12	2.897e+12	2.958e+12	4.228e+12
Gov. Debt ex gov. holdings		4.391e+12	2.959e+12	3.039e+12	3.296e+12	4.391e+12
Gov. Debt holdings of domestic sectors ex fin. corp. and gov.		6.819e+11	5.694e+11	6.566e+11	6.453e+11	7.409e+11
Non - fin. corp. partially consolidated debt	$L_f$	7.666e+12	4.264e+12	6.331e+12	6.317e+12	7.762e+12
Households partially consolidated debt	$L_h$	6.198e+12	3.258e+12	5.086e+12	4.940e+12	6.210e+12
Consolidated Domestic Banking sector - Total Liabilities		2.801e+13	1.069e+13	2.839e+13	2.601e+13	3.165e+13
Consolidated Domestic Banking sector - Equity	$E_b$	1.554e+12	5.948e+11	1.506e+12	1.340e+12	1.554e+12
Consolidated Domestic Banking sector - Deposits	$M$	1.203e+13	3.874e+12	1.196e+13	1.058e+13	1.215e+13

Table A.2 – Descriptive Statistics of Data

## A.2 GAMLSS

The functions estimated using the GAMLSS procedure are at the core of our model and therefore we will explain in detail the selection criteria. For all three functions we estimate polynomials up to the 4th degree for all four moments combined with the different distributions for the error term,  $e$ . All combinations of polynomials up to the 4th degree are tried to find the best fit. We use the data up to the calibration date: 2012 Q4. Only candidates with significant coefficients are considered. The two criteria are the AIC value and the wormplot. During the calibration process all candidates are tried out and the ones selected which yield the best fit regarding the EC forecast.

The consumption function with the highest AIC (NO 2311) has a normal error distribution and is a second degree polynomial. The second moment is estimated with a polynomial of third degree and the third and fourth moment with polynomials of first degree. The starting point coincides with negative consumption growth and all three candidate functions lie above. Figure A.1 shows the data points on which the functions are estimated.

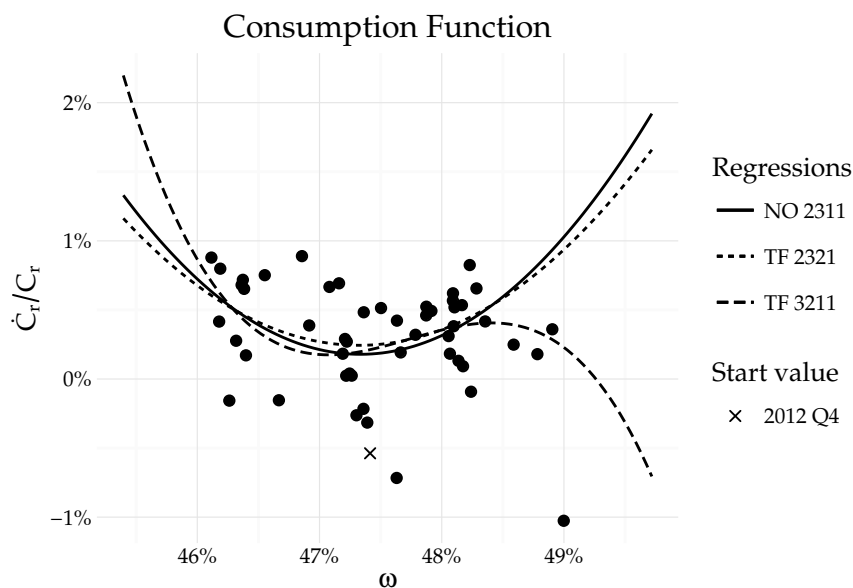


Figure A.1 – Consumption Function

The investment function with the highest AIC (NO 1211) has a normal error distribution and is a first degree polynomial. The second moment is estimated with a polynomial of second degree and the third and fourth moment with polynomials of first degree. The starting point coincides with negative investment growth and all three candidate functions lie above.<sup>1</sup> Figure A.2 shows the data points on which the functions are estimated.

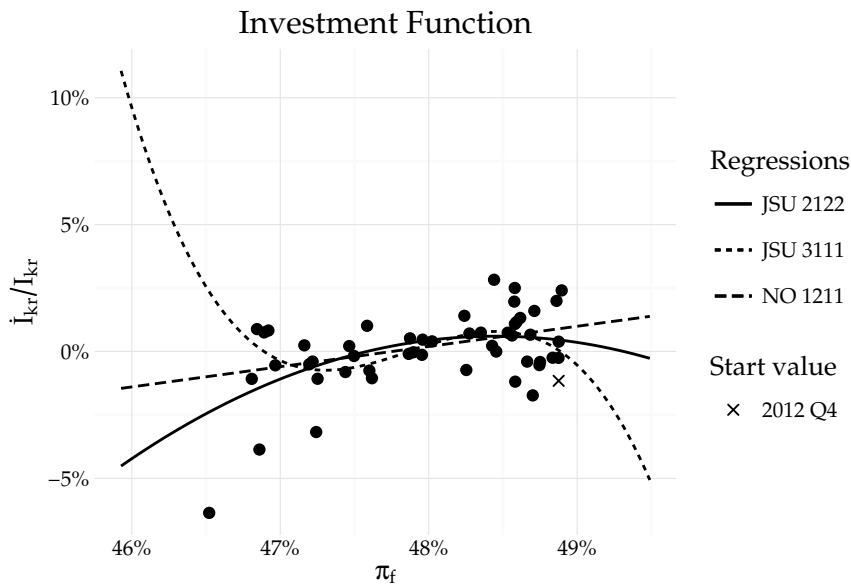


Figure A.2 – Investment Function

The Philips curve function with the highest AIC (TF2 3131) has a t student error distribution and is a third degree polynomial. The second and fourth moment is estimated with a polynomial of first degree and the third moment with polynomials of third degree. The starting point coincides with a positive wage per capita growth. Figure A.3 shows the data points on which the functions are estimated.

<sup>1</sup>The actual starting point can be marginally off, because interest payments are not automatically calibrated so as to continue the historical time series.



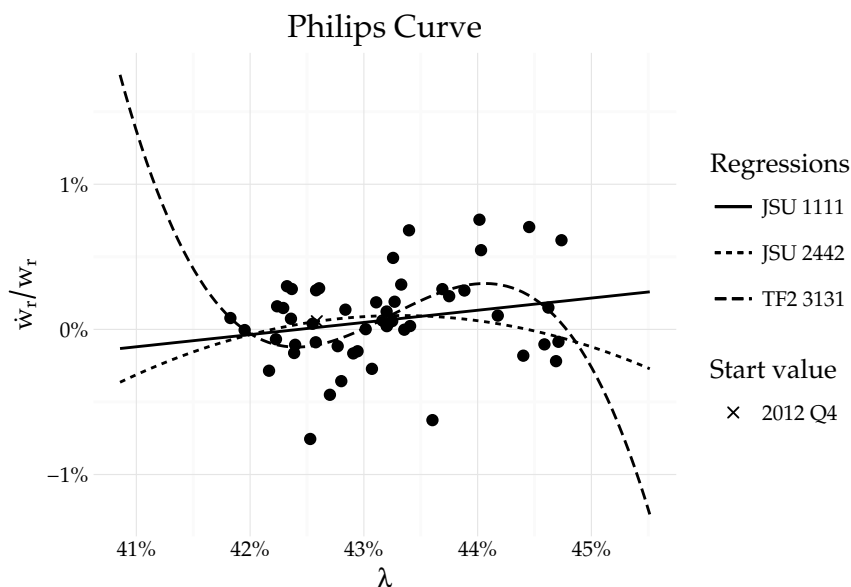


Figure A.3 – Philips Curve

### A.3 Endogenous money creation

This section shall demonstrate formally how endogenous money creation is incorporated in our model. Observe that the accounting identity of financial balances and flow of funds in Section 1.2.4 does not preclude money from being endogenously created by credit origination in the banking sector. To understand this, suppose that the banking sector issues an additional amount,  $\Delta > 0$ , of loans for households. This created money increases the households' loans  $L_h$ . Obviously, households borrowed money in order to spend it for consumption purposes. This translates into an increase of  $Y$  by  $(1 - c)\Delta$ ,

$$\dot{V} = Y - Y_d$$

$$Y = Y_d + \dot{V}$$

The higher  $Y$  means that firms see their profit increase by the same amount,

$$\Pi_{nf} = (p - c)(C + I_k + \hat{G} + (X - IM)) + cY + p(G_f - T_f - W) + r_{B\tau_f}B - rD_f.$$

Dividends on the other hand are not effected because they are paid on the expected profit,

$$\Pi_{nef} = pY_e + cI_p - p(G_f - T_f - W) + r_B\tau_f B - rD_f$$

$$Div_f = \mu\Pi_{nef}.$$

Starting with firms, we can see that their deposits will change by  $+\Delta$  in real terms and  $+(p-c)\Delta$  in nominal terms; because of the link between  $Y$  and  $\Pi_{nf}$ ,

$$\begin{aligned} \dot{M}_f &= \Pi_{nf} - Div_f \\ &= (p-c)(C + I_k + \widehat{G} + (X - IM)) + cY + p(G_f - T_f - W) + r_B\tau_f B - rD_f - Div_f. \end{aligned}$$

The firms loans are impacted via the change in inventories. Here, loans will change by  $-c\Delta$  in nominal terms,

$$\begin{aligned} \dot{L}_f &= c\dot{V} + pI_k \\ &= c(Y - C - \widehat{G} - (X - IM)) + (p-c)I_k. \end{aligned}$$

Debt of firms being the residual of loans and deposits change by  $-p\Delta$  in nominal terms,

$$\begin{aligned} \dot{D}_f &= \dot{L}_f - \dot{M}_f \\ &= p(W - C - \widehat{G} - (X - IM) - G_f + T_f) - r_B\tau_f B + rD_f - pDiv_f \end{aligned}$$

Turning to households, we can immediately see that loans will increase by  $p\Delta$ , since consumption is loan financed by definition in our model,

$$\dot{L}_h = pC.$$

Deposits of households are not influenced by the change in consumption,

$$R_h = p(W + G_h - T_h) + Div_f + Div_b + r_B \tau_h B - r D_h$$

$$\dot{M}_h = R_h$$

$$\dot{M}_h = p(W + G_h - T_h) + Div_f + Div_b + r_B \tau_h B - r D_h.$$

Household net debt shows that households would increase their debt by  $+p\Delta$ ,

$$\dot{D}_h = p(C - R_h)$$

$$= p(C - W - G_h + T_h) - Div_f - Div_b - r_B \tau_h B + r D_h.$$

On the aggregate level of the banking sector, we see that deposits will increase by  $+(p - c)\Delta$ ,

$$\begin{aligned} \dot{M} = \dot{M}_h + \dot{M}_f &= (p - c)(C + I_k + \hat{G} + X - IM) + cY + p(G_h - T_h + G_f - T_f + Div_b) + \\ &\quad r_B(\tau_h + \tau_f)B - r(D_f + D_h) \end{aligned}$$

Aggregate loans will equally increase by  $+(p - c)\Delta$ ,

$$\dot{L} = \dot{L}_h + \dot{L}_f$$

$$= (p - c)(C + I_k + \hat{G}) - c(X - IM) + cY$$

Finally, debt is unchanged on the aggregate level due to the increase of  $\Delta$ ,

$$\dot{D} = \dot{L} - \dot{M}$$

$$= -p(X - IM + G_h - T_h + G_f - T_f) + Div_b - r_B(\tau_h + \tau_f)B + r(D_f + D_h).$$

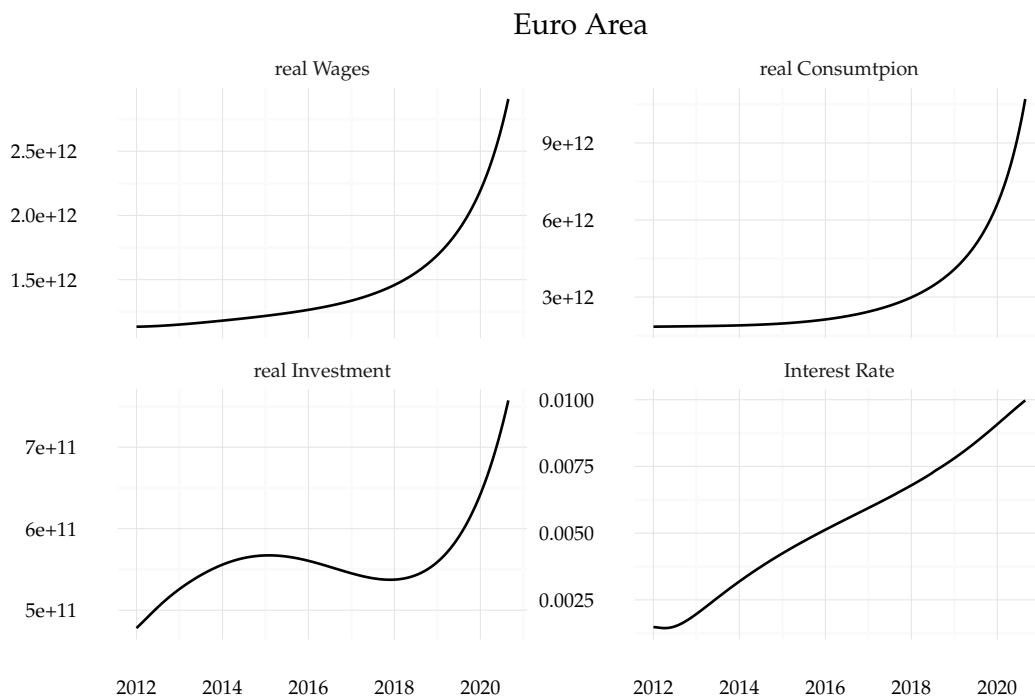
This shall demonstrate, that the banking sector creates a loan by creating a deposit for the household and firm sector. Hence, money creation lies with the banking sector for firms and households. Furthermore, the net worth of banks is not affected by this creation of fresh money. The very fact, that  $S_b$  remains independent from  $\Delta$  helps to understand, why there is a debate about

endogenous money creation at all. Indeed, at some aggregate level, money creation cannot be observed on the stock-flow matrix. One needs to decompose  $S_b$  into  $M$  and  $L$  in order to be able to observe money creation at work.

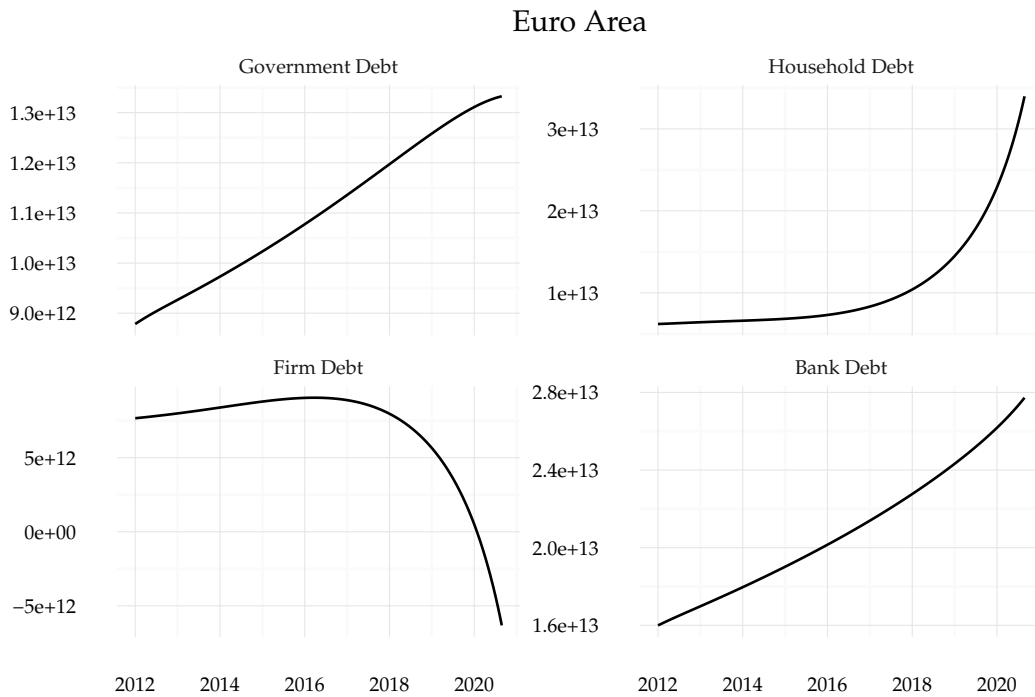
## A.4 Long term behaviour

Next to the scenario analysis, we explore the long term characteristics of the model in the base scenario. This is a first attempt at studying the equilibrium characteristics in the spirit of the mathematical and empirical analysis of the models by Keen, Grasselli, et al..

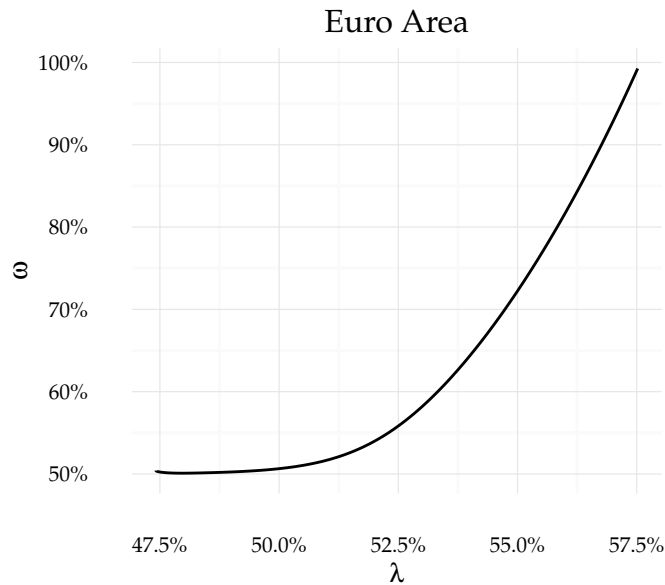
The chosen calibration for the base scenario of the Euro Area tends towards an equilibrium with low wages, high growth and employment in the long term, as can be seen in Figures A.4 and A.5. We stop the simulation once  $\lambda$  reaches an unrealistic value of more than 1. At that point firm debt decreased significantly and household debt eventually rose strongly.



**Figure A.4** – 10 year simulation of model calibrated to Euro Area



**Figure A.5** – 10 year debt simulation of model calibrated to Euro Area



**Figure A.6** – long term simulation of the  $\omega - \lambda$  (wage share - employment rate) space

Figure A.6 demonstrates that the model for the Euro Area reaches an endpoint in the  $\omega - \lambda$  space with  $\lambda = 1$ . Nonetheless, further investigation is needed to fully understand the possible equilibria regarding other calibrations of the model.

## **A.5 Endogenous and non-neutral money**

The Quantitative Easing policies put into place by the Fed, the Bank of Japan, the Bank of England or the ECB, since 2008, were based on the assumption that credit issuance by commercial banks is caused by Central Bank money creation. If this “money multiplier” theory was always correct, the trillions that have been injected in the various interbank markets by their respective central banks should have boosted credit, and therefore investment and growth. As is well known this is not what we have observed since 2008. The last decade makes it hard to take such a scenario for granted: the significant increase in base money (which more than doubled between 2008 and 2011) hardly induced any revival of credit flow. This casts some doubts on the current relevance of the “money multiplier” theory. In addition, there is a long-standing tradition of practitioners who assert that, in everyday life, money is endogenously created by commercial banks (which need only to refinance ex post part of their loans in the interbank market).<sup>2</sup> As the authors of McLeay et al. (2014) say:

*“the majority of money in the modern economy is created by commercial banks making loans. Money creation in practice differs from some popular misconceptions. Banks do not act simply as intermediaries, lending out deposits that savers place with them, and nor do they “multiply up” central bank money to create new loans and deposits.”* (loc. cit. Abstract)

Were we to apply a standard “money multiplier” - based model, some additional money injection by the Central Bank would normally suffice to restore the well-functioning of the banking system after our hypothetical shock: by creating enough new money, so the theory goes, the ECB should be able to stimulate again bank credit flow, and therefore investment and growth. As we shall see, using *endogenous money creation* enables to capture the possibility that a shock

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<sup>2</sup>cf. Holmes (1969); Jakab and Kumhof (2015); Kydland and Prescott (1990); McLeay et al. (2014); Moore (1979, 1988).

be followed by a credit crunch, analogous to the one observed in the Euro Area since 2010, which prevents the economy from recovering almost automatically from any disaster.

Another assumption behind the Quantitative Easing policies was that money is non-neutral in the short-run. Neutrality of money means that the quantity of money has no impact on the economy, apart from determining the absolute level of prices. According to this view, market forces drive the relative prices, while the quantity of money (pumped in by the Central Bank) fixes their absolute level. Therefore, short-run money *non-neutrality* is necessary to understand the effect of money creation by banks or central banks on the real economy. In large scale times, monetary policy is non neutral either in our model. However, notice that, for a broad family of monetary policies, the underlying real economy always converges, in the very long-run, to a full-employment steady state. This shows that money turns out to be weakly neutral in the long-run , in the sense that it does not modify the qualitative properties of the ultimate equilibrium.

## **A.6 Emergence phenomena**

Obviously, that money does not become (strongly) neutral in the long-run arises from the very fact that, in the present model, aggregate demand (and investment) are not assumed to behave as that of a representative household (or producer) sharing rational expectations. Were we to adopt such an assumption, we would almost necessarily end up with an intertemporal *equilibrium* model. Therefore, both the out-of-equilibrium dynamical feature of our analysis and the specific properties of money go back to our tolerance for the possibility of *emergence phenomena*, that is, for aggregate behaviours that need not be deducible from individual ones. The Sonnenschein-Mantel-Debreu conditions (Kirman (1989); Shafer and Sonnenschein (1993); Sonnenschein (1972, 1973)) establish quite general conditions under which the demand of an Arrow-Debreu

economy may exhibit such phenomena. On the supply side, Mas-Colell (1989) also demonstrated that standard general equilibrium theory is not immune against emergence phenomena. Thus, modelling the demand side of a macro-economy as if it had been generated by the behaviour of a unique (representative) household or firm is debatable. Hence, the need for a modelling approach where such a short-cut is not postulated from the beginning.<sup>3</sup>

## A.7 Private debt

Irving Fisher theorized in the 30s' how a private debt overhang might lead to a deflationary trap. This strong *influence of private debt* is a must in light of the high indebtedness of households and firms in the Euro Area. Only a few applied general equilibrium models include a banking sector and private debt (both in the corporate and household sector).<sup>4</sup> Indeed, many of them rely on the simplifying assumption that households and/or firms are captured through one representative agent. This usually means that they cannot both have debts. At least one of them must be a creditor to the other. This restriction is viewed as being harmless, in as much the distribution of private debts is often understood as being irrelevant for economic growth. Nonetheless, this issue is pressing in the analysis of the Euro Area, since private actors' debt is significantly higher than sovereign debt.<sup>5</sup>

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<sup>3</sup>An immense literature tries to circumvent the stumbling block induced by the celebrated SMD theorem (cf. Giraud and Quah (2003)). Our contention is that the main conclusion of these numerous attempts is essentially that emergence is inescapable in economics.

<sup>4</sup>One notable exception is Eggertsson and Krugman (2010), which considers households private debt in a DSGE model —though without money, nor a banking sector, nor a production sector.

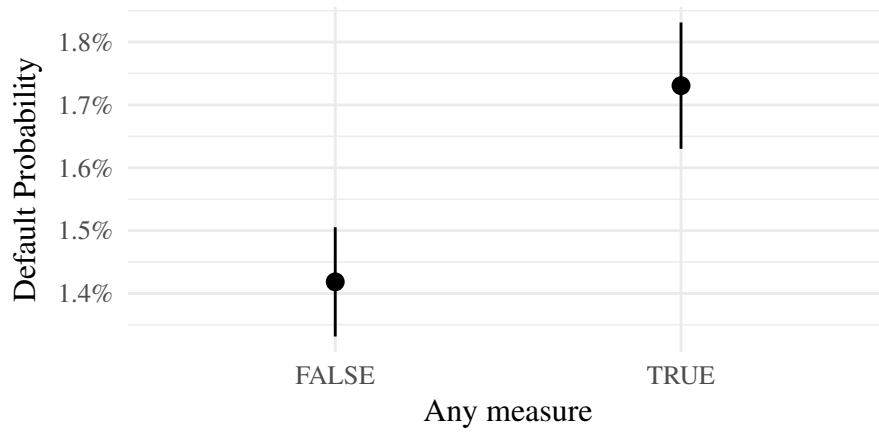
<sup>5</sup>Private debts in the euro area stood at 140% of GDP and public debt at 93% in 2014.



## Appendix B

# Forbearance Patterns in the Post-Crisis Period

## B.1 Additional Graphs



**Figure B.1** – Predicted probability of default for a loan, depending on any measure being taken and any measure having been taken before. All other variables at mean or mode.

*Source: Author's Calculations; Data: CBI*

## B.2 Additional Tables

**Table B.1** – Robustness: Additional double interaction term Texas Ratio  $\times$  Outstanding Balance

	<i>Dependent variable:</i>						
	<i>Any Measure<sub>j</sub></i>						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rating Average <sub><i>l</i></sub>	-0.149 (0.299)	-0.132 (0.298)	-0.199 (0.241)	0.031 (0.124)	-0.149 (0.115)	-0.158 (0.115)	-0.088 (0.173)
Rating Risky <sub><i>l</i></sub>	-0.845 (0.587)	-0.857 (0.590)	-0.888*** (0.339)	-0.409 (0.271)	-0.565** (0.263)	-0.579** (0.264)	-0.597** (0.275)
ln(Out. Bal. <sub><i>l</i></sub> )	0.271** (0.105)	0.264** (0.107)	0.261** (0.108)	0.244** (0.109)	0.180** (0.083)	0.178** (0.083)	0.185** (0.086)
ln(Out. Bal. <sub><i>l</i></sub> ):Texas Ratio <sub><i>k</i></sub>	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.0003 (0.001)	-0.0005 (0.001)	-0.0005 (0.001)	-0.001 (0.001)
Rating Average <sub><i>l</i></sub> :Texas Ratio <sub><i>k</i></sub>	0.003 (0.003)	0.003 (0.003)	0.003 (0.003)	0.001 (0.001)	0.003** (0.001)	0.003** (0.001)	0.002 (0.002)
Rating Risky <sub><i>l</i></sub> :Texas Ratio <sub><i>k</i></sub>	0.009 (0.006)	0.009 (0.006)	0.011*** (0.004)	0.006* (0.003)	0.008*** (0.003)	0.008*** (0.003)	0.008** (0.003)
Forbearance Before <sub><i>k</i></sub>							1.179*** (0.098)
Fixed Effects:							
Loan age		Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time			Yes	Yes	Yes	Yes	Yes
Bank x Time				Yes	Yes	Yes	Yes
Bank x Segment x Prod. Type					Yes	Yes	Yes
County						Yes	Yes
Observations	1,393,284	1,393,284	1,393,284	1,393,284	1,393,284	1,393,284	1,324,317

*Note: Logit Regression with standard errors clustered at Bank x Time level. The dependent variable is the probability of receiving forbearance in  $t + 1$  whereas the independent variables are measured in  $t$ . We split the borrowers in Safe, Average and Risky based on their ex-ante probability of default. Forbearance Before is a dummy which is one if a borrower has ever received forbearance before  $t + 1$ . Significance levels: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$*

**Table B.2** – Logit regression: Probability of default in one to six periods ahead for any loan by borrower - Influence of different measures taken by borrower

Time:	<i>Dependent variable: Probability of Default<sub>j</sub></i>					
	t+1	t+2	t+3	t+4	t+5	t+6
	(1)	(2)	(3)	(4)	(5)	(6)
Rating - Risky <sub>j</sub> :Any measure <sub>j</sub>	0.281*** (0.077)	0.246*** (0.050)	0.269*** (0.043)	0.273*** (0.040)	0.274*** (0.039)	0.284*** (0.020)
Observations	1,292,685	1,082,965	888,638	721,261	556,138	407,507
Rating - Risky <sub>j</sub> :Term extension <sub>j</sub>	0.114 (0.130)	0.218** (0.090)	0.212*** (0.073)	0.202*** (0.060)	0.196*** (0.057)	0.233*** (0.038)
Observations	799,152	657,785	526,096	410,257	296,674	194,008
Rating - Risky <sub>j</sub> :Interest rate change <sub>j</sub>	-0.005 (0.062)	-0.013 (0.054)	0.052 (0.048)	0.057 (0.061)	0.150*** (0.051)	0.148*** (0.011)
Observations	1,109,815	919,948	741,435	586,613	432,833	294,974
Rating - Risky <sub>j</sub> :Limit extension <sub>j</sub>	-0.251*** (0.076)	-0.133*** (0.050)	-0.050 (0.042)	-0.049 (0.044)	-0.031 (0.036)	-0.041 (0.052)
Observations	1,100,091	915,549	740,629	587,655	435,649	298,885
Rating - Risky <sub>j</sub> :Rollover <sub>j</sub>	0.077 (0.125)	0.329*** (0.062)	0.434*** (0.047)	0.493*** (0.041)	0.491*** (0.044)	0.417*** (0.089)
Observations	1,100,091	915,549	740,629	587,655	435,649	298,885
Rating - Risky <sub>j</sub> :Amortisation Stop <sub>j</sub>	1.166*** (0.092)	1.019*** (0.082)	0.911*** (0.077)	0.858*** (0.075)	0.771*** (0.068)	0.674*** (0.072)
Observations	1,291,121	1,081,726	887,638	720,434	555,471	406,982
Fixed Effects:						
Loan age	Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Time	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Segment x Product Type	Yes	Yes	Yes	Yes	Yes	Yes
Region	Yes	Yes	Yes	Yes	Yes	Yes

*Note: Logit Hazard Regression with standard errors clustered at Bank x Time level. The dependent variable is the probability of default of any loan held by borrower  $j$  in one to six periods in the future whereas the independent variables are measured in  $t$ . We split the borrowers in Safe, Average, and Risky based on their ex-ante probability of default. The loan exits the sample once a default occurs. Significance levels: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$*

**Table B.3** – Logit regression: Probability of application of any forbearance measure - NPL Ratio and Tier 1 Ratio

	<i>Dependent variable: Any measure<sub>j</sub></i>								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Rating Average <sub>l</sub>	-0.150 (0.218)	-0.134 (0.220)	-0.138 (0.177)	0.032 (0.076)	-0.051 (0.060)	-0.055 (0.059)	-0.036 (0.100)	0.136 (0.427)	-0.828* (0.435)
Rating Risky <sub>l</sub>	-0.829*** (0.309)	-0.844*** (0.311)	-0.568*** (0.198)	-0.400*** (0.124)	-0.400*** (0.109)	-0.412*** (0.108)	-0.344** (0.149)	0.219 (0.563)	-0.875* (0.466)
ln(Outstanding Balance <sub>l</sub> )	0.219*** (0.013)	0.214*** (0.013)	0.208*** (0.013)	0.213*** (0.013)	0.133*** (0.008)	0.132*** (0.008)	0.098*** (0.008)	0.096*** (0.009)	0.098*** (0.008)
NPL Ratio <sub>k</sub>	-0.024* (0.013)	-0.024* (0.013)	-0.018 (0.014)						
Rating Average <sub>l</sub> :NPL Ratio <sub>k</sub>	0.008 (0.007)	0.008 (0.007)	0.008 (0.006)	0.002 (0.003)	0.006** (0.003)	0.006** (0.002)	0.004 (0.003)		0.008*** (0.003)
Rating Risky <sub>l</sub> :NPL Ratio <sub>k</sub>	0.031*** (0.010)	0.032*** (0.010)	0.026*** (0.007)	0.020*** (0.005)	0.022*** (0.005)	0.023*** (0.005)	0.019*** (0.006)		0.024*** (0.006)
Forbearance Before <sub>j</sub>							1.175*** (0.099)	1.177*** (0.098)	1.175*** (0.098)
Rating Average <sub>l</sub> :Tier 1 Ratio <sub>k</sub>								-0.001 (0.026)	0.041* (0.024)
Rating Risky <sub>l</sub> :Tier 1 Ratio <sub>k</sub>								-0.003 (0.034)	0.023 (0.027)
Fixed Effects:									
Loan age		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time			Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Time				Yes	Yes	Yes	Yes	Yes	Yes
Bank x Segment x Prod. Type					Yes	Yes	Yes	Yes	Yes
County						Yes	Yes	Yes	Yes
Observations	1,393,284	1,393,284	1,393,284	1,393,284	1,393,284	1,393,284	1,324,317	1,324,317	1,324,317

Note: Logit Regression with standard errors clustered at Bank x Time level. The dependent variable is the probability of receiving forbearance in  $t + 1$  whereas the independent variables are measured in  $t$ . We split the borrowers in Safe, Average and Risky based on their ex-ante probability of default. Forbearance Before is a dummy which is one if a borrower has ever received forbearance before  $t + 1$ . Significance levels: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$

## B.3 Description of variables

All of our forbearance measures are dummy variables that switch to 1 if the forbearance measure  $i$  has been applied in time  $t$ . In the following, we provide the exact definition for each measure.

### B.3.1 Rollover

A loan is considered rolled over if for a given borrower one of its significant loans disappears from the sample (expired or concordantly ended) but the borrower limit does not decrease by more than half of the expired loan's amount. This implies that limits on other products were increased or new products issued to increase the borrower limit. A loan is considered significant if it makes up for at least half of the total borrower limit.

### B.3.2 Change in interest rate

In essence, we use the definition of “zombie lending” by Caballero et al. (2008) which we extend to account for the environment of decreasing interest rates for the our sample period. Therefore, we first calculate the percentage change in the interest rate per loan across time,  $\Delta r_l$  followed by the average change in the interest rate for buckets,  $\Delta r_b$ , by: Sector, Segment, Product Type, and Rating. Next, we take the deviation of an individual loan from its bucket mean,  $\Delta r_{l,b} = \Delta r_l - \Delta r_b$ . Finally, we define an advantageous change in the interest if this decrease in deviation from the bucket mean is larger than that of the lowest decile of the two best rating categories,  $\Delta r_{l,b} < \Delta r_{l,b} || \text{lowest decile of best rating categories}$ .

### **B.3.3 Amortisation stop**

We extract this information on the basis of the banks' reports whether a loan is amortising or not. Therefore, this dummy variable is 1 if a loan switches from amortising to non amortising and 0 otherwise.

### **B.3.4 Limit extension**

This dummy variable is 1 if we observe an increase in the borrower's total limit (sum of all loans).

### **B.3.5 Term extension**

This variable is defined by whether we see a positive change of the maturity of a loan product.

### **B.3.6 Overall forbearance dummy**

The overall forbearance dummy switches to 1 if any loan of a borrower received any of the these forbearance measures in a given period.

## Appendix C

### Economic consequences of manipulation in commodity markets – Evidence from a DSGE model



## C.1 Equilibrium Optimality Conditions

In the following I will describe the log-linearised version of the model laid out in Section 3.2. Small letters denote log-deviations from steady state. Each representative agents maximisation problem yields the following optimality conditions:

Households:

$$\beta\delta\xi\mathbb{E}_t[i_{t+1} - k_{t+1}] = \delta\xi(i_t - k_t) - \frac{\sigma(\mathbb{E}_t[c_{t+1}] - c_t)}{1-h} + \frac{h\sigma(c_t - c_{t-1})}{1-h} + (1 - \beta(1 - \sigma))\mathbb{E}_t[\hat{r}_{t+1}^K]$$

$$c_t \frac{\sigma}{1-h} - c_{t-1} \frac{\sigma h}{1-h} + \varphi n_t = \hat{w}_t$$

$$\mathbb{E}_t[c_{t+1}] - c_t = h(c_t - c_{t-1}) + \frac{1-h}{\sigma}(r_t - \mathbb{E}_t[\pi_{t+1}])$$

with  $\hat{r}^K = r^K - p$  being the real rental rate of capital and  $\hat{w} = w - p$  being the real wage.

Capital accumulation:

$$\mathbb{E}_t[k_{t+1}] = (1 - \delta)k_t + \delta i_t$$

Firms:

$$\hat{w}_t + \frac{1}{\rho_v} n_t + \frac{1 - \rho_v}{\rho_v} a_{n,t} = \hat{r}_t^K + \frac{1}{\rho_v} k_t$$

$$l_{y,t} = y_t - a_{y,t} + \rho_y(1 - w_{ly})w_{ny}(\hat{w}_t - a_{n,t}) + \rho_y(1 - w_{ly})(1 - w_{ny})\hat{r}_t^K - \rho_y(1 - w_{ly})\hat{p}_{l,t}$$

$$mc_t = -a_{y,t} + (1 - w_{ly})(1 - w_{ny})\hat{r}_t^K + (1 - w_{ly})w_{ny}(\hat{w}_t - a_{n,t}) + w_{ly}\hat{p}_{l,t}$$

with  $\hat{p}_l = p_l - p$  being the real price of aluminium and  $r \approx \log(1 + R)$  being the nominal interest rate.

Calvo Pricing New-Keynesian Phillips Curve:

$$\pi_t = \frac{\beta}{1 + \beta\varsigma} \mathbb{E}_t[\pi_{t+1}] + \frac{\varsigma}{1 + \beta\varsigma} \pi_{t-1} + \frac{(1 - \theta)(1 - \theta\beta)}{\theta(1 + \beta\varsigma)} mc_t$$

Goods market equilibrium:

$$y_t = G_y^{ss} g_t + I_y^{ss} i_t + (1 - G_y^{ss} - I_y^{ss}) c_t$$

CES Production Function:

$$v_t = w_{ny} (n_t + a_{n,t}) + (1 - w_{ny}) k_t$$

$$y_t = a_{y,t} + (1 - w_{ly}) v_t + w_{ly} l_{y,t}$$

Aluminium market:

$$s_t = \Theta \left[ \mathbb{E}_t [\hat{p}_{l,t+1} + \pi_{t+1}] - r_t - \hat{p}_{l,t} - \frac{\phi_s}{\alpha\beta} (s_t - s_{t-1} - a_{s,t}) + \frac{\phi_s}{\alpha} (\mathbb{E}_t [s_{t+1} - a_{s,t+1}] - s_t) \right]$$

$$L_y^{ss} l_{y,t} = l_{s,t} + \alpha L_s^{ss} s_{t-1} - L_s^{ss} s_t$$

Monetary policy:

$$r_t = \phi_r r_{t-1} + (1 - \phi_r) (\phi_\pi \pi_t + \phi_y y_t) + a_{r,t}$$



## Essays on Macro-Financial Linkages

Le thème principal de cette thèse est celui des liens macro-financiers. J'ai couvert trois questions différentes liées à ce sujet. Dans le premier chapitre, Gaël Giraud et moi-même développons un modèle pour la zone euro en réponse à de nombreuses critiques des modèles de politiques avant le GFC et en mettant l'accent sur l'interaction entre le secteur financier et la macroéconomie. Les deuxième et troisième chapitres portent sur le comportement du secteur financier au lendemain de la crise financière mondiale et ses implications pour la macroéconomie. Le chapitre 2 examine la pratique de l'abstention à l'égard des emprunteurs en difficulté. La question finalement pertinente dans ce chapitre est de savoir dans quelle mesure ce comportement influe sur l'économie réelle. Enfin, le troisième chapitre met en lumière un épisode de manipulation sur les marchés des matières premières. Cette prétendue manipulation n'était apparemment possible qu'en raison de la position dominante des banques sur le marché pendant la période qui a précédé la crise et par la suite. En fin de compte, je quantifie les effets d'un tel comportement et apporte la preuve d'un changement structurel du marché manipulé au cours de la période de manipulation alléguée. Le premier chapitre exploite un ensemble de données au niveau des banques, tandis que dans les chapitres 2 et 3, je développe des modèles macroéconomiques structurels. En particulier, le modèle de système dynamique du deuxième chapitre est une innovation. Cette catégorie de modèles, et plus particulièrement un modèle de la taille que nous développons, n'a jamais été estimée et utilisée par la suite pour l'analyse des politiques.

**Mots-clés :** liens macro-financiers, stabilité financière, DSGE, prêts zombies, produits de base.

## Essays on Macro-Financial Linkages

The main theme of this thesis are macro-financial linkages. I covered three different questions related to this topic. In the first chapter Gaël Giraud and I develop a model for the Euro Area answering to many of the critiques of policy models before the Global Financial Crisis and with a focus on the interaction between the financial sector and the macroeconomy. The second and third chapter focus on behaviour of the financial sector in the aftermath of the Global Financial Crisis and it's implications for the macroeconomy. Chapter 2 investigates the practice of forbearance towards stressed borrowers. The ultimately relevant question in this chapter is to what extent there is a feedback to the real economy due to this behaviour. Finally, the third chapter sheds light on an episode of manipulation in commodity markets. This alleged manipulation was apparently only possible due to the dominant market position banks took in the run up to the crisis and thereafter. Ultimately I quantify the effects of such behaviour and provide evidence of a structural change of the manipulated market during the period of alleged manipulation. The first chapter exploits a bank level dataset, whereas in chapter 2 and 3 I develop structural macroeconomic models. Especially the dynamical system model in the second chapter is an innovation. This class of models and more specifically a model of the size we develop has never been estimated and subsequently used for policy analysis.

**Keywords:** macro-financial linkages, financial stability, DSGE, zombie lending, commodities