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# Monetary Policy in Troubled Times : Three Essays on Quantitative Easing in a Non-Linear Financial Environment

Thibaud Cargoët

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**Thibaud Cargoët**

Préparée à l'unité de recherche CREM (UMR CNRS 6211)  
Centre de Recherche en Économie et Management  
Faculté de Sciences Économiques

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**Monetary Policy in  
Troubled Times:  
Three Essays on  
Quantitative Easing  
in a Non-Linear  
Financial  
Environment**

**Thèse rapporté par :**

**Frédéric Dufourt**

Professeur, Aix-Marseille School of Economics  
*Rapporteur*

**Fabien Tripiier**

Professeur, Université d'Evry Val d'Essonne  
*Rapporteur*

**et soutenue à Rennes  
le 3 Juillet 2018**

devant le jury composé de :

**Jean-Sébastien Pentecôte**

Professeur, Université de Caen Normandie  
*Examineur*

**Jean-Guillaume Sahuc**

Chef du service de recherche en économie financière,  
Banque de France  
*Examineur*

**Thepthida Sopraseuth**

Professeur, Université de Cergy-Pontoise  
*Examineur*

**Jean-Christophe Poutineau**

Professeur, Université de Rennes 1  
*Directeur de thèse*



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# Résumé en français

## Faits stylisés

Les deux décennies ayant précédé la crise financière internationale de 2007, connues sous le nom de “grande modération”, se sont illustrées par un niveau d’inflation et de croissance économique relativement faible et stable dans la plupart des pays développés. Ce contexte de faible inflation est généralement attribué à la mise en place de politiques monétaires ciblant les taux d’intérêt de court terme plutôt que la masse monétaire, et poursuivant comme objectif principal une stabilisation de l’inflation. En effet, en l’absence de réel stress financier dans l’économie, la stabilité des prix était alors perçue comme la principale condition nécessaire à la stabilisation des cycles économiques. Taylor (1993) pose les bases théoriques de la “politique monétaire conventionnelle”, ciblage des taux d’intérêt de court terme par la banque centrale avec comme objectif principal une stabilisation de l’inflation et comme objectif secondaire une stabilisation de la production.

Nous représentons de manière synthétique le fonctionnement de la politique monétaire conventionnelle dans la Figure 1 : la banque centrale réalise des achats ou ventes de titres à l’open-market de manière à impacter l’offre de liquidités sur le marché interbancaire, ce qui lui donne un contrôle indirect sur le taux de l’argent au jour le jour. Le taux de l’argent au jour le jour détermine le coût de refinancement des banques sur le marché interbancaire, i.e leur coût marginal associé à la création de prêts. Les banques répercutent ce coût marginal sur le taux d’intérêt sur les prêts à destination des firmes et des ménages, ce dernier déterminant le volume de crédit en circulation dans l’économie, qui lui-même impacte de manière directe le niveau d’activité et le taux d’inflation, cibles

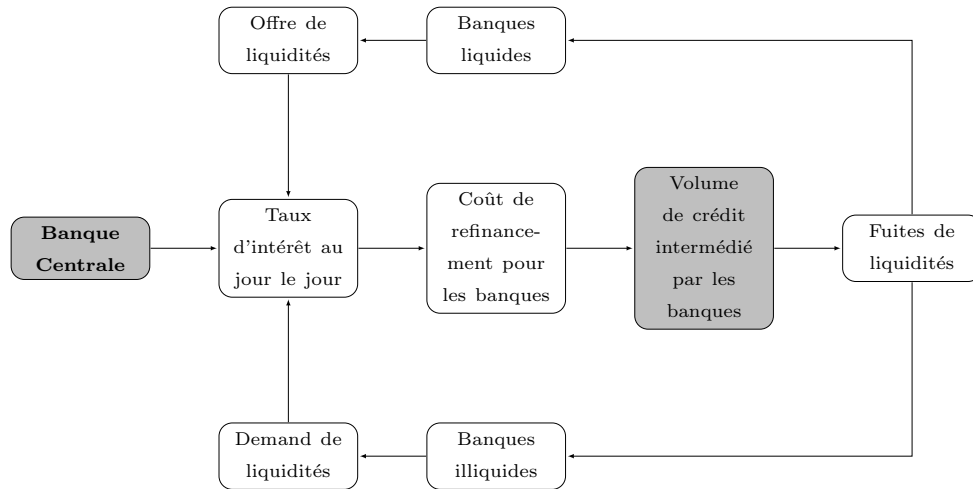


FIGURE 1 : Fonctionnement simplifié des mécanismes de politique monétaire conventionnelle

de la politique monétaire conventionnelle menée par la banque centrale. Le processus de distribution de crédit génère des déficits de liquidités chez certaines banques, tandis que d'autres sont sujettes à des excédents de liquidités : offre et demande de liquidité se rencontrent sur le marché interbancaire, clôturant ainsi le processus de distribution du crédit.

On peut citer comme principal déclencheur de la crise financière de 2007 la crise des sub-primes sur le marché immobilier américain, rapidement diffusée vers l'Europe du fait des fortes interdépendances entre bilans des intermédiaires financiers. L'une des caractéristiques les plus remarquables associées à la crise financière fut la forte augmentation du stress financier dans les économies développées (Figures 2, 3), conduisant les intermédiaires financiers à interrompre leurs prêts sur le marché interbancaire, ce qui contribua à faire chuter de manière spectaculaire l'offre de prêts des banques vers les firmes non financières et les ménages, impactant ainsi le secteur réel. Dans ce nouveau contexte, la stabilisation du secteur financier s'imposa naturellement comme nouvelle condition nécessaire à une stabilisation des fluctuations économiques.

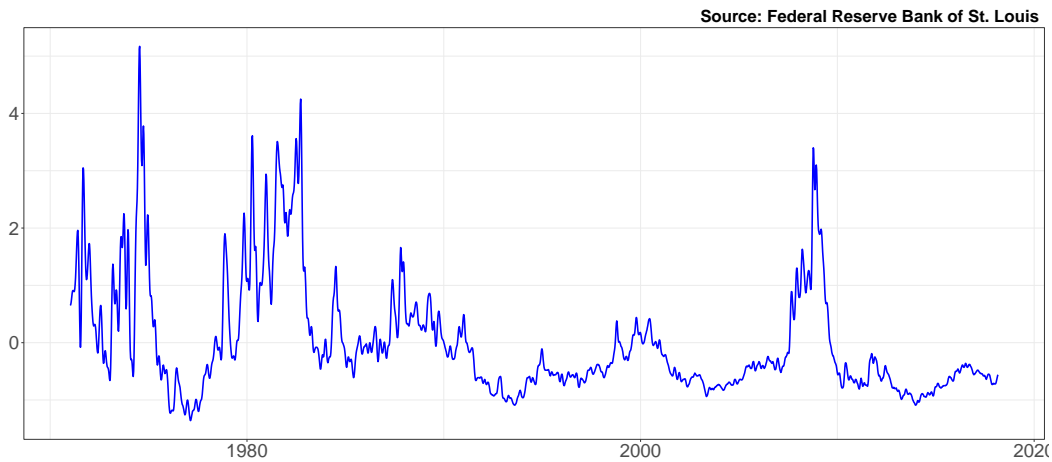


FIGURE 2 : Chicago Fed Adjusted National Financial Conditions Index, de 1971 à 2018, Etats-Unis



FIGURE 3 : Composite Indicator of Systemic Stress, de 1999 à 2017, zone euro

La politique monétaire conventionnelle s'avéra rapidement insuffisante pour assurer simultanément stabilité des prix et stabilité financière, du fait de la déconnection croissante entre les taux d'intérêt directeurs fixés par la banque centrale et le comportement d'offre de crédit des intermédiaires financiers, du fait de l'interruption des prêts sur le marché interbancaire. A cette déconnection s'ajouta le problème de la contrainte de taux



zéro - situation dans laquelle les taux d'intérêt de court terme dans l'économie sont égaux à zéro, et ne peuvent donc descendre plus bas à la suite d'injections de liquidités dans l'économie par la banque centrale, ce qui rend la politique monétaire conventionnelle inefficace. En réaction aux programmes d'achats massifs de titres mis en place par la Réserve Fédérale des Etats-Unis, l'économie américaine entra dans une période de taux d'intérêt proches de zéro dès Janvier 2009. La Banque Centrale Européenne (BCE) ne s'engageant elle-même que plus tardivement et dans de moins grandes proportions dans des programmes d'achats massifs de titres, les taux d'intérêt de court terme en zone euro restèrent supérieurs à ceux des Etats-Unis jusqu'en Septembre 2014, date à laquelle ils heurtèrent finalement la contrainte de taux zéro. La politique monétaire conventionnelle s'étant avérée insuffisante pour atteindre à la fois l'objectif de stabilité financière et l'objectif de stabilité des prix, les banques centrales commencèrent à développer un nouveau panel d'outils de politique monétaire, adaptables aux spécificités individuelles de chaque pays, à même de lutter contre l'interruption des prêts interbancaires ou les situations de taux d'intérêt zéro, et connus sous le nom générique de politiques monétaires non conventionnelles.

Contrairement à la politique monétaire conventionnelle, ciblant l'inflation et l'output gap par le biais des taux d'intérêt courts en accord avec la règle de Taylor, les politiques monétaires non conventionnelles ne s'appuient pas sur un cadre théorique aussi clairement défini : les banques centrales utilisent les différents instruments de politiques monétaires non conventionnels de manière pragmatique, en les adaptant aux besoins et spécificités de chaque zone monétaire. On distingue trois grandes catégories d'outils de politique monétaire non conventionnelle : l'assouplissement quantitatif, l'assouplissement qualitatif, et les engagements relatifs aux décisions à venir (guidage prospectif).

L'assouplissement quantitatif correspond à une large expansion du bilan de la banque centrale avec pour objectif d'augmenter la quantité de liquidités détenue par les banques commerciales afin de leur permettre de relancer l'offre de crédit. Ce type de politiques est particulièrement utile en cas de dysfonctionnement du marché interbancaire, situation dans laquelle les banques commerciales illiquides ne sont plus en mesure de se fournir des liquidités en empruntant sur ce marché car les banques liquides refusent de prêter. Introduit par la Banque du Japon en 1994, le terme d'assouplissement quantitatif était ini-

tialement utilisé pour désigner un changement de cible de politique monétaire depuis une règle de Taylor vers un objectif quantitatif. En pratique, depuis la crise de 2007 la plupart des banques centrales ont été amenées à utiliser des politiques d'assouplissement quantitatif - expansion de leur bilan - en conjonction avec des politiques d'assouplissement qualitatif, ces dernières désignant un changement dans la composition de leur bilan. Dans son introduction au programme mis en place par la Réserve Fédérale en Novembre 2008 en réponse à la crise financière de 2007, Ben Bernanke introduisit ce nouveau type de programmes sous le terme de "credit easing" (assouplissement du crédit), correspondant à une augmentation de la taille du bilan de la banque centrale en conjonction avec un changement dans la nature des actifs entrant dans sa composition, le distinguant ainsi de l'assouplissement quantitatif de type Japonais, qui impliquerait de garder constante la composition du bilan de la banque centrale. Comme la plupart des banques centrales utilisent actuellement le terme d'assouplissement quantitatif pour parler d'une augmentation de la taille de leur bilan associée à une variation de sa composition, nous utiliserons le même terme pour désigner ce type de politiques, par opposition à l'assouplissement quantitatif de type Japonais. Le dernier type de politique monétaire non conventionnelle, le guidage prospectif, consiste à annoncer à l'avance et de manière explicite les mesures de politique monétaire à venir, de manière à ancrer les anticipations d'inflation des agents aux objectifs de politique monétaire de la banque centrale. Ce type de politiques s'est avéré extrêmement utile pour clarifier les intentions de la banque centrale en période de crise.

Les mécanismes reliant la mise en place de programmes d'assouplissement quantitatif à la réduction de l'instabilité financière ont été résumés dans un article de Joyce et al. (2012) pour la Banque d'Angleterre à travers deux canaux d'action : le canal du Financement Bancaire et le canal de Substitution de Portefeuille. Ces deux canaux sont illustrés dans la Figure 4.<sup>1</sup> Le canal du Financement Bancaire considère uniquement des politiques d'assouplissement quantitatif dans lesquelles la banque centrale concentre ses achats d'actifs sur le marché secondaire. Lorsque la banque centrale achète sur le marché secondaire des actifs détenus par les intermédiaires financiers, ces derniers échangent des actifs non liquides contre des réserves liquides, ce qui leur fournit un accès la liqui-

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1. Cette figure est fortement inspirée de la Figure 2 de l'article de Joyce et al. (2012).

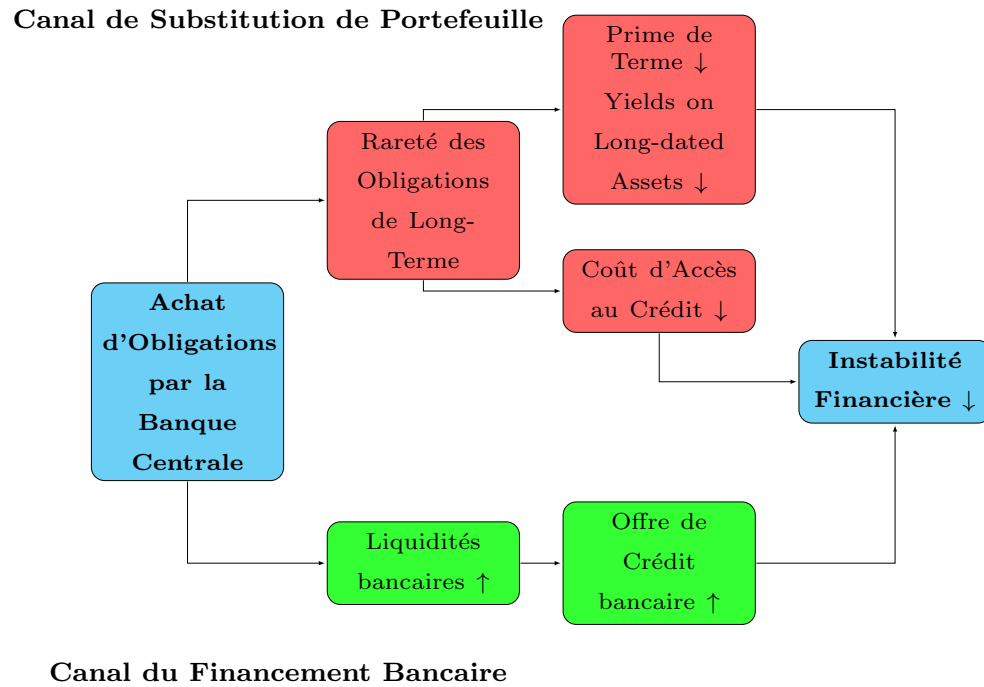


FIGURE 4 : Fonctionnement simplifié des mécanismes de politique monétaire non conventionnelle - inspiré de Joyce et al. (2012)

dité dont ils ne pouvaient précédemment pas profiter du fait du dysfonctionnement du marché interbancaire en période de stress financier. Cet accès des banques à la liquidité leur permet de relancer leur offre de prêts à destination du secteur privé non bancaire, ce qui diminue le stress financier présent dans l'économie.<sup>2</sup> On obtient un mécanisme similaire lorsque la banque centrale achète des actifs sur le marché secondaire aux agents non-financiers plutôt qu'aux banques, car la liquidité ainsi délivrée est ensuite détenue

2. On observe le même mécanisme lorsque la banque centrale fournit aux banques commerciales un accès direct au refinancement à un taux d'intérêt inférieur à celui du marché. Ce type de mesures a été implémenté notamment par la Réserve Fédérale en Décembre 2007 à travers le "Term Auction Facility" (TAF), mesure donnant aux banques un accès direct à des prêts en provenance de la banque centrale, à un taux d'intérêt déterminé par un mécanisme d'enchères.

sous forme de dépôts auprès des banques commerciales, ce qui augmente également les réserves liquides de ces dernières, leur permettant ainsi d'accorder de nouveaux prêts.<sup>3</sup>

A l'inverse, le canal de Substitution de Portefeuille étudie les conséquences de l'assouplissement quantitatif sur l'économie non pas via son impact sur la liquidité du secteur bancaire, mais via la contrepartie de cette augmentation de liquidité : la raréfaction des actifs non liquides. Le canal de Substitution de Portefeuille se concentre plus particulièrement sur des politiques d'assouplissement quantitatif dans lesquelles la banque centrale concentre ses achats d'actifs sur des titres à maturité élevée. Lorsque la banque centrale achète des actifs de long terme sur le marché secondaire, la composition du portefeuille des agents change en faveur de la liquidité, au détriment de ces actifs. Or, d'après la théorie de l'habitat préféré (Modigliani et Sutch, 1966), les investisseurs ont une préférence pour un segment particulier de la courbe des taux ; les fonds de pension et les compagnies d'assurance, par exemple, ont un passif de long terme et préfèrent donc acquérir des actifs de long terme. Selon cette théorie, la raréfaction des actifs de long terme suite à un programme d'assouplissement quantitatif devrait se traduire par une augmentation de leur prix relatif, ce qui conduirait mécaniquement à une diminution de leur rendement via une diminution de la prime de maturité. Cette diminution du taux d'intérêt sur les actifs de long terme fournit aux agents économiques en mesure d'émettre ce type d'actifs un accès plus facile au crédit, ce qui diminue les tensions financières dans l'économie.

Comme nous l'avons déjà souligné, les programmes d'assouplissement quantitatif sont composés d'une vaste collection d'outils pouvant être combinés librement les uns avec les autres, de manière pragmatique, en réponse aux objectifs de chaque banque centrale et en prenant en compte les caractéristiques individuelles de chaque zone monétaire. Un des exemples les plus parlants réside dans l'achat massif par le Réserve Fédérale de titres adossés à des créances hypothécaires à partir de Novembre 2008. Pourquoi la Réserve Fédérale a-t-elle souhaité concentrer ses achats de titres sur ce type d'actifs en particulier ? Au début de la crise des sub-primes sur le marché immobilier américain, les

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3. Ce dernier mécanisme est le mécanisme principal considéré par Joyce et al. (2012), car dans le cas de l'assouplissement quantitatif de la banque d'Angleterre, la plupart des achats d'actifs ont été réalisés sur les marchés secondaires auprès d'agents non financiers. A l'inverse, les programmes d'assouplissement quantitatif de la BCE ou de la Réserve Fédérale reposent principalement sur l'achat d'actifs sur le marché secondaire auprès des intermédiaires financiers.

banques américaines, possédant à l'actif de leur bilan un grand nombre de titres adossés à des créances hypothécaires, étaient particulièrement exposées à un risque massif de défaut sur ce type d'actif. En concentrant ses achats de titres sur ces actifs, la Réserve Fédérale fit d'une pierre deux coups en fournissant des liquidités au système bancaire américain tout en réduisant le risque systémique associé à la détention de ces actifs risqués par les banques américaines. A l'inverse, du côté européen, les banques n'étant de leur côté que peu exposées à un risque de défaut sur les titres adossés à des créances hypothécaires en provenance des Etats-Unis, la BCE préféra concentrer ses achats massifs de titres sur des actifs plus traditionnels.

La Figure 5 montre l'évolution de l'actif du bilan de la Réserve Fédérale suite à ses trois programmes successifs d'assouplissement quantitatif. Avant même le premier programme d'assouplissement quantitatif et suite à la dégradation rapide des conditions de prêt sur le marché interbancaire, la Réserve Fédérale mit en place entre Décembre 2007 et Avril 2010 un programme de prêts directs à destination des intermédiaires financiers connu sous le nom de "Term Auction Facility" (TAF), permettant aux banques de se refinancer directement auprès de la banque centrale à un taux d'intérêt déterminé par un système d'enchères. Le premier programme d'assouplissement quantitatif fut lancé en Novembre 2008, avec l'achat par la Réserve Fédérale de 600 milliards de dollars de titres adossés à des créances hypothécaire dans le but à la fois d'injecter des liquidités dans les banques américaines et de diminuer leur exposition au risque de défaut associé à la crise des sub-primes. En Juin 2010, la Réserve Fédérale détenait 2100 milliards de dollars en dettes d'agences fédérales, titres adossés à des créances hypothécaire et obligations d'états à long terme. En Octobre 2010, la Réserve Fédérale s'engagea dans une seconde vague de mesures d'assouplissement quantitatif, cette fois-ci restreinte aux seules obligations d'états à long terme - l'exposition des banques nationales au risque de défaut ayant été amortie lors de la première vague de mesures d'assouplissement quantitatif - atteignant un total de 600 milliards de dollars à la fin du second trimestre de 2011. Entre Septembre 2011 et Décembre 2012 eut lieu l'"Opération Twist", un échange de 600 milliards de dollars d'obligations d'état de maturités inférieures ou égales à 3 ans contre des obligations d'état de maturités comprises entre 6 et 30 ans. Cette mesure prend son sens lorsqu'on la considère selon le canal de Substitution de Portefeuille. Enfin, une troisième

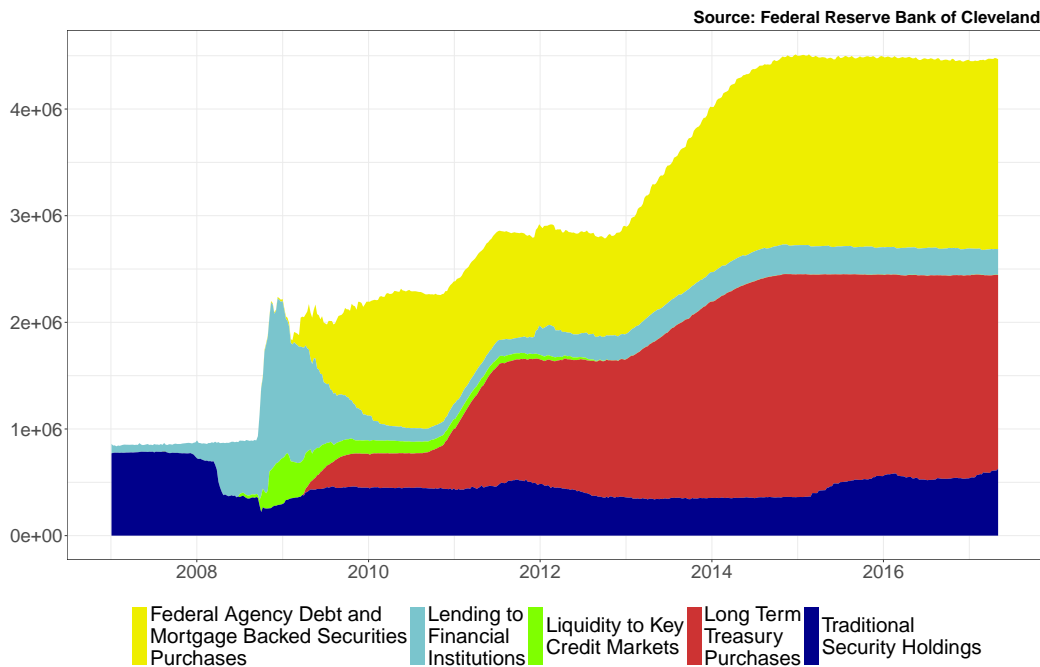


FIGURE 5 : Actif du bilan de la Réserve Fédérale, de 2007 à 2018

et dernière vague de mesures d'assouplissement quantitatif fut lancée en Septembre 2012, avec l'achat par la Réserve Fédérale de 40 milliards de dollars, renouvelables, de titres adossés à des créances hypothécaires. Ce montant fut élevé à 85 milliards par mois en Décembre 2012, par l'ajout de 45 milliards par mois d'obligations d'état de long terme aux 40 milliards par mois initiaux de titres adossés à des créances hypothécaires. L'expansion du bilan de la Réserve Fédérale prit fin en Octobre 2014. Sa taille n'a pas significativement varié depuis.

Les programmes d'assouplissement quantitatif menés par la BCE se démarquent de ceux de la Réserve Fédérale en de nombreux points, ces deux institutions ne poursuivant pas exactement les mêmes objectifs. Ainsi, la BCE concentra la majeure partie de ses achats d'actifs sur des titres plus classiques que ceux acquis par la Réserve Fédérale, et, contrairement à cette dernière, limita son exposition au risque à l'acceptation d'une plus grande assiette d'actifs éligibles comme collatéral lors de ses opérations de

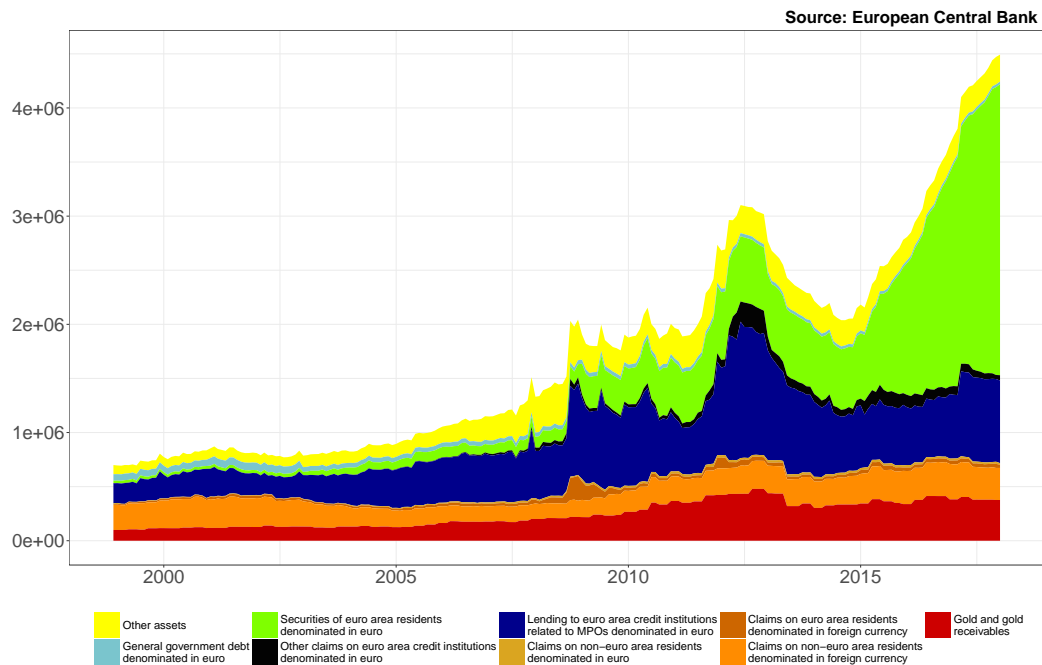


FIGURE 6 : Actif du bilan de la BCE, de 1999 à 2017

refinancement. La Figure 6 représente l'expansion de l'actif du bilan de la BCE résultant de ses programmes d'assouplissement quantitatif successifs. L'ensemble des achats d'actifs réalisés par la BCE depuis 2009 avec pour objectif de lutter contre les perturbations du système financier et les pressions déflationnistes sont rassemblés sous la dénomination commune d'"expanded Asset Purchase Program" (APP). En juin 2009, la BCE lança son premier "Covered Bond Purchase Program" (CBPP), qui atteignit un total de 60 millions d'euros d'obligations sécurisées (i.e obligations garanties sur des créances hypothécaires ou des créances sur administrations publiques) en Juin 2010. Ce programme fut complété par un "Security Market Program" (SMP) lancé en Mai 2010 - consistant en un rachat par la BCE de titres de dette publique et privée en zone euro de manière à diminuer les tensions financières sur certains segments de marché - ainsi que par un second CBPP de 16,4 milliards d'euros en Novembre 2011, ces deux programmes prenant fin en Septembre/Octobre 2012. Un troisième CBPP de moindre ampleur fut lancé en Octobre

2014, complété en Novembre 2014 par un “Asset-Backed Securities Purchase Program” (ABSPP) de faible ampleur composé d’obligations adossées à des actifs. Un virage conséquent dans la conduite de la politique monétaire non conventionnelle fut opéré en Janvier 2015 lorsque suivant le Consensus de Jackson Hole, Mario Draghi, président de la BCE, annonça un changement d’ampleur de l’APP, via l’ajout d’un “Public Sector Purchase Program” (PSPP) consistant en l’achat de 60 milliards d’euros par mois de créances d’administrations centrales et régionales européennes ainsi que d’agences gouvernementales et d’institutions européennes, avec pour objectif d’atteindre un montant total de 1100 milliards d’euros en Septembre 2016. En Mars 2016, la BCE augmenta le montant d’achats mensuels de titres jusqu’à 80 milliards d’euros, ajoutant des obligations d’entreprise aux actifs déjà cités. En parallèle de l’APP, la BCE procéda également à partir de Septembre 2007 à une augmentation de ses prêts à destination du secteur bancaire via un recours aux opérations de refinancement à long terme, de manière à injecter des liquidités dans le bilan des banques et permettre au secteur privé non financier d’accéder plus facilement au crédit via le canal de Substitution de Portefeuille. Cette opération fut engagée à grande ampleur à partir de Décembre 2011, date à laquelle la BCE décida simultanément de s’engager dans deux opérations de refinancement avec une maturité de 3 ans et d’augmenter l’assiette des actifs éligibles comme collatéral dans ces opérations de refinancement.

## Littérature

Malgré leur caractère récent, les politiques monétaires non conventionnelles ont fait l’objet de nombreuses études empiriques depuis le début de la crise financière. Si l’on en croit le FMI, les programmes d’assouplissement quantitatif menés par les banques centrales de la plupart des pays développés depuis le début de la crise financière de 2007 ont contribué à réduire significativement le risque systémique de défaut bancaire ayant suivi la faillite de Lehman Brothers. Un large consensus est actuellement en vigueur dans la littérature empirique concernant la capacité des mesures d’assouplissement quantitatif à réduire le stress financier dans l’économie et à amortir les conséquences macroéconomiques de la crise financière.



La littérature empirique concernant l'impact des mesures de politique monétaire non conventionnelle sur le crédit et l'activité économique est principalement construite autour des modèles Vecteurs Autoregressifs Structurels (SVAR). Introduits par Sims (1980), les modèles SVAR constituent l'un des principaux outils de la macroéconomie empirique, en particulier dans l'analyse des mécanismes de transmission de la politique monétaire et des fluctuations des cycles économiques. Ils offrent une solution possible au problème standard de macroéconomie empirique consistant à trouver de vraies variables exogènes pouvant être utilisées comme instruments lors de l'estimation de modèles dynamiques à équations simultanées,<sup>4</sup> en traitant toutes les variables du modèle comme endogènes les unes par rapport aux autres. Les résidus de chaque équation sont considérés comme des séries de chocs exogènes non anticipés appliqués à chaque variable du modèle. Un des outils d'analyse connaissant le plus de succès dans le cadre de la modélisation SVAR sont les fonctions de réponse, simulant l'impact d'un choc exogène non anticipé sur l'une des variables du modèle, et étudiant la réponse conjointe de l'ensemble des variables du modèle suite à ce choc. L'identification des chocs exogènes requiert une série de restrictions informelles basées sur des hypothèses théoriques implicites. Le fait que ces hypothèses soient souvent compatibles avec un large spectre de théories alternatives explique en grande partie le succès des modèles SVAR dans l'étude des phénomènes de transmission de la politique monétaire. Pour toutes les raisons préalablement citées, les modèles SVAR apparaissent comme des candidats naturels pour l'évaluation empirique des effets des politiques monétaires non conventionnelles sur les variables macroéconomiques. Lenza et al (2010), utilisant un VAR Bayésien, trouvent que les effets sur l'économie des programmes d'assouplissement quantitatif conduits par la BCE et la Banque d'Angleterre transitent majoritairement par les écarts de taux d'intérêt. Peersman (2011) utilise un modèle SVAR avec des restrictions de signe et montre que la BCE est en mesure de stimuler l'économie au-delà du contrôle du taux d'intérêt directeur via une augmentation de la taille de son bilan. Mittnik et Semmler (2013), utilisant un modèle VAR à régimes multiples sur données européennes et américaines, montrent que des chocs négatifs importants sur le stress financier ont des effets positifs significatifs sur l'activité économique, soutenant

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4. Ceci est particulièrement vrai concernant le champ de l'économie monétaire, car quasiment toutes les variables monétaires ou financières sont dans une certaine mesure déterminées de manière endogène.

l'idée d'interventions non conventionnelles de la banque centrale dans des situations de stress financier extrême. Fahr et al. (2013), utilisant à la fois un modèle DSGE estimé et un modèle SVAR, mettent en évidence le fait que les politiques monétaires non conventionnelles conduites par la BCE depuis 2007 ont permis de prévenir une chute encore plus dramatique de l'activité économique en réduisant l'impact des chocs financiers négatifs sur celle-ci. Wu et Xia (2016) étudient quant à eux l'efficacité des politiques monétaires non conventionnelles menées par la Réserve Fédérale en période de taux zéro, estimant un taux d'intérêt implicite dans le cadre d'un modèle VAR à facteur augmenté.

Du côté de la littérature théorique, les modèles DSGE (Dynamic Stochastic General Equilibrium) fournissent un cadre privilégié pour l'étude de l'impact des politiques monétaires non conventionnelles sur le système financier et l'activité économique. Popularisés à travers le modèle RBC (Real Business Cycle) de Kydland et Prescott (1982), les modèles DSGE se caractérisent par une approche de la macroéconomie reposant sur le microfondement des comportements individuels des agents et l'hypothèse d'agents représentatifs. Les premiers modèles RBC considèrent une économie composée d'un consommateur représentatif qui opère sur les marchés parfaitement compétitifs des biens et services, des facteurs de production et des actifs. Le caractère stochastique de ces modèles se reflète dans le fait que les fluctuations des cycles économiques autour de leurs valeurs d'équilibre sont causées par des chocs exogènes, la majeure partie de la volatilité du modèle étant expliquée par un choc technologique. Du fait de l'absence de frictions sur le marché du travail, les fluctuations de l'activité économique agrégée constituent une réponse efficiente aux chocs exogènes, ce qui rend les interventions gouvernementales inutiles par nature. Dans une nouvelle génération de modèles DSGE - les modèles DSGE Néo-Keynésiens - des frictions nominales furent ajoutées aux marchés des biens et services et au marché du travail de manière à mieux répliquer les faits décrits par les données. On peut citer notamment les modèles de Clarida et al. (1999) et Woodford (2003). Certains modèles DSGE d'avant crise prennent en compte l'existence de frictions financières, comme le modèle de Bernanke et al. (1999) dans lequel ces frictions sont à l'origine d'un mécanisme d'"accélérateur financier" amplifiant les effets des chocs macroéconomiques. Cependant, la majeure partie de la littérature DSGE incorporant des frictions financières fut développée à la suite de la crise financière de 2007. La crise financière, mettant en évidence

le rôle clé des facteurs financiers dans les fluctuations des cycles économiques, rendit nécessaire le développement d'un cadre théorique incorporant ces nouveaux facteurs et les reliant aux fluctuations économiques. Les modèles DSGE, du fait de leur nature microfondée, constituaient le candidat idéal pour le développement de ce cadre théorique. De plus, Smets et Wouters (2001, 2003) ayant introduit la possibilité d'estimer empiriquement les modèles DSGE à l'aide de méthodes Bayésiennes, ces modèles ont également la capacité de produire des résultats empiriques, en plus de leur fonction traditionnelle d'instruments d'analyse théorique. Gertler et Karadi (2011) proposent un cadre d'analyse pour étudier les phénomènes de perturbation financière via l'introduction d'une contrainte quantitative sur les banques, créant un effet de levier entre les ressources de la banque et la quantité de prêts qu'elle est en mesure de fournir. Ce cadre d'analyse, axé sur le canal du Financement Bancaire, constitue une première étape dans l'apport de fondements théoriques aux programmes d'assouplissement quantitatif. Gertler et Kiyotaki (2010) et Gertler et Karadi (2013) étendent cette modélisation à d'autres types de mesures d'assouplissement quantitatif. Dedola et al. (2013) construisent un modèle à deux pays avec une contrainte quantitative corrélée entre les banques de différents pays de manière à étudier les externalités internationales des politiques d'assouplissement quantitatif. Vayanos et Vila (2009), Gagnon et al. (2011) et Chen et al. (2012) s'intéressent quant à eux à l'efficacité des programmes d'assouplissement quantitatif via le canal de Substitution de Portefeuille.

Comme les modèles DSGE peuvent être estimés à l'aide de techniques Bayésiennes, ils fournissent également un outil permettant d'évaluer empiriquement l'efficacité des politiques monétaires non conventionnelles conditionnellement à la structure sous-jacente du modèle. Fahr et al. (2013) (déjà cités plus haut) trouvent à l'aide d'un modèle DSGE à la Christiano et al. (2010) un impact significativement négatif des injections de liquidités de la BCE sur la taille de la crise. Engen et al. (2015) utilisent les changements dans les perceptions privées de la politique monétaire de la Fed pour évaluer les effets macroéconomiques des politiques monétaires non conventionnelles aux Etats-Unis. Cahn et al. (2017) estiment à l'aide d'un modèle inspiré de Gertler et Kiyotaki (2010) les effets macroéconomiques des opérations de refinancement à long terme conduites par la BCE.

## Contributions

La conduite de la politique monétaire par les banques centrales au cours des dix dernières années a soulevé de nombreuses questions concernant la place respective des politiques monétaires conventionnelles et non conventionnelles dans la conduite de la politique monétaire. **L'objectif de cette thèse est de fournir un certain nombre d'éléments de réponse à ces questions en abordant le sujet à travers une modélisation approfondie de la nature non-linéaire du phénomène de crise financière.** Comme nous l'avons déjà souligné dans la section précédente, une fraction importante des articles visant à donner un ancrage théorique au phénomène de crise financière dans la littérature repose sur l'introduction de contraintes quantitatives portant sur le bilan des agents. Certains modèles DSGE tentent de modéliser la nature non-linéaire de la crise en introduisant la possibilité pour la contrainte quantitative de n'être qu'occasionnellement saturée.<sup>5</sup> Le caractère fortement non-linéaire de la crise financière est sujet à un large consensus dans la littérature. Le fait d'introduire une dimension temporelle à la crise financière conduit à se poser la question suivante : l'assouplissement quantitatif a-t-il un impact, pas seulement sur l'amplitude de la crise mais également sur sa durée ? Nous répondons à cette question dans le premier chapitre de cette thèse à l'aide d'un modèle DSGE non-linéaire en économie fermée avec une contrainte occasionnellement saturée sur la capacité des banques à fournir du crédit.

La zone euro constitue un cas unique de politique monétaire parmi les pays développés. En effet, elle inclut au sein de la même union monétaire 19 pays fortement hétérogènes au niveau de leurs secteurs financier et réel. Dans cet environnement hétérogène, se pose la question de savoir si la BCE doit prendre en compte les hétérogénéités entre les différents pays de la zone lors de la conduite de sa politique monétaire ? Jusqu'à aujour-

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5. Mendoza (2010) introduit une contrainte sur la quantité maximale d'endettement que les entrepreneurs sont en mesure de supporter. Lorsque cette quantité maximale est atteinte, l'économie se trouve dans une situation de crise.

He et Krishnamurthy (2013) modélisent l'évolution de la prime de risque pendant les périodes de crise financière en considérant une contrainte de collatéral sur la quantité maximale d'actions que les ménages sont en mesure d'acheter étant donnée leur richesse nette.

Brunermeier et Sannikov (2014) introduisent des non-linéarités dans l'accumulation de la richesse des entrepreneurs en fonction de leur degré d'exposition au risque.

d'hui, la réponse négative a toujours prévalu, les statuts de la BCE spécifiant clairement que sa politique monétaire devait être conduite de manière homogène entre les différents pays de la zone euro.<sup>6</sup> Dans le cas de la politique monétaire non conventionnelle, les achats d'actifs sont donc effectués dans chaque pays en proportion du poids de son secteur financier au sein de la zone euro dans son ensemble. Nous adaptons la spécification non-linéaire des périodes de crises utilisée dans le premier chapitre au cas d'un modèle DSGE à deux pays calibré sur la zone euro, de manière à étudier la transmission du phénomène de crise financière entre pays de la zone suite à la mise en place de différents types de programmes d'assouplissement quantitatif (prenant en compte les spécificités propres à chaque pays ou choisissant de les ignorer). Ainsi, nous sommes en mesure d'étudier le rôle central de l'intégration financière dans le processus de transmission de la crise financière.

La majeure partie des fluctuations des variables macroéconomiques associées à la crise financière de 2007 a maintenant disparu, et la plupart des économies des pays développés (à quelques exceptions notables) reviennent progressivement à la normale ; cependant, les banques centrales détiennent toujours un grand nombre d'actifs dans leurs bilans suite à leurs programmes d'assouplissement quantitatif successifs. Cette situation a donné lieu à un débat concernant la place de la politique monétaire non conventionnelle. Les mesures de politique monétaire non conventionnelle doivent-elles devenir un instrument standard de la politique monétaire, ou doivent-elles être restreintes aux seules périodes de crise ? Cette question a déjà donné lieu à plusieurs articles théoriques.<sup>7</sup> Cependant, alors que l'assouplissement quantitatif a déjà été reconnu comme efficace en période de crise par un certain nombre d'études empiriques, peu d'études empiriques ont été réalisées à ce jour pour déterminer l'efficacité de ces mesures une fois l'écono-

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6. Ce statut a été créé dans le but d'éviter des situations dans lesquelles la BCE se trouverait en mesure de financer indirectement les déficits publics de certains pays membres de la zone euro en concentrant ses achats d'actifs sur des obligations d'états détenues par ces pays, remettant ainsi en cause l'indépendance de la banque centrale et la crédibilité de sa politique monétaire. Cette situation pourrait fortement augmenter le coût associé à la conduite de la politique monétaire future, comme cela a été le cas à de nombreuses reprises dans l'histoire de la plupart des banques centrales.

7. Voir par exemple Angeloni et al. (2014), Foerster (2015).

mie revenue à son état initial.<sup>8</sup> De plus, certaines études empiriques mettent en avant les dangers associés à ma conduite de la politique monétaire non conventionnelle sur le long terme. Toujours à l'aide de méthodes non-linéaires, nous tentons de combler ce manque dans la littérature en estimant un VAR à changements de régimes markoviens (MS-VAR) sur données européennes avec deux régimes correspondant respectivement à une période "normale" sur le plan financier et à une période de crise financière. Ce cadre d'analyse nous permet de comparer l'efficacité relative des programmes d'assouplissement quantitatif lorsque l'économie est sujette à des périodes de perturbation financière et lorsqu'elle ne l'est pas.

Dans le premier chapitre de cette thèse, nous construisons un modèle DSGE non-linéaire dans lequel la situation du secteur financier varie de manière endogène entre des périodes d'absence de perturbation financière et des périodes de perturbation financière. La crise financière se déclenche lorsque la quantité maximale de prêts qu'une banque est en mesure d'offrir (du fait d'une contrainte quantitative héritée de Gertler et Karadi (2011)) devient inférieure à la demande de prêts des entrepreneurs, suite à un choc financier négatif. Ce cadre d'analyse non-linéaire nous permet d'introduire la dimension temporelle de la crise financière et d'étudier l'impact de l'assouplissement quantitatif non seulement sur l'amplitude mais également sur la durée de la crise financière.

Dans le second chapitre, nous construisons un modèle DSGE à deux pays, calibré sur les deux groupes de pays composant la zone euro (pays du centre et pays de la périphérie), chaque groupe de pays étant sujet à une contrainte de crédit occasionnellement saturée similaire à celle développée dans le premier chapitre, ce qui nous permet d'étudier les effets de transmission internationale de la crise financière entre les deux groupes de pays pour différents niveaux d'intégration financière et différents types de mesures d'assouplissement quantitatif. Une grande partie de l'hétérogénéité entre groupes de pays présente dans notre modèle provient de l'hypothèse selon laquelle le système financier des pays de la périphérie de la zone euro est plus fragile que celui des pays du centre. Ce cadre d'analyse nous permet de quantifier la perte relative d'activité et de bien-être associée à

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8. Hubrich et Tetlow (2015), utilisant un VAR à changement de régime markovien sur données américaines, montrent que la politique monétaire conventionnelle est efficace en période de faible stress financier mais beaucoup moins en période de stress élevé, mais n'abordent pas la question de l'efficacité relative des politiques monétaires non conventionnelles en fonction du degré de stress financier dans l'économie.

la conduite d'une politique d'assouplissement quantitatif non optimale (i.e une politique d'assouplissement quantitatif ne prenant pas en compte les hétérogénéités entre pays), et l'impact de l'intégration financière.

Dans le troisième chapitre, nous estimons l'efficacité relative des politiques d'assouplissement quantitatif de la BCE en fonction du régime dans lequel se situe la zone euro (crise financière ou période normale), en utilisant la méthodologie MS-VAR développée par Sims et al. (2008). Cette approche donne une dimension non-linéaire à notre modèle empirique, l'ensemble des périodes composant notre échantillon étant séparé entre deux états markoviens. Comme les techniques d'estimation non-linéaire nécessitent, pour atteindre une convergence des estimateurs, un nombre de données plus important que ce qu'il est possible de collecter en pratique du fait de la nature récente de la construction européenne et de la difficulté d'obtenir des données macroéconomiques d'une fréquence infra-mensuelle, nous utilisons des techniques Bayésiennes pour introduire de l'information a priori dans l'algorithme d'estimation, complétant l'information présente dans les données.

## Résultats

Dans le premier chapitre, nous construisons un modèle DSGE non-linéaire en économie fermée, calibré sur l'économie américaine, visant à étudier l'efficacité des mesures d'assouplissement quantitatif sur la crise financière. Le caractère non-linéaire du modèle nous permet de capturer la dimension temporelle du phénomène de crise financière, rendant ainsi possible l'étude des effets de l'assouplissement quantitatif non seulement sur l'amplitude de la crise (comme déjà traité dans la littérature), mais également sur sa durée.

**Nos principales contributions en terme de modélisation sont les suivantes :**

*Un cadre d'analyse non-linéaire dans lequel l'économie peut changer de régime de manière endogène entre une situation normale et une situation de crise financière.* Nous introduisons une contrainte de crédit quantitative à la Gertler et Karadi (2011) sur le bilan des banques dans un accélérateur financier à la Bernanke et al. (1999). La contrainte de crédit est saturée uniquement lorsque l'économie est impactée par un choc financier ou réel d'amplitude suffisante. Dans cette situation, les banques ne sont plus en mesure d'of-

frir suffisamment de crédit pour satisfaire la demande de prêts en provenance du secteur productif. Cette situation de rareté du crédit est à l'origine d'une forte augmentation du taux d'intérêt sur les nouveaux prêts accordés, qui vient diminuer la demande de prêts de manière à assurer l'équilibre sur le marché du crédit. En dehors de cette situation particulière, la contrainte de crédit n'est pas saturée : les banques peuvent offrir du crédit librement car la demande de prêts en provenance du secteur productif est inférieure au montant maximal qu'elles sont en mesure de prêter. Bien que l'état stationnaire de l'économie se situe dans le régime normal, un choc financier d'amplitude suffisante est à même de déclencher la saturation de la contrainte de crédit et de faire basculer l'économie dans un régime de crise financière. Après un certain nombre de périodes, l'économie retourne ensuite à son régime normal, puis à l'équilibre. Nous utilisons la méthode développée par Guerrieri et Iacoviello (2015) pour construire ce que les auteurs nomment un modèle "linéaire par partie", qui constitue une approximation satisfaisante du modèle entièrement non-linéaire pour de faibles réalisations des chocs exogènes. Ce modèle est cependant difficile à estimer empiriquement du fait de la nature non-linéaire de sa contrainte de crédit.

*Une politique monétaire non conventionnelle dépendante du régime dans lequel se situe l'économie.* Nous faisons l'hypothèse implicite que la politique monétaire non conventionnelle n'est utile qu'en période de crise financière (nous testons empiriquement cette hypothèse dans le troisième chapitre). La politique monétaire non conventionnelle considérée ici est une politique d'assouplissement quantitatif inspirée de Gertler et Karadi (2011). Lorsque l'économie est en période de crise financière, la banque centrale prête directement au secteur privé, contournant le secteur bancaire contraint sur la quantité de prêts qu'il est en mesure de fournir. Gertler et Karadi (2011) font référence à cette mesure particulière d'assouplissement quantitatif sous le terme de "politique de crédit". La règle de politique de crédit que nous utilisons est différente de celle de Gertler et Karadi (2011) : nous supposons que la banque centrale met en place une politique de crédit dont l'ampleur est proportionnelle à la taille de la crise. Par conséquent, lorsque l'économie se situe dans un régime d'absence de crise, aucune politique de crédit n'est mise en place.

**Nos principaux résultats sont les suivants :**



*La politique de crédit diminue l'amplitude de la crise financière mais augmente sa durée.* Comme la politique de crédit de la banque centrale consiste à prêter directement au secteur privé, cette politique diminue le degré de saturation de la contrainte quantitative pesant sur les banques, ce qui diminue le taux d'intérêt sur les prêts. Le taux d'intérêt sur les prêts diminuant, la demande de prêts en provenance des entrepreneurs augmente, mais comme elle ne peut être satisfaite directement, elle est reportée sur un nombre de périodes plus important.

Pour des valeurs raisonnables des paramètres du modèle, lorsque l'on considère les effets intertemporels cumulés d'une politique de crédit sur le bien être, on trouve que *l'impact de la politique de crédit est toujours positif en termes de bien-être* malgré ses effets opposés sur l'amplitude et la durée de la crise.

*Des variations de certains paramètres du modèle peuvent réduire considérablement l'efficacité de la politique de crédit.* Par exemple, si l'effet de levier entre les ressources des entrepreneurs et leur demande de prêts augmente, les entrepreneurs utilisent davantage de crédit pour produire, ce qui augmente l'effet durée de crise associé à la conduite d'une politique de crédit.

Dans le second chapitre, nous utilisons un modèle DSGE à deux pays, calibré sur le centre et la périphérie de la zone euro, pour étudier la question de l'impact de politiques de crédit homogènes ou hétérogènes sur une union monétaire composée de pays avec des secteurs financiers hétérogènes. Nous étendons le cadre non-linéaire du chapitre précédent à un modèle à deux pays, ce qui signifie que chaque pays peut être dans un régime de crise financière, même si le pays voisin se situe dans le régime opposé.

**Nos principales contributions en terme de modélisation sont les suivantes :**

*L'introduction d'une contrainte de crédit occasionnellement saturée dans un cadre d'économie ouverte, et plus particulièrement dans le cadre d'une union monétaire.* Ce cadre d'analyse nous permet d'étudier les effets de transmission de la crise financière entre les deux économies pour différents degrés d'intégration financière et différents types de politiques de crédit. Comme les statuts de la BCE lui interdisent de concentrer ses interventions sur les marchés financiers de certains pays de manière à tenir compte des spécificités propres à ces pays lors de la conduite de sa politique monétaire, une question

intéressante serait de connaître le coût d'opportunité en termes d'activité générée par la conduite d'une politique de crédit non optimale, et l'impact de l'intégration financière sur l'évolution de ce coût d'opportunité. On peut également se poser la question des inégalités entre les deux groupes de pays générées par la conduite d'une politique de crédit non optimale.

*La distinction entre les politiques de crédit homogènes et hétérogènes.* On construit la politique de crédit dans le même esprit que Gertler et Karadi (2011). Une politique de crédit homogène consisterait à fournir la même quantité de crédit à chaque pays indépendamment de ses caractéristiques et besoins individuels, la quantité totale de crédit délivrée dans l'économie étant déterminée par le niveau moyen de perturbation financière au sein de la zone euro. Une politique de crédit hétérogène consisterait à offrir du crédit dans chaque pays en proportion de ses besoins, c'est-à-dire de l'amplitude de la crise financière dans ce pays.

**Nos principaux résultats sont les suivants :**

*Les prêts transfrontaliers constituent le canal de transmission principal des perturbations financières entre pays.* Lorsque les pays périphériques de la zone euro sont touchés par un choc financier, si le modèle prend en compte l'existence de prêts transfrontaliers les entrepreneurs périphériques ont la possibilité d'emprunter aux banques du centre de manière à faire face à la raréfaction des prêts accordés par les banques périphériques. Dans le cas d'un niveau d'intégration financière élevé entre les pays du centre et ceux de la périphérie, les entrepreneurs périphériques transfèrent une grande partie de leur demande de prêts vers les banques du centre en cas de choc financier sur les banques de la périphérie, ce qui est susceptible de déclencher une saturation de la contrainte de crédit pour les banques du centre, générant ainsi une transmission de la crise financière entre pays. On peut donc dire que l'intégration financière lisse le phénomène de crise financière entre les différents pays membres de la zone euro.

*Pour des degrés d'intégration financière réalistes, un choc financier sur les pays de la périphérie est susceptible d'être transmis aux pays du centre.*

*L'intégration financière a un effet ambigu sur la zone euro dans son ensemble.* Alors que l'intégration financière limite les effets macroéconomiques associés à un choc sur les pays de la périphérie en autorisant les entrepreneurs périphériques à emprunter aux banques

du centre, elle crée également une récession dans les pays du centre en déclenchant une saturation de la contrainte de crédit des banques du centre, générant ainsi une pénurie de crédit dans les pays du centre. On trouve une solution intérieure pour le degré d'intégration optimal, pour laquelle les effets du choc financier au niveau de la zone euro dans son ensemble atteignent leur minimum. Ce degré d'intégration financière optimal se situant à un niveau relativement proche du degré d'intégration financière effectivement observé dans les données, il constitue un objectif crédible de politiques publiques.

*Une politique de crédit homogène, ignorant les spécificités propres à chaque pays, est toujours moins efficace qu'une politique de crédit hétérogène, calibrant ses achats de titre dans chaque pays en fonction des besoins spécifiques de celui-ci.*

*Les politiques de crédit diminuent les inégalités entre pays pour de faibles niveaux d'intégration financière, mais les augmentent pour des niveaux d'intégration financière élevés.*

Dans le troisième chapitre, nous utilisons un modèle MS-VAR estimé sur données européennes à l'aide de méthodes Bayésiennes, avec deux états de Markov correspondant respectivement à un faible niveau de stress financier et à un niveau de stress financier élevé. Cette spécification non-linéaire nous permet d'étudier l'efficacité relative des politiques d'assouplissement quantitatif en période de crise financière et en période normale, et ainsi de répondre à la question suivante : l'utilisation des politiques monétaires non conventionnelles devrait-elle être restreinte aux seules périodes de crise, ou peut-elle être étendue à la période normale ? Nous ajoutons une variable financière au modèle de manière à étudier les canaux d'action par lesquels l'assouplissement quantitatif agit sur l'inflation et l'activité économique.

**Nos principales contributions en terme de modélisation sont les suivantes :**

*L'ajout de variables relatives aux politiques d'assouplissement quantitatif dans un modèle MS-VAR. Nous pouvons ainsi estimer les effets de l'assouplissement quantitatif sur les grandeurs macroéconomiques et financières, à la fois en période de crise et en période normale. Nous introduisons deux variables relatives aux politiques d'assouplissement quantitatif, capturant les deux principales sources de variation du bilan de la BCE depuis 2007 : les titres achetés par la BCE dans le cadre de l'APP à partir de Juillet 2009, et les*

opérations de refinancement à long-terme, utilisées comme outils de politique monétaire non conventionnelle dès Septembre 2007.

*L'estimation d'un modèle VAR non-linéaire axé sur l'étude des relations de politique monétaire dans la zone euro.* Nous sommes ainsi en mesure de capturer les non-linéarités dans la réaction des variables macroéconomiques et financières de la zone euro aux politiques monétaires mises en place par la BCE, en fonction du degré de stress financier en zone euro.

*L'introduction de fonctions de réponse généralisées de manière à prendre en compte les non-linéarités dans la réaction des variables macroéconomiques et financières aux politiques monétaires.* Comme le modèle varie de manière endogène entre un régime de stress financier élevé et un régime de stress financier faible, les fonctions de réponse traditionnelles sont biaisées car elles ne prennent pas en compte la probabilité de transition entre ces deux régimes lors de la simulation de l'impact des chocs structurels exogènes sur la trajectoire des variables. Karamé (2010) adapte les fonctions de réponse généralisées au cas du MS-VAR. Ces fonctions de réponse nous permettent de prendre en compte la probabilité de transition entre régimes lors de la simulation de l'impact d'un choc structurel sur les variables macroéconomiques et financières.

**Nos principaux résultats sont les suivants :**

*Alors que les achats de titre dans le cadre de l'APP ne sont efficaces qu'en période de stress financier élevé, les opérations de refinancement à long-terme sont efficaces à la fois en période de stress financier élevé et en période de stress financier faible* (bien que plus efficaces en période de stress financier élevé). En effet, les opérations de refinancement à long-terme étant composées de prêts à maturité élevée offerts par la banque centrale à destination des banques commerciales, leurs effets via le Canal de Substitution de Portefeuille sont particulièrement importants, et comme ce canal de transmission de la politique monétaire non conventionnelle est toujours actif en période de stress financier faible, contrairement au Canal du Financement Bancaire, on conserve des effets positifs des opérations de refinancement à long-terme même en-dehors des périodes de stress financier élevé.

*Lors des périodes de stress financier élevé, les opérations de refinancement à long-terme sont plus efficaces pour soutenir l'activité économique et lutter contre la déflation que les achats de titre dans le cadre de l'APP.* En effet, comme les opérations de refinancement

à long-terme permettent aux banques non seulement d'obtenir un accès à la liquidité mais également de bénéficier de contraintes de collatéral plus souples, elles sont plus efficaces pour restaurer l'offre de crédit, et par conséquent relancer l'activité économique. D'après Jäger et Grigoriadis (2017), cette différence d'amplitude entre les effets macroéconomiques des différentes mesures constituant le programme d'assouplissement quantitatif de la BCE peut également être due à des différences dans leurs effets de redistribution entre les différents pays de la zone euro.

*L'efficacité plus importante des opérations de refinancement à long-terme est associée à une possible augmentation du risque systémique, du fait de la plus grande flexibilité des contraintes de collatéral donnant accès à la liquidité.*

# General Introduction

## 1 Stylized facts

The two decades preceding the international financial crisis of 2007, known as “the great moderation”, were characterized by low and stable inflation and output growth in most developed economies. This low inflation framework was generally associated with the conduct of monetary policies targeting short term interest rates rather than the money supply, and pursuing the stabilization of inflation at a low level as a primary objective. Financial stress in the economy being contained at a very low level, price stability was perceived as the main condition of business cycles stabilization around long term macroeconomic values. “Conventional monetary policy”, as we describe the steering of short term interest rates by the central bank as an instrument to control inflation as a primary goal and output gap as a secondary goal, was given its theoretical foundations in Taylor (1993).

Conventional monetary policy mechanisms in the Eurosystem are summarized in Figure 7: The central bank uses open-market operations to impact the liquidity supply on the interbank market, which gives it an indirect control on the overnight interest rate. The overnight rate determines the refinancing cost of banks on the interbank market, corresponding to their marginal cost associated with the provision of loans. This marginal cost is transmitted to the interest rate set by banks on corporate and households’ loans, which has a direct impact on the volume of credit intermediated in the economy, finally affecting economic activity and inflation, i.e the central bank’s targets. After the process of credit distribution, some banks are subject to liquidity shortages while others have

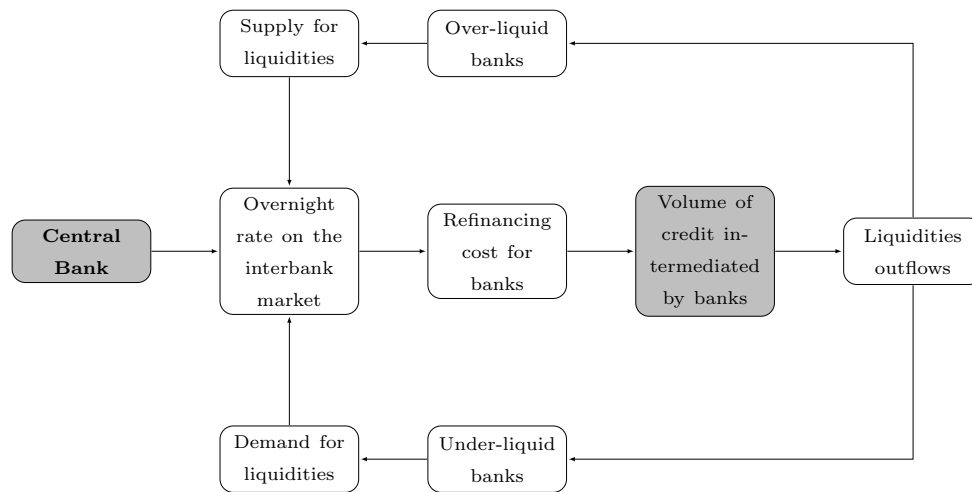


Figure 7: Conventional monetary policy mechanisms

access to liquidity surplus. Liquidity demand and liquidity supply meet on the interbank market, which closes the loop.

The origin of the financial crisis of 2007 mainly lies in the sub-prime crisis on the US real estate market, that quickly spread to European countries through strong international linkages between financial intermediaries' balance sheets. One of the key features of the financial crisis was a strong increase in financial stress throughout developed economies (Figures 8, 9), leading financial intermediaries to disrupt interbank lending, which had dramatic consequences on the loan supply towards non-financial corporations and households, finally affecting the real sector. In this new context, financial stability appeared as a new necessary condition to stabilize business cycle fluctuations.

Conventional monetary policy quickly proved to be insufficient to insure both price stability and financial stability. Indeed, financial disruption in the interbank market induced a disconnection between the central bank policy rates and the behavior of credit supply of financial intermediaries. Furthermore, there is the problem of the zero lower

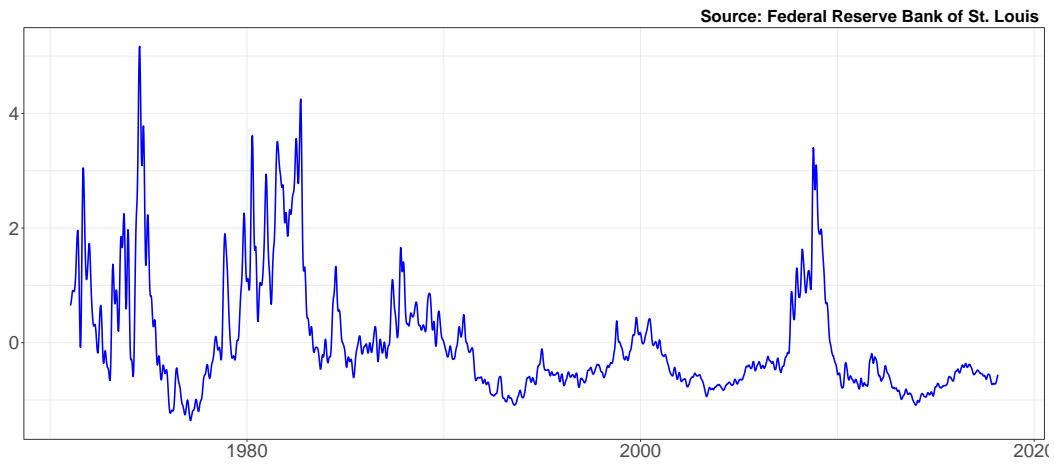


Figure 8: Chicago Fed Adjusted National Financial Conditions Index from 1971 to 2018, USA



Figure 9: Composite Indicator of Systemic Stress from 1999 to 2017, Eurozone

bound - the situation where short term interest rates are equal to zero.<sup>9</sup> Short term in-

9. As the Federal Reserve early engaged in massive asset purchases programs, the federal funds rate became very close to zero in January 2009, a level it kept until the exit of the crisis and the progressive increase in the policy rates since January 2016. Since the European Central Bank (ECB) engaged in massive asset purchase programs later and in lower amounts, the policy rate of the ECB remained higher than the federal funds rate until September 2014, when they finally hit the zero lower bound.



terest rates close or equal to zero imply a disconnection between open market operations of the central bank and official interest rates, under which conditions conventional monetary policy ceases to be efficient. In a situation where conventional monetary policy was not sufficient anymore to meet both price and financial stability goals, the landscape of monetary policy was deeply altered by the development of unconventional monetary policies, a new set of widely adaptable tools which could be designed either to fight against financial disruption in key credit markets or to bypass a zero lower bound situation, and could be adapted in each monetary zone taking into account its local specificities.

While conventional monetary policy is based on substantial evidence on how short term interest rates affect the economy, no such evidential basis yet exists for unconventional monetary policy. So, unlike conventional monetary policy, which is based on the control of short term interest rate with an inflation target according to a Taylor rule, unconventional monetary policies constitute a wide panel of monetary policy tools used in a pragmatic way by central banks, following their own objectives, according to the specificities of local financial markets, with theoretical foundations depending on their local specificities and objectives. We distinguish three categories of unconventional monetary policy measures: Quantitative easing, qualitative easing, and forward guidance.

Quantitative easing corresponds to a broad expansion on the size of the central bank's balance sheet, with the objective of increasing the quantity of cash reserves held by commercial banks at the central bank - thus allowing them to catch up with credit supply. First introduced by the Bank of Japan in 1994, this term was initially meant to indicate a shift in focus from a Taylor rule towards targeting quantity variables. In practice, since the financial crisis of 2007, most central banks used quantitative easing - an expansion of their balance sheet - in conjunction with qualitative easing, which is defined as a shift in the composition of assets held by the central bank. In introducing the Federal Reserve's response of November 2008 to the 2007 financial crisis, Ben Bernanke defined the new program, which he termed "credit easing", as a quantitative easing program associated with a shift in the nature of assets purchased, thus distinguishing it from Japanese-style quantitative easing, which would have involved holding constant the composition of the central bank's balance sheet. As most central banks use the term of "quantitative easing"

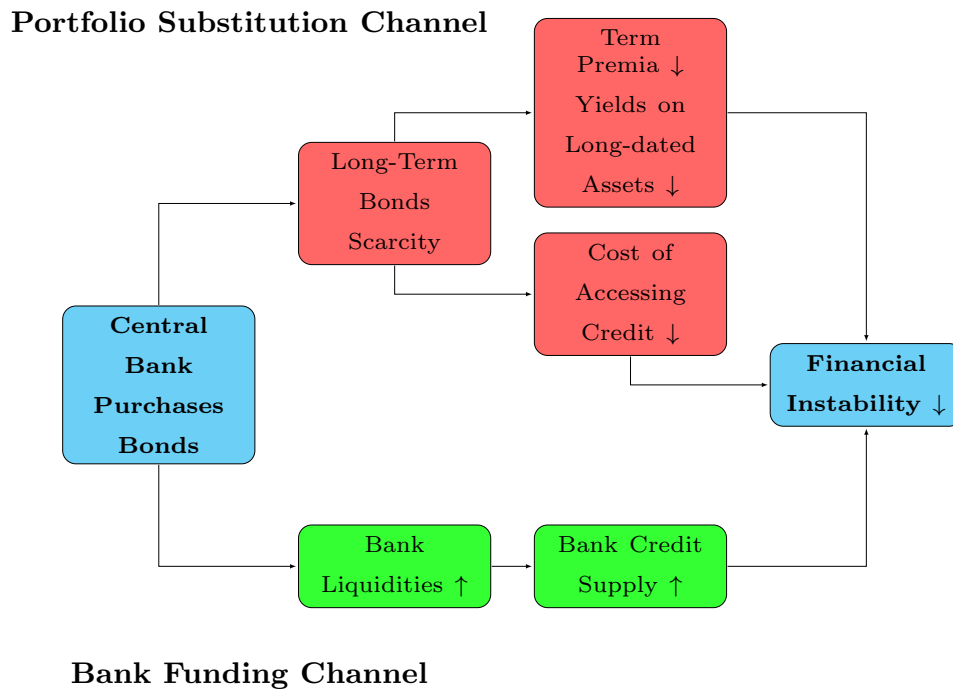


Figure 10: Unconventional monetary policy mechanisms - borrowed from Joyce et al. (2012)

when speaking of quantitative easing programs associated with a shift in the nature of assets purchased, we will use the same term to refer to this type of policies, in opposition to Japanese-style quantitative easing. Standing at the other side of unconventional monetary policies, forward guidance consists in communicating more explicitly about the future path of monetary policy, in order to insure that market expectations are indeed consistent with the policy intentions of the Central Bank. This kind of measures have been helpful in clarifying policy intentions in highly unusual economic circumstances.

The effects of quantitative easing in reducing financial instability have been summarized in a work of Joyce et al. (2012) for the Bank of England, along two channels: The Bank Funding Channel and the Portfolio Substitution Channel. Figure 10 displays these

two channels.<sup>10</sup> When studying the Bank Funding Channel, we consider only situations where the central bank concentrates its massive asset purchases on the secondary market. If the central bank purchases assets held by financial intermediaries, then these financial intermediaries exchange non-liquid assets against cash-reserves, which gives them a direct access to liquidity that was unavailable in period of high financial stress because of the disruption in the interbank market. When getting access to liquidity, banks are able to increase again their credit supply, thereby decreasing financial stress in the economy.<sup>11</sup> A similar mechanism applies if the central bank purchases assets to non-financial agents on the secondary market, because the liquidity delivered in exchange of these assets is then held as deposits on the liability side of the banking system, which increases the amount of excess reserves banks can use to create new loans.<sup>12</sup>

In the opposite way, the Portfolio Substitution Channel studies the consequences of quantitative easing not through its liquidity increase effect on the balance sheets of banks, but through the counterpart of this liquidity increase: The scarcity of bonds. When studying the Portfolio Substitution Channel, we focus more particularly on situations where the central bank purchases long-term bonds. In order to deliver liquidity into the banking system, the central bank buys long term bonds on the primary or secondary market. This changes the composition of agents portfolio towards liquidities instead of long-term bonds. According to the preferred-habitat theory (Modigliani and Sutch, 1966), investors have a preference for a particular segment of the yield curve; For example, pension funds and insurance companies have long-term liabilities and prefer to match them with equally long-dated assets. As a result, the scarcity of long-term bonds induced by a quantitative easing program triggers an increase in the price of these long-term bonds, which lowers their yield by reducing the term premium. This reduction in long-term yields allows

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10. This figure is strongly inspired by the Fig.2 in the article of Joyce et al. (2012).

11. The same mechanism applies if the central bank gives to commercial banks a direct access to refinancing with an interest rate lower than the market rate. An example of such measure was the Term Auction Facility (TAF) operated by the Federal Reserve in December 2007, allowing banks to have access to direct loans from the central bank through an auction mechanism.

12. This is the main mechanism investigated in Joyce et al. (2012), because in the case of the Bank of England's quantitative easing, most assets were purchased on secondary markets from non-banks. This is not the case for the European Central Bank or the Federal Reserve's quantitative easing, where most assets purchased on the secondary market were purchased from banks.

economic agents to have an easier access to credit by issuing long-term bonds, which decreases the financial tensions in the economy.

As already noted before, is not “A quantitative easing”. There are “Quantitative easings”, large collections of tools that can be combined in infinite ways, pragmatically, in response to the unique features of each monetary zone. A meaningful example lies in the mortgage-backed securities purchase program operated by the Federal Reserve in November 2008. Why specifically targeting mortgage-backed securities instead of any other financial asset? Because in the beginning of the crisis in the US real estate market, US banks were deeply exposed to a default risk on this particular type of asset, as they held important amounts of this asset on their balance sheet. By concentrating its purchases on this particular type of assets, the Federal Reserve intended to kill two birds with one stone, both providing important amounts of liquidities to the US banking system and reducing the systemic risk associated to US banks exposure to this particular type of assets. In the meantime, as European banks were not exposed in such amounts to a default risk in mortgage-backed securities from the United States, the ECB did not focus its purchase on those particular types of assets, but rather purchased more traditional claims.

Figure 11 shows the expansion in the asset part of the Federal Reserve’s balance sheet resulting from its three successive quantitative easing programs. Before the first quantitative easing program, the Federal Reserve proceeded between December 2007 and April 2010 to direct lending to financial intermediaries through the Term Auction Facility (TAF), a policy instrument allowing banks, in a period of interbank market disruption, to refinance themselves from the central bank with an interest rate determined as the result of an auction. All advances were fully collateralized. The first quantitative easing program began in November 2008, with the Federal Reserve buying \$600 billion in mortgage-backed securities, in order to both inject liquidities into banks’ balance sheets and reduce systemic risk in the economy by buying assets subject to a high risk occurring from the sub-prime crisis in the US real estate market. By June 2010, it held \$2.1 trillion of federal agency debt, mortgage-backed securities and long-term treasuries. In October 2010, the Federal Reserve announced a second wave of quantitative easing, this time restricted to long-term treasuries - as national agents exposure to default risk had

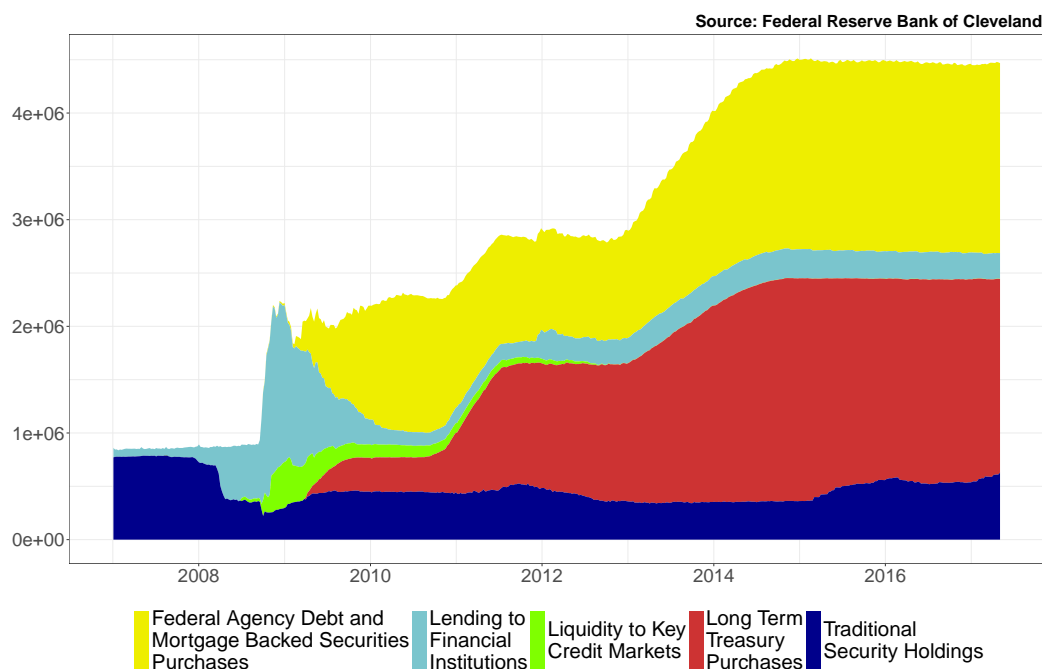


Figure 11: Asset part of the Fed's balance sheet, from 2007 to 2018

already been dampened down by the first quantitative easing wave - for a total of \$600 billion by the end of the second quarter of 2011. From September 2011 to December 2012, the Federal Reserve engaged into "Operation Twist", a swap of more than \$600 billion involving purchases of treasury securities with maturities of 6 to 30 years and sales of treasury securities with maturities of three years or less, in order to reduce long-term yields through the Portfolio Substitution Channel. This measure makes sense when we consider the Portfolio Substitution Channel. Finally, a third round of quantitative easing was announced on September 2012, the Federal Reserve deciding to launch a new \$40 billion per month, open-ended bonds purchasing program of mortgage-backed securities. This amount was increased to \$85 billion per month in December 2012, adding \$45 billion per month of long-term treasury purchases to the initial mortgage-backed securities purchases. The expansion of the Federal Reserve's balance sheet ceased in October 2014. The size of this balance sheet has remained constant until now.

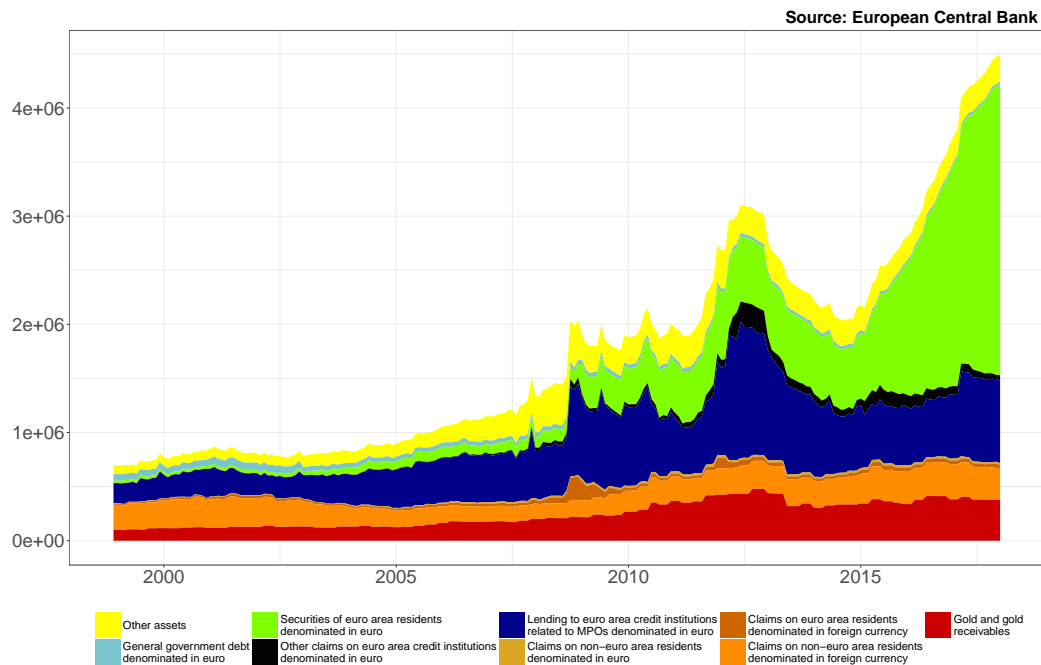


Figure 12: Asset part of the ECB's balance sheet, from 1999 to 2017

The European Central Bank's quantitative easing was different from the quantitative easing of the Federal Reserve, as the two institutions did not pursue the same objectives. The European Central Bank mainly purchased long-term bonds with more classic characteristics than the ones purchased by the Federal Reserve, and limited its risk exposure to the acceptance of a broader category of assets as collateral for refinancing operations. Figure 12 displays the expansion of the asset part of European Central Bank's balance sheet resulting from its successive asset purchase programs. All the asset purchase programs operated by the ECB since 2009 with the objective of fighting low inflation and financial disruption are gathered under the denomination "expanded Asset Purchase Program" (APP). In July 2009, the ECB launched its first "Covered Bond Purchase Program" (CBPP), for a total amount of €60 billion of covered bonds (i.e corporate debt covered by mortgages or claims on the public sector) held on June 2010. This program was completed by a "Security Market Program" (SMP) launched in May 2010 - the ECB buying euro area

public and private debt securities to dampen financial tensions in some specific market segments - and a second CBPP of €16.4 billion in November 2011, both programs ending in September/October 2012. A third smaller CBPP was operated in October 2014, completed in November 2014 by a small-amount “Asset-Backed Securities Purchase Program” (ABSPP). A dramatic turnover was operated in ECB’s monetary policy when in January 2015, following the Jackson Hole Consensus, Mario Draghi, president of the ECB, announced a large expansion of the APP in the form of a “Public Sector Purchase Program” (PSPP), buying €60 billion per month of euro area bonds from central and regional governments, recognized agencies and European institutions, planned to reach a total of €1.1 trillion in September 2016. Finally, on March 2016, the ECB increased its monthly bonds purchases to €80 billion, and included corporate bonds under the APP. In addition to this expanded asset purchase program, the ECB proceeded since September 2007 to an increase of its lending to the banking sector, through an expansion of Longer-Term Refinancing Operations (LTROs), in order to inject liquidity in the banking system and ease credit conditions for the non-banking private sector through the Portfolio Substitution Channel. But the largest expansion in these operations was decided on December 2011, when the ECB simultaneously decided to conduct two longer-term refinancing operations with a three-year maturity and to expand the range of assets eligible as collateral for refinancing operations.

## 2 Literature

Despite their recent nature, unconventional monetary policies have been widely documented in the empirical literature. According to the IMF, the quantitative easing programs undertaken by the central banks of major developed countries since the beginning of the late-2000s financial crisis have contributed to the reduction in systemic risks following the bankruptcy of Lehman Brothers. There is a large consensus in the existing empirical literature about the efficiency of quantitative easing programs in both easing financial conditions and reducing the macroeconomic consequences of the financial crisis.

Empirical literature focusing on the impact of unconventional monetary policy measures on financial conditions and global activity is mainly built around Structural Vector Autoregression (SVAR) models. Introduced by Sims (1980), SVAR models are widely used in empirical macroeconomics, in particular when analyzing the monetary transmission mechanisms and sources of business cycle fluctuations. They offer a solution to the problem of finding truly exogenous variables that can be used as instruments when estimating dynamic simultaneous equation models,<sup>13</sup> by treating all variables as endogenous. The residuals of each equation are considered as series of exogenous, non anticipated shocks applying to each variable of the model. One of the most successful analytical tools within the SVAR methodology are the Impulse Response Functions (IRFs), simulating the impact of a non anticipated exogenous shock on one of the model's variables, and studying the responses of the other variables to this shock. The identification of exogenous structural shocks requires a series of informal restrictions on the equations of the model, based on implicit theoretical assumptions. The fact that these assumptions are often compatible with a wide spectrum of alternative theories explains the success of structural VAR methodology in investigating the monetary transmission mechanisms. For all these reasons, SVAR models emerged as a natural candidate for an empirical evaluation of the effectiveness of unconventional monetary policies. Lenza et al. (2010), using a Bayesian VAR model, find that the effects of the quantitative easing (conducted by both the European Central Bank, the Federal Reserve and the Bank of England) on the economy have mainly transited through the channel of interest rate spreads. Peersman (2011), using a SVAR with sign restrictions, shows that the ECB can stimulate the economy beyond the policy rate by increasing the size of its balance sheet. Mitnik and Semmler (2013), using a Multi-Regime VAR model on US and European data, show that large negative shocks to financial-stress have sizable positive effects on real activity, supporting the idea of unconventional monetary policy measures in case of extreme financial stress. Fahr et al. (2013) use both an estimated DSGE model and a Structural VAR model to assess the effectiveness of ECB's unconventional monetary policy in preventing the economy from

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13. This is particularly true in the field of monetary economics, because practically every variable in the monetary or financial sector is to some extent endogenously determined given well established financial markets and rational expectations.



an even more disruptive collapse by reducing the impact of negative financial shocks. Wu and Xia (2016) study the efficiency of unconventional monetary policy measures undertaken by the Fed in a zero lower bound situation using a factor-augmented VAR with the estimation of a shadow interest rate.

On the theoretical side, Dynamic Stochastic General Equilibrium (DSGE) models appear as perfectly suited tools to analyze the impact of unconventional monetary policy on financial conditions and global activity. Popularized in the Real Business Cycle (RBC) model associated with Kydland and Prescott (1982), DSGE models fulfilled the need of a more microfounded macroeconomy. The early RBC models consider an economy populated by a representative consumer who operates in perfectly competitive goods, factors and assets markets. The stochastic nature of these models is reflected by the fact that business cycle fluctuations around the equilibrium are driven by exogenous orthogonal shocks, the main source of uncertainty lying on a technology shock. Because of the frictionless nature of the labor market, fluctuations in aggregate economic activity are an efficient response of the economy to exogenous shocks, which means that government interventions are useless by nature. In order to improve the replication of the features observed in the data, nominal frictions were added to labor and goods market in a new generation of DSGE models, such as Clarida et al. (1999) and Woodford (2003), referred as New Keynesian (NK) DSGE models. Some pre-crisis authors introduced financial frictions in DSGE models, as Bernanke et al. (1999) where financial frictions generate a “financial accelerator” mechanism amplifying the effects of macroeconomic shocks. However, most of the DSGE literature on financial frictions was developed in response to the financial crisis of 2007. The financial crisis, by underlying the key role of financial factors in macroeconomic fluctuations, triggered an urgent need for a strong theoretical framework linking those factors to business cycle fluctuations. The microfoundations of DSGE models made them a good candidate for developing this theoretical framework, along with the fact that Smets and Wouters (2001, 2003) had allowed an empirical estimation of DSGE models by application of Bayesian techniques, so that DSGE models could be used not only as theoretical instruments but were also able to provide some empirical evidence. The paper of Gertler and Karadi (2011) introduced a framework to study financial disruption episodes through the introduction of a quantitative constraint on banks, creating a

leverage effect between banks' resources and the quantity of credit they are able to provide to non-financial corporations. This framework is a first step to provide theoretical foundations to quantitative easing programs, acting through the Bank Funding Channel. Gertler and Kiyotaki (2010) and Gertler and Karadi (2013) extended this framework to more complex environments to assess the efficiency of other types of quantitative easing programs. Dedola et al. (2013) built a two-country model with quantitative constraints on banks correlated across countries in order to investigate the international spillover effects of quantitative easing programs. Vayanos and Vila (2009), Gagnon et al. (2011) and Chen et al. (2012) investigated the efficiency of quantitative easing programs focusing on the Portfolio Substitution Channel.

As DSGE models can be estimated using Bayesian techniques, they also provide a tool to empirically assess the efficiency of unconventional monetary policies, conditional to the underlying theoretical structure of the model. Fahr et al. (2013) (already quoted before), using an estimated DSGE model à la Christiano et al. (2010), find a significant impact of liquidity injections from the ECB in reducing the magnitude of the crisis. Engen et al. (2015) use changes in private-sector perceptions of the monetary policy of the Fed to evaluate the macroeconomic effects of unconventional monetary policies in the United States. Cahn et al. (2017) estimate a model inspired by Gertler and Kiyotaki (2010) to study the effects on macroeconomic variables of longer-term refinancing operations conducted by the ECB.

### 3 Contributions

The conduct of monetary policy by central banks during the last ten years raises many questions regarding the respective role of conventional and unconventional monetary policy measures. **The aim of this thesis is to provide some clues to answer these questions, focusing modelization efforts on the highly non-linear nature of financial disruption events.** As already seen in the previous section, a large strand of the literature aiming at providing theoretical foundations to financial crisis events relies on the introduction of quantitative constraints on agents' balance sheets. Some DSGE models tried to capture the non-linear nature of the financial crisis by allowing for the

possibility that this balance sheet constraints do not always bind.<sup>14</sup> As the non-linear nature of the financial crisis is subject to a large consensus in the literature, this implies that quantitative easing policies should have a state-dependent nature too. When introducing a temporal dimension to the crisis phenomenon, one question naturally arises: Does quantitative easing have an impact not only on the magnitude of the financial crisis, but also on its duration? We answer this question in the first chapter of this thesis, using a one-country non-linear DSGE model with an occasionally binding credit constraint.

The Eurozone constitutes a unique case for monetary policy in developed countries, as it includes 19 countries with highly heterogeneous financial and real sectors within the same monetary union. In such an environment, one shall ask whether the ECB should take into account these heterogeneities when conducting unconventional monetary policy measures? Until now, the negative answer has always prevailed, the ECB status clearly specifying that monetary policy should be conducted the same way amongst all Eurozone members, financial assets being purchased in each country proportionally to the weight of each country's financial system within the whole Eurozone.<sup>15</sup> Using the same non-linear specification for crisis events as we did in the last chapter in a two-country DSGE model calibrated on the Eurozone allows us to investigate the transmission of financial disruption events between Eurozone countries in reaction to different types of quantitative easing policies (taking into account country-specific factors or ignoring them). We are also able to investigate the central role of financial integration in the transmission process of financial crises.

The sources of financial disruption gradually disappear and most economies progressively go back to normal times, but central banks' balance sheets are still wide, as a result of their past quantitative easing programs. A further debate emerged: Should uncon-

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14. Mendoza (2010) introduces a limit on the total debt entrepreneurs can support. When this limit is reached, the economy is in a crisis situation. He and Krishnamurthy (2013) modelize the risk premia during financial crises using a collateral constraint on the quantity of equities households can purchase based on their net wealth. Brunnermeier and Sannikov (2014) introduce non-linearities on entrepreneurs' net wealth accumulation relative to their risk exposure.

15. This status was created in order to avoid situations where the ECB would indirectly finance some of the Eurozone members' public deficits by focusing its government bonds purchases into this specific countries' financial markets, thus questioning the independency of the ECB and credibility of its monetary policy. This situation could dramatically raise the cost of conducting monetary policies, as it has often been the case in most Central Banks' history.

ventional monetary policies be part of the new normal? This question has already been addressed in theoretical studies.<sup>16</sup> However, while quantitative easing has been empirically proven efficient in times of high financial stress, few empirical studies have been realized to assess their efficiency when the economy goes back to normal times.<sup>17</sup> Moreover, some existing empirical studies have put the emphasis on the dangers associated with long-lasting unconventional monetary policies.<sup>18</sup> Still relying on non-linear techniques, we try to fill this gap in the literature by estimating a Markov-Switching VAR model on Eurozone data with two regimes corresponding to normal times and financial crisis times. This framework allows us to compare the relative efficiency of quantitative easing when the economy is subject to financial disruption events and when it is not.

In the first chapter of this thesis, we build a non-linear DSGE model where the situation of the financial system endogenously shifts from a situation where there is no financial disruption to a situation where the financial system is subject to disruption, back and forth. The financial crisis situation is triggered if the maximum quantity of loans banks can offer (because of a quantitative constraint borrowed from Gertler and Karadi (2011)) falls short to the loan demand from entrepreneurs, because of a negative financial shock. This non-linear framework allows us to introduce the time dimension of a financial disruption event, and thus to study the impact of quantitative easing not only on the magnitude of the financial crisis, but also on the duration of the financial crisis.

In the second chapter, using a two-country DSGE model, calibrated on the two groups of countries forming the Eurozone (core countries and peripheral countries), with an occasionally binding credit constraint similar to the one developed in the first chapter, we study the international transmission effects of the financial crisis between the two groups of countries for different degrees of financial integration and different types of quantitative easing. Most of the heterogeneities in our model come from the assumption that peripheral countries' financial systems are weaker than core countries' ones. This analytical framework allows us to study the magnitude of economic and welfare losses gen-

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16. See for example Angeloni et al. (2014), Foerster (2015).

17. Hubrich and Tetlow (2015), using a Markov-Switching VAR (MS-VAR) model on US data, show that conventional monetary policy is efficient in periods of low financial stress but weak on periods of high financial stress, but do not question the efficiency of unconventional monetary policies in those situations.

18. See for example Benigno and Nistico (2017), McMahon et al. (2018)

erated by a second-best quantitative easing (i.e. a quantitative easing that does not take into account heterogeneities between countries), and the impact of financial integration.

In the third chapter, we investigate the relative efficiency of the quantitative easing programs of the ECB depending on the state of the Eurozone economy (financial disruption vs no financial disruption), using the MS-VAR methodology developed by Sims et al. (2008). This approach gives a non-linear dimension to our empirical model, splitting all the time periods between two Markov states. This allows us to distinguish between financial crisis times and non financial crisis times, and to investigate the relative efficiency of quantitative easing in each situation, thus answering the question of the interest of maintaining unconventional monetary policies when the financial crisis is over. As non-linear estimation techniques require, to insure convergence, an important amount of data which is not collectible in practice because Eurozone is young and we cannot find macroeconomic data with a frequency inferior to monthly, we use Bayesian techniques to introduce prior information in the estimation algorithm, complementing information provided by the data.

## 4 Results

In the first chapter, we use a closed economy non-linear DSGE model, calibrated on the US economy, to assess the efficiency of quantitative easing in reducing the financial crisis. In particular, the non-linear dimension of our model allows us to capture the time dimension of the financial crisis, making it possible to study the effects of quantitative easing not only on the magnitude of the crisis (as already documented in the literature), but also on the duration of the crisis.

### **Our main analytical contributions can be listed as follows:**

*A non-linear framework where the economy can endogenously shift between normal times and financial crisis times.* We introduce a quantitative credit constraint on banks' balance sheet à la Gertler and Karadi (2011) in a financial accelerator model à la Bernanke et al. (1999). The quantitative credit constraint is only binding if the economy is impacted by a financial or real shock large enough. In this situation, banks can not supply enough credit to meet the demand from the productive sector. This situation of loan shortage

creates a dramatic increase of the interest rate on new loans, insuring the loan market equilibrium. The rest of the time, the credit constraint is slack: Banks can offer credit freely because the loan demand from the productive sector is inferior to the maximal amount they can lend. While the steady-state of the economy lies in normal times, a financial shock large enough can trigger the credit constraint and bring the economy to financial crisis times. After a certain number of periods, the economy goes back to normal times, and then to the equilibrium. We use the method developed in Guerrieri and Iacoviello (2015) to build what the authors call a “piecewise-linear model”, which is a close approximation of a non-linear model for small realizations of exogenous shocks. However, the model is difficult to estimate because of the non-linear nature of the credit constraint.

*A state dependent unconventional monetary policy.* We make the assumption that there is some room for unconventional monetary policy only in financial crisis times (we check the empirical relevance of this assumption in the third chapter). We build in this model a quantitative easing policy close to Gertler and Karadi (2011). When financial disruption occurs, the central bank lends credit directly to the private sector, bypassing the banking sector which is constrained on the quantity of loans it can provide. Using the words of Gertler and Karadi (2011), we will refer to this specific type of quantitative easing as “credit policy”. We depart from Gertler and Karadi (2011) in the setting of the credit policy rule, as we link the size of credit policy with the magnitude of the crisis. As a consequence, when there is no crisis (in normal times), there is no credit policy.

**Our main results can be listed as follows:**

*A credit policy decreases the magnitude of the financial crisis, but increases its duration.* As the central bank’s credit policy consists in lending directly to the non-banking private sector, it lightens the quantitative constraint on banks, which decreases the interest rate on loans. As the interest rate on loans decreases, the loan demand from entrepreneurs increases, which, as it cannot be directly satisfied, is reported along a greater number of periods.

For reasonable values of the model parameters, when considering the cumulated effects of a credit policy on welfare over time, we find that *credit policy is always welfare-improving despite its opposite effects* on the magnitude and duration of the financial crisis.

*Variations in some of the model parameters can considerably reduce the efficiency of a credit policy.* For example, if the leverage effect between entrepreneurs resources and their loan demand increases, entrepreneurs use more credit to acquire productive capital, which increases the crisis duration effect associated to the conduct of a credit policy.

In the second chapter, we use an two-country DSGE model, calibrated on core and peripheral countries of the Eurozone, to investigate the question of the impacts of homogeneous and heterogeneous credit policies on a heterogeneous monetary union, and more specifically a monetary union with heterogeneous financial sectors. We extend the non-linear framework of the previous chapter to a two-country framework, which means that each country can potentially be subject to financial disruption, even if the neighbor country is in the opposite situation.

**Our main analytical contributions can be listed as follows:**

*The introduction of an occasionally binding credit constraint in an open economy framework,* and more specifically in a two-country monetary union. This framework allows us to study the transmission effects of the financial crisis between the two countries for different degrees of financial integration and different types of credit policies. As the ECB status forbid it to focus its interventions on some countries' financial markets to deal with country-specific factors, an interesting question is, what are the output losses, in terms of opportunity cost, generated by the conduct of a second-best credit policy, and what is the impact of financial integration on the size of this output losses? We can also address the question of the inequalities effects between the two groups of countries arising from the conduct of second-best credit policy?

*The distinction between homogeneous and heterogeneous credit policy.* Credit policy is still built in the same spirit as in Gertler and Karadi (2011). A homogeneous credit policy consists in delivering the same quantity of credit to each country, this total quantity of credit delivered being determined by a mean of total financial disruption in the Eurozone. A heterogeneous credit policy consists in delivering credit to each country according to its specific needs, i.e. the magnitude of financial disruption is the country.

**Our main results can be listed as follows:**

*Cross-border lending is the main transmission channel of financial disruption events between countries.* When peripheral countries of the Eurozone are hit by a shock on their financial sector, if there is cross-border lending, entrepreneurs from the periphery have the possibility to increase their borrowing from core banks in order to face the situation of loan shortage in the peripheral banking system. If there is a high degree of financial integration between core and periphery, peripheral entrepreneurs have the technical possibility to buy important amounts of loans in core banks in order to face the loan shortage situation, which can potentially trigger the saturation of the credit constraint in core countries too, and thus results in a transmission of the financial disruption event between countries. So financial integration smoothes the financial crisis between Eurozone members.

*For realistic values of financial integration, a financial shock in peripheral countries can spread towards core countries.*

*Cross-border lending has ambiguous macroeconomic effects on the overall Eurozone.* While financial integration dampens the initial effects of the shock on peripheral countries, by allowing entrepreneurs to borrow from abroad, it creates a recession in core countries by triggering the saturation of the core banks' credit constraint, generating a loan shortage in core countries. We find an interior solution for the optimal degree of financial integration, for which the overall macroeconomic effects of financial disruption on the Eurozone following a shock reach a minimum. This optimal degree of financial integration, being close to the one observed in the data, seems to be a realistic target for public policies.

*A homogeneous credit policy, ignoring country-specific factors, is always less efficient than a heterogeneous credit policy, calibrating its assets purchases in each country according to its specific needs.*

*Credit policies decrease inequalities for low levels of financial integration but increase inequalities for high levels of financial integration.*

In the third chapter, we use a Markov-Switching VAR model based on Sims et al. (2008) estimated on Eurozone data using Bayesian techniques, with two Markov states corresponding respectively to low financial stress times and high financial stress times.



This non-linear specification allows us to investigate the relative efficiency of quantitative easing in financial crisis times and normal times, answering the question: Should unconventional monetary policies belong to the new normal of monetary policy? We add financial variables to the model in order to study the channels of action of quantitative easing on inflation and activity.

**Our main analytical contributions can be listed as follows:**

*The inclusion of quantitative easing variables in a MS-VAR model.* It allows us to estimate the impact of quantitative easing in macroeconomic and financial variables, both in crisis times and in normal times. We introduce two quantitative easing variables, accounting for the two main sources of variation in the ECB's balance sheet since 2007: Securities purchased by the ECB in the context of the Large Scale Asset Purchase Program since July 2009, and Longer-Term Refinancing Operations (LTROs), used as an unconventional monetary policy tool by the ECB since September 2007.

*The estimation of a non-linear VAR model investigating monetary policy relations using Eurozone data.* We are able to capture the non-linearities in the reaction of macroeconomic and financial variables of the Eurozone to the ECB monetary policy, depending on the level of financial stress in the Eurozone.

*The introduction of Generalized Impulse Response Functions to deal with non-linearities in the reaction function of macroeconomic and financial variables to monetary policy.* As the model can endogenously shift from one period to another from a low-financial stress regime to a high-financial stress regime, traditional Impulse Response Functions (IRFs) are biased as they fail to include this shifting probability when simulating the impact of exogenous structural shocks on variables trajectory after the end of the estimation period. Karamé (2010) adapts the GIRF methodology to the case of Markov-Switching VAR models. Using it allows us to deal with non-linearities when simulating the impact of a structural shock on macroeconomic and financial variables.

**Our main results can be listed as follows:**

*While securities purchases are efficient only in high-financial stress periods, LTROs are efficient in both high and low-financial stress periods, even they are clearly more efficient in high-financial stress periods.* This can be explained by the fact that LTROs, being exclusively composed of long-term loans from the central bank to commercial banks,

have strong effects through the Portfolio Substitution Channel, and that this channel is still active even in low-financial stress periods (unlike the Bank Funding Channel).

*Even during high-financial stress periods, LTROs are more efficient in supporting economic activity and fighting against deflation than securities purchases.* Indeed, as Longer-Term Refinancing Operations allow banks not only to have access to liquidity but also to benefit from looser collateral constraints, they are more efficient in restoring credit supply, and thus reviving economic activity. According to Jäger and Grigoriadis (2017), the difference on the magnitude of effects can also be explained if we take into account the heterogeneities between Eurozone's members, by differences between distributional effects.

*The higher efficiency of LTROs comes with a potential increase of systemic risk, generated by the flexibility of collateral constraints giving access to liquidity.*



# Chapter 1

## Financial Disruption and State Dependent Credit Policy

### 1 Introduction

The financial crisis that erupted in 2007 has deeply modified the nature of monetary policy in developed countries. The initial financial disruption that affected the loan market, followed by the sharp decrease of the official interest rate down to the Zero Lower Bound, made the usual monetary transmission mechanism ineffective. These phenomena led most central banks to adopt unconventional monetary policy practices to provide liquidity to the economy.

Although such unconventional measures were necessary at short notice to avoid a generalized collapse of the financial system and to dampen the macroeconomic effects of the financial crisis, they are still part of today's monetary policy. This situation raises questions. First, what should be the required length of unconventional policy measures? The temporary nature of these policies has regularly been emphasized over the last decade and, we now seem to be at a point where some central banks, such as the Federal Reserve or the Bank of England begin the process of reversing loose monetary policy decisions to go back to more conventional practices. A second main question concerns the medium run consequences of the enduring conduct of unconventional policy

decisions. The extension for a longer time period of unconventional measures based on quantitative easing creates new distortions in the economy. As underlined by Ben Bernanke at Jackson Hole in 2012, “While there is substantial evidence that the Federal Reserve’s asset purchases have lowered longer-term yields and eased broader financial conditions, obtaining precise estimates of the effects of these operations on the broader economy is inherently difficult, as the counterfactual – how the economy would have performed in the absence of the Federal Reserve’s actions - cannot be directly observed.”

Ten years after the Lehman-Brother collapse, the unwinding of unconventional policy measures is now on the agenda. However, apart a few papers, the theoretical literature devoted to the assessment of unconventional monetary policies that follows Gertler and Karadi (2011), considers the adoption of such measures as belonging to the "new normal" of monetary policy. Noticeably, only a very small number of papers have proposed analytical frameworks to study the exit from these policies. This chapter contributes to this strand of the literature by analyzing the state dependent nature of unconventional policy measures related to a financial disruption. Although the reaction of central banks over the last decade has targeted different objectives, this chapter concentrates more particularly on the link between unconventional policy decisions and financial intermediation disruption. This focus accounts for a main stylized fact: In the wake of the crisis, many commercial banks were affected by a sharp deterioration of their balance sheet and restricted the supply of loans, being concerned about their ability to refinance themselves. Fears that commercial banks were keeping funds to improve their liquidity rather than lending to the private sector, led central banks to intervene with the direct provision of credit to restore the functioning of the loan market.

The objective of this chapter is twofold. First, we provide a compact approach to describe how negative financial shocks transmit to the economy by generating a shortened provision of loans which endogenously determines the length of the stressed situation. Second, we evaluate the effect of credit policies aimed at restoring a normal functioning of the financial sector, accounting for their two effects, both on the length and on the magnitude of financial crisis.

Our results are three. First, in line with the existing literature, we find that unconventional monetary policy measures significantly reduce the negative consequences of a

financial crisis on the main aggregates of the economy in the short run. However adopting such measures may generate a longer period of stress on the loan market: When the central bank delivers credit directly to the private sector, this quantitative decision has a further effect on the interest rate on loans that decreases, thus marginally increasing loan demand more than proportionally with respect to loan supply, and delaying the transition back to normal times. Second, accounting for the joint effect of shocks on the length of the stressed period and on the fluctuation of activity in the transitory period back to normal times, we assess the interest of conducting credit policy measures. We find that in the medium run, the positive effect of this policy requires some qualification as part of its positive effects may vanish when firms are heavily leveraged. Third, extending our analysis to the Zero Lower Bound situation we find that credit policy is helpful not only for dampening the negative macroeconomic effects of the financial disruption, but also suppresses the Zero Lower Bound phenomenon, which gives the control of interest rates back to the central bank.

The rest of the chapter is organized as follows. Section 2 presents the policy and theoretical backgrounds of our analysis. Section 3 presents the loan market equilibrium. Section 4 describes the non financial part of the model. Section 5 is devoted to the calibration of the model and to the analysis of the effect of endogenous quantitative lending shortage on the dynamics of the economy. Section 6 evaluates the consequences of a credit policy implemented according to a state dependent dimension. Section 7 analyses the Zero Lower Bound situation. Section 8 concludes.

## **2 Background**

### **2.1 Policy Background**

The conventional approach to monetary policy that characterized the "great moderation" (1985-2007) rests on the setting of short term interest rates through open market operations. The financial crisis that erupted in 2007 sharply affected this operational framework. On the one side, emergency measures adopted by the Federal Reserve led to a sharp reduction in the interest rate that hit the zero lower bound a few months later. On the

other side, the banking sector shortened loan supply for liquidity reasons, thus introducing a disconnection between policy and market rates. To overcome these consequences of financial disruption and the problem of the transmission of monetary policy decisions through conventional channels, most central banks embarked in the implementation of policies focussing on the quantity rather than on the price of liquidity.

Unconventional monetary policy encompasses a wide array of procedures - ranging from an unconventional use of conventional instruments to the development of new practices - with the common objective of overcoming the inefficiency of conventional practices based on the manipulation of the short term interest rate. Unconventional policy tools can broadly be divided into three categories: Quantitative Easing (QE), Targeted Asset Purchases (TAP), and Forward Guidance (FG). QE involves an expansion of the central bank's balance sheet while TAP involves a change in the mix of central bank assets—keeping the balance sheet scale and supply of reserves unchanged—in order to alter the relative prices of different assets. FG is a form of communication by the central bank about its future policy rate path.

As an example, Figure 1.1 presents the measures undertaken by the Federal Reserve and the consequences on its balance sheet.<sup>1</sup> The three main measures adopted to address the problem of the financial crisis were direct lending to financial institutions, mortgage-backed securities purchases, and long term treasury purchases.

As summarized by Joyce and al. (2012), the efficacy of such measures rests on two channels. First, the portfolio substitution channel aims at affecting the interest rates of the different assets, as the direct buying of assets by the central bank affects their relative yield through their relative availability.<sup>2</sup> By focusing on a specific segment of the yield curve (e.g. Long Term Treasury Purchases (LTTP)) they can lead to a decrease of long term interest rates even if the short term interest rates are set at the Zero Lower Bound. Second, the bank funding channel aims at providing direct credit to the non financial pri-

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1. By undertaking these unconventional policy measures, the central bank expands its balance sheet and shifts the portfolio mix of assets held by the private sector who comes to hold more claims on the central bank (e.g money) and fewer of the claims that the central bank has acquired (e.g mortgage-backed securities purchases). Thus, the central bank's balance sheet rises.

2. For an analysis of this channel, see for example Vayanos and Villa (2009), Gagnon et al. (2011), Chen et al. (2012).

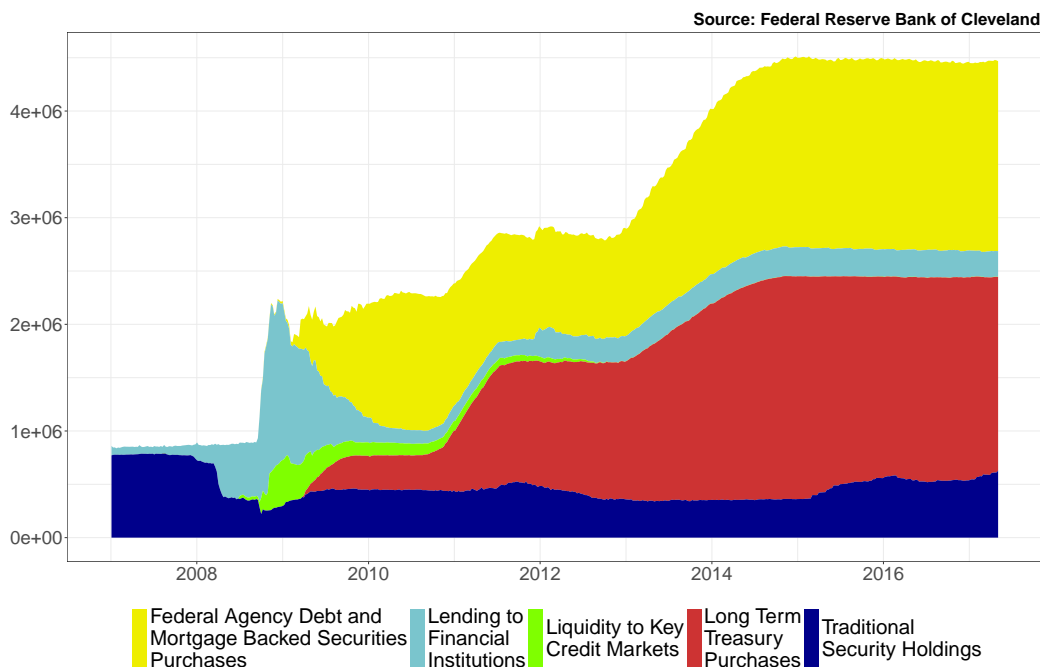


Figure 1.1: Fed's balance sheet

vate sector, in order to ease the negative effects of financial disruption on the availability of loans.<sup>3</sup> Among all the measures undertaken by the Federal Reserve, some can be more directly related to the bank funding channel such as Mortgage Backed Securities (MBS), still in effect today.

## 2.2 Relation to the literature

Our approach follows Gertler and Karadi (2011) and focuses on the MBS measures via their effect on the credit market. Gertler and Karadi (2011) set the standard framework to analyze the economic environment requiring the implementation of unconventional policy measures. They provide a DSGE model with financial intermediaries facing en-

3. See for example Gertler and Karadi (2011 and 2013), Gertler and Kiyotaki (2010), Dedola and Lombardo (2012), Dedola and al (2013), Curdia and Woodford (2009), Eggertsson and Woodford (2003), Kiyotaki and Moore (2012).



dogenuously determined balance sheet constraints. In their model, the deterioration in the financial positions of financial intermediaries leads to a disruption in the flow of funds between lenders and borrowers. Unconventional monetary policy is modelled as an expansion of central bank credit intermediation needed to offset a disruption of private financial intermediation and improve the economic situation.

This framework has furthermore been extended to more complex policy environments. Gertler and Karadi (2013) assess the consequences of Large Scale Asset Purchases (LSAP) such as the ones implemented by the Federal Reserve. They study the consequences of purchases of both long term government bonds (i.e. long term treasury purchases) and securities with some private risks (i.e. mortgage backed securities purchases). As a main result they find that the latter policy has stronger effects and that these benefits may be significantly enhanced if the zero lower bound bites. Dedola and al. (2013) extend the model to the international environment and show how financial integration makes bank balance sheet constraints highly correlated across countries. In this environment, unconventional policies aimed at stabilizing domestic financial and credit conditions could entail large international spillovers and stabilization by one country will also benefit other countries, reducing incentives to implement credit policies in a classic free-riding problem.

As a main point of departure from the above literature, we do not consider these policies as a permanent component of the "new normal" monetary policy framework. We model unconventional monetary decisions as a particular policy outcome related to a temporary situation of financial crisis characterized by a disruption in the flow of funds between lenders and borrowers.

Only a very small number of papers have proposed an analytical framework to study the unwinding of unconventional monetary policies. To our knowledge, Angeloni and al. (2015) is the first paper to assess the key role of exit strategies from accommodating monetary and fiscal policies. They show that reversing a loose conventional monetary policy may confront policy makers with more serious and enduring problems than the crisis itself. In particular fiscal adjustment is heavily influenced by the timing and modality of monetary exit, but the reverse is also true, because fiscal consolidation will affect a number of macro-variables that are taken into account by central bankers. Foerster (2015)

departs from this analysis as he neglects fiscal policy issues and focuses on the exit from unconventional monetary policies based on asset purchases. His paper addresses the issue of a central bank exiting from its large balance sheet, and how the strategy for unwinding its asset position affects the balance sheets of the financial sector and ultimately the macroeconomy. He shows that a double-dip recession ensues a quick unwinding of assets by the central bank, while a slow policy reversal generates a smooth recovery by keeping asset values elevated.

We offer some main novelties with regard to the existing analyses of temporary unconventional policy measures. First, as in Foerster (2015) we concentrate on monetary policy and we build a model where the crisis situation is a particular regime that can be contrasted to normal times. However, we depart from his analysis by considering that the triggering and the length of the crisis period are endogenously determined, whereas in his model the duration of the crisis is exogenously determined by the given probability of transition between regimes, with the duration and unwinding of unconventional policy measures being choice variables for the regulator. Second, in contrast with Angeloni and al. (2015) and Foerster (2015), we define the financial crisis as a transitory situation of loan supply shortage, with loan supply from banks not able to meet the loan demand anymore. In normal times, the banking system sets the loan interest rate, with a margin over the policy rate, and the quantity of loans is determined on the demand side given this interest rate.<sup>4</sup> In crisis times, the provision of loans is constrained by the banking system and loan demand is shortened.<sup>5</sup> Thus in our analysis, the unwinding of unconventional policy ends when the economy returns to normal times.

### 3 Loan market equilibrium

This section introduces the main contribution of the analysis regarding the demand and supply of loans and the setting of loan interest rates in the economy. We more particularly focus on the behavior of entrepreneurs (on the borrowing side) and financial intermedi-

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4. For the specification of our model in normal times, we follow closely Poutineau and Vermandel (2015), in line with the main concept of borrowing accelerator from Bernanke, Gertler and Gilchrist (1999)

5. For our model in crisis times, we follow Gertler and Karadi (2011)

aries (on the lending side). The non financial part of the model is presented in the next section.

### 3.1 Loan market equilibrium in a nutshell

In the economy, loan demand emanates from entrepreneurs. Entrepreneurs finance investment projects decided by firms with their wealth and loans.<sup>6</sup> The number of entrepreneurs is normalized to 1. As in Poutineau and Vermandel (2015), the representative entrepreneur  $e \in [0, 1]$  finances the capital renting of intermediate firms. In period  $t$ , this entrepreneur conducts a great number of heterogeneous projects with total value  $Q_t K_{t+1}(e)$ , where  $Q_t$  is the price of capital and  $K_{t+1}(e)$  is the amount of capital financed. These projects are financed by his net wealth  $N_t^E(e)$  and by loans contracted from the banking system  $L_t^D(e)$ . The balance sheet of the representative entrepreneur is determined by,  $Q_t K_{t+1}(e) = N_t^E(e) + L_t^D(e)$  and, as he finances projects in proportion of his net wealth, the value of capital he finances is proportional to his net wealth,  $Q_t K_{t+1}(e) = \phi_t^E(e) N_t^E(e)$ , where  $\phi_t^E(e) > 1$  is the entrepreneur's accelerator - or borrowing accelerator - while the entrepreneur's loan demand is defined as,

$$L_t^D(e) = (\phi_t^E(e) - 1) N_t^E(e). \quad (1.1)$$

Here, the higher his net wealth, the greater is the quantity of loans he may obtain. Both the quantity of loans subscribed and the amount of capital financed by the entrepreneur depend on the expected profitability of investment projects through the variable  $\phi_t^E(e)$  defined as,

$$\phi_t^E(e) \equiv \left[ 1 - \frac{\kappa - 1}{\kappa} \left( \frac{\mathbb{E}_t [R_{t+1}^k] \gamma^{1-\chi^E}}{R_t^L e^{\varepsilon_t^{opt}}} \right)^{\frac{1}{\chi^E}} \right]^{-1}, \quad (1.2)$$

where  $\varepsilon_t^{opt}$  is an  $AR(1)$  shock on entrepreneurs optimism. The size of the borrowing accelerator - captured by  $\phi_t^E(e)$  - is determined by the external finance premium  $\frac{\mathbb{E}_t [R_{t+1}^k]}{R_t^L}$ , with elasticity  $\chi^E$ . The external financial premium corresponds to the ratio between the expected rentability of productive capital  $\mathbb{E}_t [R_{t+1}^k]$  gained by entrepreneurs on the

6. We provide an extended analysis of entrepreneur's choices in Appendix A.

capital they rent to productive firms, and the loan interest rate ( $R_t^L$ ) charged by banks on the loans contracted by entrepreneurs in order to purchase their productive capital. The higher the external finance premium, the more the entrepreneurs are able to acquire productive capital in proportion to their net wealth, by borrowing from banks. This phenomenon is observed for values of  $\varkappa^E > 0$ , and disappears for  $\varkappa^E = 0$ . Finally, the net wealth of the entrepreneur that enters the loan demand function is equal to  $N_t^E(e) = (1 - \tau^E) \Pi_t^E(e)$ , where  $\tau^E$  is a proportional tax on the profits and  $\Pi_t^E(e)$  the entrepreneur profit.

On the other side of the market, the representative financial intermediary  $b \in [0, 1]$  (the total number of banks is normalized to 1) provides loans to entrepreneurs using resources obtained from the deposits of the households  $B_{t+1}(b)$  and from its net wealth  $N_t^B(b)$ , so its balance sheet is determined by,  $L_t^S(b) = N_t^B(b) + B_{t+1}(b)$ , with  $L_t^S(b)$  the amount of loans supplied by the bank.<sup>7</sup> Banks are subject to an occasionally binding credit constraint on the maximum amount they can lend ( $L_t^{S,\max}(b)$ ). This maximum amount is determined as a function of their net wealth and a lending accelerator  $\phi_t^B(b)$  as,  $L_t^{S,\max}(b) = \phi_t^B(b) N_t^B(b)$ . The nature of this lending accelerator is detailed in section 3.3.

The resource situation of banks affects the equilibrium on the loan market. In "normal times", financial intermediaries are not constrained and they have enough resources to meet the quantity of loans demanded by entrepreneurs (i.e.,  $L_t^D \leq L_t^{S,\max}$ ). In "crisis times", banks have trouble to get enough resources to create as much loans as demanded by entrepreneurs (either because of a drop in the amount of deposits or a decrease in their capital value following an adverse financial shock), and restrict their supply of loans to  $L_t^{S,\max}$ . In this situation the notional demand for loans emanating from entrepreneurs is not met. So the situation on the credit market can be summarized by the following system,

$$\begin{cases} L_t \leq L_t^{S,\max} & \text{if } L_t^{D,n} \leq L_t^{S,\max} \text{ (normal times),} \\ L_t = L_t^{S,\max} & \text{if } L_t^{D,n} > L_t^{S,\max} \text{ (crisis times),} \end{cases}$$

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7. As in the original setting of Gertler and Karadi (2011), banks are owned by households (see the next section) and the landlord of the bank cannot put deposits in his bank.

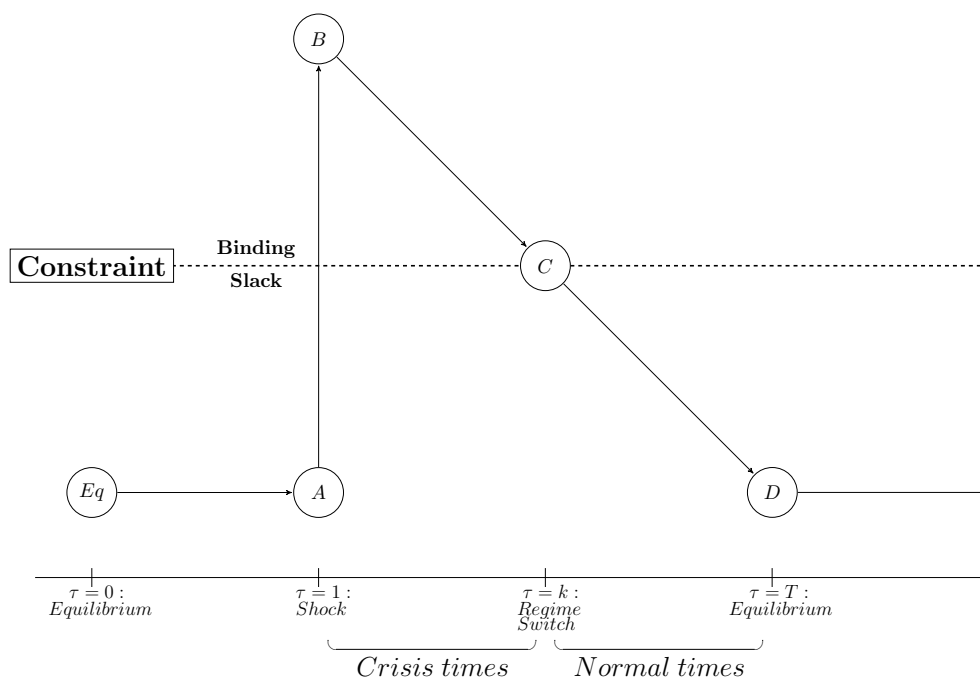


Figure 1.2: Dynamic constraint

where  $L_t^{D,n}$  is the notional demand for loans, i.e. the demand for loans that would be observed in the economy if there was no credit constraint, and  $L_t$  is the effective quantity of credit in the economy at the equilibrium on the credit market, i.e. the quantity that meets  $L_t^S = L_t^D$ . If the notional loan demand from entrepreneurs is smaller than the maximal amount of loans banks can offer, then the quantity of loans in the economy is not constrained. If the notional loan demand from entrepreneurs is higher than the maximal amount of loans bank can offer, then the quantity of loans in the economy becomes constrained.

In our analysis exogenous shocks affect the situation of the banking system and may move the economy from a normal time equilibrium to a crisis time equilibrium through their effect on the resources of the banking system. As illustrated in Figure 1.2, the analy-

sis conveyed in this chapter can be summarized as follows: In period  $t = 0$ , the economy initially lies on its steady state. In contrast with Gertler and Karadi (2011), the steady state is computed for normal times (i.e., a situation with a loose constraint on loan creation). In period  $t = 1$ , exogenous shocks may trigger a financial disruption in the economy, leading to a provision of loans smaller than the amount required by the non-financial sector of the economy. The economy thus immediately moves from A to B, towards a crisis time period where the notional loan demand emanating from the private sector is not entirely met. During this crisis period (between points B and C), the central bank may undertake unconventional policy decisions taking the form of a credit policy such as the one described in Gertler and Karadi (2011). As reported in the figure, the length of the crisis period (that corresponds to a constrained equilibrium on the loan market) is endogenously determined in the model and the economy goes back to normal times in period  $t = k$  (that corresponds to an interior equilibrium of the loan market). Finally the economy goes back to its steady state (from point C to D) reached in period  $t = T$ .

As underlined by Figure 1.2, the implementation of unconventional policy measures is state dependent. The central bank is able to conduct such policy measures during the crisis period and these actions are no longer part of the new normal when the economy goes back to an interior equilibrium of the loan market. Thus, during the transition of the economy back to the steady state between  $t = k$  and  $t = T$ , the central bank moves back to the implementation of conventional policy decisions. As the equilibrium of the loan market plays a key role in both the adoption and the unwinding of credit policy the rest of the section formally describes how the resource constraint of financial intermediaries shapes the solution procedure.

### 3.2 Normal times

The representative bank  $b \in [0, 1]$  operates in a regime of monopolistic competition to provide deposit and credit services to households and firms. Each period, the bank collects deposits  $B_{t+1}(b)$  from households remunerated at the risk free real interest rate  $R_t$ , and supplies loans  $L_t^S(b)$  to entrepreneurs whose rate is  $R_t^L(b)$ . In providing resources to the banking system, households are faced with a problem of moral hazard. Banks may decide

to divert a fraction  $\lambda_t$  of their resources and transfer this back to the household of which it is a member. Depositors can force the intermediary to go bankrupt and they recover the remaining fraction  $(1 - \lambda_t)$  of assets. We assume that  $\lambda_t = \lambda e^{\varepsilon_t^\lambda}$ , with  $\varepsilon_t^\lambda \sim AR(1)$ . This moral hazard problem may lead depositors to shrink the quantity of resources needed by the banking system. This, in turn, induces quantitative restrictions in the provision of loans from banks to entrepreneurs. For lenders to be willing to supply funds to the banker, the following incentive constraint must be satisfied,  $V_t(b) \geq \lambda_t L_t^S(b)$ , where  $V_t(b)$  is the expected discounted intertemporal profit of the bank in all his remaining periods of activity. The constraint states that households accept to hold deposits  $B_{t+1}(b)$  at the bank only until they reach a maximum amount of deposits for which the bank is indifferent between continuing his activity of lender and going into bankruptcy by diverting a fraction  $\lambda_t$  of his resources  $L_t^S(b) = N_t^B(b) + B_{t+1}(b)$  normally used for lending.<sup>8</sup>

In normal times, this incentive constraint is checked and the banking system has no trouble to get resources from households to create loans. In this interior solution, the total amount of loans intermediated by the banking system depends on the quantity of loans demanded by entrepreneurs. The setting of the loan interest rate in normal times is intended to maximize the expected profit of the bank that takes into account the possibility of entrepreneurs to fail to pay back their loans (with probability  $E_t[\eta_{t+1}^E]$ ),

$$\begin{aligned} \Pi_{t+1}^B(b) &= (1 - \tau^B) E_t[\eta_{t+1}^E] R_t^L(b) L_t^S(b) - R_t B_{t+1}(b) \\ &= ((1 - \tau^B) E_t[\eta_{t+1}^E] R_t^L(b) - R_t) L_t^S(b) + R_t N_t^B(b), \end{aligned} \quad (1.3)$$

with  $\tau^B$  a tax on bank profit.<sup>9</sup> Finally, the value of bank assets is determined by its profit, as,

$$N_t^B(b) = \frac{((1 - \tau^B) \eta_t^E R_{t-1}^L(b) - R_{t-1}) L_{t-1}^S(b) + R_{t-1} N_{t-1}^B(b)}{e^{\varepsilon_t^{NB}}}, \quad (1.4)$$

where  $\varepsilon_t^{NB} \sim N(0, \sigma_{\varepsilon^{NB}})$ , represents an exogenous shock on bank net wealth. As banks are in a situation of monopolistic competition, they can raise their price above their

8. More details about this constraint are provided in the next subsection.

9. As Benigno and Woodford (2005), we introduce a proportional tax  $\tau^B$  on profits that restores the first-best allocation in the steady state.

marginal cost of production,

$$R_t^L(b) = R_t^L = \frac{1}{1 - \tau^B} \frac{\varepsilon^B}{\varepsilon^B - 1} \frac{R_t}{E_t [\eta_{t+1}^E]}, \quad (1.5)$$

where  $\varepsilon^B$  is the elasticity of substitution between different types of loans.<sup>10</sup>

In normal times the amount of loans is determined by loan demand given the interest rate set by the banking system. Imposing symmetry between all entrepreneurs and between all banks, and defining  $L_t^D$  as the total amount of loans demanded in the economy (namely,  $L_t^D = Q_t K_{t+1} - N_t^E$ ), the quantity of loans supplied by the representative bank is  $L_t^S = L_t^D$ . In normal times, the quantity of loans that is contracted corresponds to the loan demand of entrepreneurs given the interest rate on loans,

$$L_t = (\phi_t^E - 1) N_t^E, \quad (1.6)$$

where the interest rate on loans affects the value of  $\phi_t^E$ .

### 3.3 Crisis times

The crisis is driven by exogenous shocks that affect the ability of the banking system to create loans. This shortage of resources can come either from less deposits or from a collapse in the capital value of the banking system. Since the resource constraint of banks bites, the amount of loans created corresponds to  $L_t^{S,\max}$ .

The computation of this loan ceiling  $L_t^{S,\max}$  follows Gertler and Karadi (2011). Each period a constant fraction  $(1 - \theta)$  of banks exits the market and is replaced by the same number of new banks.<sup>11</sup> At the end of its life, the bank gives back the amount of wealth it has accumulated through its activity to its landlord. The representative bank  $b$  thus

10. More details regarding the computation of bank marginal cost are provided in Appendix B.

11. This assumption is required to avoid an infinite expansion of bank assets, that would allow financial intermediaries to issue loans without the need of deposits.



maximizes its expected terminal wealth,

$$V_t(b) = \max E_t \sum_{\tau=0}^{\infty} (1 - \theta) \theta^\tau \beta^{\tau+1} \Lambda_{t,t+1+\tau} (N_{t+1+\tau}^B(b)), \quad (1.7)$$

where the discount rate  $(1 - \theta) \theta^\tau \beta^{\tau+1} E_t [\Lambda_{t,t+1+\tau}]$  accounts for the survival rate of the bank and the marginal rate of intertemporal substitution between  $t$  and  $t + 1 + \tau$  ( $\beta^{\tau+1} E_t [\Lambda_{t,t+1+\tau}]$ ), so as its surplus can be expressed in terms of marginal utility of consumption. The maximum amount of loan creation is determined by the binding of the incentive constraint  $V_t(b) \geq \lambda_t L_t^S(b)$ , so that,

$$L_t^S(b)^{\max} \equiv \frac{V_t(b)}{\lambda_t}, \quad (1.8)$$

i.e., the total amount of loans intermediated by the representative bank depends on its expected terminal wealth  $V_t(b)$  that can be expressed as,

$$V_t(b) = \nu_t(b) L_t^S(b) + \eta_t(b) N_t^B(b), \quad (1.9)$$

with,  $\nu_t(b) = E_t \left[ (1 - \theta) \beta \Lambda_{t,t+1} \left( (1 - \tau^B) \eta_{t+1}^E R_t^L(b) - R_t \right) + \Lambda_{t,t+1} \theta \beta \frac{L_{t+1}^S(b)}{L_t^S(b)} \nu_{t+1}(b) \right]$ , and  $\eta_t(b) = E_t \left[ (1 - \theta) \beta \Lambda_{t,t+1} R_{t+1} + \Lambda_{t,t+1} \theta \beta \frac{N_{t+1}^B(b)}{N_t^B(b)} \eta_{t+1}(b) \right]$ . Collecting terms, in crisis times the amount of loans provided by the banks depends on its net wealth,

$$L_t^S(b) = L_t^S(b)^{\max} = \phi_t^B(b) N_t^B(b), \quad (1.10)$$

with,  $\phi_t^B(b) \equiv \frac{\eta_t(b)}{\lambda_t - \nu_t(b)}$  features the lending accelerator.

In this situation, the interest rate on loans ( $R_t^L$ ) becomes a jump variable determined at the market level to force demand to equalize loan supply. Imposing symmetry between all entrepreneurs and between all banks,  $R_t^L$  solves,

$$\phi_t^B N_t^B = (\phi_t^E - 1) N_t^E, \quad (1.11)$$

with,

$$\begin{aligned}\phi_t^B &\equiv \frac{\eta_t}{\lambda_t - \nu_t}, \\ N_t^B &= \theta \left[ ((1 - \tau^B) \eta_t^E R_{t-1}^L - R_{t-1}) L_{t-1}^S + R_{t-1} N_{t-1}^B \right] / e^{\varepsilon_t^{NB}} + \omega L_{t-1}^S, \\ \phi_{t+1}^E &\equiv \left[ 1 - \frac{\kappa - 1}{\kappa} \left( \frac{E_t [R_{t+1}^k]}{R_t^L} \gamma^{1-\chi^E} \right)^{\frac{1}{\chi^E}} \right]^{-1}, \\ N_{t+1}^E &= (1 - \tau^E) \Pi_t^E.\end{aligned}$$

In this expressions,  $\theta \left[ ((1 - \tau^B) \eta_t^E R_{t-1}^L - R_{t-1}) L_{t-1}^S + R_{t-1} N_{t-1}^B \right] / e^{\varepsilon_t^{NB}}$  is the aggregate net wealth of bankers that already existed at period  $t - 1$ , and  $\omega L_{t-1}^S$  is the aggregate net wealth of new bankers, with  $\frac{\omega}{1-\theta}$  the fraction of the total final period assets of exiting bankers at period  $t - 1$  ( $(1 - \theta) L_{t-1}^S$ ) transferred by the households to the new bankers.<sup>12</sup> In crisis times, loan market tightness can be measured as follows: The interest rate that balances the loan market can be written as  $R_t^L$  with,

$$R_t^L = \frac{1}{1 - \tau^B} \frac{R_t + \zeta_t}{E_t [\eta_{t+1}^E]}, \quad (1.12)$$

where  $\zeta_t > 0$  measures the tightness of the loan market.<sup>13</sup> Defining  $R_t^{L,S}$  as the shadow value of the loan interest rate, i.e. the value that the loan interest rate would have taken if the banks were not subject to a financial constraint we get,

$$R_t^L - R_t^{L,S} = \frac{1}{1 - \tau^B} \frac{R_t + \zeta_t}{E_t [\eta_{t+1}^E]} - \frac{1}{1 - \tau^B} \frac{R_t}{E_t [\eta_{t+1}^E]}. \quad (1.13)$$

Rearranging this expression, the tightness of the loan market,  $\zeta_t$ , is defined as,

$$\zeta_t = (1 - \tau^B) E_t [\eta_{t+1}^E] (R_t^L - R_t^{L,S}). \quad (1.14)$$

12. Gertler and Karadi (2011) use this way to close the system.

13. See Appendix B for more details in the computation of the interest rate on loans from a maximization program of bank's profit with an occasionally binding constraint on their leverage ratio.

To summarize, in normal times,  $\zeta_t = 0$ , as the interest rate that balances the loan market corresponds to the interest rate set that would have prevailed without the existence of the credit constraint (i.e.,  $R_t^{L,S} = R_t^L$ ). In crisis times,  $\zeta_t > 0$ , as the tightness of the loan market is proportional to the interest rate spread between the interest rate on loans that balances loan supply and demand and the interest that would have been set by the banking system without the credit constraint. This variable will be used as an indicator to characterize the situation of the loan market and the policy to be adopted (either conventional for  $\zeta_t = 0$  or combining conventional and unconventional measures for  $\zeta_t > 0$ , as long as the economy does not hit the Zero Lower Bound).

## 4 The rest of the model

The rest of the model is standard to the DSGE literature: The economy is populated by households, intermediate and final firms and capital suppliers. Households are made of workers and bankers (workers supply labor to firms, consume and save, while bankers manage financial intermediaries). Firms are made of intermediate and final sectors (the intermediate sector produces intermediate goods using capital and labor, while final firms produce final goods by combining intermediate goods and set sticky prices for these goods that are consumed by households and invested by intermediate firms). The supply and refurbishment of capital is operated by capital suppliers.

### 4.1 Households

The number of households is normalized to 1. The representative household  $j \in [0, 1]$  is made of two parts: A fraction  $(1 - f)$  of the household consumes, offers labor and saves, while a fraction  $f$  acts as a banker. Each period a fraction  $(1 - \theta)$  of bankers (thus  $(1 - \theta)f$  individuals) become workers while an equivalent number of workers become bankers, to maintain a constant proportion between the two components. New bankers are endowed with an initial amount of wealth. We define the household one period welfare as  $\Omega_t(j) \equiv \ln(C_t(j) - hC_{t-1}(j)) - \chi^C \frac{1}{1+\varphi} H_t^S(j)^{1+\varphi}$ , with  $C_t(j)$  the aggregate consumption of the household in period  $t$  and  $H_t^S(j)$  the amount of labor supplied by the household, with

$\chi^C, \varphi > 0$ . Thus we can write the intertemporal welfare of the representative household as,

$$\max_{\{C_{t+\tau}(j), H_{t+\tau}(j), B_{t+1+\tau}(j)\}} \sum_{\tau=0}^{+\infty} \beta^\tau \left[ e^{\varepsilon_t^C} \ln(C_{t+\tau}(j) - hC_{t+\tau-1}(j)) - \chi^C \frac{1}{1+\varphi} H_{t+\tau}^S(j)^{1+\varphi} \right], \quad (1.15)$$

with  $\varepsilon_t^C \sim AR(1)$ ,  $0 < \beta < 1$  and  $0 < h < 1$  a habit parameter as in Boldrin et al. (2001). The household maximizes its welfare subject to a budget constraint,

$$C_t(j) + B_{t+1}(j) + T_t(j) = W_t^h(j)H_t^S(j) + R_tB_t(j), \quad (1.16)$$

where  $W_t^h(j)$  is the real wage of the worker, and  $T_t(j)$  is the total amount of tax paid in period  $t$ . The first order conditions that solve this problem can be combined as follows,

$$\beta E_t[\Lambda_{t,t+1}(j)R_{t+1}] = 1, \quad (1.17)$$

$$\varrho_t(j)W_t^h(j) = \chi^C H_t^S(j)^\varphi, \quad (1.18)$$

with,

$$\varrho_t(j) = \frac{1}{C_t(j) - hC_{t-1}(j)} - \frac{\beta h}{E_t[C_{t+1}(j)] - hC_t(j)}, \quad (1.19)$$

$$\Lambda_{t,t+1}(j) = \frac{\varrho_{t+1}(j)}{\varrho_t(j)}, \quad (1.20)$$

where  $\varrho_t(j)$  is the marginal utility of consumption. Households provide differentiated labor types, sold by labor unions to perfectly competitive labor packers who assemble them in a CES aggregator and sell the homogeneous labor to intermediate firms. Each representative union is related to an household  $j \in [0; 1]$ . The aggregated amount of labor in the economy  $H_t$  is defined as,

$$H_t = \left[ \int_0^1 H_t^S(j)^{(\varepsilon^W - 1)/\varepsilon^W} dj \right]^{\varepsilon^W / (\varepsilon^W - 1)}, \quad (1.21)$$

where  $\varepsilon^W$  is the elasticity of substitution between differentiated types of labor. The demand for an individual type of labor is defined as,

$$H_t^S(j) = \left( \frac{W_t^h(j)}{W_t} \right)^{-\varepsilon^W} H_t, \quad (1.22)$$

where  $W_t^h(j)$  is the wage for labor of type  $j$  and,

$$W_t = \left[ \int_0^1 W_t^h(j)^{1-\varepsilon^W} dj \right]^{1/(1-\varepsilon^W)}. \quad (1.23)$$

Wage stickiness arises from the fact that each labor union cannot adjust immediately nominal wages. We assume that each labor union is able to choose an optimal wage  $W_t^{h*}(j)$  with probability  $(1 - \theta^W)$  while the remaining of workers have their wage indexed on the previous period ( $\Pi_t = \frac{P_t}{P_{t-1}}$ , with  $P_t$  the price level in the economy). As a consequence, the representative labor union chooses the optimal wage  $W_t^{h*}(j)$  to maximize its expected sum of profits defined as,

$$\max_{\{W_t^{h*}(j)\}} E_t \sum_{\tau=0}^{+\infty} (\theta^W)^\tau \beta^\tau \Lambda_{t,t+\tau}(j) \left[ \frac{W_t^{h*}(j)}{P_{t+\tau}} \prod_{k=1}^{\tau} (\Pi_{t+k-1})^{\gamma^{pw}} - \frac{W_t^h(j)}{P_{t+\tau}} \right] H_{t+\tau}^S(j), \quad (1.24)$$

subject to,  $H_{t+\tau}^S(j) = \left( \frac{W_t^{h*}(j)}{W_{t+\tau}} \prod_{k=1}^{\tau} (\Pi_{t+k-1})^{\gamma^{pw}} \right)^{-\varepsilon^W} H_{t+\tau}$ , with  $\gamma^{pw}$  featuring the indexation parameter. The first order condition that governs the dynamics of the nominal wage is,

$$E_t \sum_{\tau=0}^{+\infty} (\theta^W)^\tau \beta^\tau \Lambda_{t,t+\tau}(j) \left[ \frac{W_t^{h*}(j)}{P_{t+\tau}} \prod_{k=1}^{\tau} (\Pi_{t+k-1})^{\gamma^{pw}} - \frac{\varepsilon^W}{\varepsilon^W - 1} \frac{W_t^h(j)}{P_{t+\tau}} \right] H_{t+\tau}^S(j) = 0, \quad (1.25)$$

where  $\frac{\varepsilon^W}{\varepsilon^W - 1}$  is the mark-up on the labor market.

## 4.2 Firms and capital suppliers

The productive sector combines intermediate firms, final firms and capital suppliers. Intermediate firms produce differentiated goods  $i$ , choose labor and capital inputs, and set prices according to the Calvo (1983) model. Final goods producers act as a consumption bundler by combining intermediate goods to produce the homogeneous final good.<sup>14</sup> Capital suppliers rent and refurbish the capital stock used by intermediate firms and financed by entrepreneurs on a competitive market.

The representative intermediate firm  $i \in [0, 1]$ , produces,

$$Y_t^s(i) = e^{\varepsilon_t^a} (U_t(i) K_t(i))^\alpha H_t(i)^{1-\alpha}, \quad (1.26)$$

where  $Y_t^S(i)$  is the production function of the intermediate good that combines capital  $K_t(i)$ , labor  $H_t(i)$  and technology  $e^{\varepsilon_t^A}$  (an  $AR(1)$  productivity shock). Intermediate goods producers solve a two-stage problem. In the first stage, taking real input prices  $W_t$  and  $Z_t^k$  as given, firms rent inputs  $H_t(i)$  and  $K_t(i)$  on a perfectly competitive factors market in order to minimize costs subject to the production constraint. They pay a cost  $\Phi(U_t(i))$  for using capital. In equilibrium the marginal cost of using capital ( $\Phi'(U_t(i))$ ) is equal to the marginal return of capital ( $Z_t^k$ ).<sup>15</sup> The marginal cost of production is thus,

$$MC_t^E(i) = \alpha^{-\alpha} (1 - \alpha)^{\alpha-1} (Z_t^k)^\alpha W_t^{1-\alpha} (e^{\varepsilon_t^a})^{-1}, \quad (1.27)$$

and the average rate of capital profitability is,

$$R_{t+1}^k = \frac{[MC_{t+1}^E \alpha \frac{Y_{t+1}^s}{K_{t+1}} + (1 - \delta_c) Q_{t+1} - \Phi(U_{t+1})]}{Q_t}, \quad (1.28)$$

14. Final good producers are perfectly competitive and maximize profits,  $P_t Y_t^d - \int_0^1 P_t(i) Y_t^S(i) di$ ,  $\forall i$  (where  $P_t(i)$  is the price of good  $i$  and  $Y_t^d$  is the aggregate demand), subject to the production function  $Y_t^d = (\int_0^1 Y_t^S(i)^{(\varepsilon^E-1)/\varepsilon^E} di)^{\varepsilon^E/(\varepsilon^E-1)}$ . We find the intermediate demand functions associated with this problem,  $Y_t^S(i) = (P_t(i)/P_t)^{-\varepsilon^E} Y_t^d$ .

15. Following Poutineau et Vermandel (2015), we define  $\Phi(U_t) = \frac{1-\Psi}{\Psi} \bar{Z} [e^{\frac{\Psi}{1-\Psi}(U_t-1)} - 1]$ . Thus, we get  $Z_t^k = \Phi'(U_t) = \bar{Z} e^{\frac{\Psi}{1-\Psi}(U_t-1)}$ .

where  $\delta_c$  is the capital depreciation parameter.

Each firm  $i$  sets the price of  $Y_t^s(i)$  according to a Calvo mechanism. Each period firm  $i$  is not allowed to re optimize its price with probability  $\theta^E$ . Thus, only a fraction  $(1 - \theta^E)$  of final firms is able to set the optimal price  $P_t^*(i)$ , other prices being partially indexed on the inflation rate. The optimization program of the representative intermediate firm is thus,

$$\max_{\{P_t^*(i)\}} E_t \sum_{\tau=0}^{\infty} (\theta^E)^\tau \beta^\tau \Lambda_{t,t+\tau} \left[ \frac{P_t^*(i)}{P_{t+\tau}} \prod_{k=1}^{\tau} (\Pi_{t+k-1})^{\gamma^{pe}} - MC_{t+\tau}^E(i) \right] Y_{t+\tau}^s(i), \quad (1.29)$$

where  $\gamma^{pe} < 1$  is the indexation parameter. The first order condition is given by,

$$\sum_{\tau=0}^{\infty} (\theta^E)^\tau \beta^\tau \Lambda_{t,t+\tau} \left[ \frac{P_t^*(i)}{P_{t+\tau}} \prod_{k=1}^{\tau} (\Pi_{t+k-1})^{\gamma^{pe}} - \frac{\varepsilon^E}{\varepsilon^E - 1} MC_{t+\tau}^E(i) \right] Y_{t+\tau}^s(i) = 0. \quad (1.30)$$

Capital suppliers are homogeneous and distributed over a continuum normalized to 1. The representative capital supplier  $q \in [0, 1]$  acts competitively to supply a quantity  $K_{t+1}(q)$  of capital. He provides a capital amount of  $Q_t K_{t+1}(q)$  by renting the non depreciated capital to entrepreneurs  $(1 - \delta_c)K_{t+1}(q)$  and investing  $I_t(q)$ . Investment is costly, *i.e.* the capital supplier pays an adjustment cost on the new capital created  $I_{nt}(q) \equiv I_t(q) - \delta_c K_t(q)$ .

The representative capital supplier thus maximizes,

$$\max_{\{I_{nt+\tau}(q)\}} E_t \left\{ \sum_{\tau=0}^{\infty} \beta^\tau \Lambda_{t,t+1+\tau} \left[ \frac{(Q_{t+\tau} - 1) I_{nt+\tau}(q)}{f\left(\frac{I_{nt+\tau}(q) + \bar{I}}{I_{nt+\tau-1}(q) + \bar{I}}\right)} (I_{nt+\tau}(q) + \bar{I}) \right] \right\}, \quad (1.31)$$

with  $f\left(\frac{I_{nt}(q) + \bar{I}}{I_{nt-1}(q) + \bar{I}}\right) = \frac{\eta^I}{2} \left(\frac{I_{nt}(q) + \bar{I}}{I_{nt-1}(q) + \bar{I}} - 1\right)^2$ , where  $\eta^I$  is a scale parameter on investment costs. The first order condition associated to this program defines the renting price of

capital as,

$$Q_t = 1 + f\left(\frac{I_{nt}(q) + \bar{I}}{I_{nt-1}(q) + \bar{I}}\right) + \frac{I_{nt}(q) + \bar{I}}{I_{nt-1}(q) + \bar{I}} f'\left(\frac{I_{nt}(q) + \bar{I}}{I_{nt-1}(q) + \bar{I}}\right) - E_t \left[ \beta \Lambda_{t,t+1} \left(\frac{I_{nt}(q) + \bar{I}}{I_{nt-1}(q) + \bar{I}}\right)^2 f'\left(\frac{I_{nt}(q) + \bar{I}}{I_{nt-1}(q) + \bar{I}}\right) \right]. \quad (1.32)$$

### 4.3 Macroeconomic policies and general equilibrium

The government finances public spending by charging proportional taxes on entrepreneurs and bankers in order to compensate price distortions in the steady state. The total amount of public spending writes,  $G_t = Ge^{\varepsilon_t^g}$  where  $G$  is the steady-state level of government spending and  $\varepsilon_t^g$  is an AR(1) exogenous shock process. The budget constraint of the government is thus defined according to,

$$G_t + \tau\psi_t Q_t K_{t+1} = \int_0^1 T_t(j) dj + \tau^E \int_0^1 \Pi_t^E(e) de + \tau^B \int_0^1 E_t [\eta_{t+1}^E] R_t^L(b) L_t^S(b) db. \quad (1.33)$$

In this relation,  $\tau\psi_t Q_t K_{t+1}$  measures inefficiencies related to the cost of implementing a credit policy (assumed less efficient than loan creation by financial intermediaries, where  $\tau$  is an inefficiency parameter if the central bank intermediates funds directly, and  $\psi_t$  the fraction of loans intermediated by the central bank). The resource constraint of the economy is,

$$Y_t^d = C_t + I_t + G_t + \tau\psi_t Q_t K_{t+1} + f\left(\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}}\right) (I_{nt} + I_{ss}), \quad (1.34)$$

where  $Y_t^d$  is the aggregate demand. Capital accumulation is defined according to,

$$K_t = (1 - \delta_c) K_{t-1} + I_t. \quad (1.35)$$



In normal times, the central bank follows a standard Taylor rule policy,

$$i_t = \frac{1}{\beta} (\Pi_t)^{\phi_\pi} \left( \frac{Y_t}{Y_t^n} \right)^{\phi_y} e^{\varepsilon_t^i}, \quad (1.36)$$

where  $\varepsilon_t^i \sim N(0, \sigma_{\varepsilon^i})$ , is a conventional monetary policy shock,  $i_t$  is the nominal interest rate, and  $Y_t^n$  the natural GDP, so that  $\frac{Y_t}{Y_t^n}$  is the output gap. There is no persistence in the interest rate rule, as following Gertler and Karadi (2011) we consider that in a crisis situation the central bank does react in a flexible way to the economic conditions it faces. Accounting for the possibility of a Zero Lower Bound (ZLB) the nominal interest rate set by the central bank,  $i_t$  is defined as,

$$i_t = \max \left\{ \frac{1}{\beta} (\Pi_t)^{\phi_\pi} \left( \frac{Y_t}{Y_t^n} \right)^{\phi_y} e^{\varepsilon_t^i}, ZLB \right\}. \quad (1.37)$$

Finally, the link between nominal and real interest rate is given by the Fisher relation,

$$i_t = R_t E_t(\Pi_{t+1}). \quad (1.38)$$

In the model, we have 5 AR(1) shocks such that  $\varepsilon_t^s = \rho^s \varepsilon_t^s + \eta_t^s$ , for  $s \in \{\lambda, a, opt, cons, g\}$ , where  $\rho^s$  is the autoregressive parameter and  $\eta_t^s$  is normally distributed, and 2 normally distributed shock  $\varepsilon_t^{NB}$  and  $\varepsilon_t^i$ . The general equilibrium combines a sequence of quantities  $\{Q_t\}_{t=0}^\infty$  and a sequence of prices  $\{P_t\}_{t=0}^\infty$ , such that, given the sequence of shocks  $\{S_t\}_{t=0}^\infty$  and monetary policy: (i) For a given sequence of prices  $\{P_t\}_{t=0}^\infty$ , the sequence  $\{Q_t\}_{t=0}^\infty$  satisfies first order conditions of households, entrepreneurs, firms, capital producers and financial intermediaries; (ii) For a given sequence of quantities  $\{Q_t\}_{t=0}^\infty$ , the sequence  $\{P_t\}_{t=0}^\infty$ , guarantees the equilibrium on all markets.

## 5 The effect of quantitative lending constraints on macroeconomic dynamics

In this section, we calibrate the model and we evaluate the macroeconomic effects of a transitory shortage in bank lending, by focusing on its effect on the length of the financial disruption.<sup>16</sup>

### 5.1 Calibration

The calibration of the model is summarized in Table 1. The value chosen for the model's parameter should meet two requirements: First, the steady state of the model should correspond to normal times (i.e., it should lie in the non saturated lending region that corresponds to a normal working of the loan market); Second, this steady state should be close enough to a loan shortage situation, thus allowing for the possibility of a transitory lending shortage as the outcome of admissible values for financial and real shocks. This feature is important to generate crisis times in the economy so as to provide the prerequisite for unconventional policy measures.

Most parameters are calibrated following Gertler and Karadi (2011). This is the case of the discount factor  $\beta$ , the weight of capital in the production function  $\alpha$ , the elasticity of substitution between goods  $\varepsilon^E$ , the habit parameter on consumption  $h$ , the parameter of wealth transfers towards new bankers  $\omega$ , the elasticity of labor supply  $\varphi$ , the price rigidity parameter  $\theta^E$ , the indexation parameter on prices  $\gamma^{pe}$ , the parameters of the Taylor rule  $\phi_\pi$  and  $\phi_y$ , and the parameter related to authorities inefficiency  $\tau$ . Furthermore, parameter  $\gamma^{pb}$  is calibrated as  $\gamma^{pe}$ . We calibrate the credit policy parameter  $v$  equal to 2, in line with the range of values tested by Gertler and Karadi ( $1 < v < 10$ ). In order to control the dynamic of acquisition of bankers' net wealth, we set a survival rate of bankers  $\theta$  equal to 0.95, slightly inferior to the value chosen by Gertler and Karadi. In

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16. To get a two regimes model (normal times and financial crisis), with endogenous shift from one to the other, we use the method developed by Guerrieri and Iacoviello (2014). The authors show how to approximate a nonlinear model by computing the matrices of two linear models with close steady states, thus creating what they call a piecewise linear model, close to the nonlinear one.

$\beta$	0.99	discount factor
$\alpha$	0.33	weight of capital in the production function
$\varepsilon^E$	4.167	elasticity of substitution between goods varieties
$h$	0.815	consumption habit parameter
$\theta$	0.95	survival rate of bankers
$\omega$	0.002	transfer parameter towards new bankers
$\eta^I$	0.06	scale parameter on investment costs
$\varphi$	0.276	labor supply elasticity
$\theta^E$	0.779	price rigidity parameter
$\gamma^{pe}$	0.241	price indexation parameter
$\phi_\pi$	1.5	Taylor coefficient on inflation
$\phi_y$	0.125	Taylor coefficient on output gap
$\tau$	0.001	inefficiency parameter for central bank intermediation
$\theta^W$	0.3	rigidity parameter on wages
$G/Y$	0.2	ratio of government spendings on GDP
$\delta_c$	0.025	depreciation rate of capital
$LEV$	1.5	leverage ratio on the steady state
$H$	1/3	steady state labor supply
$\chi^E$	0.05	elasticity of the external finance premium
$\varepsilon^B$	100	elasticity of substitution between varieties of loans
$\varepsilon^W$	10	elasticity of substitution between varieties of labor
$\eta^E$	0.995	probability of reimbursement of firms in the steady state
$\Psi$	0.5	shape parameter of the marginal cost of using capital
$\lambda$	0.86	diversion parameter / banking risk perception
$\rho^\lambda$	0.95	shock autocorrelation (banking risk perception)
$\rho^a$	0.95	shock autocorrelation (productivity)
$\rho^{opt}$	0.9	shock autocorrelation (optimism)
$\rho^{cons}$	0.8	shock autocorrelation (consumption)
$\rho^g$	0.8	shock autocorrelation (public spendings)
$R^L - R$	0.01	steady state interest rate spread
$v$	2	credit policy parameter

Table 1.1: Calibration of parameters

the same spirit, we consider a very low markup for the banks, by setting the elasticity of substitution between loans  $\varepsilon^B$  equal to 100.

The parameter related to the rigidity of wages  $\theta^W$  is calibrated at a relative lower value (0.3). We fix the steady state value of the leverage ratio ( $LEV = QK/N^E$ , equal to the shape parameter in the Pareto distribution  $\kappa$ ) to  $3/2$ . In this situation, borrowing affects the steady state, as firms' capital stock correspond to 1.5 times the capital stock they would have chosen on the sole basis of their net wealth. As in Poutineau and Vermandel (2015) we calibrate the shape parameter of the marginal cost of using capital  $\Psi$  equal to 0.5, we set the labor disutility parameter  $\chi^C$  to get a stock of labor  $H$  equal to  $1/3$ , we calibrate the probability of reimbursement of firms at the steady state  $\eta^E$  equal to 0.995 and we fix the elasticity of the external finance premium  $\chi^E = 0.05$ . We also calibrate the elasticity of substitution between the different varieties of labor  $\varepsilon^W$  equal to 10. Finally, the depreciation rate on capital  $\delta_c$  is set in a standard way at 0.025, and the ratio of public spending to the GDP ( $G/Y$ ) is equal to 0.2. The tax parameters on entrepreneurs' profit  $\tau^E$  and bank's profit  $\tau^B$  are calculated to reach the required value of the equilibrium leverage ratio and interest rate spread.

To meet our requirements regarding the characteristics of the steady state that should correspond to normal times and be close enough to a loan shortage situation, we fix the steady state value of the diversion parameter  $\lambda$  (i.e., the fraction of available funds that financial intermediaries may choose to divert from the financial project of depositors) equal to 0.86. This value (that is higher than the one selected by Gertler and Karadi (2011)) has been chosen so that the credit constraint does not bite in the steady state but can be saturated for reasonable values of exogenous shocks (namely 5% shocks as in Gertler and Kiyokati (2010)). The scale parameter on investment  $\eta^I$  is fixed equal to 0.06. The steady state spread between the interest rate on loans and the policy rate ( $R^L - R$ ) is equal to 0.01. Finally, shock persistency parameters are given as follows:  $\rho^\lambda = \rho^a = 0.95$ ,  $\rho^{cons} = \rho^g = 0.8$ ,  $\rho^{opt} = 0.9$ .

## 5.2 The worsening effect of financial disruption

We illustrate the effect of a binding loan constraint on the transmission of shocks in two steps. Since the binding of the constraint on loan supply operates as a transmission channel of shocks on the dynamics of the economy, we first concentrate on one financial shock,  $\varepsilon_t^{NB}$ . A positive realization of  $\varepsilon_t^{NB}$  features a decrease in the net wealth of banks, following for example, a stock exchange collapse. This shock is consistent with what happened on the onset of the crisis: The stock exchange collapse on the real estate market generated a net loss in the balance sheet of financial intermediaries, which led them to decrease dramatically the amount of loans they provided to the private sector. For admissible values, this financial shock reduces the resources of financial intermediaries, decreases loan supply and leads to quantitative restrictions on the loan market as the notional demand for loans is not met. Even if in our setting the nature of financial shocks departs from Gertler and Karadi (they concentrate on a capital quality shock while we simulate a shock affecting the value of bank capital), we get close results. However the values reported in Figure 1.3 are lower since in Gertler and Karadi the quantitative constraint always bites.

Figure 1.3 depicts the consequences of a 5% increase in  $\varepsilon_t^{NB}$ . In this figure, we contrast two versions of the model. In the version that neglects the possibility of quantitative shortage of loan supply (dashed lines), this shock has no effect on the variables of the model, because if there is no balance sheet constraint (i.e. no agency problem between households and financial intermediaries), banks are always able to intermediate funds from households to the productive sector, even if their own resources are restricted following the shock. In this case, the financial shock does not transmit to the real economy. However, when we take into account the existence of the quantitative constraint, the restriction of their own resources leads banks to a situation where the maximum amount of loans they can lend is reduced, and so becomes inferior to the notional loan demand. In this situation, the quantitative constraint bites, which creates a quantitative restriction on loan availability. As reported by the gray area the loan shortage situation lasts for 7 periods, and implies a sharp increase in the interest rate on loans to reduce loan demand in the short run and thus insure the equilibrium on the loan market. In this situation,

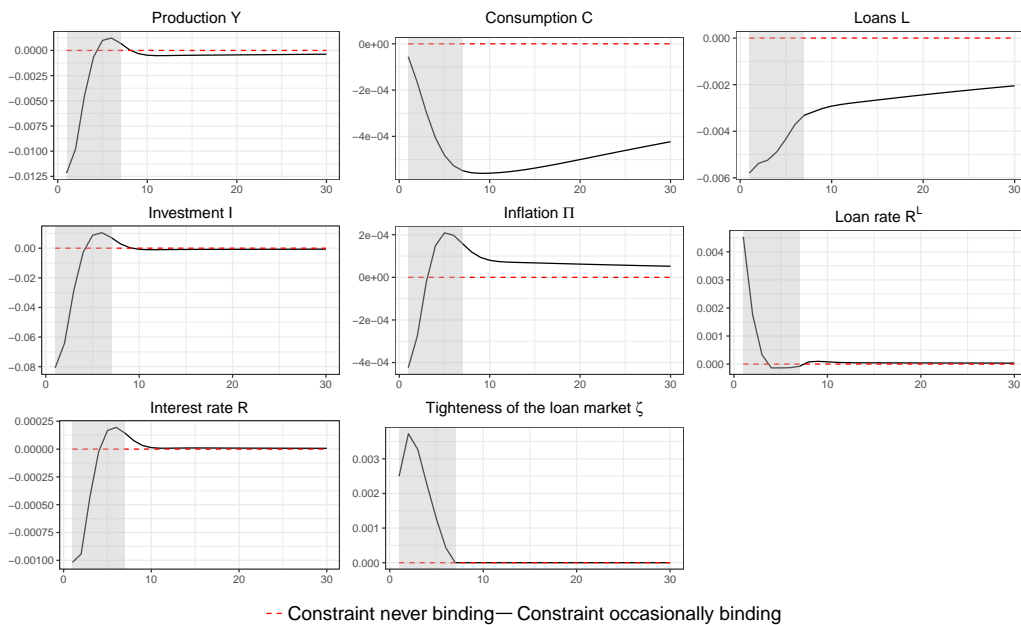


Figure 1.3: Shock on  $N^B$ , response of the model with and without credit constraint

the increase in the interest rate on loans faced by entrepreneurs reflects the scarcity of loans in the economy. This increase in the cost of borrowing transmits to the real economy, through a decrease in the quantity and size of investment projects undertaken by entrepreneurs, which generates a sharp recession. As reported in Figure 1.3, even if the shortage of loans lasts for a limited number of periods, it has sizable consequences on the rest of the analysis. The policy reaction (a decrease in the policy rate) tends to dampen the effect in the following periods so the economy slowly goes back to equilibrium.

Noticeably, the possibility of a lending shortage also affects the transmission of real shocks, as soon as they have a sizable effect on the capacity of entrepreneurs to reimburse contracted loans. Figure 1.4 reports the consequences of a negative productivity shock (i.e. a 5% decrease of  $\varepsilon_t^a$ ), with and without the possibility of a loan supply shortage. In dashed lines the model does not take into account the quantitative shortage of loans and we find standard results. As widely documented in the literature, this shock leads to a

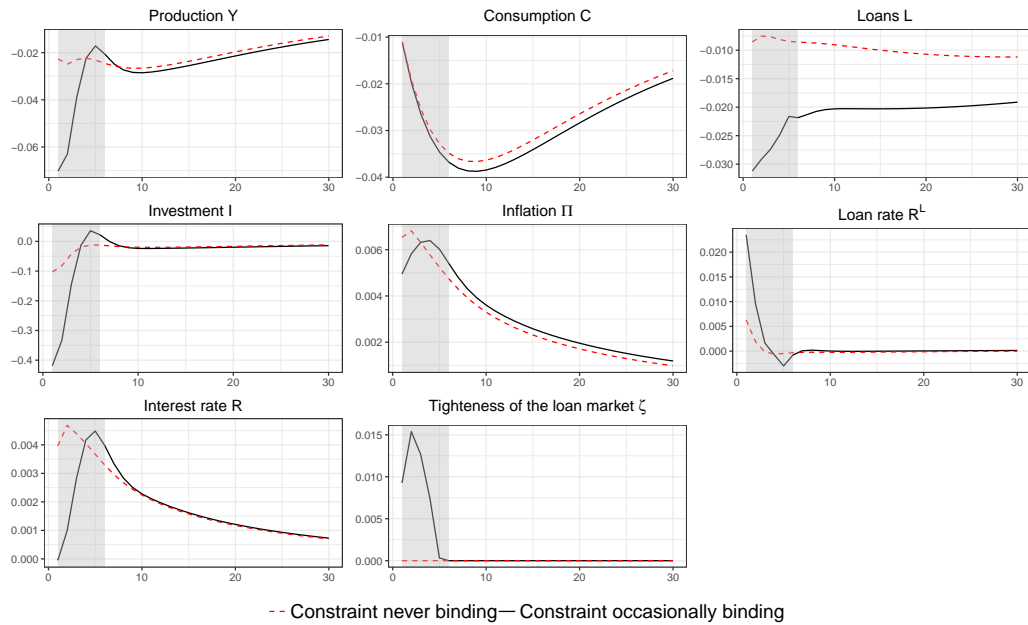


Figure 1.4: Shock on technology, response of the model with and without credit constraint

slump in activity and an increase in the inflation rate. As capital productivity decreases so does investment. The central bank reaction leads to an interest rate increase to fight inflation, which affects the interest rate on loans. As observed the interest rate on loans increases more than the policy rate, as the shock leads also to a decrease in investment profitability, which in turn increases the risk premium correction of banks.

The possibility of a transitory lending constraint (plain line) sharply deteriorates the adjustment of the economy. Even if the quantitative shortage lasts for 6 periods, it amplifies the negative impact of the shocks and reinforces its persistency on the main aggregates. This feature is in line with the Impulse Response Functions of the technology shock displayed in Gertler and Karadi (2011). However, the values reported are higher in their analysis as the loan constraint always bites, while this phenomenon is only temporary in our model. As depicted in Figure 1.4, it takes more time for the economy to recover, as the main effect of the shortage affects the initial 6 quarters with respect to

the standard DSGE model. The negative productivity shock affects the profitability of entrepreneurs projects which, in turn, reduces the net wealth of the banking system, and the resources of households (and their deposits in the banking system as a by-product). As documented above, these two elements create a shortage in the supply of loans that reinforces the initial negative effect of the shock on investment and activity. Following the decrease in loan supply, the interest rate on loans required to balance the loan market increases sharply which leads to a deeper impact of the real shock on both investment and activity. As reported, the further effect on activity and investment due to the loan shortage requires a stronger reaction of the central bank. Finally, inflation increases less, while activity loss is higher which dampens the authorities reaction with regard to the standard DSGE model during the saturated period.

### 5.3 The length of the binding regime

As reported in the Impulse Response Functions (IRFs), we see that even if the binding regime is transitory, this situation clearly affects the time path of macro variables. In Figure 1.5, we assess how key parameters affect the length of the constrained regime. We more particularly find that three parameters have a significant effect on this phenomenon:  $\kappa$  (the shape ratio of the Pareto distribution, that determines the leverage ratio of firms in the steady state  $QK/N^E$ ),  $\lambda$  (the share of resources that can be diverted by financial intermediaries in the steady state) and  $\Psi$  (the shape parameter of the marginal cost of using capital).

In Figure 1.5, the benchmark value of each of the parameters selected for the analysis of the IRFs is presented as a vertical line. We test the sensitivity of the parameters for the two financial shocks, the shock on banks net wealth  $N_t^B$  and the shock on the diversion parameter  $\lambda_t$ . We focus on these two shocks, because they affect the economy only through the financial channel, in contrast with real shocks (for example the technology shock) that affect the economy through both the financial and the real channels. This allows us to isolate the effects of the variation of the parameters only on the saturation mechanism of the constraint.



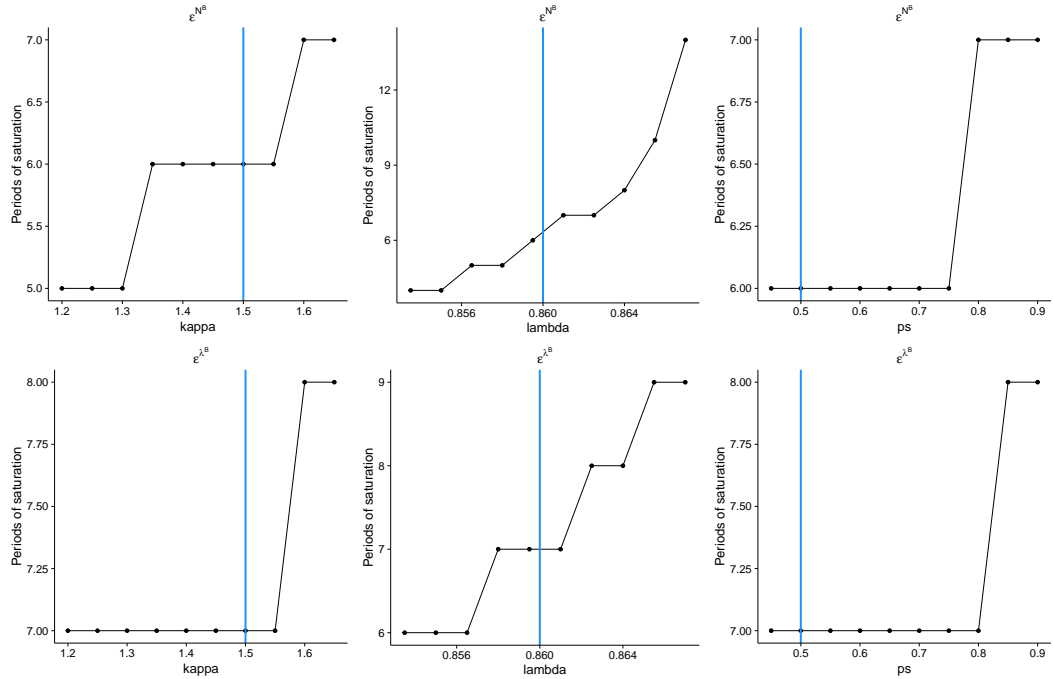


Figure 1.5: Sensitivity Analysis for the model without credit policy - number of periods of saturation

The first column reports the sensitivity of the length of the loan shortage period to the value of the  $\kappa$  parameter. As reported, in all cases, an increase in this parameter increases the length of the saturation constraint. Indeed, an increase in the value of  $\kappa$  increases the leverage ratio in the steady state (namely the ratio between capital and net wealth) which mechanically makes the loan demand consequence of shocks higher and, by so, increases the length of the saturation period (i.e., the excess loan demand that is reported from period to period).

The second column is devoted to the effect of the value of the  $\lambda$  parameter on the results. A higher value of this parameter means that in the steady state, financial intermediaries have a higher incentive to divert households' savings when leaving the loan market, which in turn decreases the trust of households in the banking system. As a consequence, households put less deposits in financial intermediaries and, by so, this requires more bank collateral to create new loans. This, in turn, makes the economy more

sensitive to loan supply shortage situations and, as a consequence, increases the length of the saturation period in the case of financial shocks.

The third column is devoted to the effect of the value of the  $\Psi$  parameter on the results. An increase in the value of this parameter increases the marginal cost of using capital to produce intermediate goods. As a consequence, *ceteris paribus*, production requires more financial resources which translates into a higher loan demand. In the meanwhile, the increase in the marginal cost of production makes some financial projects less profitable, which in turn reduces the reimbursement of contracted loans and the resources of the banking system. The two channels reinforce each other to sharpen the financial disruption. Finally, this leads to an increase in the length of the shortage period for higher values of the  $\Psi$  parameter.

## 6 Credit Policy

Our model generates a transitory disruption of lending coming from the worsening of financial intermediaries' balance sheet. This credit tightening raises the cost of borrowing and amplifies the transmission of financial and real shocks in the economy. The transitory loan shortage may thus justify the adoption of non conventional monetary policy measures to reinforce a loosen conventional policy.

### 6.1 Credit policy rule

We follow Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) by assuming that the central bank proceeds to direct lending measures.<sup>17</sup> However, we depart from their analysis by restricting credit policy measures to the sole crisis time sub-period characterized by the financial disruption (see Figure 1.2).

At the onset of a crisis, the central bank injects credit in response to movements in credit spreads as a mean to mitigate the impact of the crisis on the macroeconomy. The

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17. Our specification also accounts for MBS purchases on the secondary market (as presented in Figure 1.1). By targeting this particular type of asset, the central bank increases the yield of this asset, so it makes it easier for the private sector to raise funds. This can be associated to an increase on the quantity of loans they are able to subscribe.

total amount of loans available to entrepreneurs thus becomes,

$$L_t^S = L_t^{Sp} + L_t^{Sg}, \quad (1.39)$$

where  $L_t^{Sp} = L_t^{S\max} = \phi_t^B N_t^B$ , is the loan supply provided by the banking sector on the basis of its own resources, and  $L_t^{Sg}$  is the quantity of supplementary loans supplied by the central bank implementing the credit policy. As in Gertler and Karadi (2011), there is no agency problem between the central bank and its creditors because it can commit to always honoring its debt.<sup>18</sup> We assume that the central bank offers loans proportionally to the quantity of total assets available in the economy,

$$L_t^{Sg} = \psi_t L_t^S, \quad (1.40)$$

where  $0 < \psi_t < 1$ , is the credit policy variable. In this situation, the lending accelerator becomes,

$$L_t^S = \phi_{c,t}^B N_t^B, \quad (1.41)$$

with,  $\phi_{c,t}^B \equiv \frac{\phi_t^B}{1-\psi_t}$ . Thus, as  $\phi_{c,t}^B > \phi_t^B$  credit policy reinforces the lending accelerator in the economy.

As already underlined, we depart from Gertler and Karadi (2011), by linking the implementation of credit policy to a situation of lending shortage from financial intermediaries. We assume that this policy is proportional to the quantity of missing loans in the economy. As we outlined above the rise in the interest rate on loans reflects financial distress in the economy. As the size of credit shortage can be approached by the value  $\zeta_t = (1 - \tau^B) E_t [\eta_{t+1}^\pi] (R_t^L - R_t^{L,S})$ , that serves as a proxy to measure financial disruption in the economy, we link the credit policy parameter to this indicator according to,

$$\psi_t = v \zeta_t, \quad (1.42)$$

where  $v$  is a scale parameter. Two policy regimes can thus be considered following adverse financial and macroeconomic shocks: (i) As long as  $\zeta_t > 0$  (i.e. crisis times), mone-

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18. We refer the reader to the discussion provided in Gertler and Karadi (2011).

tary policy combines the use of short term interest rates and credit policy measures; (ii) As soon as  $\zeta_t = 0$ , the economy goes back to normal times and the central bank stabilizes economic fluctuations using the Taylor rule.

## 6.2 The dampening effect of credit policy

We evaluate the macroeconomic impact of a credit policy by contrasting the Impulse Response Functions of the model under this policy with regard to the benchmark of a conventional intervention of the central bank. Results are reported in figures 1.6 and 1.7, depending on the nature of shocks. As a general feature in line with the literature, the implementation of credit policy moderates the contraction that follows adverse real and financial shocks. The prime reason is that central intermediation dampens the rise in the interest rate spread, which in turn dampens the investment decline.

As reported in Figure 1.6, following a 5% positive shock on  $\varepsilon_t^{NB}$  a credit policy has two consequences on the dynamics of the model: It reduces the negative impact of the shock on the one side but it increases the length of the shortage period on the other side (as reported, the grey areas correspond to 7 periods without the credit policy and to 11 periods with the credit policy). This second effect means that with unconventional policy measures, it takes a longer time for the economy to come back to normal times.

The dampening effect can be explained as follows: As observed, following the shock, the central bank applies an expansionary loan supply policy ( $\psi_t$  increases) which in turn increases the number of new loan contracts. This has a marginally positive impact on investment and activity with respect to the no credit policy situation (in dashed lines).

In the meanwhile, the length of the transitory period needed to go back to a non binding situation on the loan market increases. This phenomenon may be understood as follows: *Ceteris paribus*, the central bank delivers credit proportionally to the magnitude of the financial disruption (proxied by  $\zeta_t$ ). However, this decision has a further effect on  $R^L$  that decreases (plain lines) with respect to the unconstrained situation (dashed lines). As  $R^L$  becomes relatively lower following the credit policy conducted by the central bank, this marginally increases loan demand with respect to the no credit situation. Accounting for the two effects, the amount of extra loan supply created through credit policy does not

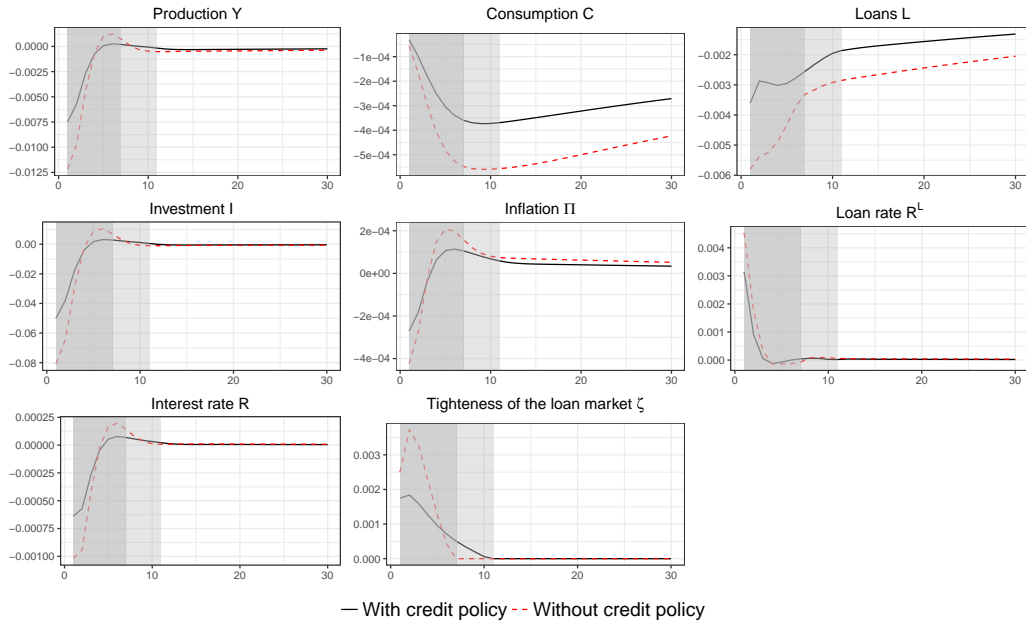


Figure 1.6: Shock on  $N^B$ , response of the model with credit constraint, with and without credit policy

exactly meet the amount of loan demanded (that takes into account the decrease in  $R^L$ ). As a consequence, a marginal quantity of loan demand not met in the current period is reported in the next period, where the same mechanism applies. Thus, the stressed situation is reported for a further number of periods. Noticeably, as observed in the panel representing the dynamics of  $\zeta_t$ , this stress becomes much lower than in the initial periods. However, as the conduct of unconventional policy measures in the economy is directly linked to this indicator ( $\zeta_t$ ), the transitory period combining conventional and unconventional policy measures lasts longer.

The same two effects are observed for the transmission of the technology shock. Figure 1.7 depicts the consequences of a negative realization of 5% on  $\varepsilon_t^a$ . As for financial shocks the implementation of credit policy measures dampens the transmission of this negative shock, as entrepreneurs can now borrow more from financial intermediaries and the saturation period is clearly increased.

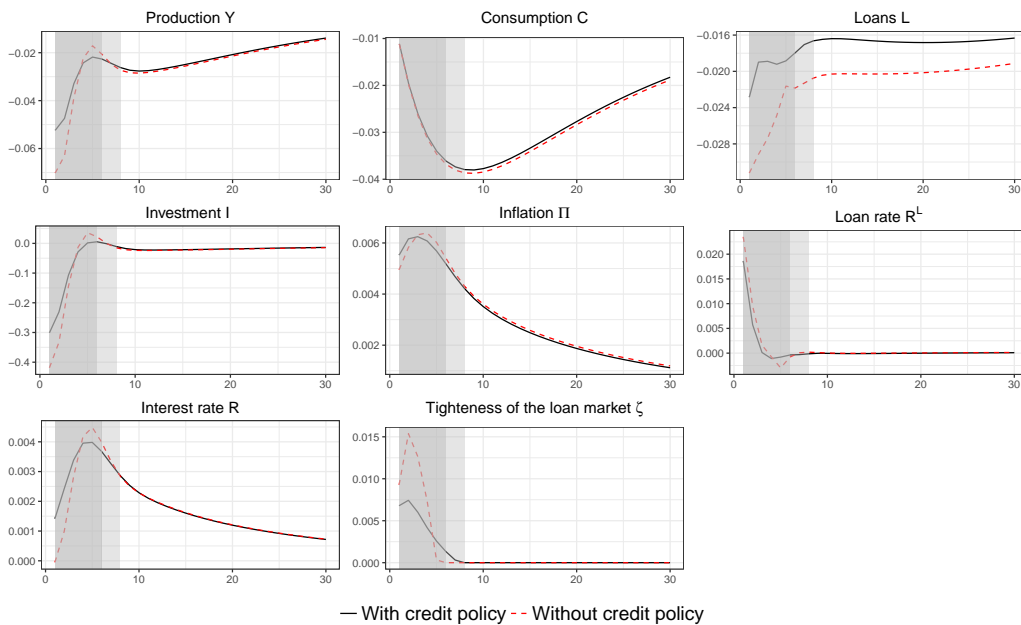


Figure 1.7: Shock on technology, response of the model with credit constraint, with and without credit policy

### 6.3 The arbitrage between the length and the magnitude

We evaluate the extent to which central bank credit interventions moderate the economic downturn by taking into account the joint effects of this policy on both the size of the stabilization and the length of the adjustment period to go back to the steady state. As credit policy partly acts as a mechanism that smooths intertemporally the consequences of real and financial shocks, we question whether the net effect of this policy is positive on households' welfare. We take into account the whole time it takes to go back to the steady state under the two policies. To this aim we proceed to a sensitivity analysis that relies the differential effect of the two policy regimes on welfare (accounting for both the

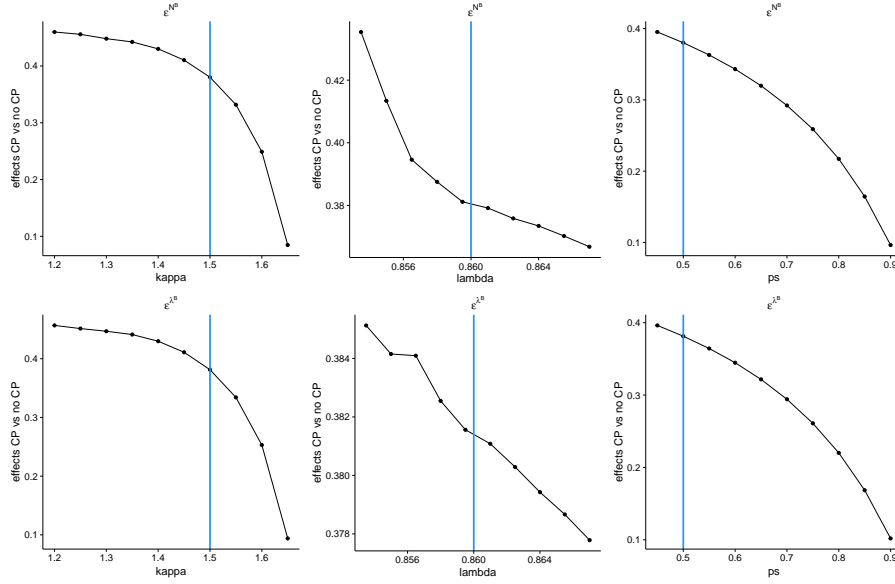


Figure 1.8: Sensitivity Analysis - comparison between the model with and without credit policy - cumulated size of IRF

magnitude and the length of the adjustment period) computed as,

$$\Delta = \frac{\sum_{\tau=0}^{+\infty} \hat{\Omega}_{t+\tau}^{noCP} - \sum_{\tau=0}^{+\infty} \hat{\Omega}_{t+\tau}^{CP}}{\sum_{\tau=0}^{+\infty} \hat{\Omega}_{t+\tau}^{CP}}, \quad (1.43)$$

with  $\hat{\Omega}_t^{CP}$  and  $\hat{\Omega}_t^{noCP}$  are respectively the aggregate welfare of households in period  $t$  in deviation from the equilibrium with and without a credit policy rule, depending on the value of the three key parameters of the model. A positive value of the ratio indicates the net dampening effect of a credit policy all along the adjustment path back to the steady state, taking into account the endogenous length of the implementation of unconventional policy measures. The results are summarized in Figure 1.8.

As observed, the net welfare gains of credit policy decrease for higher values of  $\kappa$ . As underlined previously, an increase in this parameter increases the length of the saturation constraint as it corresponds to a higher steady state value of the leverage ratio. In

this situation, entrepreneurs borrow more from financial intermediaries, which tends to increase the length of the saturated period in both regimes but also reduces the speed of the return to the steady state under the credit policy regime. Thus, for higher value of  $\kappa$  it seems less interesting to adopt such credit policy measures because of the marginally higher cost of this policy related to the longer period of the saturation of the constraint.

The second column of Figure 1.8 depicts the value of  $\Delta$  following an increase in parameter  $\lambda$ . As reported a higher value of the diversion parameter reduces the difference between situations with and without credit policy. A higher value of this parameter means that financial intermediaries have an incentive to divert more deposits in the steady state. Thus for a higher value of the parameter, households put less deposits in the banking sector and reduce the loan leverage ratio in the steady state. As a consequence, the amplifying effect of the lending channel is dampened and credit policy has less effect on the economy, and by so on the dampening of shocks.

Finally, the positive net effect of a credit policy tends to vanish with an increased value of  $\Psi$ . As underlined above, a higher value of this parameter increases the marginal cost of using capital to produce intermediate goods. Thus loan demand becomes less responsive to loan interest rate decrease that follows the credit policy, as the profitability of projects decreases since production is more costly. Thus, credit policy has less impact on investment and activity.

## 7 The Zero Lower Bound case

The previous sections have analyzed the dynamics of the economy for 5% financial and real shocks leading to a transitory shortage in loan provision. However, since in our setting this size of financial shocks does not trigger a Zero Lower Bound situation, the previous results have been obtained assuming that even during crisis times the central bank is able to keep implementing a conventional monetary policy combined with temporary credit policy measures.

The possibility of hitting the Zero Lower Bound is endogenously determined by the size of adverse financial shocks. The Zero Lower Bound situation is thus a situation that arises as a natural outcome of troubled financial times if the stabilization of the



economy requires a sharp decrease in the policy rate.<sup>19</sup> To explore the consequences of the Zero Lower Bound on the previous results we thus simulate a 38% increase in  $\varepsilon_t^{NB}$  that is necessary to generate this environment. This size of shock is consistent with what has been observed at the onset of the crisis, where banks assets dramatically decreased following the collapse of the real estate market.

In Figure 1.9, the ninth panel presenting the gross value of the policy interest rate displays the length of the Zero Lower Bound subperiod as long as the value of the variable is unitary. As depicted, the qualitative consequences of this adverse financial shock with (in plain lines) and without (in dashed lines) introducing a Zero Lower Bound constraint are almost similar. In both situations, the quantitative restrictions on loan availability imply a sharp increase in the interest rate on loans to reduce loan demand in the short run to meet the loan market equilibrium. This sharp increase in the lending rate decreases investment, activity and inflation. Finally, as reported, the Zero Lower Bound has no noticeable consequence on the length of the lending disruption. The main difference between the two regimes concerns the policy environment: In the no Zero Lower Bound situation the decrease in the policy rate has a clear stabilizing effect in the periods following the shock, while the Zero Lower Bound constraint reduces the ability of the central bank to reduce activity losses as the policy rate cannot become negative. Unsurprisingly the Zero Lower Bound environment leads to deeper negative consequences on the macroeconomic equilibrium and the difference on the activity and investment declines is sizable (it would be even more sizable with a higher shock). Accordingly, the decrease in loan demand and in consumption are much longer and more pronounced in the Zero Lower Bound case.

Finally, Figure 1.10 assesses the effect of credit policy with the Zero Lower Bound situation. As observed, credit policy affects the dynamics of the economy on two main aspects. First, by providing credit to the economy, unconventional policy decisions reduce the slump in the quantity of loans contracted, which in turn clearly dampens the negative consequences of the adverse financial shock. Second, as the negative consequences of the

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19. We do not put too much emphasis on the interpretation of the ZLB situation as we should be aware that this situation requires high value for shocks that may affect the reliability of the linearized relations of the model when analysing the IRFs.

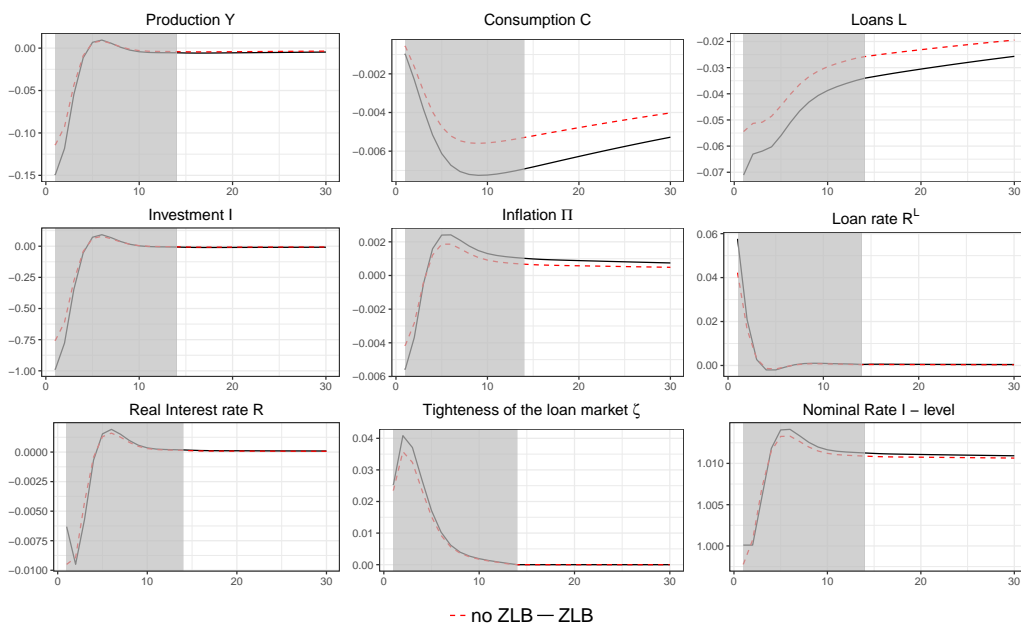


Figure 1.9: 38% Shock on  $N^B$ , response of the model with and without ZLB

shock are dampened, the central bank has less need to decrease the nominal interest rate which does not hurt the Zero Lower Bound anymore, so the central bank is able to use conventional actions. Finally as noted in the previous section for the non Zero Lower Bound situation, the implementation of credit policy increases the length of the shortage period along the same value.

## 8 Concluding Remarks

In official statements, unconventional monetary measures are considered as exceptional decisions to solve the consequences of a financial crisis when conventional measures become ineffective. As a matter of fact, such policies should be considered as temporary outcomes, which is in sharp contrast with most of the models currently provided in the literature that have flourished during the last decade.

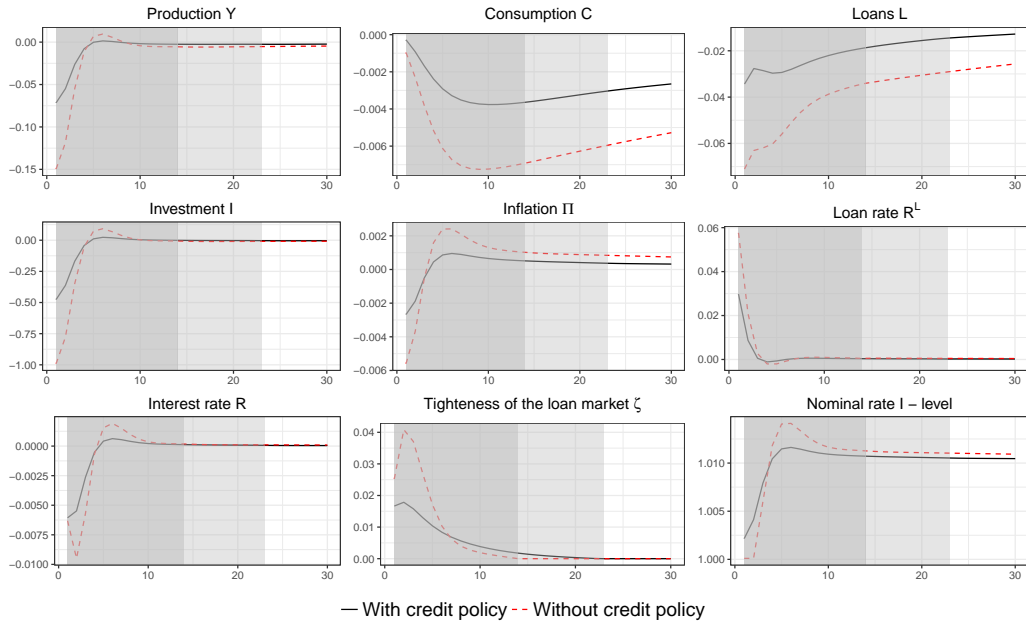


Figure 1.10: 38% Shock on  $N^B$ , response of the model with ZLB, with and without credit policy

As a point of departure, this chapter has treated unconventional monetary policy as a temporary policy aimed at dampening the consequences of financial and real shocks on the provision of loans. In a DSGE model with financial frictions, we provide a simple approach to the decision to begin and end up unconventional policy measures, by specializing this kind of policies to periods with loan supply shortages.

Accounting for an endogenous implementation length of policy we find that it has two main effects. As previously found in the literature, by raising the value of the lending accelerator in a situation of loan scarcity, it dampens the consequences of shocks. As a second effect (new in the literature), such policy measures increase the length of the loan saturation period. Accounting for these two effects, we find that in the medium run such policy measures may have very low effects on welfare, depending on baseline parameter values. These results extend to the Zero Lower Bound situation.

Our analysis mainly concentrates on state dependent credit policies, as a way for

exploring the temporary nature of unconventional policy measures. The unwinding of such policies is part of the analysis provided in this chapter. However, this situation only recovers part of the practices encountered in real life situations. Future avenues for research thus should be considered. Among them, considering time dependent policies (aimed at anchoring future expectations) or a broader range of policies aimed at affecting the financial market equilibrium through portfolio effects appears to provide a natural extension of the analysis provided in this chapter.



## **Chapter 2**

# **The Effects of a Homogeneous Unconventional Monetary Policy on a Financially Heterogeneous Monetary Union**

### **1 Introduction**

The 2007 financial crisis had a strong impact on the Eurozone. Besides its aggregate effects on the area considered as a whole, it further unveiled a high degree of financial discrepancies between participating countries. As documented by Ciccarelli et al. (2013), a considerable degree of country heterogeneities has been observed at the disaggregated level in terms of credit developments, financial fragility of borrowers and lenders and real activity.

This environment framed the transmission of the unconventional monetary policy decisions that were adopted by the European Central Bank (ECB) at the onset of the crisis, to avoid a crude disruption of the European credit market. However, according to her status the ECB mostly focused on union-wide macroeconomic and financial developments while neglecting the aforementioned national heterogeneities. As underlined

by Buriel and Galesi (2017), even if the macroeconomic and financial effects of the ECB's unconventional monetary policies between 2007 and 2015 have had beneficial effects on aggregate output and inflation, a substantial degree of heterogeneity has been observed between the 19 countries participating to the European Monetary Union (EMU). In particular, they find that countries with less fragile banking systems benefited the most from unconventional monetary policies in terms of output gains while the effects were smaller in those countries which were mostly affected by the crisis such as Portugal, Greece and Spain.

The aim of this chapter is to analyze the heterogeneous consequences of homogeneous unconventional policy measures undertaken by the ECB to fight the financial disruption that affected the Eurozone at the beginning of the crisis. We provide a two country DSGE model that accounts for cross border lending relations as a major source of spillovers between Eurozone members. In line with the stylized facts, we describe a situation where some peripheral countries of the monetary union were mostly affected by an initial stress. This phenomenon - that arises endogenously following exogenous financial shocks - is characterized by a lending disruption implying a fall in loan distribution and a sharp increase in interest rate spreads needed to balance the loan market. In our setting this credit disruption is transmitted to the rest of the Eurozone through cross border bank relations. On the policy side we combine a conventional monetary policy based on the steering of a short run interest rate with a state dependent credit policy aiming at providing liquidity to the banking sector to dampen down the disruption in credit supply. We assess the global macroeconomic and welfare consequences of the unconventional part of monetary policy by contrasting its effects to a first best situation where credit policy actions would have been conducted owing the particular situation of each part of the Eurozone.

Our analysis mostly focuses on two related questions regarding the consequences of applying homogeneous unconventional monetary policy measures on a heterogeneous group of countries sharing a common currency. First, we assess how the financial connection of national banking systems - through cross border lending flows - shapes the transmission of asymmetric financial and real shocks. Second we evaluate the effect of a credit policy, using the benchmark of a first best situation where policy actions could

target each country's financial system independently.

As a theoretical contribution our analysis underlines the ambiguous role of cross border lending for transmitting a regional financial stress arising in the periphery to the global EMU level, as it affects national situations in opposite directions. For countries affected by a financial disruption it improves the situation through the import of loans while it deteriorates the situation of countries that were initially not affected directly by a financial disruption. Owing to these opposite national reactions, we find that there exists an optimal level of financial integration for which the net effects of financial shocks are minimized for the Eurozone as whole.

As a policy contribution our analysis studies the heterogeneous effects of a homogeneous policy on a heterogeneous monetary union. We find that the conduct of credit policy unambiguously improves the situation of the monetary union, albeit with differing consequences on core and peripheral economies. Unsurprisingly, we find that in most situations, a common credit policy leads to a second best situation with respect to unconventional policy measures targeting directly national situations based on financial stress. However, credit policy has non-linear consequences on the inequalities arising from the financial crisis.

The rest of the chapter is organized as follows: Section 2 presents the empirical and theoretical backgrounds of the chapter. Section 3 presents the baseline component of the model. Section 4 describes the financial component of the model. Section 5 analyzes the transmission of financial and supply shocks between countries depending on the size of cross border bank relations. Section 6 discusses the conduct of unconventional monetary policy and assesses the consequences coming from the heterogeneous situation of participating countries. Section 7 concludes.



## 2 Background

### 2.1 Stylized facts and Institutional background

Figure 2.1 reports the value of the Composite Indicator of Systemic Stress (CISS) published by the ECB (see Holo et al., 2012), for 7 main Eurozone countries (France, Germany, Greece, Ireland, Italy, Portugal, Spain) between January 2000 and December 2017.<sup>1</sup> As underlined by the sharp rise of this index in 2007 the financial crisis that originated in the United States transmitted quickly and sharply to the Eurozone as a whole. However, after a few quarters, this index began to decrease significantly for France and Germany, while increasing furthermore for countries belonging to the periphery of the Eurozone.

The period of high financial stress between September 2007 and June 2009 corresponds to the bank crisis. During this period, banks suffered strong losses in the asset part of their balance sheet, so they dramatically decreased both the amount of loans granted to the non banking sector and their interbank lending, which created a vicious circle of financial stress increase and loan shortages until the massive intervention of the ECB. The second period of high financial stress that began in September 2009 corresponds to the sovereign debt crisis phase. Having suffered high public deficits in the first period of the financial crisis, as their governments had to borrow massively in order to address the real consequences of the bank crisis, European countries were subject to a serious increase of their debt ratio. As a consequence, confidence on their debt sustainability began to drop, increasing their difficulties to raise funds at an affordable cost, thus creating another vicious circle on public debt this time.

Two groups of countries clearly emerge from Figure 2.1. Although core and peripheral countries seem to have suffered the initial phase of the financial crisis (i.e the bank crisis) with a similar strength, financial stress during the debt crisis period that followed directly

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1. The CISS captures the systemic dimension of financial instability. It is composed of 5 stress subindexes on 5 market segments, each of one targeting a different channel by which the funds of savers are reallocated to borrowers. The segments include: (1) money market; (2) bond market; (3) equity market; (4) financial intermediaries; (5) foreign exchange markets. The aggregation takes into account the time-varying cross-correlations between the subindexes, in the same way that portfolio risk is computed from individual asset risks. As a result, the CISS puts more weight on situations in which stress prevails in several market segments at the same time.

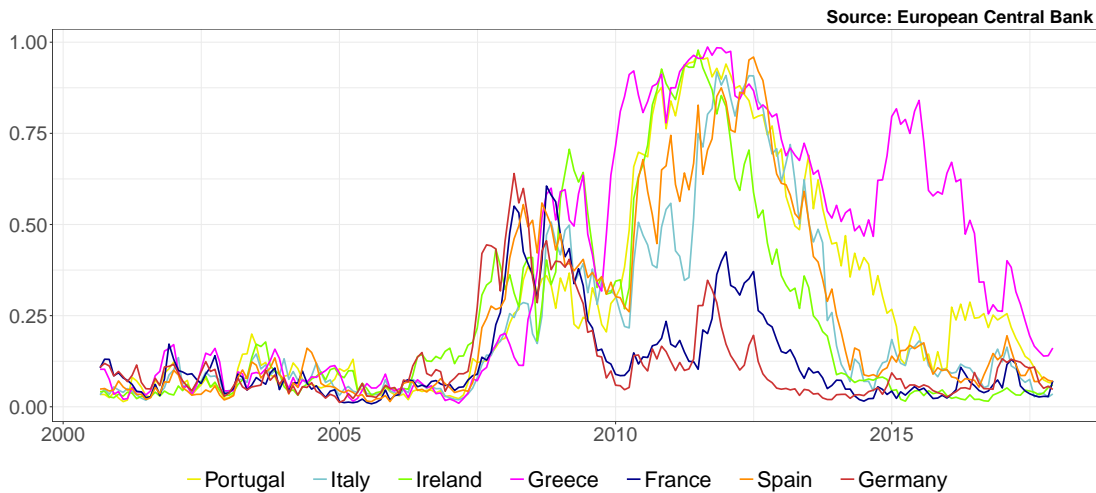


Figure 2.1: Composite Indicator of Systemic Stress for Eurozone members

the bank crisis in September 2009 was clearly much more pronounced for peripheral countries. Indeed, suffering from a weakest financial sector, peripheral governments had to raise more funds as they faced higher deficits following the bank crisis, which increased their debt ratio more than those of core countries, thus introducing a real asymmetry in their respective ability to raise funds.

The heterogeneous situation of Eurozone countries can further be illustrated by Figure 2.2. In line with Gertler and Karadi (2011), we can approach the financial stress in a concrete manner through the spread between the short-term interest rate on loans to corporations and the main refinancing operation rate. During the financial crisis, the banking sector shortened loan supply for liquidity reasons, thus introducing a disconnection between policy and market rates. Figure 2.2 displays a mean of this interest-rate spread for the two groups of countries considered before, between January 2003 and December 2017. During the bank crisis period, we observe an increase in the spread for both core and peripheral countries: As financial stress increased, banks restricted their supply of loans, which induced an increase in the cost of credit to adjust the credit demand with the decreasing supply. In periods of very high financial stress, we observe a growing decorrelation between the policy rates and the market rates, under which conventional

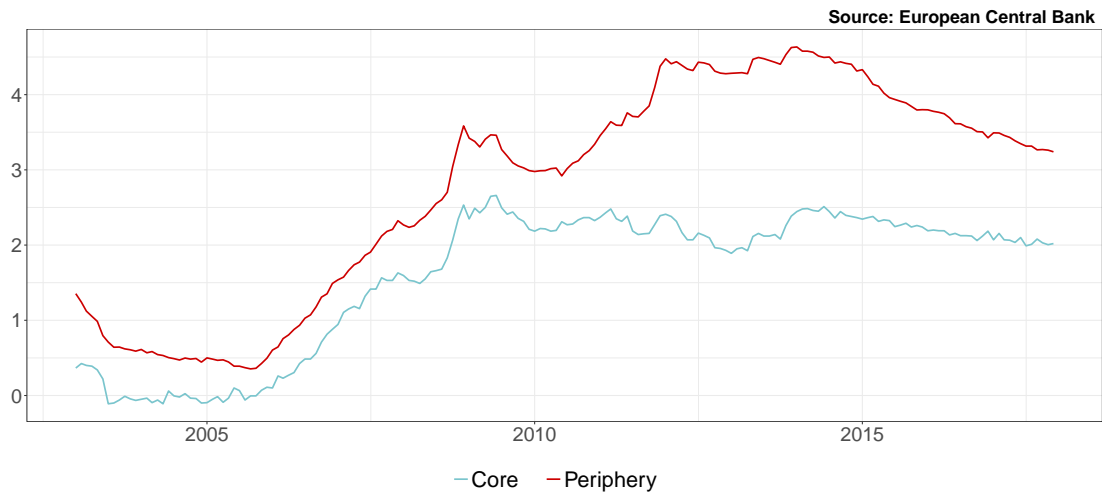


Figure 2.2: Interest rate spread - Core and peripheral countries

monetary policy tools become ineffective.

During the first period of the financial crisis (i.e the bank crisis), the increase in the interest rate spread was symmetric for core and peripheral countries, reflecting the symmetric increase in financial stress between this two groups already observed in Figure 2.1. However, in September 2009 we observe a growing asymmetry between core spreads, stabilized, and peripheral spreads, continuing to increase. The asymmetric path of interest rate spreads reflects the asymmetric effects of the debt crisis between the two groups of countries. Indeed, as peripheral countries, subject to a higher debt ratio, encountered difficulties to raise funds at an affordable price, the resulting financial stress had also an impact on the availability of credit to firms, which led to an increase of the interest rate spread characterized by high levels of financial stress in the EMU countries, which generated loan shortages that strongly affected real economy. However, some countries were far more affected than others.

Even if the ECB maintained a conventional monetary policy based on short run interest rate control until 2014, it introduced unconventional monetary policy measures at the onset of the financial crisis partly in reaction to this decorrelation between interest rate on loans and the policy rate, which decreased the efficiency of conventional

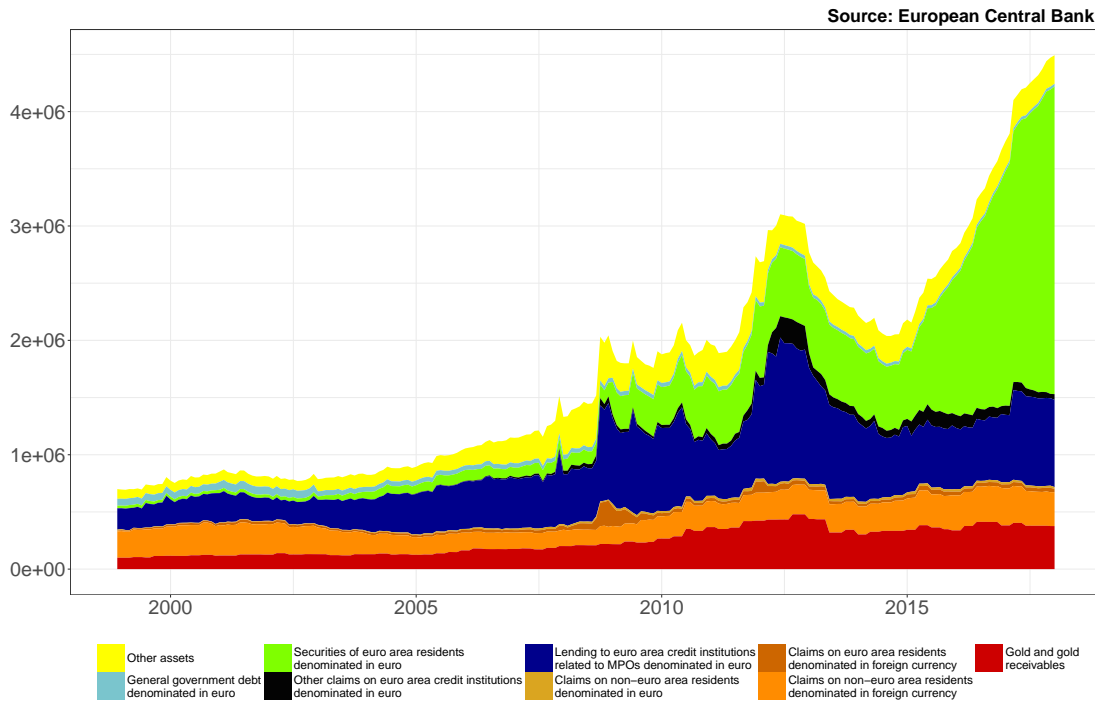


Figure 2.3: ECB balance sheet

monetary policy tools. Decisions of the ECB can be divided into three categories: The large-scale asset purchases programs (quantitative easing), the lending facilities, and the forward guidance. Figure 2.3 represents the evolution of the European Central Bank's balance sheet and its components between January 2000 and December 2017. It clearly appears from the figure that the two main sources of the wide increase in the ECB's balance sheet since 2008 are the lending to euro area credit institutions related to monetary policy operations, and the purchase of securities from euro residents.

The strong increase in securities of euro residents held by the ECB is a consequence of the expanded Asset Purchase Program (APP) undertaken since July 2009. This expanded Asset Purchase Program includes a variety of asset purchase programs under which public and private sector securities are purchased, in order to inject liquidity into the banking system. In the beginning of 2018, assets held by the ECB as part of the APP

are public sector securities (for the biggest part), corporate bonds, asset-backed securities and covered bonds. Lending to euro area credit institutions related to monetary policy operations encompasses both short term refinancing operations (main refinancing operations) and longer-term refinancing operations (LTROs). The strong increase of lending to credit institutions is a consequence of the large increase in LTROs since 2007, used by the European Central Bank as a monetary policy tool to offer long-term funding at attractive conditions to banks in order to stimulate bank lending to the real economy. Credit policy in this model is largely inspired by Gertler and Karadi (2011), and is more suited to capture the large scale asset purchase program than it is to capture LTROs, so we will focus on the APP component of the ECB's quantitative easing.

The ECB adapted its monetary policy to introduce unconventional tools, but maintained a key element of its status, namely to operate in a way that considers the EMU as a homogeneous region despite the clear heterogeneous situation of countries belonging to the Eurozone. As a consequence, asset purchases for monetary policy purposes are always equally divided between the different Eurozone's countries, forbidding the ECB to locally adjust its policy to country specific economic and financial factors.

## **2.2 Relation to the literature**

We evaluate the conduct of unconventional monetary policy decisions in a monetary union with an heterogeneous financial situation using a two country DSGE model. In this model the financial crisis initially affects a part of the monetary union - the peripheral countries - and transmits to the other part of the monetary union - the core countries - through cross border banking spillovers. As the post 2007 DSGE literature offers multiple modeling solutions regarding three key aspects of the analysis - the crisis experiment, the cross border banking relations and the nature of the unconventional monetary policy - we had to make choices so as to keep the model as simple as possible to assess the question at hands while capturing the main features of the problem.

First, the crisis experiment corresponds to a credit disruption in one part of the monetary union - the peripheral country group - following a financial shock affecting the soundness of the banking system. This crisis situation, implying a sharp increase in lend-

ing rates required to balance the local credit market, is contrasted with "normal times" where lending rates are set on the basis of the official policy rate and the amount of loans is determined by the needs of the producing sector of the economy. In normal times the financial part of the model corresponds to the Bernanke et al. (1999) model, with an accelerator phenomenon for entrepreneurs. In crisis times, our model accounts for the situation described by Gertler and Karadi (2011) and the amount of loans provided to the economy is constrained by the reduced resources of the banking system. The length of the crisis is endogenously determined in our model. This focus is in line with Foerster (2015), who uses a Markov-Switching DSGE model with fixed transition probabilities between crisis and non-crisis regimes. However, we do not impose a fixed probability of transition between regimes (that would make the length of the crisis exogenous), but we combine two opposite regimes along the lines of Cargoët and Poutineau (2018) using the approach of transitory binding constraints introduced in Guerrieri and Iacoviello (2015). In contrast to Gertler and Karadi (2011), the steady state of the economy before the financial crisis corresponds to normal times as described in Bernanke et al. (1999).

Second we consider that financial problems arise in peripheral countries and transmit to core countries through the cross border bank lending channel. This channel played a critical role during the international transmission of the crisis in the Eurozone (Cicarelli and al. (2013)) revealing a troubled aspect of financial integration. The existing literature provides different ways for modelling this aspect. In their two-country setting Dedola et al. (2013) show how financial integration makes bank balance sheet constraints highly correlated across countries. They account for cross border banking relations both for the assets component and for the liabilities component (deposits). However, building on the evidence conveyed by Poutineau and Vermandel (2015), we abstract for the deposit side and concentrate on cross border lending between banks and entrepreneurs. Furthermore, to keep the model tractable we leave aside interbank liquidity aspects covered in the model of Poutineau and Vermandel (2015). We concentrate on cross border lending at the entrepreneur level by outlining the channel of transmission to investment and activity, that penalized the Eurozone after the 2007 crisis. Our analysis thus contrasts with the one conveyed by Palek and Schwanebeck (2017) that concentrates on the interbank market which allows him to assess two aspects of unconventional monetary policy, depending

on the level of intervention.

Third, turning to monetary policy, we combine conventional and unconventional instruments. Conventional monetary policy is described as a simple interest rule in the spirit of Taylor (1993) while unconventional policy is based on Gertler and Karadi (2011) and is related to a situation where the provision of loans falls short with respect to loan demand. As in Cargoët and Poutineau (2018) the length of this policy action is endogenously determined in the model. As was mostly the case at the beginning of the crisis in the Eurozone, the adoption of unconventional policy measures is linked to the crude disruption in transmission of short run policy interest rate fluctuations to lending rates. Describing unconventional policy measures as state dependent measures has a further interest to describe the unwinding of this policy as the economy goes back to normal times. Putting aside its transitory nature, the solution adopted to describe the unconventional policy decision is standard in the literature and similar to Gertler and Karadi (2011) and Dedola et al. (2013): Unconventional monetary policy is modelled as an expansion of central bank credit intermediation needed to offset a disruption of private financial intermediation and improve the economic situation.

### **3 Baseline model**

We consider a two-country model of a monetary union. Each economy is populated by households, intermediate and final firms and capital suppliers. The interplay of agents and countries is summarized in Figure 2.4. As in Gertler and Karadi (2011), households are made of workers and bankers (workers supply labor to firms, consume and save, while bankers manage financial intermediaries), firms are made of intermediate and final sectors (the intermediate sector produces intermediate goods using capital and labor, while final firms produce final goods by combining intermediate goods and set sticky prices for these goods that are consumed by households and invested by intermediate firms), capital is provided by capital suppliers. The role of entrepreneurs will be presented in the next section (financial part of the model). In the presentation of the model, we will refer to the group of core countries as the home country and to the group of peripheral countries as the foreign country.

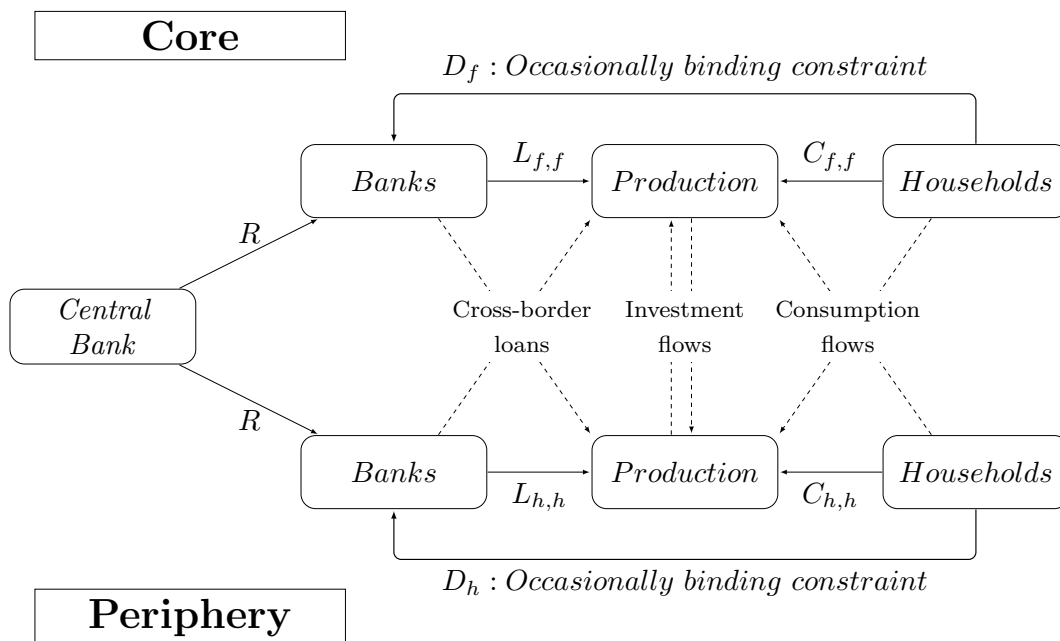


Figure 2.4: The model of a two-country monetary union with cross-border lending

### 3.1 Households

The number of households in each economy is normalized to 1. The representative household  $j \in [0, 1]$  in economy  $i$  is made of two parts: a fraction  $(1 - f_i)$  of the household consumes, supply labor services and saves, while a fraction  $f_i$  acts as a banker. Each period a fraction  $(1 - \theta_i)$  of bankers (thus  $(1 - \theta_i)f_i$  individuals) become workers while an equivalent number of workers become bankers, to maintain a constant proportion between the two components. New bankers are endowed with an initial amount of wealth.



We define  $C_{i,t}(j) = \left[ (1 - \alpha_i^C)^{\frac{1}{\mu_i^C}} (C_{i,h,t}(j))^{\frac{\mu_i^C - 1}{\mu_i^C}} + (\alpha_i^C)^{\frac{1}{\mu_i^C}} (C_{i,f,t}(j))^{\frac{\mu_i^C - 1}{\mu_i^C}} \right]^{\frac{\mu_i^C}{\mu_i^C - 1}}$  as the consumption bundle of household  $j$  from country  $i$ , where  $C_{i,h,t}(j) = (1 - \alpha_i^C) \left( \frac{P_{h,t}}{P_{i,t}^C} \right)^{-\mu_i^C} C_{i,t}(j)$  is the consumption of home good and  $C_{i,f,t}(j) = \alpha_i^C \left( \frac{P_{f,t}}{P_{i,t}^C} \right)^{-\mu_i^C} C_{i,t}(j)$  is the consumption of foreign good by the household  $j$  from country  $i$ .  $\alpha_i^C$  is the degree of home bias in the decisions of consumption from households of country  $i$  (with  $\alpha_h^C = 1 - \alpha_f^C < \frac{1}{2}$ ),  $\mu_i^C$  is the elasticity of substitution between consumption goods, and  $P_{i,t}^C = \left[ (1 - \alpha_i^C) P_{h,t}^{1-\mu_i^C} + \alpha_i^C P_{f,t}^{1-\mu_i^C} \right]^{\frac{1}{1-\mu_i^C}}$  is the aggregate price index for consumption goods, where  $P_{h,t}$  (resp.  $P_{f,t}$ ) is the price of the home (resp. foreign) goods.

Following Dedola, Karadi and Lombardo (2012), we consider two types of risk-free assets: deposits ( $D_{i,t}(j)$ ), held by banks and bonds  $B_{i,t}(j)$  traded between the households of each country, in zero net supply ( $B_{h,t} + B_{f,t} = 0$ ). Defining  $H_{i,t}(j)$  as the supply of labour, we can write the welfare of the representative household as,

$$\Omega_{i,t}(j) = \sum_{\tau=0}^{+\infty} \beta^\tau \left[ e^{\varepsilon_{i,t}^C} \ln(C_{i,t+\tau}(j) - h_i C_{i,t+\tau-1}(j)) - \chi_i^C \frac{1}{1 + \varphi_i} H_{i,t+\tau}(j)^{1+\varphi_i} \right], \quad (2.1)$$

with  $\varepsilon_{i,t}^C \sim AR(1)$ ,  $0 < \beta < 1$  and  $0 < h < 1$  a habit parameter. He maximizes its welfare with respect to  $C_{i,t+\tau}(j)$ ,  $H_{i,t+\tau}(j)$ ,  $D_{i,t+1+\tau}(j)$ , subject to the budget constraint,

$$P_{i,t}^C C_{i,t}(j) + D_{i,t+1}(j) + B_{i,t+1}(j) + AC_{i,t}^B(j) = W_{i,t}^h(j) H_{i,t}(j) + T_{i,t} + R_t (D_{i,t}(j) + B_{i,t}(j)), \quad (2.2)$$

where  $B_{i,t+1}(j)$  is the amount of international bonds subscribed by household  $j$  at the end of period  $t$ ,  $W_{i,t}^h(j)$  the nominal wage,  $T_{i,t}$  the total amount of net transfers received in period  $t$ , and  $AC_{i,t}^B(j) = \frac{\kappa_i^B}{2} (B_{i,t+1}(j) - B_{i,t}(j))^2$  are the quadratic adjustment costs the household has to pay to buy new bonds (Schmitt-Grohé and Uribe, 2003), with  $B_{i,t}(j)$  the steady state level of bonds held by household  $j$ . Defining  $\Pi_{i,t+1}^C = \frac{P_{i,t+1}^C}{P_{i,t}^C}$  as the gross

inflation rate on the economy, we summarize the agent's FOC as,

$$\beta \frac{E_t[\Lambda_{i,t,t+1}(j)R_{t+1}]}{1 + \varkappa_i^B (B_{i,t+1}(j) - B_i(j))} = \Pi_{i,t+1}^C, \quad (2.3)$$

$$\varrho_{i,t}(j)W_{i,t}^h(j) = \chi_i^C H_{i,t}(j)^{\varphi_i}, \quad (2.4)$$

where  $\varrho_t(j)$  is the marginal utility of consumption defined as,

$$\varrho_{i,t}(j) = \frac{e^{\varepsilon_{i,t}^C}}{C_{i,t}(j) - h_i C_{i,t-1}(j)} - \frac{\beta h_i}{E_t[C_{i,t+1}(j)] - h_i C_{i,t}(j)}, \quad (2.5)$$

and,

$$\Lambda_{i,t,t+1}(j) = \frac{\varrho_{i,t+1}(j)}{\varrho_{i,t}(j)}. \quad (2.6)$$

Households provide differentiated labor types, sold by labor unions to perfectly competitive labor packers who assemble them in a CES aggregator and sell the homogeneous labor to intermediate firms. Each representative union is related to an household  $j \in [0, 1]$ . Each household provides a differentiated type of labor  $H_{i,t}(j)$ . The aggregated amount of labor in the economy  $H_{i,t}$  is defined as,  $H_{i,t} = \left[ \int_0^1 H_{i,t}(j)^{(\varepsilon_i^W - 1)/\varepsilon_i^W} dj \right]^{\varepsilon_i^W / (\varepsilon_i^W - 1)}$ , where  $\varepsilon_i^W$  is the elasticity of substitution. The demand for an individual type of labor is defined as,  $H_{i,t}(j) = \left( \frac{W_{i,t}^h(j)}{W_{i,t}} \right)^{-\varepsilon_i^W} H_{i,t}$ , where  $W_{i,t}^h(j)$  is the wage for labor of type  $j$

and,  $W_{i,t} = \left[ \int_0^1 W_{i,t}^h(j)^{1-\varepsilon_i^W} dj \right]^{1/(1-\varepsilon_i^W)}$  is the aggregate wage index in the  $i^{th}$  part of the monetary union.

In line with Calvo (1983), wage stickiness arises from the fact that each labor union cannot adjust immediately nominal wages. We assume that each labor union is able to choose an optimal wage  $W_{i,t}^{h*}(j)$  with probability  $(1 - \theta_i^W)$  while the remaining of workers have their wage indexed on the previous period  $\left( \Pi_{i,t} = \frac{P_{i,t}}{P_{i,t-1}} \right)$ . The labor union thus

maximizes,

$$\max_{\{W_{i,t}^*(j)\}} E_t \sum_{\tau=0}^{+\infty} (\theta_i^W)^\tau \beta^\tau \Lambda_{i,t,t+\tau}(j) \left[ \frac{W_{i,t}^{h*}(j)}{P_{i,t+\tau}} \prod_{k=1}^{\tau} (\Pi_{i,t+k-1})^{\gamma_i^{pw}} - \frac{W_{i,t}^h(j)}{P_{i,t+\tau}} \right] H_{i,t+\tau}(j), \quad (2.7)$$

subject to,  $H_{i,t+\tau}(j) = \left( \frac{W_{i,t}^{h*}(j)}{W_{i,t+\tau}} \prod_{k=1}^{\tau} (\Pi_{i,t+k-1})^{\gamma_i^{pw}} \right)^{-\varepsilon_i^W}$ , where  $\gamma_i^{pw}$  is the indexation parameter. The FOC that governs the dynamics of the nominal wage is,

$$E_t \sum_{\tau=0}^{+\infty} (\theta_i^W)^\tau \beta^\tau \Lambda_{i,t,t+\tau}(j) \left[ \frac{W_{i,t}^{h*}(j)}{P_{i,t+\tau}} \prod_{k=1}^{\tau} (\Pi_{i,t+k-1})^{\gamma_i^{pw}} - \frac{\varepsilon_i^W}{\varepsilon_i^W - 1} \frac{W_{i,t}^h(j)}{P_{i,t+\tau}} \right] H_{i,t+\tau}(j) = 0, \quad (2.8)$$

where  $\frac{\varepsilon_i^W}{\varepsilon_i^W - 1}$  is the mark up on the labor market.

### 3.2 Firms and capital suppliers

The productive sector of each country combines intermediate firms, final firms and capital suppliers. Intermediate firms produce differentiated goods  $i$ , choose labor and capital inputs, and set prices according to a Calvo (1983) technology. Final goods producers act as a consumption bundler by combining national intermediate goods to produce the homogeneous final good<sup>2</sup>. Capital suppliers rent and refurbish the capital stock used by intermediate firms and financed by entrepreneurs on a competitive market.

The representative intermediate firm  $i \in [0, 1]$  from country  $i$ , produces,

$$Y_{i,t}^S(i) = e^{\varepsilon_{i,t}^A} (U_{i,t}(i) K_{i,t}(i))^{\alpha_i} H_{i,t}(i)^{1-\alpha_i}, \quad (2.9)$$

where  $Y_{i,t}^S(i)$  is the production function of the intermediate good that combines capital  $K_{i,t}(i)$ , labor  $H_{i,t}(i)$  and technology  $e^{\varepsilon_{i,t}^A}$  (an  $AR(1)$  productivity shock). Intermediate goods producers solve a two-stage problem. In the first stage, taking the real input prices

2. Final good producers are perfectly competitive and maximize profits,  $P_{i,t} Y_{i,t}^D - \int_0^1 P_{i,t}(i) Y_{i,t}^S(i) di$  (with  $P_{i,t}(i)$  the price of good  $i$ ), subject to the production function  $Y_{i,t}^D = \left( \int_0^1 Y_{i,t}^S(i)^{(\varepsilon_i^E - 1)/\varepsilon_i^E} di \right)^{\varepsilon_i^E / (\varepsilon_i^E - 1)}$ . We find the intermediate demand functions associated with this problem are,  $Y_{i,t}^S(i) = (P_{i,t}(i)/P_{i,t})^{-\varepsilon_i^E} Y_{i,t}^D$ ,  $\forall i$  where  $Y_{i,t}^D$  is the aggregate demand.

$W_{i,t}$  and  $Z_{i,t}^k$  as given, firms rent inputs  $H_{i,t}(i)$  and  $K_{i,t}(i)$  in a perfectly competitive factor markets in order to minimize costs subject to the production constraint. They pay a cost  $\Phi(U_{i,t}(i))$  for using capital that is affected to entrepreneurs through the  $R_{i,t}^k$ . In equilibrium this marginal cost of using capital ( $\Phi'(U_{i,t}(i))$ ) is equal to the marginal return of capital denoted  $Z_{i,t}^k$ <sup>3</sup>. The marginal cost of production is thus,

$$MC_{i,t}^E(i) = \alpha_i^{-\alpha_i} (1 - \alpha_i)^{\alpha_i - 1} (Z_{i,t}^k)^{\alpha_i} W_{i,t}^{1-\alpha_i} (e^{\varepsilon_{i,t}^a})^{-1}. \quad (2.10)$$

The average rate of capital profitability is,

$$\frac{R_{i,t+1}^k}{1 + \varkappa_i^B (B_{i,t+1}(j) - B_i(j))} = \frac{[MC_{i,t+1}^E \alpha_i \frac{Y_{i,t+1}^s}{K_{i,t+1}} + (1 - \delta_{i,c}) Q_{i,t+1} - \Phi(U_{i,t+1})]}{Q_{i,t}}, \quad (2.11)$$

with  $\delta_{i,c}$  is the depreciation parameter.

Each firm  $i$  sets the price of  $Y_{i,t}^s(i)$  according to a Calvo mechanism. Each period only a fraction  $(1 - \theta_i^E)$  of final firms is able to set the optimal price  $P_{i,t}^*(i)$ , other prices being partially indexed on the inflation rate. The optimization program of the representative intermediate firm is thus,

$$\max_{\{P_{i,t}^*(i)\}} E_t \sum_{\tau=0}^{\infty} (\theta_i^E)^\tau \beta^\tau \Lambda_{i,t,t+\tau} \left[ P_{i,t}^*(i) \prod_{k=1}^{\tau} (\Pi_{i,t+k-1})^{\gamma^{pe}} - MC_{i,t+\tau}^E(i) \right] Y_{i,t+\tau}^s(i), \quad (2.12)$$

where  $\gamma_i^{pe} < 1$  is the indexation parameter. The First order condition is given by,

$$\sum_{\tau=0}^{\infty} (\theta_i^E)^\tau \beta^\tau \Lambda_{i,t,t+\tau} \left[ P_{i,t}^*(i) \prod_{k=1}^{\tau} (\Pi_{i,t+k-1})^{\gamma^{pe}} - \frac{\varepsilon_i^E}{\varepsilon_i^E - 1} MC_{i,t+\tau}^E(i) \right] Y_{i,t+\tau}^s(i) = 0, \quad (2.13)$$

where  $\frac{\varepsilon_i^E}{\varepsilon_i^E - 1}$  is the mark up on the final good market.

Capital suppliers are homogeneous and distributed over a continuum normalized to one. The representative capital supplier  $q \in [0, 1]$  acts competitively to supply a

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3. Following Poutineau et Vermandel (2015), we define  $\Phi(U_{i,t}) = \frac{1-\Psi_i}{\Psi_i} \bar{Z} [e^{\frac{\Psi_i}{1-\Psi_i}(U_{i,t}-1)} - 1]$ . Thus, we get  $Z_{i,t}^k = \Phi'(U_{i,t}) = \bar{Z}_i e^{\frac{\Psi_i}{1-\Psi_i}(U_{i,t}-1)}$ .

quantity  $K_{i,t}(q)$  of capital. Investment is costly, *i.e.* the capital supplier pays an adjustment cost function  $f\left(\frac{I_{n,i,t+\tau}(q)+\bar{I}_i(q)}{I_{n,i,t+\tau-1}(q)+\bar{I}_i(q)}\right) = \frac{\eta_i^I}{2}\left(\frac{I_{n,i,t}(q)+\bar{I}_i(q)}{I_{n,i,t-1}(q)+\bar{I}_i(q)} - 1\right)^2$  on new investment  $I_{n,i,t}(q) \equiv I_{i,t}(q) - \delta(U_{i,t})K_{i,t}(q)$  (with  $\delta(U_{i,t})K_{i,t}(q)$  the depreciated capital and  $\bar{I}_i$  the steady-state level of investment in country  $i$ ). It provides a real amount of capital valued  $Q_{i,t}(q)K_{i,t+1}(q)$  by buying the non depreciated capital to entrepreneurs  $(1 -$

$\delta(U_{i,t}))K_{i,t+1}(q)$  and investing  $I_{i,t}(q) = \left[ (1 - \alpha_i^I)^{\frac{1}{\mu^I}} (I_{i,h,t}(q))^{\frac{\mu^I-1}{\mu^I}} + (\alpha_i^I)^{\frac{1}{\mu^I}} (I_{i,f,t}(q))^{\frac{\mu^I-1}{\mu^I}} \right]^{\frac{\mu^I}{\mu^I-1}}$ ,

with price  $P_{i,t}^I = (1 - \alpha_i^I) P_{h,t}^{1-\mu^I} + \alpha_i^I P_{f,t}^{1-\mu^I}$ . Here,  $I_{i,h,t}(q) = (1 - \alpha_i^I) \left(\frac{P_{h,t}}{P_{i,t}^I}\right)^{-\mu^I} I_{i,t}(q)$

and  $I_{i,f,t}(q) = \alpha_i^I \left(\frac{P_{f,t}}{P_{i,t}^I}\right)^{-\mu^I} I_{i,t}(q)$ .

The representative capital supplier chooses  $I_{n,i,t+\tau}(q)$  to maximize,

$$\max_{\{I_{n,i,t+\tau}(q)\}} E_t \sum_{\tau=0}^{\infty} \theta_{i,t+\tau}^{\beta} \Lambda_{i,t,t+1+\tau} \left[ \begin{array}{c} (Q_{i,t+\tau}(q) - 1)I_{n,i,t+\tau}(q) \\ -f\left(\frac{I_{n,i,t+\tau}(q)+\bar{I}_i(q)}{I_{n,i,t+\tau-1}(q)+\bar{I}_i(q)}\right) (I_{n,i,t+\tau}(q) + \bar{I}_i(q)) \end{array} \right]. \quad (2.14)$$

The first order condition associated to this program defines the renting price of capital,

$$Q_{i,t}(q) = 1 + f\left(\frac{I_{n,i,t}(q) + \bar{I}_i(q)}{I_{n,i,t-1}(q) + \bar{I}_i(q)}\right) + \frac{I_{n,i,t}(q) + \bar{I}_i(q)}{I_{n,i,t-1}(q) + \bar{I}_i(q)} f' \left(\frac{I_{n,i,t+i}(q) + \bar{I}_i(q)}{I_{n,i,t+i-1}(q) + \bar{I}_i(q)}\right) - E_t \left[ \beta (C_{i,t}) \Lambda_{i,t,t+1} \left(\frac{I_{n,i,t+i}(q) + \bar{I}_i(q)}{I_{n,i,t+i-1}(q) + \bar{I}_i(q)}\right)^2 f' \left(\frac{I_{n,i,t+i}(q) + \bar{I}_i(q)}{I_{n,i,t+i-1}(q) + \bar{I}_i(q)}\right) \right] \quad (2.15)$$

## 4 Financial relations and general equilibrium

### 4.1 Loan market equilibrium in a nutshell

Loan demand emanates from entrepreneurs. The representative entrepreneur  $e \in [0, 1]$  from country  $i$  finances the capital renting of intermediate firms with her wealth and with loans from financial intermediaries. Formally, as in Poutineau and Vermandel (2015), in period  $t$ , this entrepreneur conducts a great number of heterogeneous projects with total value  $Q_{i,t}K_{i,t+1}(e)$ , where  $Q_{i,t}$  is the price of capital and  $K_{i,t+1}(e)$  is the amount

of capital financed. These projects are financed by his net wealth  $N_{i,t}^E(e)$  and by loans contracted from the banking system  $L_{i,t}^D(e)$ . The balance sheet of the representative entrepreneur is determined by,  $Q_{i,t}K_{i,t+1}(e) = N_{i,t}^E(e) + L_{i,t}^D(e)$ , with the value of capital financed being proportional to her net wealth,  $Q_{i,t}K_{i,t+1}(e) = \phi_{i,t}^E(e)N_{i,t}^E(e)$ , while the entrepreneur's loan demand is defined as,  $L_{i,t}^D(e) = (\phi_{i,t}^E(e) - 1)N_{i,t}^E(e)$ , where variable  $\phi_{i,t}^E(e)$  is a borrowing accelerator à la Bernanke et al. (1999), defined as,  $\phi_{i,t}^E(e) \equiv \left[ 1 - \frac{\kappa_i - 1}{\kappa_i} \left( \frac{\mathbb{E}_t[R_{i,t+1}^k]}{P_{i,t}^L} \frac{\gamma_i^{1-\chi_i^E}}{e^{\varepsilon_{i,t}^{opt}}} \right)^{\frac{1}{\chi_i^E}} \right]^{-1}$ ,  $\gamma_i$  is as scale parameter,  $\kappa_i$  is a shape parameter of the Pareto law on investment projects, and  $\varepsilon_{i,t}^{opt}$  is an  $AR(1)$  shock on entrepreneurs optimism.<sup>4</sup> The size of the borrowing accelerator is determined by the external finance premium  $\frac{\mathbb{E}_t[R_{i,t+1}^k]}{P_{i,t}^L}$ , with elasticity  $\chi_i^E$ .

Loan supply emanates from banks. The representative bank  $b \in [0, 1]$  from country  $i$  operates in a regime of monopolistic competition to provide deposits and credit services to households and firms. Each period, the bank collects a total amount of deposits  $D_{i,t+1}(b)$  from its own country's households, remunerated at the risk free nominal interest rate  $R_t$  (as we consider a monetary union situation, the nominal interest rate is common between the two economies), and supplies loans  $L_{i,t}^S(b)$  to both domestic and foreign entrepreneurs at a rate  $R_{i,t}^L(b)$ . When providing resources to their national banking system, households are faced with a problem of moral hazard. As in Gertler and Karadi (2011), banks may decide to divert a fraction  $\lambda_{i,t}$  of their resources and transfer it back to the household of which she is a member. Depositors can force the intermediary to go bankrupt and they recover the remaining fraction  $(1 - \lambda_{i,t})$  of assets. We assume that  $\lambda_{i,t} = \lambda_i e^{\varepsilon_{i,t}^\lambda}$ , with  $\varepsilon_{i,t}^\lambda \sim AR(1)$ .

On the asset side of her balance sheet, the representative financial intermediary provides loans to both domestic and foreign entrepreneurs using resources obtained from the deposits of her country's households ( $D_{i,t+1}(b)$ ) and from its net wealth ( $N_{i,t}^B(b)$ ). The balance sheet of the representative financial intermediary is thus defined as,  $L_{i,t}^S(b) = N_{i,t}^B(b) + D_{i,t+1}(b)$ , where  $L_{i,t}^S(b)$  is the total amount of loans supplied to the economy.<sup>5</sup>

4. More details about the computation of the borrowing accelerator are provided in Appendix A.

5. As in the original setting of Gertler and Karadi (2011), banks are owned by households (see the next section) and the landlord of the bank cannot put deposits in his bank.

Banks from each country are subject to an occasionally binding credit constraint on the maximum amount of loans they can issue. Indeed, because of the agency problem, households only agree to put deposits at the bank in a limited amount (that does not trigger the diversion incentive from the bank). This, in turn, imposes a maximum amount of loans ( $L_{i,t}^{S \max}(b)$ ) banks can not exceed. This maximum amount is determined as a function of their net wealth and a lending accelerator  $\phi_{i,t}^B(b)$  as,  $L_{i,t}^S(b)^{\max} = \phi_{i,t}^B(b) N_{i,t}^B(b)$ .

Cross border lending affects the asset side of the banking system balance sheet. Accounting for cross border lending, the total amount of loans contracted by the representative entrepreneur,  $L_{i,t}^D(e)$ , is defined as a CES bundle of loans purchased from both domestic banks ( $L_{i,h,t}^D(e)$ ) and foreign banks ( $L_{i,f,t}^D(e)$ ),

$$L_{i,t}^D(e) = \left[ (1 - \alpha_i^L)^{\frac{1}{\mu_i^L}} (L_{i,h,t}^D(e))^{\frac{\mu_i^L - 1}{\mu_i^L}} + (\alpha_i^L)^{\frac{1}{\mu_i^L}} (L_{i,f,t}^D(e))^{\frac{\mu_i^L - 1}{\mu_i^L}} \right]^{\frac{\mu_i^L}{\mu_i^L - 1}}. \quad (2.16)$$

where  $\alpha_i^L$  is a home bias ( $\alpha_h^L = 1 - \alpha_f^L < \frac{1}{2}$ ), parameter  $\mu_i^L$  is the elasticity of substitution between domestic and foreign loans and  $ToT_t \equiv \frac{P_{f,t}}{P_{h,t}}$  is the terms of trade between the two economies (with  $P_{h,t}$  (resp.  $P_{f,t}$ ) representing the price level in the domestic (resp. foreign) economy).<sup>6</sup> Variable  $R_{h,t}^L(e)$  (resp.  $R_{f,t}^L(e)$ ) is the interest rate on loans obtained by the representative entrepreneur  $e$  from domestic (resp. foreign) banks, and,

$$P_{h,t}^L(e) = \left[ (1 - \alpha_h^L) R_{h,t}^L(e)^{1 - \mu_h^L} + \alpha_h^L \left( \frac{ToT_{t+1}}{ToT_t} R_{f,t}^L(e) \right)^{1 - \mu_h^L} \right]^{1/(1 - \mu_h^L)}, \quad (2.17)$$

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6. Loans purchased by a domestic entrepreneur  $e$  from domestic (resp. foreign) banks are defined as  $L_{h,h,t}^D(e) = (1 - \alpha_h^L) \left( \frac{R_{h,t}^L(e)}{P_{h,t}^L(e)} \right)^{-\mu_h^L} L_{h,t}^D(e)$  (resp.  $L_{h,f,t}^D(e) = \alpha_h^L \left( \frac{ToT_{t+1} R_{f,t}^L(e)}{P_{h,t}^L(e)} \right)^{-\mu_h^L} L_{h,t}^D(e)$ ), while loans purchased by a foreign entrepreneur  $e$  from domestic (resp. foreign) banks write  $L_{f,h,t}^D(e) = (1 - \alpha_f^L) \left( \frac{ToT_t R_{h,t}^L(e)}{P_{f,t}^L(e)} \right)^{-\mu_f^L} L_{f,t}^D(e)$  (resp.  $L_{f,f,t}^D(e) = \alpha_f^L \left( \frac{R_{f,t}^L(e)}{P_{f,t}^L(e)} \right)^{-\mu_f^L} L_{f,t}^D(e)$ ).

is the total cost of loans for a domestic entrepreneur  $e$ .<sup>7</sup> In the equilibrium, the total loan supply in the economy  $i$  is equal to the total loan demand addressed to the economy  $i$ ,

$$L_{i,t}^S = L_{h,i,t}^D + L_{f,i,t}^D, \quad (2.18)$$

with  $L_{h,i,t}^D$  the loan demand from domestic entrepreneurs to the economy  $i$  and  $L_{f,i,t}^D$  the loan demand from foreign entrepreneurs to the economy  $i$ .<sup>8</sup>

## 4.2 Normal times vs crisis times

Financial troubles affect the equilibrium of the market through a quantitative constraint on loan availability. As previously underlined, households face a moral hazard problem when providing deposits to the banking system. This moral hazard problem may lead depositors to shrink the quantity of resources needed by the banking system. This, in turn, induces a quantitative shortage in the provision of loans from banks to entrepreneurs. For lenders to be willing to supply funds to the banker, the following incentive constraint must be satisfied,  $V_{i,t}(b) \geq \lambda_{i,t} L_{i,t}^S(b)$ , where  $V_{i,t}(b)$  is the expected discounted intertemporal profit of the bank in all his remaining periods of activity. The constraint states that households accept to hold deposits  $D_{i,t+1}(b)$  at the bank only until they reach a maximum amount of deposits for which the bank is indifferent between

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7. Conversely,  $P_{f,t}^L(e) = \left[ (1 - \alpha_f^L) \left( \frac{T_o T_t}{T_o T_{t+1}} R_{h,t}^L(e) \right)^{1 - \mu_f^L} + \alpha_f^L R_{f,t}^L(e)^{1 - \mu_f^L} \right]^{1/(1 - \mu_f^L)}$  is the total cost of loans for a foreign entrepreneur  $e$ .

8. At the equilibrium on the loan market, total credit supply in the economy  $i$  is a bundle of loans supplied by individual banks in this economy:  $\frac{L_{i,t}^S}{\Delta_{i,t}^L} = \left[ \int_0^1 L_{i,t}^S(b)^{(\epsilon_i^B - 1)/\epsilon_i^B} db \right]^{\epsilon_i^B/(\epsilon_i^B - 1)}$ , with  $\epsilon_i^B$  the elasticity of substitution between loans and  $\Delta_{i,t}^L = \int_0^1 (R_{i,t}^L(b)/R_{i,t}^L)^{-\epsilon_i^B/(\epsilon_i^B - 1)} db$  the dispersion term for interest rates on loans. The demand of loans addressed to each bank individually is  $L_{i,t}^S(b) = \left( \frac{R_{i,t}^L(b)}{R_{i,t}^L} \right)^{-\epsilon_i^B} L_{i,t}^S$ ,

where  $R_{i,t}^L = \left[ \int_0^1 R_{i,t}^L(b)^{1 - \epsilon_i^B} db \right]^{1/(1 - \epsilon_i^B)}$  is the aggregate cost of loans in the economy. In this model, we consider flexible interest rates on loans, so  $R_{i,t}^L(b) = R_{i,t}^L$ , and  $\Delta_{i,t}^L = 1$ . If the incentive constraint is checked, the total amount of loans intermediated by the banking system depends on the quantity of loans demanded by both home and foreign entrepreneurs.



lending to entrepreneurs and going bankrupt by diverting a fraction  $\lambda_{i,t}$  of his resources  $L_{i,t}^S(b) = N_{i,t}^B(b) + D_{i,t+1}(b)$  normally used to back loans.<sup>9</sup>

In "normal times", financial intermediaries are not constrained and they have enough resources to meet the quantity of loans demanded by both home and foreign entrepreneurs (i.e.,  $L_{h,i,t}^D + L_{f,i,t}^D \leq L_{i,t}^{S,\max}$ ). In "crisis times", banks have troubles to get enough resources to issue as much loans as demanded by entrepreneurs (either because of a drop in the amount of deposits or because of a decrease in their capital value following an adverse financial shock), and restrict their supply to  $L_{i,t}^{S,\max}$ . In this situation the notional demand for loans emanating from entrepreneurs is not met. So the situation on each country's credit market can be summarized by the following system,

$$\begin{cases} L_{i,t} \leq L_{i,t}^{S,\max} & \text{if } L_{i,t}^{D,n} \leq L_{i,t}^{S,\max} \text{ (normal times),} \\ L_{i,t} = L_{i,t}^{S,\max} & \text{if } L_{i,t}^{D,n} > L_{i,t}^{S,\max} \text{ (crisis times),} \end{cases} \quad (2.19)$$

where  $L_{i,t}^{D,n}$  is the notional demand for loans, i.e. the sum of demands for loans coming from both domestic and foreign entrepreneurs that would be observed in the economy  $i$  if there was no credit constraint, and  $L_{i,t}$  is the effective quantity of credit in the economy at the equilibrium on the credit market, i.e. the quantity that meets  $L_{i,t}^S = L_{h,i,t}^D + L_{f,i,t}^D$ . If the notional loan demand from entrepreneurs is smaller than the maximal amount of loans banks can offer, then the quantity of loans in the economy is not constrained. If the notional loan demand from entrepreneurs is higher than the maximal amount of loans banks can offer, then the quantity of loans in the economy becomes constrained.

In normal times, the incentive constraint is checked and the banking system has no trouble to get resources from households to create loans. In this interior solution, the total amount of loans intermediated on country  $i$  by the banking system depends on the quantity of loans demanded by domestic entrepreneurs ( $L_{h,i,t}^D$ ) and foreign entrepreneurs ( $L_{f,i,t}^D$ ). The setting of the loan interest rate for the representative bank  $b$  of country  $h$  in normal times is intended to maximize the expected profit of the bank that takes into account the possibility of domestic and foreign entrepreneurs to fail to pay back their

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9. More details about this constraint are provided in the next subsection.

loans, with respective probabilities  $(1 - E_t [\eta_{h,t+1}^E])$  and  $(1 - E_t [\eta_{f,t+1}^E])$ ,

$$\begin{aligned} R_{h,t}^L(b) &= \frac{\epsilon_h^B}{\epsilon_h^B - 1} MC_{h,t}^B(b) \\ &= \frac{\epsilon_h^B}{\epsilon_h^B - 1} \frac{1}{1 - \tau_h^B} \frac{R_t}{(E_t [\eta_{h,t+1}^E] - (E_t [\eta_{h,t+1}^E] - E_t [\eta_{f,t+1}^E]) \Xi_{h,t})}, \end{aligned} \quad (2.20)$$

$$\begin{aligned} R_{f,t}^L(b) &= \frac{\epsilon_f^B}{\epsilon_f^B - 1} MC_{f,t}^B(b) \\ &= \frac{\epsilon_f^B}{\epsilon_f^B - 1} \frac{1}{1 - \tau_f^B} \frac{R_t}{(E_t [\eta_{f,t+1}^E] - (E_t [\eta_{f,t+1}^E] - E_t [\eta_{h,t+1}^E]) \Xi_{f,t})}, \end{aligned} \quad (2.21)$$

where  $MC_{h,t}^B(b)$  is the marginal cost of creating new loans.<sup>10</sup> In the right hand side of these expressions,  $\epsilon_i^B$  is the elasticity of substitution between different types of loans (so  $\frac{\epsilon_i^B}{\epsilon_i^B - 1}$  is the bank markup),

$\Xi_{f,t} \equiv \frac{L_{f,h,t}^D(b)}{L_{h,h,t}^D(b) + L_{f,h,t}^D(b)} = \left( \frac{1 - \alpha_h^L}{1 - \alpha_f^L} \left( \frac{P_{f,t}^L}{P_{h,t}^L} \frac{E_t[ToT_{t+1}]}{ToT_t} \right)^{-\mu_h^L} \frac{Q_{h,t} K_{h,t} - N_{h,t}^E}{Q_{f,t} K_{f,t} - N_{f,t}^E} + 1 \right)^{-1}$  is the share of loan demand from foreign entrepreneurs to the domestic bank  $b$  on the total loan demand to the domestic bank  $b$ ,  $\Xi_{f,t} \equiv \frac{L_{h,f,t}^D(b)}{L_{h,f,t}^D(b) + L_{f,f,t}^D(b)} = \left( \frac{\alpha_f^L}{\alpha_h^L} \left( \frac{P_{h,t}^L}{P_{f,t}^L} \frac{ToT_t}{E_t[ToT_{t+1}]} \right)^{-\mu_f^L} \frac{Q_{f,t} K_{f,t} - N_{f,t}^E}{Q_{h,t} K_{h,t} - N_{h,t}^E} + 1 \right)^{-1}$  is the share of loan demand from domestic entrepreneurs to the foreign bank  $b$  on the total loan demand to the foreign bank  $b$ , and  $\tau_i^B$  a tax set by the social planner of country  $i$  on the revenue of the bank. In normal times the amount of loans in country  $i$  is determined by loan demand from both home and foreign entrepreneurs given the interest rate set by the banking system of country  $i$ .

Imposing symmetry between all entrepreneurs and between all banks, and defining  $L_{h,i,t}^D$  (resp.  $L_{f,i,t}^D$ ) as the total amount of loans demanded by home (resp. foreign) entrepreneurs to banks of country  $i$ , the quantity of loans supplied in the whole country  $i$  is  $L_{i,t}^S = L_{h,i,t}^D + L_{f,i,t}^D$ . Calling  $L_{i,t}$  the total amount of loans circulating in the economy

10. More details regarding the computation of bank marginal cost are provided on the Appendix B.

$i$  and using the expression of the loan demand, we can write,

$$\begin{aligned} L_{h,t} &= L_{h,t}^S = (1 - \alpha_h^L) \left[ \frac{R_{h,t}^L}{P_{h,t}^L} \right]^{-\mu_h^L} (\phi_{h,t}^E - 1) N_{h,t}^E \\ &\quad + (1 - \alpha_f^L) \left[ \frac{\frac{T_o T_t}{T_o T_{t+1}} R_{h,t}^L}{P_{f,t}^L} \right]^{-\mu_h^L} (\phi_{f,t}^E - 1) N_{f,t}^E, \end{aligned} \quad (2.22)$$

$$\begin{aligned} L_{f,t} &= L_{f,t}^S = \alpha_h^L \left[ \frac{\frac{T_o T_{t+1}}{T_o T_t} R_{f,t}^L(e)}{P_{h,t}^L(e)} \right]^{-\mu_f^L} (\phi_{h,t}^E - 1) N_{h,t}^E \\ &\quad + \alpha_f^L \left[ \frac{R_{f,t}^L(e)}{P_{f,t}^L(e)} \right]^{-\mu_f^L} (\phi_{f,t}^E - 1) N_{f,t}^E, \end{aligned} \quad (2.23)$$

The crisis is driven by exogenous shocks that affect the ability of the banking system to create loans. This resource shortage may come either from less deposits or from a collapse in the capital value of the banking system. Since the resource constraint of banks bites, the amount of loans created in economy  $i$  corresponds to  $L_{i,t}^{S,\max}$ . The computation of this loan ceiling  $L_{i,t}^{S,\max}$  follows Gertler and Karadi (2011). Here,  $L_{i,t}^S(b) = L_{i,t}^{S,\max}(b)^{\max} = \phi_{i,t}^B(b) N_{i,t}^B(b)$ , where  $\phi_{i,t}^B(b) \equiv \frac{\eta_{i,t}(b)}{\lambda_{i,t} - \nu_{i,t}(b)}$  features the lending accelerator<sup>11</sup>.

In this situation, the interest rate on loans ( $R_{i,t}^L$ ) becomes a jump variable determined at the market level to force demand to equalize loan supply. Imposing symmetry between

11. This lending accelerator is the accelerator from Gertler and Karadi (2011), adapted to a two-country framework in the spirit of Dedola et al. (2013). The components of the accelerator write,

$$\begin{aligned} \nu_{h,t}(b) &= E_t \left[ \begin{aligned} &(1 - \theta_h) \beta_h \Lambda_{h,t,t+1} \left( (1 - \tau_h^B) \eta_{h,t+1}^E R_{h,t}^L(b) - R_t \right) \\ &- (1 - \tau_h^B) R_{h,t}^L(b) \left( \eta_{h,t+1}^E - \eta_{f,t+1}^E \right) \Xi_{h,t+1} + \Lambda_{h,t,t+1} \theta_h \beta_h \frac{L_{h,t+1}^S(b)}{L_{h,t}^S(b)} \nu_{h,t+1}(b) \end{aligned} \right], \\ \nu_{f,t}(b) &= E_t \left[ \begin{aligned} &(1 - \theta_f) \beta_f \Lambda_{f,t,t+1} \left( (1 - \tau_f^B) \eta_{f,t+1}^E R_{f,t}^L(b) - R_t \right) \\ &- (1 - \tau_f^B) R_{f,t}^L(b) \left( \eta_{f,t+1}^E - \eta_{h,t+1}^E \right) \Xi_{f,t+1} + \Lambda_{f,t,t+1} \theta_f \beta_f \frac{L_{f,t+1}^S(b)}{L_{f,t}^S(b)} \nu_{f,t+1}(b) \end{aligned} \right], \text{ and} \\ \eta_{i,t}(b) &= E_t \left[ (1 - \theta_i) \beta_i \Lambda_{i,t,t+1} R_{t+1} + \Lambda_{i,t,t+1} \theta_i \beta_i \frac{N_{i,t+1}^B(b)}{N_{i,t}^B(b)} \eta_{i,t+1}(b) \right]. \end{aligned}$$

all entrepreneurs and between all banks,  $R_{i,t}^L$  solves,

$$\begin{aligned} \phi_{h,t}^B N_{h,t}^B &= (1 - \alpha_h^L) \left[ \frac{R_{h,t}^L}{P_{h,t}^L} \right]^{-\mu_h^L} (\phi_{h,t}^E - 1) N_{h,t}^E \\ &\quad + (1 - \alpha_f^L) \left[ \frac{\frac{T_o T_t}{T_o T_{t+1}} R_{h,t}^L}{P_{f,t}^L} \right]^{-\mu_h^L} (\phi_{f,t}^E - 1) N_{f,t}^E, \end{aligned} \quad (2.24)$$

$$\begin{aligned} \phi_{f,t}^B N_{f,t}^B &= \alpha_h^L \left[ \frac{\frac{T_o T_{t+1}}{T_o T_t} R_{f,t}^L(e)}{P_{h,t}^L(e)} \right]^{-\mu_h^L} (\phi_{h,t}^E - 1) N_{h,t}^E \\ &\quad + \alpha_f^L \left[ \frac{R_{f,t}^L(e)}{P_{f,t}^L(e)} \right]^{-\mu_h^L} (\phi_{f,t}^E - 1) N_{f,t}^E \end{aligned} \quad (2.25)$$

with,

$$\phi_{i,t}^B \equiv \frac{\eta_{i,t}}{\lambda_{i,t} - \nu_{i,t}}, \quad (2.26)$$

$$\begin{aligned} N_{h,t}^B &= \theta_h \frac{(1 - \tau_h^B) \left[ \left( \eta_{h,t}^E R_{h,t-1}^L - \frac{1}{1 - \tau_h^B} R_{t-1} \right) - R_{h,t-1}^L (\eta_{h,t}^E - \eta_{f,t}^E) \Xi_{h,t-1} \right] L_{h,t-1}^S + R_{t-1} N_{h,t-1}^B}{e^{\varepsilon_{h,t}^{NB}}} \\ &\quad + \omega_h L_{h,t-1}^S, \end{aligned} \quad (2.27)$$

$$\begin{aligned} N_{f,t}^B &= \theta_f \frac{(1 - \tau_f^B) \left[ \left( \eta_{f,t}^E R_{f,t-1}^L - \frac{1}{1 - \tau_f^B} R_{t-1} \right) - R_{f,t-1}^L (\eta_{f,t}^E - \eta_{h,t}^E) \Xi_{f,t-1} \right] L_{f,t-1}^S + R_{t-1} N_{f,t-1}^B}{e^{\varepsilon_{f,t}^{NB}}} \\ &\quad + \omega_f L_{f,t-1}^S, \end{aligned} \quad (2.28)$$

$$\phi_{i,t+1}^E \equiv \left[ 1 - \frac{\kappa_i - 1}{\kappa_i} \left( \frac{E_t [R_{i,t+1}^k]}{R_{i,t}^L} \gamma_i^{1 - \chi_i^E} \right)^{\frac{1}{\chi_i^E}} \right]^{-1}, \quad (2.29)$$

$$N_{i,t+1}^E = (1 - \tau_i^E) \Pi_{i,t}^E, \quad (2.30)$$

where  $(\theta_h [((1 - \tau_h^B) \eta_{h,t}^E R_{h,t-1}^L - R_{t-1}) - (1 - \tau_h^B) R_{h,t-1}^L (\eta_{h,t}^E - \eta_{f,t}^E) \Xi_{h,t-1}] L_{h,t-1}^S + R_{t-1} N_{h,t-1}^B) / e^{\varepsilon_{h,t}^{NB}}$  is the aggregate net wealth of home bankers that already existed at period  $t - 1$ .<sup>12</sup> the value  $\omega_h L_{h,t-1}^S$  is the aggregate net wealth of new home bankers, with  $\frac{\omega_h}{1 - \theta_h}$  the fraction of

12. See Appendix B for the computation of existing banks' net wealth.

the total final period assets of exiting bankers at period  $t - 1$   $((1 - \theta_h)L_{h,t-1}^S)$  transferred by the households to the new bankers.<sup>13</sup>

### 4.3 Loan market tightness

The previous analysis can be summarized through the computation of a tightness indicator on the loan market that accounts for cross border bank relations. In crisis times, loan market tightness can be measured as follows: The interest rate that balances the domestic loan market can be written as  $R_{h,t}^L$  with,

$$R_{h,t}^L = \frac{\epsilon_h^B}{\epsilon_h^B - 1} \frac{1}{1 - \tau_h^B} \frac{R_t + \zeta_{h,t}}{(E_t[\eta_{h,t+1}^E] - (E_t[\eta_{h,t+1}^E] - E_t[\eta_{f,t+1}^E])\Xi_{h,t})}, \quad (2.31)$$

where  $\zeta_{h,t} > 0$  measures the tightness of domestic loan market.<sup>14</sup> Defining  $R_{h,t}^{L,S}$  as the shadow value of the loan interest rate, i.e. the value that the loan interest rate would have taken if the banks were not subject to a financial constraint we get,

$$R_{h,t}^L - R_{h,t}^{L,S} = \left\{ \begin{array}{l} \frac{\epsilon_h^B}{\epsilon_h^B - 1} \frac{1}{1 - \tau_h^B} \frac{R_t + \zeta_{h,t}}{(E_t[\eta_{h,t+1}^E] - (E_t[\eta_{h,t+1}^E] - E_t[\eta_{f,t+1}^E])\Xi_{h,t})} \\ - \frac{\epsilon_h^B}{\epsilon_h^B - 1} \frac{1}{1 - \tau_h^B} \frac{R_t}{(E_t[\eta_{h,t+1}^E] - (E_t[\eta_{h,t+1}^E] - E_t[\eta_{f,t+1}^E])\Xi_{h,t})} \end{array} \right\}.$$

Rearranging this expression, the tightness of the loan market,  $\zeta_{h,t}$ , is defined as,

$$\zeta_{h,t} = \frac{\epsilon_h^B - 1}{\epsilon_h^B} (1 - \tau_h^B) (E_t[\eta_{h,t+1}^E] - (E_t[\eta_{h,t+1}^E] - E_t[\eta_{f,t+1}^E])\Xi_{h,t}) (R_{h,t}^L - R_{h,t}^{L,S}). \quad (2.32)$$

Symmetrically, for the foreign country, the tightness of the loan market is defined by,

$$\zeta_{f,t} = \frac{\epsilon_f^B - 1}{\epsilon_f^B} (1 - \tau_f^B) (E_t[\eta_{f,t+1}^E] - (E_t[\eta_{f,t+1}^E] - E_t[\eta_{h,t+1}^E])\Xi_{f,t}) (R_{f,t}^L - R_{f,t}^{L,S}). \quad (2.33)$$

13. Gertler and Karadi (2011) use this way to close the system.

14. See Appendix B for more details in the computation of the interest rate on loans from a maximization program of bank's profit with an occasionally binding constraint on their leverage ratio.

To summarize, in normal times,  $\zeta_{i,t} = 0$ , as the interest rate that balances the loan market corresponds to the interest rate that would have prevailed without the existence of the credit constraint (i.e.,  $R_{i,t}^{L,S} = R_{i,t}^L$ ). In crisis times,  $\zeta_{i,t} > 0$ , as the tightness of the loan market is proportional to the interest rate spread between the interest rate on loans that balances loan supply and demand and the interest that would have been set by the banking system without the credit constraint. This variable will be used as an indicator to characterize the situation of the loan market and the policy to be adopted (either conventional for  $\zeta_{h,t} = \zeta_{f,t} = 0$ , or otherwise combining conventional and unconventional measures).

#### 4.4 Macroeconomic policies and general equilibrium

In our setting we assume that Fiscal policy is exogenous, i.e.  $G_{i,t} = G_i e^{\varepsilon_{i,t}^g}$  with,  $G_i$  the steady state level of public spending and  $\varepsilon_{i,t}^g \sim AR(1)$  representing a public spending shock in period  $t$ , that affects the resource constraint of the economy,

$$Y_{i,t}^D = C_{h,i,t} + C_{f,i,t} + I_{h,i,t} + I_{f,i,t} + \frac{\eta_i^I}{2} \left( \frac{I_{n,i,t} + \bar{I}}{I_{n,i,t-1} + \bar{I}} - 1 \right) + G_{i,t} + \tau_i \psi_{i,t} K_{i,t+1} \quad (2.34)$$

As in Gertler and Karadi (2011),  $\tau_i Q_{i,t} K_{i,t+1}$  measures inefficiencies related to the cost of implementing a credit policy (assumed less efficient than loan creation by financial intermediaries, where  $\tau_i$  is an inefficiency parameter if the central bank intermediates funds directly). Capital accumulation is defined according to,

$$K_{i,t} = (1 - \delta(U_{i,t}))K_{i,t-1} + I_{i,t}. \quad (2.35)$$

The central bank of the monetary union follows a standard Taylor rule policy, taking into account inflation and output gaps from the two countries,

$$R_t = \frac{1}{\beta} (\beta R_{t-1})^{\rho^r} \left[ (\Pi_{h,t} \Pi_{f,t})^{\phi_\pi} \left( \frac{Y_{h,t}}{Y_{h,t-1}} \frac{Y_{f,t}}{Y_{f,t-1}} \right)^{\phi_y} \right]^{1-\rho^r} \varepsilon_t^r, \quad (2.36)$$

Where  $\varepsilon_t^r \sim N(0, \sigma_{\varepsilon^r})$  is a conventional monetary policy shock, and  $\rho^r$  is the persistence of interest rate in the Taylor rule.

Finally, defining the current account of country  $i$  as  $CA_{i,t}$  and taking into account the international equilibrium of monetary union (i.e.,  $CA_{h,t} = -CA_{f,t}$ ), the dynamics of the current account for the domestic country is,

$$CA_{h,t} = C_{h,h,t} + Inv_{h,h,t} - C_{f,h,t} - Inv_{f,h,t} \quad (2.37)$$

In the model, we have two countries, 10 AR(1) shocks such that  $\varepsilon_{i,t}^s = \rho_i^s \varepsilon_{i,t}^s + \eta_{i,t}^s$ , for  $s \in \{\lambda, a, g, opt, cons\}$  and  $i \in \{h, f\}$ , where  $\rho_i^s$  is the autoregressive parameter and  $\eta_{i,t}^s$  is normally distributed, and 3 normally distributed shocks  $\varepsilon_{i,t}^{NB}$  for  $i \in \{h, f\}$ , and  $\varepsilon_t^r$ . The general equilibrium combines a sequence of quantities  $\{Q_t\}_{t=0}^\infty$  and a sequence of prices  $\{P_t\}_{t=0}^\infty$ , such that, for a given sequence of shocks  $\{S_t\}_{t=0}^\infty$  and conditional on the monetary policy: (i) For a given sequence of prices  $\{P_t\}_{t=0}^\infty$ , the sequence  $\{Q_t\}_{t=0}^\infty$  satisfies first-order conditions of households, entrepreneurs, firms, capital producers and financial intermediaries; (ii) For a given sequence of quantities  $\{Q_t\}_{t=0}^\infty$ , the sequence  $\{P_t\}_{t=0}^\infty$ , guarantees the equilibrium on all markets.<sup>15</sup>

## 5 Crisis experiment

In this section, we calibrate the model and we evaluate the macroeconomic effects of transitory shortages in bank lending, for both core and peripheral countries.

### 5.1 Calibration and steady state

The calibration of the model is summarized in Table 1. We borrow most parameter values from Poutineau and Vermandel (2015) and Gertler and Karadi (2011). The value chosen for the model's parameter should meet two requirements: First, the steady state of the model should correspond to normal times (i.e., it should lie in the non binding lending region that corresponds to a normal working of the loan market); Second, this steady

15. The general equilibrium of the model is formally presented in Appendix C.

state should be close enough to a loan shortage situation thus allowing for the possibility of a transitory lending shortage at the outcome of admissible values for financial and real shocks.<sup>16</sup> This feature is important to generate crisis times in the economy so as to provide the pre requisite for unconventional policy measures.

Most parameters are calibrated following Poutineau and Vermandel (2015). This is the case of the weight of capital in the production function  $\alpha$ , the depreciation rate of capital  $\delta_c$ , the portfolio adjustment costs  $\varkappa^B$ , the ratio of government spending on GDP  $G/Y$ , the steady state labor supply  $H$ , the steady state interest rate spread  $R^L - R$ , the probability of reimbursement of firms in the steady state  $\eta^E$ , the Taylor coefficients on inflation  $\phi_\pi$  and output  $\phi_y$ , the openness on goods market  $\alpha_h^C = 1 - \alpha_f^C$  and investment market  $\alpha_h^I = 1 - \alpha_f^I$ , the elasticity of substitution between core and peripheral consumption goods  $\mu^C$  and between core and peripheral loans  $\mu^L$  (the elasticity of substitution between core and peripheral investment goods  $\mu^I$  is calibrated as  $\mu^C$ ), the consumption habit parameter  $h$ , the shape parameter of the marginal cost of using capital  $\Psi$ , the labor supply elasticity  $\varphi$ , the price rigidity parameter  $\theta^E$  and rigidity parameter on wages  $\theta^W$ , the price indexation parameter  $\gamma^{pe}$  and indexation parameter on wages  $\gamma^{pw}$ , the bias parameter on entrepreneur expectations  $\chi^E$ , and the interest rate persistence  $\rho^r$ .

Parameters related to the dynamics of the banking system are calibrated following Gertler and Karadi (2011). This is the case of the transfer parameter towards new bankers  $\omega$ , the credit policy parameter  $v$  and the inefficiency parameter for government spending  $\tau$ . The discount factor  $\beta$  is also calibrated following Gertler and Karadi (2011).

The elasticity of substitution between goods varieties  $\varepsilon^E$ , varieties of loans  $\varepsilon^B$  and varieties of labour  $\varepsilon^W$ , that have no values in Poutineau and Vermandel (2015) and Gertler and Karadi (2011) are calibrated as in Cargoët and Poutineau (2018) in order to meet our requirements regarding the characteristics of the steady state that should correspond to normal times and be close enough to a loan shortage situation: The steady state value of the diversion parameter is set to  $\lambda = 0.867$ , the steady state value of the leverage ratio ( $LEV = N^E/K$ ) is set to 1.5, the survival rate of bankers  $\theta$  is set to 0.95. Finally, the

16. To get a four regime model (normal times and financial crisis, for both core and peripheral countries), we use the method developed by Guerrieri and Iacoviello (2015). The authors show how to approximate a nonlinear model by computing the matrices of several linear models with close steady states, thus creating what they call a piecewise linear model, close to the nonlinear one.



Parameter	h	f	Definition
$\beta$	0.99		discount factor
$\delta_c$	0.02		depreciation rate of capital
$\alpha$	0.25		weight of capital in the production function
$H$	1/3		steady state labor supply
$\varkappa^B$	0.0007		portfolio adjustment costs
$G/Y$	0.24		ratio of government spending on GDP
$LEV$	1.5		leverage ratio at the steady state
$R^L - R$	0.0248/4		steady state interest rate spread
$\varepsilon^E$	4.167		elasticity of substitution between goods varieties
$\varepsilon^B$	100		elasticity of substitution between varieties of loans
$\varepsilon^W$	10		elasticity of substitution between varieties of labour
$\eta^E$	0.995		probability of reimbursement of firms in the steady state
$\theta$	0.95		survival rate of bankers
$\omega$	0.002		transfer parameter towards new bankers
$\eta^I$	0.05		scale parameter on investment costs
$\phi_\pi$	1.85		Taylor coefficient on inflation
$\phi_y$	0.15		Taylor coefficient on output
$\tau$	0.001		inefficiency parameter for government spending
$\lambda$	0.867		share of deposit in the steady state
$v$	10		credit policy parameter
$\alpha_h^C = 1 - \alpha_f^C$	0.17		openness on goods market
$\alpha_h^I = 1 - \alpha_f^I$	0.06		openness on investment market
$\mu^C$	4.43		elasticity of substitution between consumption goods
$\mu^I$	4.43		elasticity of substitution between investment goods
$\mu^L$	2.02		elasticity of substitution between loans
$h$	0.32	0.57	consumption habit parameter
$\Psi$	0.66	0.68	shape parameter of the marginal cost of using capital
$\varphi$	0.59	0.66	labor supply elasticity
$\theta^E$	0.56		price rigidity parameter
$\gamma^{pe}$	0.07	0.08	price indexation parameter
$\theta^W$	0.67	0.6	rigidity parameter on wages
$\gamma^{pw}$	0.46	0.36	indexation parameter on wages
$\chi^E$	0.05	0.08	bias parameter on entrepreneur expectations
$\rho^r$	0.41		interest rate persistence
$\rho^\lambda$	0.4		shock autocorrelation (banking risk perception)
$\rho^a$	0.95		shock autocorrelation (productivity)
$\rho^g$	0.8		shock autocorrelation (public spending)
$\rho^{cons}$	0.8		shock autocorrelation (consumption)
$\rho^{opt}$	0.9		shock autocorrelation (optimism)

Table 2.1: Calibration of parameters

scale parameter on investment costs  $\eta^I$  is set to 0.05 and shock persistency parameters are given as follows:  $\rho_i^\lambda = 0.4$ ,  $\rho_i^a = 0.95$ ,  $\rho_i^g = 0.8$ ,  $\rho_i^{opt} = 0.9$ ,  $\rho_i^{cons} = 0.8$ .

## 5.2 Cross border lending and the international transmission of financial troubles

We study the effects of asymmetric financial and supply shocks affecting the peripheral part of the monetary union. This perspective aims at capturing the heterogeneity of Eurozone members following the transmission of the subprime crisis into the Eurozone and the fragility of countries belonging to this group. We assess the national and global impact of this shocks depending on the size of cross border lending relations between core and peripheral countries.

### Loan market fragmentation

We first evaluate how the possibility of a financial disruption in one part of the monetary union affects the aggregate situation of the union under a conventional monetary policy. We study the responses of the model assuming loan market fragmentation (we set  $\alpha_h^L = 1 - \alpha_f^L = 0$ ).

Figure 2.5 depicts the consequences of a 5% negative realization of  $\varepsilon_{f,t}^\lambda$  that can be understood as a sudden loss of confidence from peripheral bank depositors (i.e peripheral households) following an increase in the perceived incentive of peripheral banks to divert assets. This shock - that decreases the amount of deposits these banks are able to use for loan creation - is similar to the financial shock considered in Dedola, Karadi and Lombardo (2013). In the peripheral countries, this shock creates a quantitative disruption of lending in the economy.<sup>17</sup> As depicted by the grey area the loan shortage situation lasts for 10 periods, and implies a sharp increase in the interest rate on peripheral loans to contain loan demand. The increase in the interest rate on loans faced by entrepreneurs reflects the scarcity of loans in the economy. As reported, even if the lending shortage

17. In this figure, we contrast 2 versions of the model. In the version that neglects the possibility of quantitative shortage of loan supply, this shock has no effect on the variables of the model, see Cargœt and Poutineau (2017).

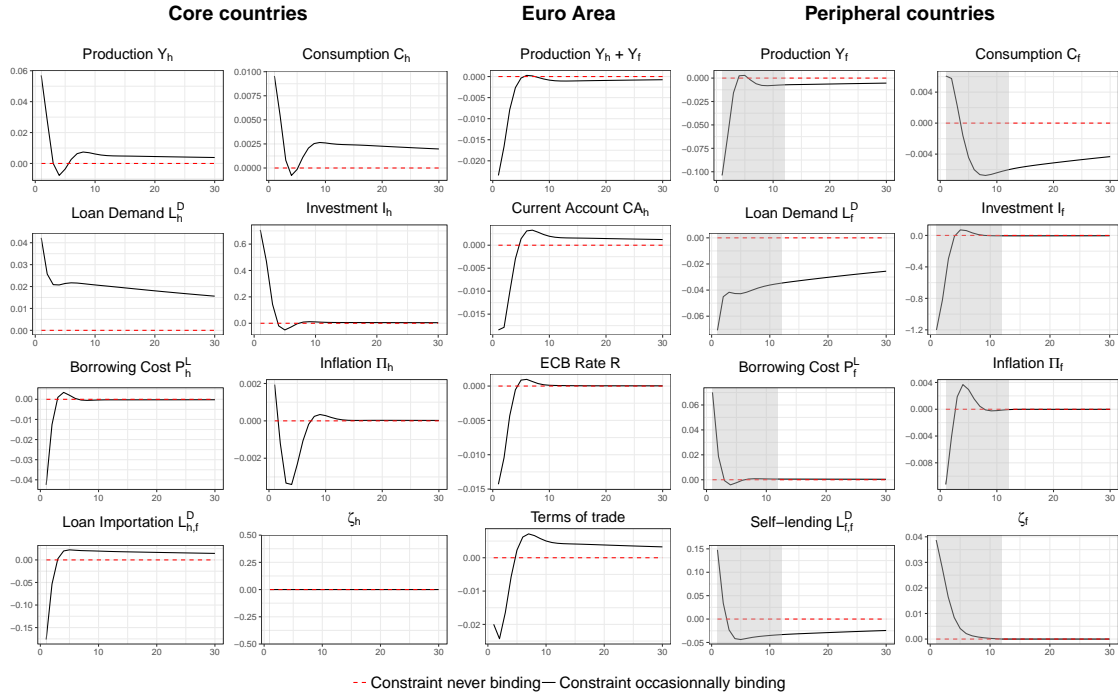


Figure 2.5: Shock on  $\lambda$ , without financial integration, response of the model with and without credit constraint

lasts for a limited number of periods, it has sizable consequences for the rest of the analysis since the rise in the interest rate spread decreases investment, activity and inflation.

The policy reaction (a decrease in the policy rate) dampens the effect of the financial shock in the following periods so the economy slowly goes back to equilibrium. However, this effect, already documented in Cargoët and Poutineau (2018), is affected by international trade. The decrease in peripheral goods prices leads to more export towards the core countries, which induces an increase in the supply - and production - of peripheral goods and thus marginally increases the loan shortage in the peripheral countries with respect to a closed economy situation.

This shock is transmitted to core countries as a demand shock through two channels that operate in opposite directions. First, as good prices decrease in the peripheral countries, core countries terms of trade appreciate, which leads to a decrease in core

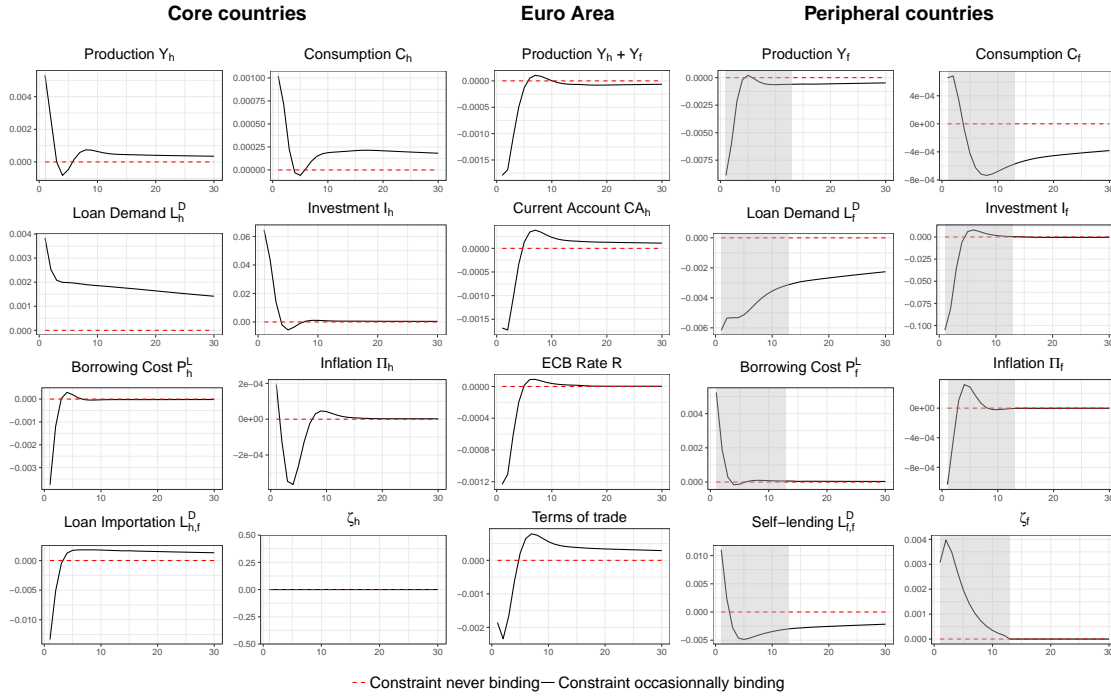


Figure 2.6: Shock on  $N^B$ , without financial integration, response of the model with and without credit constraint

countries exports. As the current account of the core countries deteriorates it has a clear negative effect on input in this part of the monetary union. Second, the accommodating conventional monetary policy undertaken by the central bank in reaction to the decrease in activity and prices in the peripheral countries affects positively activity in core countries. As reported, this positive effect clearly overcomes the negative consequences of the core countries current account deficit. Thus we observe a net increase in the core countries' GDP, but a decrease in core inflation.

Figure 2.6 reports the consequences of a 5% negative realization of  $\varepsilon_{f,t}^{N^B}$  which can be understood as a sudden depreciation of peripheral banks' assets. Due to the close nature of the two shocks, we observe almost the same results as for the shock on  $\varepsilon_{f,t}^\lambda$ , the only difference lying on the size of those effects, slightly lower for the shock on banks' assets. This discrepancy in the size of effects comes from the multiplicative impact of  $\lambda_{f,t}$  on the

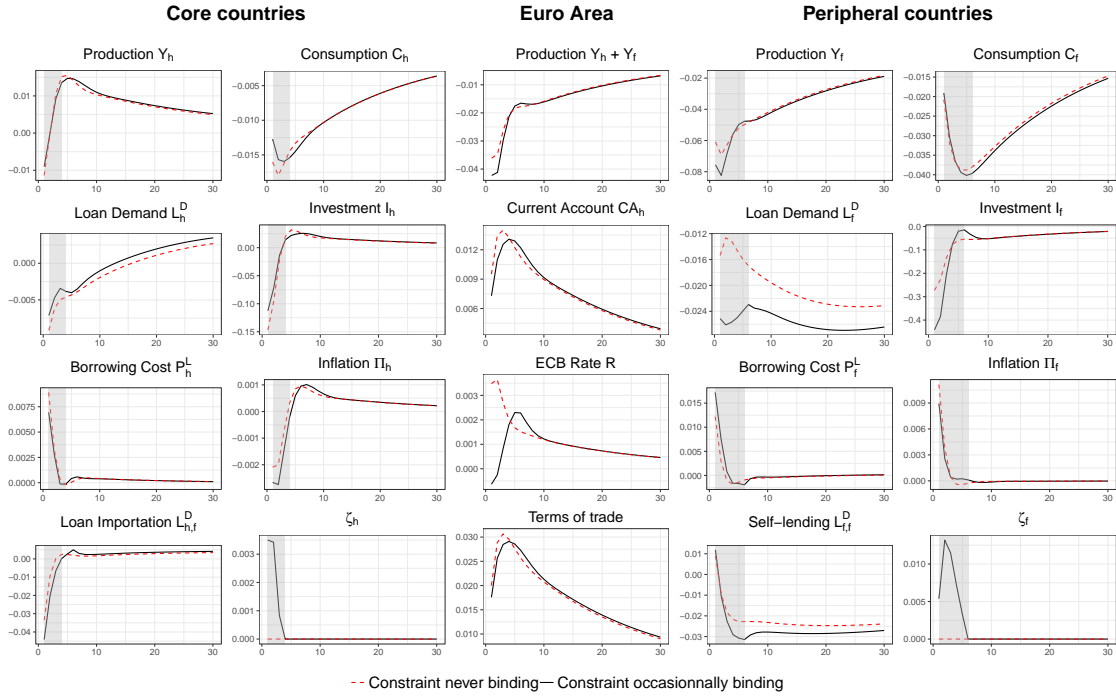


Figure 2.7: Shock on technology, without financial integration, response of the model with and without credit constraint

maximum quantity of resources ( $D_{f,t+1} + N_{f,t}^B$ ) peripheral banks are allowed to keep to avoid a fund diversion.

Figure 2.7 reports the consequences of a negative peripheral productivity shock (i.e. a 5% decrease of  $\varepsilon_{f,t}^a$ ). To assess the amplifying features of a loan shortage, we contrast the IRFs obtained ignoring this phenomenon (in dotted lines) with the financial disruption case. Ignoring the quantitative shortage of loans, we find standard results documented in the literature, as this shock leads to a slump in activity while it increases inflation in the peripheral countries. As capital productivity decreases so does investment. Monetary policy reaction induces an interest rate increase to fight inflation, which in turn affects the interest rate on loans. As reported, the interest rate on loans increases more than the policy rate, as the shock leads also to a decrease in investment profitability, which in turn increases the risk premium correction of banks.

The possibility of a transitory lending shortage (plain line) clearly deteriorates the macroeconomic adjustment of the monetary union. Even if the quantitative shortage lasts only for 5 periods, it amplifies the negative impact of the shock and reinforces its persistency on the main aggregates. As reported, it takes more time for the economy to recover. The negative productivity shock affects the profitability of entrepreneurs projects which, in turn, reduces the net wealth of the banking system, and the resources (and so the bank deposits) of households. These features induce a decrease in the supply of loans that reinforces the initial negative effect of the shock on investment and activity. Following the decrease in loan supply, the interest rate spread required to balance the loan market increases sharply which leads to a deeper impact of the real shock on both investment and activity. The further effect on activity and investment due to the loan shortage requires a lower increase of the central bank interest rate with regard to the standard DSGE model.

To get a clear insight of the consequences of the shock on the core part of the monetary union, it is worthwhile to distinguish the consequences coming from trade integration (that further deteriorates the situation of the periphery) from those coming from the consequences of the reaction of the central bank.

As usually documented in the literature, the negative productivity shock leads to a decrease in GDP, while leading to an increase in inflation in peripheral countries. Ignoring financial disruption, this increases the terms of trade (which decreases peripheral export, worsens the peripheral current account and furthermore reinforces the decrease in activity). Due to loan shortage, the profitability of peripheral entrepreneurs' projects and the number of profitable projects decrease furthermore, which in turn decreases banks' net wealth in the peripheral countries and further saturates the credit constraint. Thus the drop in peripheral activity is higher. In the core countries, the improvement in the terms of trade increases the current account surplus which increases both GDP and inflation. However the binding of the credit constraint in the peripheral countries dampens this effect, as it affects negatively peripheral demand (and thus core exports). The credit constraint in the peripheral countries thus affects negatively activity in the core part of the monetary union, so that the net increase of core activity is smaller than the one observed without the binding financial constraint.

The decrease in the central bank interest rate partly dampens the consequences of the shock. Following the drop in the interest rate, the binding of the financial constraint decreases. The interest rate spread decreases which translates into a looser financial constraint and marginally reduces the output drop.

### **Loan market integration**

We now study the impact of cross border lending on the consequences of asymmetric financial and supply shocks in the monetary union, owing to the possibility of financial disruption on the credit market.

Figure 2.8 depicts the consequences of a 5% decrease in  $\varepsilon_{f,t}^\lambda$ , depending on different levels of mutual openness on the loan market. As observed, the possibility for entrepreneurs to engage in cross border lending has a dampening effect on adjustment in peripheral countries as it makes the credit constraint looser than in the autarkic situation. Entrepreneurs are now able to purchase a fraction of their loans to core banks which lightens the stress on the peripheral credit market (as reported in the figure, the cost variable  $\zeta_{f,t}$  decreases). More financial openness means less stress on the peripheral credit market and a less important increase of peripheral credit costs in the monetary union. This, in turn, dampens the initial recession and deflation on the peripheral countries.

Conversely, cross border lending deteriorates the macroeconomic situation of the core countries' group. Indeed, as the demand of core loans increases - both from peripheral entrepreneurs who are not able to borrow from peripheral banks anymore and from core entrepreneurs that previously borrowed in the other part of the monetary union - the credit constraint in the core countries becomes binding, which generates a net increase on loans' interest rates, and thus a recession in this part of the monetary union.

As the international connection of the national loan markets smoothes the effects of financial disruption between the two groups of countries, it has union-wide consequences on monetary union aggregates. While financial integration clearly leads to a better outcome than the autarkic situation, it is unclear if perfect loan market integration corresponds to a first best situation. Numerical simulations reveal a non linear effect of loan market integration on the global recession, with a minimum reached around  $\alpha_h^L = 0.15$

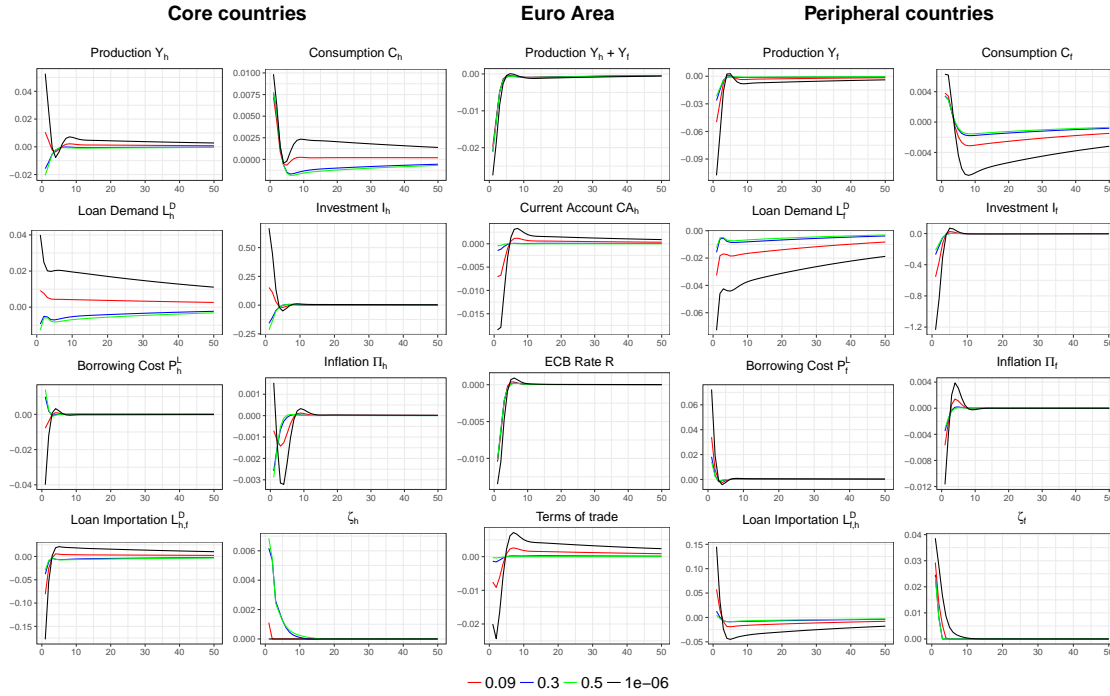
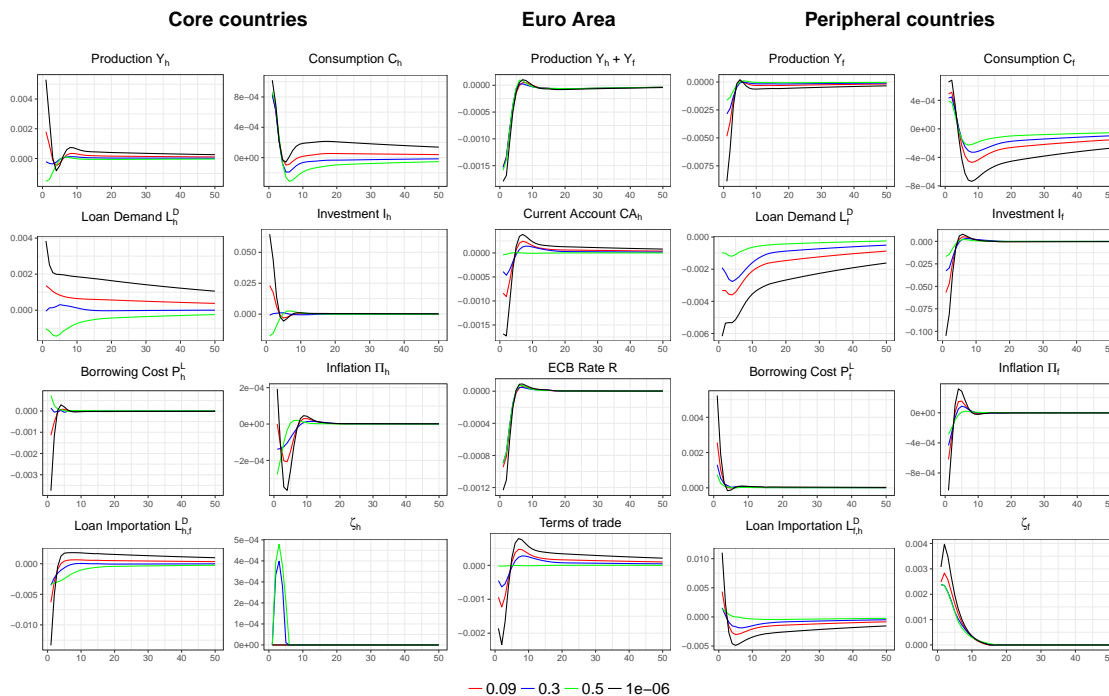


Figure 2.8: Shock on  $\lambda$ , different levels of financial integration

when taking into account the variance of the GDP in the entire zone following a shock on banks' net wealth. This result comes from the ambivalent effect of loan market integration and it should be interpreted as follows: For a very low value of financial integration, the marginal positive effect of a 1% increase in  $\alpha_h^L$  will be much higher for the peripheral countries than the marginal negative effect on the core countries. Conversely, for a very high value of financial integration, the marginal effect of a 1% increase in  $\alpha_h^L$  will cause much more damages in the core countries than it will resolve troubles in the peripheral countries. Thus adopting a marginal analysis of the effect of a higher connection of loan market, we get an optimal value for cross border lending equal to  $\alpha_h^L = 0.15$ . Noticeably, this optimal value for cross border lending could be seen as a reasonable policy objective, as it is not so far from the baseline calibration ( $\alpha^L = 0.09$ ). It should also be noted that the length of the constrained period in the peripheral countries is only marginally



Figure 2.9: Shock on  $N^B$ , different levels of financial integration

affected by the choice of  $\alpha_h^L$ .

Figure 2.9 reports the consequences of a 5% decrease in  $N_{f,t}^B$ , for different levels of financial integration. Once again - putting aside the size of the variables' log deviation - the effects are quite similar to those of the confidence shock. However, when testing for different degrees of financial integration, it appears that the magnitude of the macroeconomic effects of the shock on  $\varepsilon_{f,t}^{N^B}$  is not sufficient to trigger the bidding of the financial constraint for the core countries through spillover effects for our baseline calibration.

Figure 2.10 reports the effect of cross border lending on the international transmission of a negative productivity shock in the peripheral economy. As observed, the degree of cross border lending does not have a significant effect on the real and price adjustment in the Eurozone. The main effect is observed on the amount of loan contracted in the Eurozone, without affecting noticeably the real equilibrium. This outcome comes from

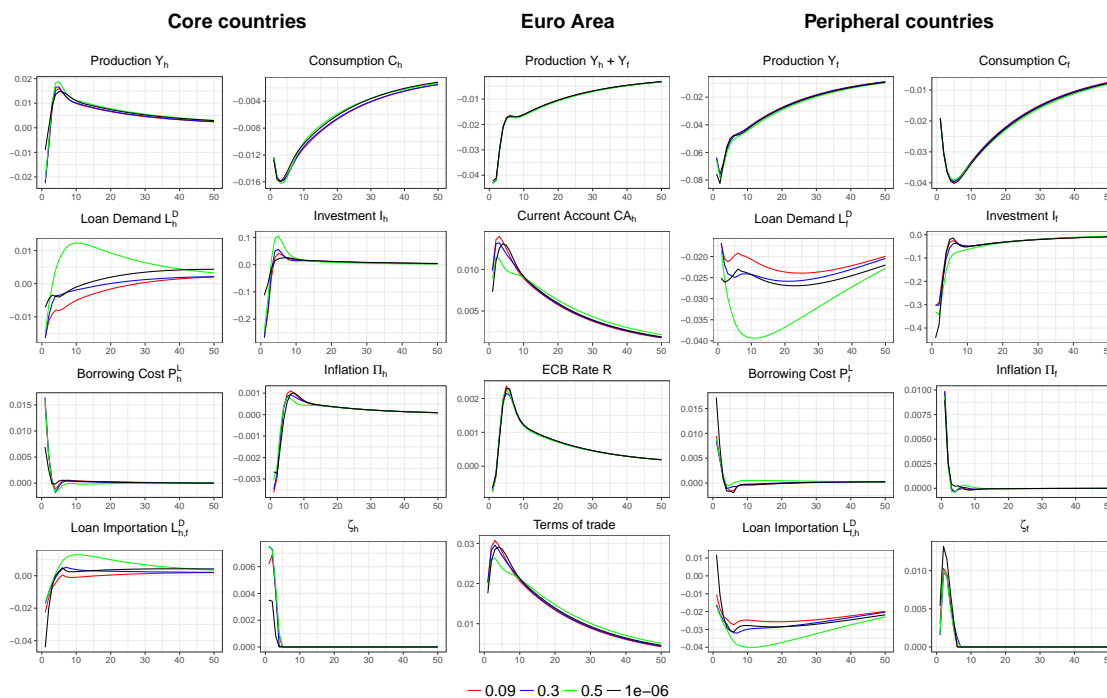


Figure 2.10: Shock on technology, different levels of financial integration

the fact that cross border lending affects the financial consequences of the shock, not the real ones.

## 6 Credit policy

Our model generates a transitory disruption of lending coming from a worsening of the balance sheet of financial intermediaries. The central bank is able to dampen the consequences of shocks on the provision of loans using a credit policy. In this section, we follow Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) by assuming that the central bank proceeds to direct lending measures. Part of the initial unconventional policy measures implemented by the ECB can be associated to direct lending measures, as they eased the credit conditions for the private sector. We evaluate the consequences

of such measures according to a state dependent perspective, assuming that they are stopped once the shortage situation ends.

## 6.1 The nature of Credit policy

A main challenge of this chapter is to assess the degree of inequalities created by a credit policy conveyed by the ECB to react to average financial stress in the Euro-area. To this aim, we assess the effect of a homogeneous credit policy and we contrast it with policy decisions implemented in relation with the national financial situation of member countries (i.e an heterogeneous credit policy). This allows us to assess the heterogeneous reaction of countries to each type of credit policy implemented, depending on both their underlying parameters and the situation related to the regional and national financial stress (since, as reported in the previous section, financial disruption can be of different magnitude and length between countries). To assess the way a homogeneous credit policy affects both the aggregate and the national situations in the Eurozone, we compare two outcomes : the actual policy stance based on the average financial stress of the monetary union and a first best policy reaction targeting national financial developments.

First, we consider as a benchmark a heterogeneous policy that would lead to a first best solution of the problem. We suppose that at the onset of a crisis, the central bank injects credit in response to movements in credit spreads in each economy proportionally to its degree of financial stress measured by  $\zeta_{i,t}$ . The total amount of loans available to entrepreneurs in each economy thus becomes,

$$L_{i,t}^S = L_{i,t}^{Sp} + L_{i,t}^{Sg}, \quad (2.38)$$

where  $L_{i,t}^{Sp} = L_{i,t}^{S\max} = \phi_{i,t}^B N_{i,t}^B$  is the loan supply of the private sector, as the initial shock triggers the binding of the credit constraint for country  $i$ , and  $L_{i,t}^{Sg}$  is the quantity of loans supplied by the central bank. As in Gertler and Karadi (2011), there is no agency problem between the central bank and its creditors because it can commit to always honoring its debt.<sup>18</sup> We assume that the central bank offers loans proportionally to the quantity of

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18. We refer the reader to the discussion provided in Gertler and Karadi (2011).

total assets supplied in the economy,

$$L_{i,t}^{Sg} = \psi_i L_{i,t}^S, \quad (2.39)$$

where  $0 < \psi_{i,t} < 1$ , is the credit policy variable. In this situation, the bank's accelerator becomes,

$$L_{i,t}^S = \frac{\phi_{i,t}^B}{1 - \psi_{i,t}} N_{i,t}^B. \quad (2.40)$$

As in Gertler and Karadi (2011),  $\phi_{i,c,t}^B \equiv \frac{\phi_{i,t}^B}{1 - \psi_{i,t}}$ , so  $\phi_{i,c,t}^B > \phi_{i,t}^B$ , i.e., the credit policy reinforces the leverage effect on bank's capitalization in the economy.

However, in contrast with Gertler and Karadi (2011), we link the implementation of a credit policy to a situation of lending shortage coming from financial intermediaries. We assume that the size of this policy is proportional to the quantity of missing loans in the economy that suffers the shock. As we outlined above the rise in the interest rate of loans is symptomatic of the financial distress in the economy and the size of credit shortage in the core countries (resp. peripheral countries) can be approached by the value of  $\zeta_{h,t}$  (resp.  $\zeta_{f,t}$ ),

$$\zeta_{h,t} = \frac{\epsilon_h^B - 1}{\epsilon_h^B} (1 - \tau_h^B) \left( \begin{array}{c} E_t [\eta_{h,t+1}^E] \\ - (E_t [\eta_{h,t+1}^E] - E_t [\eta_{f,t+1}^E]) \Xi_{h,t} \end{array} \right) (R_{h,t}^L - R_{h,t}^{L,S}) \quad (2.41)$$

$$\zeta_{f,t} = \frac{\epsilon_f^B - 1}{\epsilon_f^B} (1 - \tau_f^B) \left( \begin{array}{c} E_t [\eta_{f,t+1}^E] \\ - (E_t [\eta_{f,t+1}^E] - E_t [\eta_{h,t+1}^E]) \Xi_{f,t} \end{array} \right) (R_{f,t}^L - R_{f,t}^{L,S}) \quad (2.42)$$

which serves as a proxy to measure the magnitude of financial disruption in the economy.

Thus, for the heterogeneous credit policy, we link the credit policy parameter to this indicator of market stress, according to,

$$\psi_{h,t} = v_h \zeta_{h,t}, \quad (2.43)$$

$$\psi_{f,t} = v_f \zeta_{f,t}, \quad (2.44)$$

with  $v_i$  a scale parameter. For low degrees of financial integration, the credit constraint

does not transmit to the core countries, so there is no financial stress in the core financial system ( $\zeta_{h,t} = 0$ ), and  $\psi_{h,t} = 0$ .

Second, according to its status, the ECB conducts monetary policy actions taking into account the average situation in the monetary union. Thus, the actual credit policy rule is related to an average level of financial disruption between the two country, and is implemented through the purchase of the same quantity of assets in each country. The credit policy rule for each country is then defined as,

$$\psi_{h,t} = \psi_{f,t} = v \frac{\zeta_{h,t} + \zeta_{f,t}}{2}, \quad (2.45)$$

so in case of a financial disruption event in at least one of the two countries, the equality  $L_{i,t}^S = \frac{\phi_{i,t}^B}{1-\psi_{i,t}} N_{i,t}^B$ , with  $\psi_{i,t} \neq 0$ , holds for each country  $i$ .

## 6.2 Impulse response functions

Here we study the consequences of both types of credit policies on the dampening of the macroeconomic consequences of the initial shock and on the magnitude of the financial disruption event for both countries. We set the degree of financial openness to the value we use in our benchmark calibration  $\alpha_h^L = 1 - \alpha_f^L = 0.09$ .

Figure 2.11 reports the consequences of a transitory credit policy following a negative shock on  $\varepsilon_{f,t}^\lambda$ . As observed, the net macroeconomic effects of credit policy are clearly positive.

Unsurprisingly, a credit policy tailored to the local situation of the periphery is more efficient than the homogeneous credit policy based on average financial developments of the monetary union. Indeed, as the homogeneous credit policy is based on the average binding degree of financial constraints in the two parts of the monetary union, the scale of this credit policy is too small to affect efficiently the peripheral financial market situation. Moreover, as half of the asset purchases is directed towards the core countries, which are affected by a lower degree of financial disruption, most of these asset purchases is useless with respect to the bank credit channel. Indeed, when the possibility of a financial disruption is totally suppressed for the core countries, there is no need to further increase

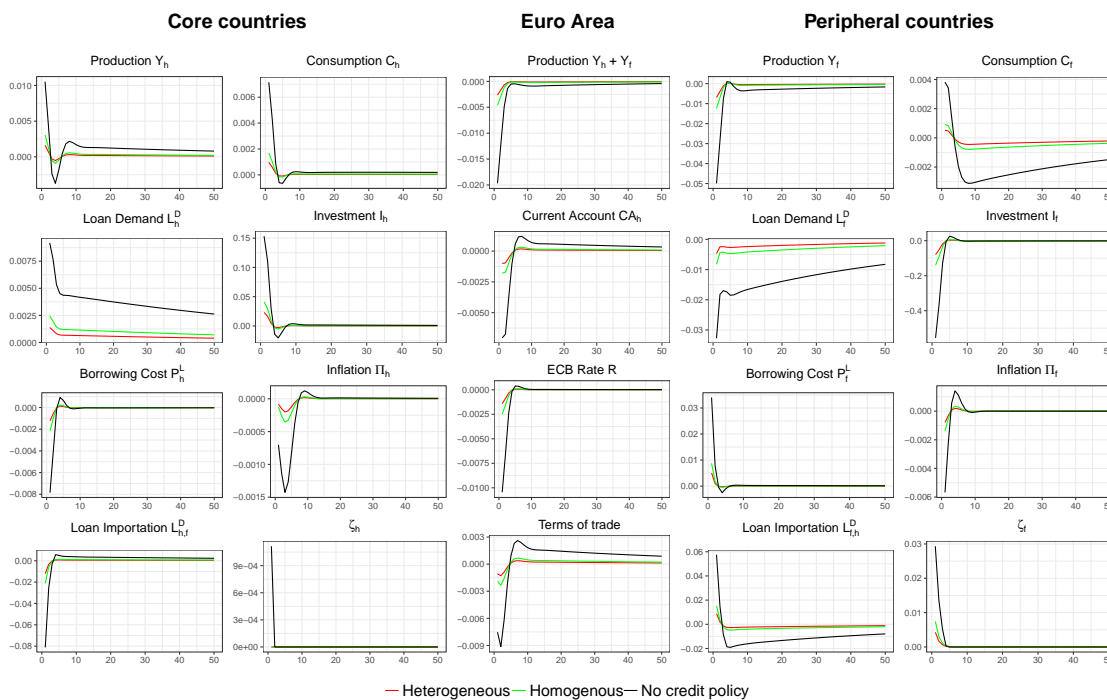
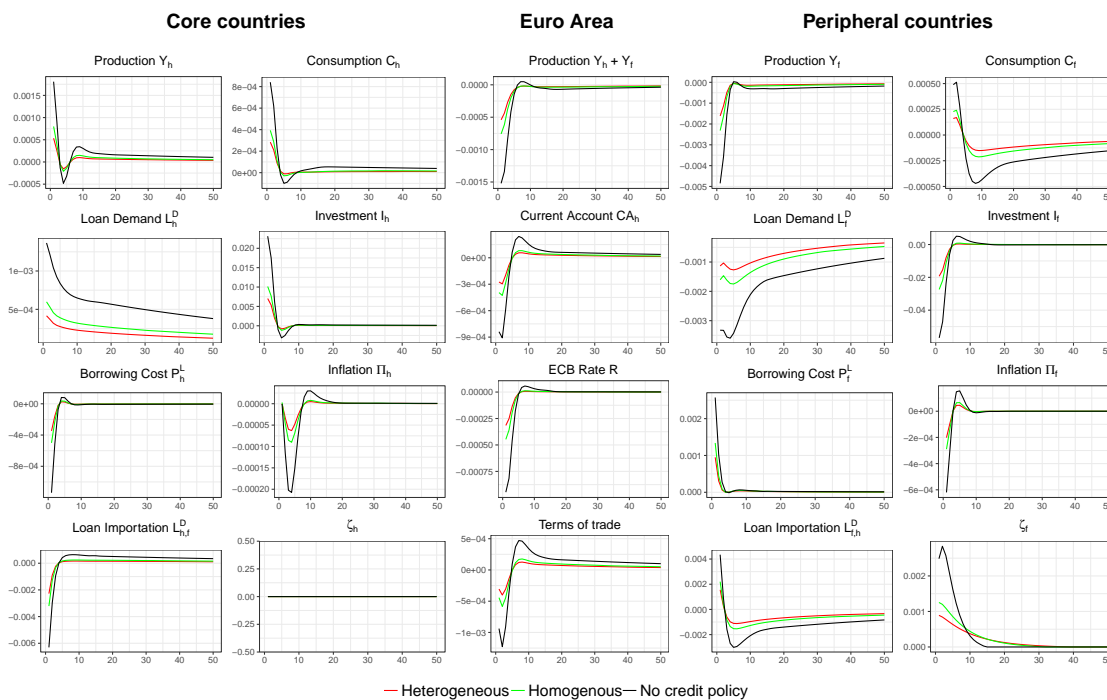


Figure 2.11: Shock on  $\lambda$ , different credit policies

the maximum credit supply, because it does not affect the amount of loans contracted in normal times. However, as in Gertler and Karadi (2011), there is no significant negative effect of expanding the central bank balance sheet, because the cost function associated to central bank credit intermediation is linear, and with cost parameter  $\tau_i$  calibrated at a very low value.

Turning to the situation of the core countries' group, we get unambiguous results. For a low benchmark value of financial integration ( $\alpha^L = 0.09$ ), the net effects of the peripheral negative financial shocks on core countries are positive, as the international transmission effects of the financial crisis from peripheral to core countries are not big enough to overcome the positive international spillover effects coming from an accommodating union-wide conventional monetary policy. Noticeably, since a credit policy would have a higher negative impact on core countries - as it leads to a dampening in the de-

Figure 2.12: Shock on  $N^B$ , different credit policies

crease of the policy interest rate - the decision to implement no credit policy at the union level should be a first best policy reaction from the point of view of these countries.

Figure 2.12 presents the effects of a negative shock on peripheral banks' asset values  $N_{f,t}^B$  along the same policy regimes. As reported, the effects are almost similar to those observed for the previous shock. Once again, the main difference with respect to the other financial shock lies on the relative size of these effects. For the benchmark calibration, the shock on peripheral banks' asset values does not trigger a binding financial constraint for core countries. Thus, a differentiated credit policy will only target peripheral countries, while a homogeneous credit policy will only have direct effects on the loan market of the peripheral countries, with half the size of the heterogeneous credit policy.

The effects of the different credit policies in case of a shock on  $\varepsilon_{f,t}^a$  are reported in Figure 2.13. As observed credit policies tend to reduce the magnitude of the shock with

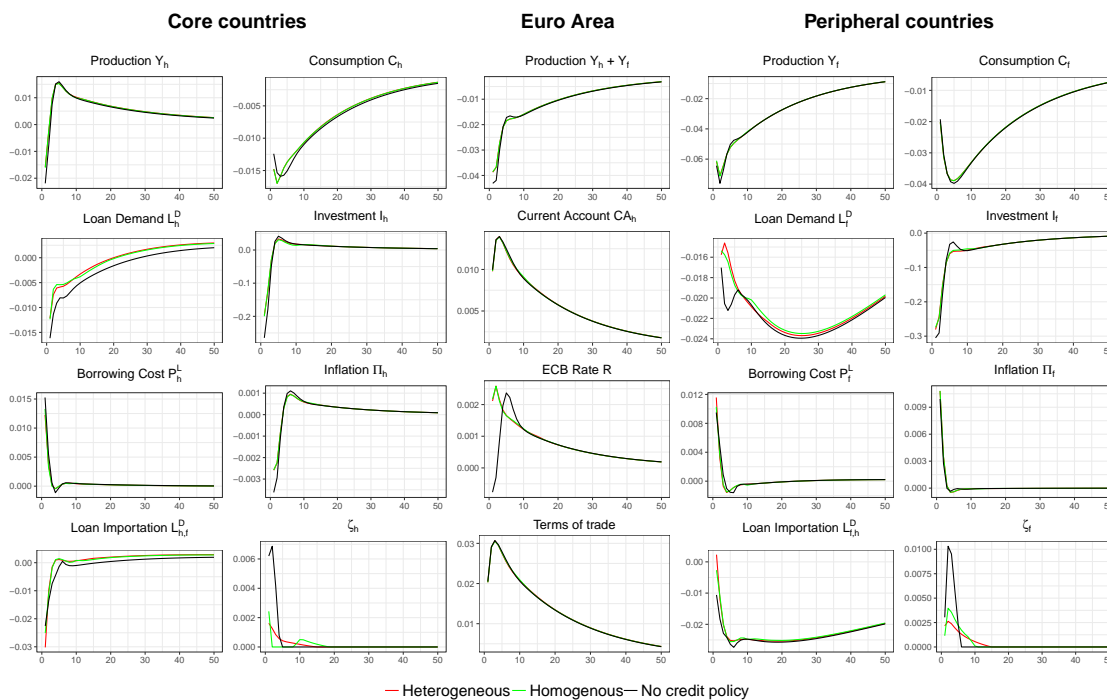


Figure 2.13: Shock on technology, different credit policies

regard to a situation with no credit policy, through the decrease in the value of the binding variable of both credit constraints. However, we can hardly distinguish between the effects of the different credit policies, because as the technology shock is a real shock, it generates direct real effects on macroeconomic variables, in addition to indirect real effects through the financial disruption channel. As a consequence, undertaking unconventional policy measures aiming at reducing the binding effects of the credit constraint is not useful to dampen the macroeconomic consequences of the productivity shock.

### 6.3 Evaluating the inefficiency of homogeneous credit policy

By responding to the average loan market tightness in the monetary union the actual (homogeneous) unconventional monetary policy does not directly target national financial problems. As a consequence, such a policy can only be considered as a second best



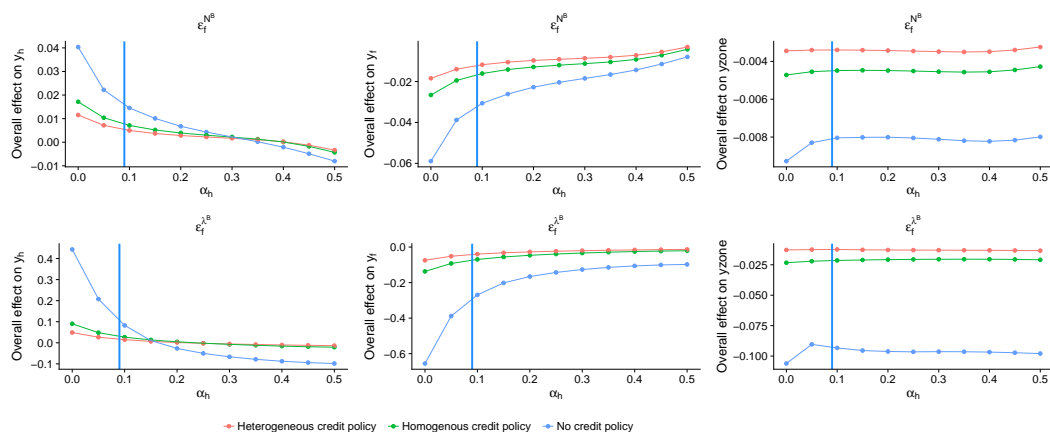


Figure 2.14: Cumulated effect of the financial shocks on the GDP of core countries, peripheral countries, and the whole Eurozone, for different types of credit policies and different levels of financial integration

solution with respect to a credit policy accounting for financial discrepancies. To assess the size of this inefficiency, we introduce two complementary indicators based on cumulated output losses along the transition path followed by the economy when going back to its steady state equilibrium after a financial shock. Results are reported in figures 2.14 and 2.15.

First, in Figure 2.14 we report the cumulated core, peripheral and monetary union output losses with respect to the steady state (i.e., the cumulated log-deviation of GDP series) under conventional and unconventional policies (distinguishing the homogeneous conduct of the effective policy from the first best solution based on national credit market tightness). We report figures for values of the loan market openness ranking from 0 (no integration) to 0.5 (full integration), following a shock on peripheral banks' net worth (higher panel) and on peripheral deposits (lower panel). The baseline cross border lending calibration ( $\alpha^L = 0.09$ ) is reported as a vertical line.

Unsurprisingly, the implementation of a credit policy dampens output developments for all values of the cross border lending parameter for both peripheral countries and the Eurozone as a whole. By contrast, the effect of this policy is mixed for core countries,

because for low levels of financial integration core countries benefit from the accommodative conventional monetary policy operated by the central bank without suffering much from financial disruption on their local credit market. So for low levels of financial integration, core countries benefit from the credit issues of peripheral countries, and this benefit decreases when the central bank decreases the magnitude of the financial crisis using unconventional monetary policy tools. Nevertheless at the aggregate monetary union level, the relative performance of credit policies responding to local financial troubles remains unaffected (even if the difference is small and represents a 20% increase in output deviation for cumulated output losses over a period of 40 quarters).

Second, the performance of homogeneous actions can also be evaluated along another metric balancing the average union wide effect with its heterogeneous consequences between core and peripheral countries. Formally, Figure 2.15 reports values for the following ratio,

$$Ratio = \left( \frac{y_{h,t} - y_{f,t}}{\frac{y_{h,t} + y_{f,t}}{2}} \right)^2 \quad (2.46)$$

for all three policy scenarios, depending on the value of cross border lending. This ratio balances the whole average performance of the policy (the denominator measures per capita average Eurozone output) with the size of heterogeneity in its transmission to national economies. The square value is useful to concentrate on asymmetry in the monetary union. A lower value of this ratio underlines a more homogeneous impact of the policy over the monetary union countries.

The main findings stemming from Figure 2.15 can be stated as follows: First, unsurprisingly the heterogeneity in the transmission of all policies disappears for perfect loan market integration ( $\alpha^L = 0.5$ ). Second, credit policies decrease inequalities for low degrees of financial integration but increase them for high degrees of financial integration. This is a mechanical effect of the model: For low levels of financial integration, according to section 5.2, financial shocks occurring in peripheral countries have positive spillovers on core countries. Indeed, core countries benefit from the common accommodative conventional monetary policy without being subject to the financial shock. On the contrary, for high level of financial integration, core countries are also subject to financial disrup-

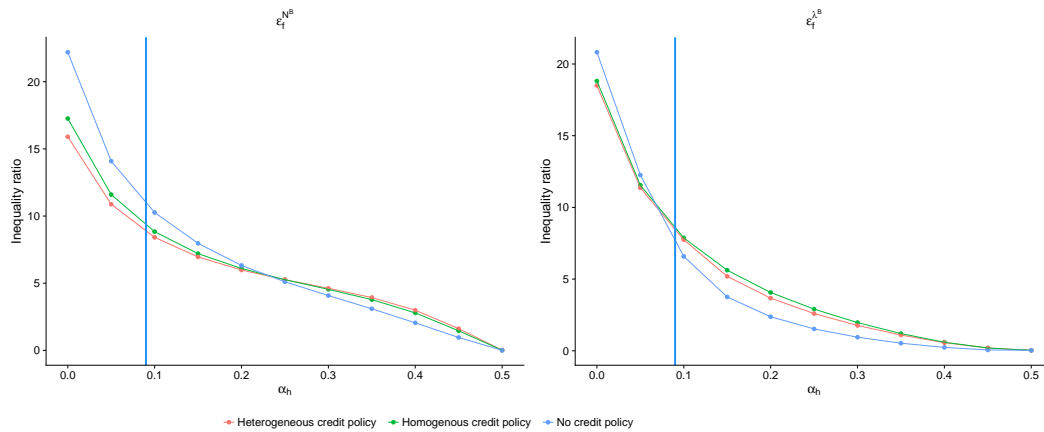


Figure 2.15: Inequality ratio following the realization of financial shocks, for different types of credit policies and different levels of financial integration

tion because in response to the financial shock, peripheral entrepreneurs transfer their excess loan demand towards core banks, thus triggering the credit constraint in the core countries. So as financial integration increases, the financial crisis splits between core and peripheral countries, reducing inequalities between those two groups of countries.

If credit policy actions - it works for both types of credit policies - are undertaken in a situation of low financial integration, they decrease the magnitude of the financial crisis in the peripheral countries, which dampens the negative macroeconomic consequences of the financial crisis for peripheral countries. As this negative macroeconomic consequences are reduced, the central bank's conventional monetary policy becomes less accommodative, which also reduces the positive spillovers of the peripheral financial crisis on core countries' economic activity. This joint reduction of the negative effects of the financial crisis on peripheral countries and of the positive effects of the financial crisis on core countries dampens the inequalities arising from the financial crisis. As the heterogeneous credit policy is more efficient than the homogeneous one in reducing the financial crisis, it also decreases more the inequality ratio.

If credit policy actions - it also works for both types of credit policies - are undertaken in a situation of high (but not perfect) financial integration, it reduces the magnitude

of the financial crisis in both countries, but it reduces more the macroeconomic consequences of the crisis for core countries than it does for peripheral countries, because of the marginally decreasing effects of the financial crisis on economic activity already underlined in section 5.2. As a consequence, credit policies increase the inequality ratio for values of financial integration beyond perfect integration, because peripheral countries were, even if the absence of credit policy, initially more affected by the financial crisis than core countries.

## 7 Concluding Remarks

The main objective of this chapter was to provide an analysis of the heterogeneous consequences of homogeneous unconventional policy measures undertaken by the ECB to fight the initial financial disruption that affected the Eurozone at the beginning of the crisis. We have introduced a two country DSGE model that accounts for cross border lending relations as a major source of spillovers between Eurozone members and the possibility of financial disruption on the loan market. On the policy side we combine a conventional monetary policy based on the steering of a short run interest rate with a state dependent credit policy aiming at providing liquidity to the banking sector to avoid a disruption in credit supply.

We find that the global macroeconomic and welfare consequences of the unconventional part of monetary policy partly rest on the size of cross border lending relations. First, cross border lending plays an ambiguous role for transmitting a regional financial stress arising in the periphery to the global EMU level as it affects core and peripheral situations in opposite directions. In particular we find that there exists an optimal level of financial integration for which the net effects of financial shocks are minimized amongst the Eurozone. Noticeably, this optimal value for cross border lending could be seen as a reasonable policy objective, as it is not so far from the baseline calibration. Second, we assess the global effect of a homogeneous temporary credit policy adopted to fight financial disruption affecting one part of the monetary union. We find that the conduct of credit policy unambiguously improves the situation of the monetary union, albeit with differing consequences on national economies. When considering the bank credit channel, a

differentiated credit policy (asset purchases in each country, depending on the magnitude of financial disruption in each country) is the best credit policy. The homogeneous credit policy is less efficient, because it is less adapted to the needs of each country (pointlessly high in the country where financial disruption is low, insufficient in the country where financial disruption is high). However, we find a non-linear effect of credit policies on the evolution of inequalities between core and peripheral countries: While credit policies dampen the inequalities arising from the financial crisis for low degrees of financial integration, it increases this inequalities for high degrees of financial integration.

## **Chapter 3**

# **The Macroeconomic Impact of Unconventional Monetary Policies Under Shifting Financial Conditions**

### **1 Introduction**

The financial crisis that erupted in 2007 has been characterized by a noticeable shift in agents' behaviors in a context of high economic and financial uncertainty. Financial intermediaries ceased to follow the central bank policy rates in their behavior of credit supply, which led to a financial disruption that could not be accommodated by an appropriate interest rate policy. In response, monetary authorities started to adopt unconventional monetary policy measures in order to ease credit conditions and to support economic activity.

As a result, the Federal Reserve and the European Central Bank's balance sheets were subject to a wide expansion through the accumulation of new assets. The Federal Reserve promptly reacted to the crisis in September 2008, by delivering liquidity to key credit markets and expending its marginal lending facilities. After these emergency actions, the Fed durably expanded its balance sheet through massive purchases of long-term Treasury bonds, federal agency debt, and mortgage-backed securities. Such unusual set

of measures constitutes what is now called quantitative easing.

The European Central Bank also engaged in large-scale assets purchases in order to give financial assistance to the euro area's banking sector and its financial markets as the subprime crisis spread to the EMU's Member States. The sovereign debt crisis in the following months further exacerbated systemic risk in the euro area. The ECB then launched a series of programs of assets purchases made of Longer-Term Refinancing Operations, and private securities on secondary markets, thus increasing the size of its balance sheet.

Since the beginning of the crisis, a broad literature has grown up, addressing in particular the impact of unconventional monetary policy measures on financial conditions and global performances in the benefited countries. The theoretical literature on financial disruption and unconventional monetary policy stance is mainly based on DSGE models. Gertler and Karadi (2011) build a DSGE model where financial disruption arises because banks are credit constrained. In this situation, the central bank can use credit policy to lend directly to the private sector.<sup>1</sup> However, only a few papers consider the possibility of a switching in agents' behaviors when a financial crisis occurs. Foerster (2015) builds a Markov-Switching DSGE model based on Gertler and Karadi (2011), where the financial crisis lasts only a pre-determined number of periods, in order to study possible exit strategies of central bankers from unconventional monetary policy. Recently, Cargoët and Poutineau (2018) provided an extension of Gertler and Karadi's (2011) setting, where the situation described in Gertler and Karadi (2011) corresponds to a temporary crisis regime, endogenously triggered by financial or real shocks, while the steady-state of the economy lies on a situation where the credit constraint is not binding, and consequently where there is no financial disruption. In that case, unconventional monetary policy should be inherently temporary because there is room for it only in case of impaired financial markets or a failed banking system.<sup>2</sup>

Meanwhile, there has been a wide development of the empirical research on the effectiveness of quantitative easing policies. Despite their various econometric approaches,

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1. See also Curdia and Woodford (2009), Gertler and Kiyotaki (2010), Gertler and Karadi (2013), Chen et al. (2012).

2. See also Mendoza (2010), He and Krishnamurthy (2013), Brunermeier and Sannikov (2014). More details are provided in the General Introduction above.

most of the existing studies confirm that balance sheet policies conducted have actually succeeded in dampening the economic recession and in avoiding an adverse deflationary spiral in countries threatened by financial instability.<sup>3</sup>

However, there are disagreements about the macroeconomic effects of unconventional monetary policy measures in normal times, namely when financial disruption is over. On one side, in his review of the empirical literature focusing on one the effects of quantitative easing on the economy, Gagnon (2016) shows that even during non-financial stressed times there is still a significant positive effect of quantitative easing (QE) programs on the real economy. This is because QE reduces the long-term yields through the Portfolio Substitution Channel,<sup>4</sup> which should result in a diminution of the cost of accessing credit for non-financial corporations able to issue those types of bonds. On the other side, Quint and Rabanal (2017) estimate a non-linear DSGE model based on Gertler and Karadi (2013) with a banking sector and long-term debt. Unlike Gagnon (2016), they find that the benefits of conducting unconventional monetary policies targeting long-term bonds spreads over the short-term deposit rate are substantial when the economy is hit by financial shocks. These gains become negligible in case of more traditional shocks. Furthermore, authors as Benigno and Nistico (2017) or McMahon et al. (2018) highlight the dangers associated to long-lasting unconventional monetary policies.<sup>5</sup>

Other empirical papers focus on the impact of financial stress on the macroeconomy, using non-linear models to capture the transitory nature of financial stress events, and a wide variety of financial stress indexes. Davig and Hakkio (2010) show evidence of regime-dependency on the two-way relationship between financial stress and real economic activity in the US economy from January 1990 to December 2009. They compare two sets of impulse response functions from a Markov Switching Vector Auto-Regressive framework assuming two states of high and low stress based on the Kansas City Fed composite index. They find that stressful financial conditions exert a stronger negative effect

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3. See Lenza et al. (2010), Peersman (2011), Fahr et al. (2013), Fratzscher et al. (2016), Cahn et al. (2017), Buriel and Galesi (2018) in the ECB case. Section 2 below will give an overview of this growing literature.

4. See General Introduction for a detailed overview of the Portfolio Substitution Channel.

5. McMahon et al. (2018) show that without a known portfolio, such as a portfolio of riskless government debt as it is often the case under conventional policies, control of inflation can be lost. Benigno and Nistico (2017) focus more on the risk of income losses on the central-bank balance sheet associated with the purchase of risky assets.



on economic activity when the economy is initially depressed than during phases of expansion. In addition, the more the domestic financial conditions worsen and the more the home economy is depressed, the more likely is a transition from a regime of moderate level of instability to a state of high level of financial stress. The negative influence of a disrupted financial system on the real side of the related economy is confirmed by Cardarelli et al. (2011). The latter authors point out a close association between upward shifts in the FSI and the occurrence of economic downturns in 17 advanced economies, even before 2007. What also appears is that the resulting contraction of real domestic output is far more severe and longer when the banking system plays a central role in financing the economy. This is explained by the greater procyclicality of debt leverage. Hollo et al. (2011) introduce a new indicator of contemporaneous stress in the Eurozone: The Composite Indicator of Systemic Stress (CISS), and test its impact on economic activity using a Threshold VAR model. Mitnik and Semmler (2013), using a Multi-Regime VAR model on US and European data, show that large negative shocks to financial-stress have sizeable positive effects on real activity. Aboura and Van Roye (2013) use a Markov Switching Bayesian VAR to study the non-linear impact of financial stress in the French economy. Van Roye (2014) estimates a financial market stress indicator for Germany and tests its impact on economic activity using a TVAR methodology. Finally, Hubrich and Tetlow (2015) estimate a Markov Switching Bayesian VAR on US data with a financial stress indicator, and show that conventional monetary policy from the Federal Reserve had little impact during periods of high stress.

Kremer (2016) is at the crossroads between the literature on unconventional monetary policy and the literature on financial stress. He estimates a Structural VAR model on European data with both financial variables (the CISS from Hollo et al. (2011)) and unconventional monetary policy variables. However, this is a fully linear model, and thus does not capture the transitory nature of financial stress events.

The objective of this chapter is to shed light on the issue of the relative efficiency of unconventional monetary policy measures in normal times and during financial crisis times. Our approach is based on the two previous strands of literature. On one hand, we follow Hubrich and Tetlow (2015) in estimating a Markov Switching Bayesian VAR with a financial stress indicator. On the other hand, we borrow from Kremer (2016) as we

build a bridge with the literature on unconventional monetary policy by adding variables relative to the central bank's balance sheet to our model. However, in contrast with Kremer (2016), we make a clear distinction between the two main unconventional monetary policy measures undertaken by the ECB. These correspond to Longer-Term Refinancing Operations (LTROs) devoted to financial intermediaries established in the euro area, and purchases on the secondary market of Private Securities issued by non-financial euro residents. This approach allows us to go a step further from Hubrich and Tetlow (2015) by contrasting the respective impact of unconventional monetary policy measures, both in normal times (low financial stress times) and in crisis times (when financial stress peaks). We get two main results: First, whereas securities purchases are strong during high financial stress periods but have no significant effect on economic activity or credit in low financial stress periods, LTROs have significant positive effects during both periods, even if those effects are clearly stronger in crisis times. Second, LTROs have more impact on financial and real variables than securities purchases during high stress periods, but they comes with a slight increase of financial stress during those periods.

The rest of the chapter is organized as follows. Section 2 describes our non-standard variables and gives an overview of previous empirical findings. Section 3 describes the model specification and estimation strategy. Section 4 performs a robustness analysis. Section 5 describes the results. Section 6 concludes.

## **2 Financial stress and unconventional monetary policy**

### **2.1 Measuring financial instability**

There are several ways of distinguishing episodes of severe financial disruption from more tranquil periods.

One possible approach is to identify crisis events through a dichotomic approach given their occurrence or not (Laeven and Valencia (2013) or Reinhart and Rogoff (2009), among many others). Using a narrative approach, a crisis occurs when some key variables

– e.g., non-performing bank loans, risk premia or debt arrears – exceed a threshold value. Dummy variables are then computed to give a chronology of financial crises. Such an approach of crisis dating has three major drawbacks:

- The corresponding dummy variable is often based on policy measures taken in reaction to a failure of the financial system, though it is supposed to signal the start of a crisis (see Boyd et al., 2009);
- These indexes usually give no idea of the intensity and the length of those episodes of financial instability, though the macroeconomic performances and the central bank's monetary policy may depend on those features (Davig and Hakkio, 2010);
- Limited data availability most often leads to a dating of events on an annual frequency for cross-country comparison purposes (Babecky et al., 2013, is an exception). But it prevents from getting a real-time perspective of the macroeconomic impact of monetary policy measures.

Another approach - adopted in this paper - is to quantify the level of stress on the capital markets. This requires building a composite indicator aimed at signaling changes in the financing conditions on the economy. Such an index should reflect the markets' perceptions about losses on assets, weaknesses of the financial system and threats to the real economy. According to authors like Grimaldi (2010), a Financial Stability Index (FSI) intends to reflect how the size and the likelihood of extreme shocks interact with financial vulnerabilities of various kinds and origins. As the index reaches extreme levels, uncertainty, sensitivity to bad news, financing costs, and non-financial institutions' failures are likely to rise markedly, while real output, employment, agents' confidence and welfare, and even wages and prices, are likely to fall.

Numerous indicators have been used since the beginning of the crisis to gauge financial stress in an economy. The main purpose of these financial stress indicators is to measure the level of frictions in the financial system using a wide variety of financial market variables (spreads, volatilities, liquidities and risk premia...), and to summarize it in a single statistic. The individual indicators are designed to capture various phenomena

associated with periods of extreme stress: Flight to quality; Flight to liquidity for both savers and borrowers; Poorer and more asymmetric information raising serious concerns about adverse selection and moral hazard; Higher risk premia that outweigh the cost of funds; Changes in lenders and borrowers behaviours.

According to Hatzius et al. (2010), a composite index of financial conditions should reflect neoclassical channels of transmission of stress as well as non-price-based channels. The former ones refer to variations in the weighted average cost of capital or in the price at which they could raise new equity capital. It involves equity prices, the yield curve, and risk premia. The latter credit channels point to measures of various kinds: The degree of asset (and market) liquidity; The extent of default risk; The capacity and willingness of intermediaries to lend which depend on the values of the loan collateral.

There are at least two channels through which impaired financial conditions may hurt the real economy, as described by Davig and Hakkio (2010). According to the real option theory, a high level of financial stress leads to a higher uncertainty about the future state of the economy. Firms and households thus have an incentive to postpone their investment decisions as they incur sunk costs. In the case of irreversible investment decisions, the option value to delay those decisions goes up when the dispersion of future outcomes widens. In addition, deleveraging is becoming widespread amid heavily indebted agents in order to restore their financial soundness. All of this has a strong negative impact on both the accumulation of physical capital and the pace of output growth.

The financial accelerator mechanism and its potential feedback effect provide a second explanation to the recession effect of overall impaired financial markets and institutions. Firms and households face a steep increase in the cost of borrowing as a result of skyrocketed risk premia. They are thus discouraged from investing. But the initial adverse impact on the economy may lead to a series of adverse second-round effects on firms' profits and financial positions so that investment falls again, dragging behind output and employment.

Because financial stress is a multidimensional problem, building a relevant index raises at least four main issues as surveyed by Kleisen et al. (2012). The first one relates to data availability on a wide range of indicators to capture stress conditions on various

market segments as well as on intermediaries, especially the banking system. When one is interested in the consequences of unconventional monetary policy measures on the real side of the economy, observations on the variables of interest should cover a time span long enough. A second related question pertains to the frequency at which financial and macroeconomic aggregates can be observed. Data at a relatively high – say, monthly or even daily – frequency are needed when one addresses real-time decision-making or the extent to which the central bankers’ decisions are taken in a timely way.<sup>6</sup>

The informational content of such a composite index is a third matter of concern. Almost all current financial stability indexes are a given mixture of various components attempting to capture one of its main dimensions:

- Credit spreads (to get an idea of risk premia),
- Size of liquidity shortages,
- Asset return volatility on the financial markets,
- Variability and misalignment of foreign exchange rates for the domestic currency,
- Some economic fundamentals to extract inflation expectations and prospects for real activity, investment, and employment,
- Cost and volume of credit to firms and households.

Thus, most indexes give an assessment of financial stability through a rather wide panel of indicators. An extreme case is Brave and Butters (2011) who considered not least than 100 indicators observed at either a weekly, monthly or quarterly frequency. There is however a risk of redundant information if several indicators are used to depict the same feature of financial instability (Grimaldi, 2010 or Vermeulen et al., 2015). A parsimonious set of relevant indicators of stress can be chosen to get rid of this shortcoming.

The last matter of concerns relates to the way of weighing the different subindexes forming the financial stress index: There is a growing family of composite indexes of financial stress, who differ not only on the individual indicators they incorporate but

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6. This leads some authors to adopt a mixed-frequency framework like Brave and Butters (2011).

also on the way these signals are aggregated into one synthetic measure. A first way is to give weights according to the variance of each variable, as it is often done in the vast empirical literature devoted to the early warning systems of financial crises. For example, Cardarelli et al. (2011) consider the variance-weighted mean of three sub-indexes related to the banking sector, and the securities and foreign exchange markets. Two of the former sub-indexes are themselves obtained by a simple arithmetic average of their respective individual components. A similar strategy has been followed by the European Central Bank (2009) to build its Global Financial Index of Turbulence (the GIFT) gathering sub-indexes of risk on the equity, fixed income, and foreign exchange markets.

Alternatively, one can weigh the sources of financial turmoil on the basis of the relative market size. Illing and Liu (2006) used this approach, considering the market shares in the total credit to the Canadian economy. The two authors also use Principal Component Analysis (PCA) in order to account for the individual importance of a large number of indicators. The weight each of them receives depends on its historical contribution to changes in the degree of financial vulnerability. As emphasized by Brave and Butters (2011), the extraction of the first principal component from a set of variables is a natural way of capturing interconnectedness across markets and intermediaries since it reflects the greatest part of their covariance. Therefore, a small variation in a heavily weighted indicator may have a stronger influence on the composite index than a large move in an indicator of secondary importance.

Focusing on the systemic dimension of financial risk, Hollo et al. (2012) provide a portfolio-based approach based to build the so-called Composite Indicator of Systemic Risk (CISS). The main purpose of the corresponding statistic is to measure “the current level of frictions, stresses and strains [...] in the financial system” (Hollo et al., 2012). We use this indicator as our financial stress variable in our Markov-Switching Bayesian VAR. The CISS is made of 5 stress subindexes on 5 market segments, each one targeting a different channel by which the funds of savers are reallocated towards borrowers. The segments include: (1) money market; (2) bond market; (3) equity market; (4) financial intermediaries; (5) foreign exchange markets. Each sub-index is a combination of three indicators that are (almost) perfectly correlated with each other, where these components

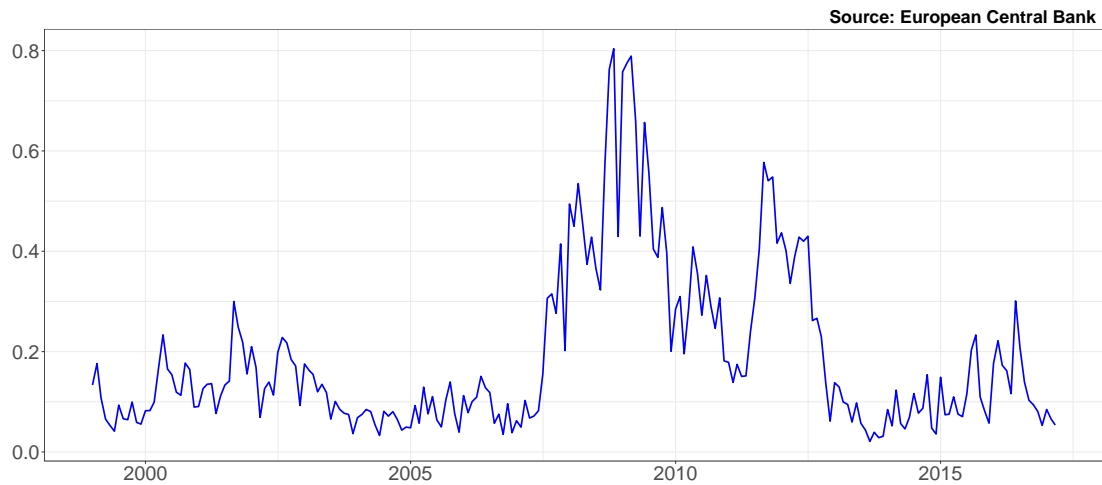


Figure 3.1: Composite Indicator of System Stress, euro area

ideally show very low comovements with those included to form a distinct sub-index. Severe levels of strains on the financial system should imply strong, perhaps perfect, correlation between the subindexes. The aggregation takes into account the time-varying cross-correlations between the subindexes, in the same way that portfolio risk is computed from individual asset risks.<sup>7</sup> As a result, the CISS puts more weight on situations in which stress prevails in several market segments at the same time. Movements in the aggregate CISS for the euro area between January 1999 and March 2017 is represented in Figure 3.1.

The CISS appears to be a relevant indicator of financial stress in the euro area. The two main periods of acute levels of stress correspond to the financial crisis that erupted in 2007, and the debt crisis in 2011.

7. See Hollo et al. (2012) for a more detailed description of the components of the subindexes and aggregation method.

## 2.2 Unconventional monetary policy: ECB's practice and its effects according to previous works

Since its creation and until the financial crisis in 2007-2008, the European Central Bank (ECB) conducted its monetary policy by manipulating its Main Refinancing Operation rate (MRO rate) in order to influence other monetary market interest rates.

The situation changed dramatically after the onset of the subprime crisis coming from the United States in 2007. Following the disruption of several market segments, a gradual decorrelation occurred between traditional interest rate spreads and lending from financial intermediaries. This disconnection impaired the conventional transmission of MRO rate decreases to the rest of the economy. In September 2014, the MRO rate hurt the Zero Lower Bound, making it impossible for the ECB to decrease it further as an accommodative monetary policy impulse.

The ECB used a wide variety of unconventional monetary policy measures in order to keep the control over its monetary policy and to fight against financial disruption and activity losses. These tools can be decomposed into 3 categories: Quantitative easing, qualitative easing and forward guidance.<sup>8</sup> This chapter attempts to capture the effect of the first two categories of unconventional monetary policy instruments.<sup>9</sup>

Figure 3.2 reports the evolution of the ECB's balance sheet and its components from January 1999 to December 2017. It clearly appears that the two main sources of increase in the ECB's balance sheet since 2007 are lending to the euro area's credit institutions related to monetary policy operations, and purchases of securities issued by euro residents.

The strong increase in securities on euro residents held by the ECB is the outcome of the Expanded Asset Purchase Program (APP) undertaken since July 2009. The latter includes a variety of programs under which public and private sector securities were purchased in order to inject liquidity into the banking system. In the beginning of 2018,

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8. See the General Introduction above for more details on the different types of unconventional monetary policies.

9. As forward guidance consists in commitments to future policy actions, it affects financial and real variables only through the expectation channel. For this reason, it will not be included in our framework. Rather we will concentrate on policies for which we can measure the direct macroeconomic effects.



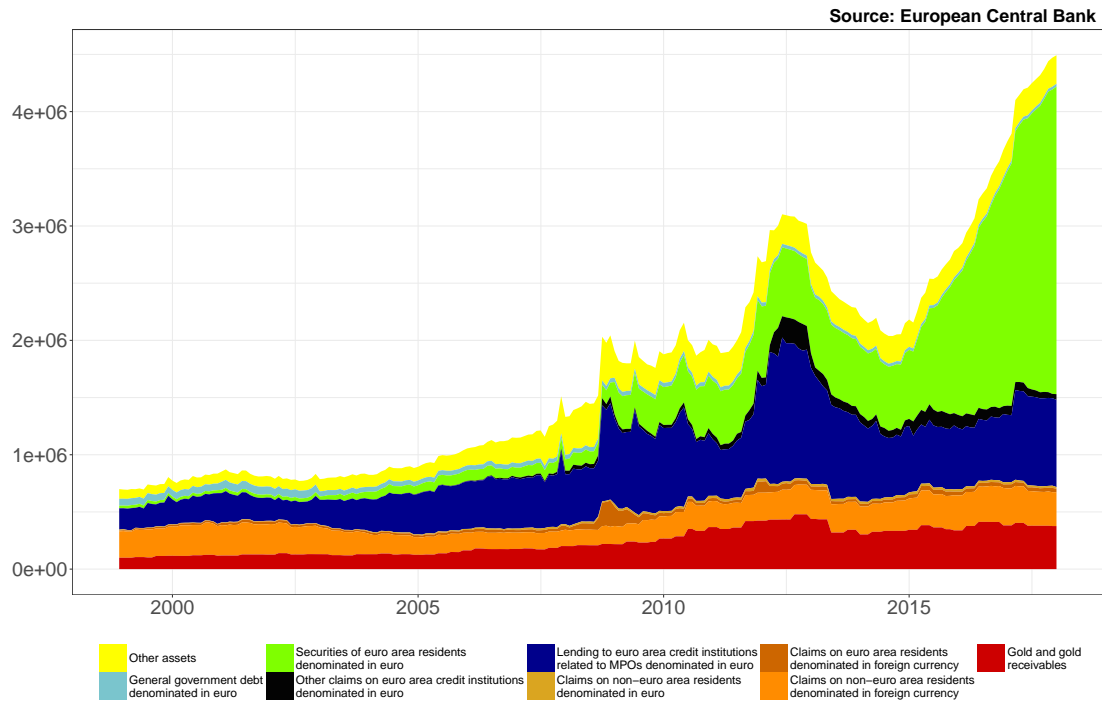


Figure 3.2: ECB balance sheet January 1999–December 2017

assets held by the ECB as part of the APP are public sector securities (for the biggest part), corporate bonds, asset-backed securities and covered bonds.

Figure 3.3 represents the different components of lending to euro area credit institutions. Until 2007, the ECB granted loans to credit institutions mainly as part of its Main Refinancing Operations (MRO). Longer-Term Refinancing Operations (3 years maturity, 4 years for Targeted Longer-Term Refinancing Operations) dramatically increased after the crisis, as a way to offer long-term funding with attractive conditions to banks in order to stimulate bank lending to the real economy and to lower long-term interest rates.

In this empirical study, we try to capture the two main sources of variation in the ECB's balance sheet since the beginning of the crisis. Our model thus includes both euro area residents' securities held by the ECB and Longer-term refinancing operations in order to quantify the macroeconomic effects of the quantitative easing program depending on whether the economy is subject to severe financial turbulences or not.

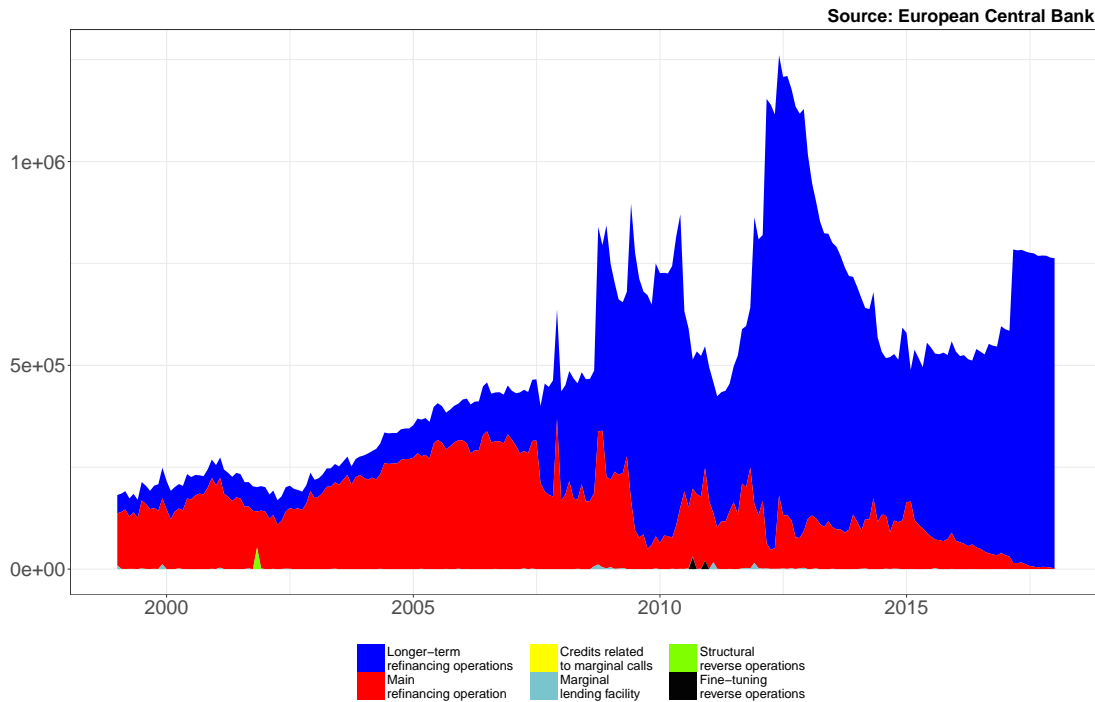


Figure 3.3: Lending to euro area credit institutions related to monetary policy operations denominated in euros, components, ECB balance sheet.

The existing literature considers various channels through which non-standard policy may impact the whole economy. The two main transmission channels of unconventional monetary policy (UMP) measures - i.e. the Bank Funding Channel and the Portfolio Substitution Channel - are already detailed in the General Introduction of this thesis. A third channel depends on the capacity of UMP measures to lower the risk of a sovereign default. Fratzscher et al. (2016) argue that the standard transmission mechanism of conventional monetary policy breaks down when the market's perception of sovereign risk is not in line with the underlying fundamentals, as a consequence of a loss of confidence. The sudden flights to quality and to liquidity the former induce have motivated the ECB's Securities Market Purchase (SMP)<sup>10</sup>: Addressing excessive risk premia on sovereign bonds was an indirect goal of the Eurosystem. Two other transmission channels become po-

10. See the General Introduction above for details on the SMP.

tentially relevant according to Bluwstein and Canova (2016). The wealth channel occurs when UMP measures alter assets prices by changing the user cost of capital. Furthermore, such policy actions may counteract excessive pessimism among individuals: By restoring confidence, the environment becomes less uncertain and less risky and this stimulates final consumption and capital accumulation. Another strand of literature focuses on the signalling channel of UMP measures (Krishnamurthy and Vissing-Jorgensen, 2011): Purchasing a large quantity of assets under a quantitative easing program works as a credible commitment by the central bank to keep low interest rates in the future, thus acting on the same channel as forward guidance.

Lenza et al. (2010), using a Bayesian VAR model, find that the effects of the quantitative easing - conducted by the European Central Bank, the Federal Reserve and the Bank of England - on the economy have mainly channelled through interest rate spreads. Peersman (2011), using a SVAR with sign restrictions, shows that the ECB can stimulate the economy beyond the policy rate by increasing the size of its balance sheet. Wu and Xia (2016) question the usefulness of unconventional monetary policy measures undertaken by the Fed when the economy hits the zero lower bound, using a factor-augmented VAR with the estimation of a shadow interest rate.

Boeckx et al. (2017) estimate the effects of exogenous innovations to the balance sheet of the ECB since the start of the financial crisis. Within a structural VAR framework, they show that a positive shock to the ECB's balance sheet has positive effects on output and prices. Quantitative easing indeed stimulates bank lending, reduces interest rate spreads, leads to a depreciation of the euro. They run a counterfactual analysis that confirms that euro-area output and inflation would have been more than 1 percent lower in 2012 without 3-year LTROs programs. However the effects on output turn out to be much smaller in the euro member countries with undercapitalized banking systems than elsewhere.

The latter conclusion is supported by Buriel and Galesi (2018). They also assess the effects of ECB's UMP measures by estimating a global VAR. This framework allows to account for cross-country interdependencies responsible for cross-border spillover effects as described above. The two authors agree with Boeckx et al. (2017) that most euro

area members have benefited from these measures, but they also estimate the heterogeneity among members of the European Union and the instability of the effects over time. The positive effects reached a maximum during the sovereign debt crisis. In addition, cross-country spillovers account for a sizable part of those heterogeneous effects. Yet, countries with more fragile banking systems benefit the least from unconventional monetary policy measures in terms of output stimulus. A crucial finding is that such heterogeneity explains the small impact QE measures have had on the whole euro area economy. What also questions the usefulness of UMP measures at all times is that such shocks lead to smaller and less persistent effects than those arising from conventional interest rate surprises according to Buriel and Galesi's (2018) estimates.

Baumeister and Benati (2013) also use a data driven approach based on the VAR methodology to gauge the success of unconventional monetary policy actions in the US and the UK. Unlike Boeckx et al. (2017), they consider a dynamic system with time-varying parameters, allowing for structural instability as a result of changes in individuals' behaviours. They study the response of macroeconomic aggregates to a fall in the long-term bond yield spread after the Great Recession of 2007. Assuming that the policy rate is already at its zero lower bound, these authors find that output growth and inflation accelerate if monetary authorities succeed in reducing risk premia on long-term bonds.

Besides the effectiveness of non-standard monetary decisions, Borio and Zabai (2016) are also interested in providing a benefit-cost analysis of UMP measures in the wake of the 2007–2008 financial crisis. They distinguish the effects of balance sheet policies from those induced by forward guidance and negative policy rates. While there is overwhelming empirical evidence on their positive impact on the ease of lending conditions in the domestic country, the responses of output and inflation to each of these instruments is more difficult to pin down. The short-run gains tend to be compensated by longer-term costs. According to Borio and Zabai (2016), UMP measures are at best well-suited in exceptional times, that is when the financial system is severely impaired.

The different UMP measures (i.e. LTROs and securities purchases) may lead to differentiated effects on financial conditions and the macroeconomy. From this perspective, Jäger and Grigoriadis (2017) conclude to a different impact of SMP and LTROs on the Eurozone, because of heterogeneities between the respective effects of these measures

on countries subject to financial disruption and those not subject to financial disruption: While LTROs lower bond yield spreads for both country groups, the SMP redistributes risk from crisis countries to the entire euro area through the ECB balance sheet, which has opposite effects on bond yield spreads for crisis and non-crisis countries, resulting in a less important effect on the whole Eurozone's spreads.

Conclusions from data driven approaches are broadly consistent with what DSGE models predict. Fahr et al. (2013) use both an estimated DSGE model and a Structural VAR model to assess the effectiveness of ECB's unconventional monetary policy in preventing the economy from an even more disruptive collapse, by reducing the impact of negative financial shocks. More recently, Cahn et al. (2017) also use an estimated DSGE model on Eurozone data. They find that LTROs have played a key role in avoiding a credit crunch. Their counterfactual analysis suggests that without these LTROs, output and inflation would have been lower on average since 2009.

### **3 The econometric approach**

#### **3.1 A dynamic non-linear data-driven specification**

The Markov-Switching framework is particularly useful in a non-linear environment as the one that is characterized by episodes of huge financial stress. It is able to capture sudden shifts and reversals in the parameters of variables, reflecting behavioral changes. It is more suited to capture crisis events than a Threshold VAR, since the source of parameters shifts is endogenous to the data. It allows discrete parameter shifts, which is also more appropriate than a Time-Varying Parameter VAR as drifting parameters are unable to capture some of the more sudden features of a financial crisis.

We use the Markov-Switching Bayesian VAR model developed by Sims et al. (2008). Therefore, our analysis is comparable to that of Hubrich and Tetlow (2015), as we try to identify non-linearities caused by the financial crisis by introducing a financial stress index. We consider a Markov-Switching Bayesian VAR of the following form:

$$y'_t A_0(s_t) = \sum_{l=1}^p y'_{t-l} A_l(s_t) + z'_t C(s_t) + \varepsilon'_t \Xi^{-1}(s_t), \quad (3.1)$$

where  $y_t$  is a  $n \times 1$  vector of  $n$  endogenous variables  $x_t$  with  $t = 1, 2, \dots, T$  where  $T$  is the sample size,  $A_0(k)$  is a non singular  $n \times n$  matrix describing contemporaneous relationships between the elements of  $y$ ,  $A_l(k)$  is an  $n \times n$  matrix of parameters of the endogenous variable ( $1 \leq l \leq p$ , with  $p$  the number of lags in the VAR model),  $z_t$  is a  $n \times 1$  vector of exogenous variables which we are going to consider as  $1_T$  (i.e a vector of constants),  $C(k)$  is the  $1 \times n$  vector of parameters of this exogenous variables,  $\Xi^{-1}(k)$  is a diagonal matrix of factors scaling the  $n \times 1$  vector of structural unobserved shocks  $\varepsilon_t$ , and  $s_t$  are the unobserved Markov states at time  $t$ . In our case, we assume two states:  $s_t \in \{1, 2\}$ . The values of  $s_t$  evolve according to a first-order Markov process with fixed transition probabilities:

$$\Pr(s_t = i | s_{t-1} = k, \dots) = P(s_t = i | s_{t-1} = k) = p_{ik}, \quad i, k \in \{1, 2\}. \quad (3.2)$$

Letting  $A'_+(k) = [A'_1(k), A'_2(k), \dots, A'_p(k), C'(k)]$  and  $x'_t = [y'_{t-1}, \dots, y'_{t-p}, z'_t]$ , the model can then be written as,

$$y'_t A_0(s_t) = x'_t A_+(s_t) + \varepsilon'_t \Xi^{-1}(s_t). \quad (3.3)$$

Assuming that the structural disturbances are normal, conditional on the state  $p(\varepsilon_t | y_0, \dots, y_t, s_t, A_0, A_+) \sim N(0_{n \times 1}, I_n)$ , the reduced-form system writes,

$$y'_t = x'_t B(s_t) + u'_t(s_t), \quad (3.4)$$

with,

$$B(s_t) = A_+(s_t) A_0^{-1}(s_t), \quad (3.5)$$

$$u'_t(s_t) = \varepsilon'_t \Xi^{-1}(s_t) A_0^{-1}(s_t). \quad (3.6)$$

We consider the vector of endogenous variables

$y'_t = [HICP_t, GDP_t, Credit_t, CISS_t, r_t, LTRO_t, Sec_t]$ . Three of the endogenous variables represent the block of core variables included in all standard monetary policy VAR models of the literature: A measure of the aggregate price level, an index of aggregate economic activity and a measure of conventional monetary policy. Prices are measured by the Harmonized Index of Consumer Prices (*HICP*), economic activity by the real Gross Domestic Product (*GDP*), and conventional monetary policy by the Main Refinancing Operation Rate (*r*), set by the ECB in the Eurosystem's regular market operations.

Together with the three core variables, we also add two financial variables, consistent with the empirical literature on financial crises. To account for financial stress in the euro area, we use the square root of the Composite Indicator of Systemic Stress (*CISS*) in line with previous work<sup>11</sup>.

We add a variable to reflect accessibility of credit in the economy. We account for the loans to the euro area non financial corporations (*Credit*) in the sample variables. The latter indicator helps identify shocks to the credit supply. It also allows us to investigate the channels of transmission of unconventional monetary policy decisions.

Finally, we add two unconventional monetary policy variables: The amount of Longer-Term Refinancing Operations (*LTROs*), and the volume of securities issued by euro area's residents held by the ECB (*Securities*). It allows us to identify the response of financial and real variables to each of these two unconventional monetary policy shocks.

### 3.2 Estimation methodology

We estimate this model using a Hamilton Filter with a Gibbs sampling algorithm to obtain draws for the parameters values and probability transition matrix. In particular, the joint posterior distribution can be factorized on three conditional distributions, which leads to the three blocks of the Gibbs sampling algorithm. The Gibbs sampling is performed using Monte Carlo Markov Chains with 10,000 draws. The last 2,000 repetitions are used to compute the Generalized Input Response Functions with their confidence interval

11. As advocated by Kremer (2016), the square root of the CISS allows to avoid potential nonlinearities coming from the quadratic form of the formula under which the CISS is computed. Hollo et al. (2012) refer to the square root of the CISS as the "volatility equivalent" CISS.

Type of prior	Value
Overall tightness of the prior	0.6
Relative tightness of the prior for $A_+(s_t)$	0.1
Relative tightness for the constant term	0.1
Tightness on lag decay	1.2

Table 3.1: Priors values

following Karamé (2010, 2015). The lag length of the autoregressive part of our system is set equal to 3 to keep enough degrees of freedom.

There are two sets of relevant priors in our model, one on the VAR parameters conditional on a state  $s$ , and the other on the transition matrix. As concerns the VAR coefficients, we use the Natural Conjugate priors that can be implemented by introducing dummy observations into the estimation system. These priors shrink the model towards an AR(1) process with a lag structure that dampens the influence of events through time. The values of priors are similar to Sims and Zha (2006) as summarized in Table 1. However, we voluntarily omit the sum of coefficients prior and the common stochastic trend prior. This choice is motivated by the fact that we take our data in annual log-differences, a transformation that removes the upward drift in the log levels of these series.

For the priors on the transition matrix, we use the Dirichlet form. If  $\alpha_{ij}$  is a hyperparameter indexing the expected duration of regime  $i$  before switching to regime  $k \neq i$ , the prior on  $Q$  is of the Dirichlet form,

$$p(Q) = \prod_{j \in H} \left[ \frac{\Gamma\left(\sum_{i \in H} \alpha_{ij}\right)}{\prod_{i \in H} \Gamma(\alpha_{ij})} \times \prod_{i \in H} (q_{i,j})^{\alpha_{ij}-1} \right], \quad H = \{1, 2\}, \quad (3.7)$$

where  $\Gamma(\cdot)$  is the standard Gamma function. In line with Hubrich and Tetlow (2015), we set Dirichlet priors of 5.6 for the two coefficient states. As stressed by the abovementioned authors, the prior probability of remaining in the same state during two successive periods should not favor a switch in shock variances over a shift in the model's parameters, and conversely.



To identify the Bayesian VAR model, we apply a lower triangle Choleski decomposition of  $A(s_t)$ , assuming that the macro-financial series ( $HICP_t, GDP_t, Credit_t$ ) are slow-moving variables, while  $CISS$  and monetary policy variables ( $CISS_t, r_t, LTRO_t, Sec_t$ ) are considered as fast-moving variables.

The model is estimated on monthly data on the euro area as a whole over the sample period January 2000 – December 2017. All variables are seasonally adjusted and taken in annual log differences, in order to get rid of any potential remaining extra seasonality, and remove the upward drift in the log components of series in levels.

## 4 Empirical evidence from GIRFs

One standard way to assess the quality of fit of a Markov switching model is to compare the estimated state probabilities with what it is known about economic record during the period under study. Figure 3.4 draws the estimated probabilities of high-stress coefficient states from our model.<sup>12</sup> As can be seen in this figure, the estimated model state probabilities match quite well the history of financial stress events since the beginning of the financial crisis. In particular, the last three clusters of high-stress correspond to negative developments of the banking and sovereign debt crisis in the euro area. We observe a strong positive correlation between the  $CISS$  displayed in Figure 3.1 and the estimated probability of switch displayed in Figure 3.4 (we will study it in greater details in the next paragraph).

As in Hubrich and Tetlow (2015), we can associate the two first stress spikes in June 2003 and January 2004 with the consequences of Argentina’s debt default, which, noticeably, took more time to propagate to the European economies than it did to reach the US financial system.

The most important cluster of high stress periods corresponds to the systemic banking crisis in the EMU. This period of unprecedented instability started in October 2008 when the Lehman Brothers’ bankruptcy in September 2008 began to spread to European monetary markets. It ended up with the 30 billions package of emergency loans granted

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12. Coefficient switching is not constrained to one variable in our model, but obviously reflects switching from low financial stress to high financial stress periods, as we will explain below.

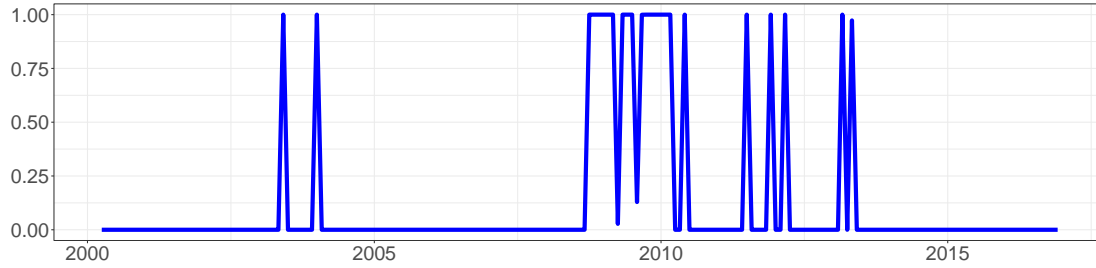


Figure 3.4: Probability of high-stress coefficient state

to Greece by its EMU partners in April 2010. It was then followed by a 110 billions rescue package allowed to Greece in May 2010. A final short-lived spike is observed in June 2010. The latter high-level stress event matches with growing concerns about sustainability of the Irish public debt, resulting from the massive bail-out of its domestic banking sector.

The next two clusters of high stress periods include three close spikes gathered in the second part of 2011 and first part of 2012, and two close spikes in the beginning of 2013, respectively. Most of them coincided to default episodes in the most fragile EMU countries.

- The July 2011 spike matches the “selective default” on the Greek sovereign debt. It happened at a time when existing Greek sovereign bonds were restructured with the agreement of bondholders, making them support the cost of this haircut.
- The December 2011 spike lines up with the adoption of the “Six-Pack” on the initiative of the European Commission (EC). This set of reforms aimed at improving the EC surveillance over the euro member states debts and deficits. An enforcement of financial penalties was decided in case of a non-fulfillment of the public deficit ceilings.
- The next peak level of financial stress in March 2012 corresponds to the second and more serious episode of Greek sovereign debt restructuring. At this time, the Greek government made use of the “collective action clause” to force bondholders to swap the current securities held in their portfolios for longer-term and depreciated ones.

This decision triggered the payment of billions of euros of debt contract insurances in the form of credit-default swaps.

- Finally, the final two episodes of extreme financial stress can be observed in March–May 2013. They coincide well with the restructuring of the Laiki Bank - Cyprus' largest bank - the depositors of which were forced to exchange 47% of their holdings beyond the guarantee limit of 100,000€ with bank shares, thus suffering from a substantial loss of financial wealth.

Given this matching exercise as a quality of fit, it is clear that financial stress events are what trigger coefficient switching in our model. As a consequence, we will be able in the next section to interpret the Generalized Impulse Response Functions conditional to the high stress regimes as the way economy would have behaved in presence of high financial stress events in the economy.

## **5 The effects of unconventional monetary policies**

### **5.1 Generalized Impulse Response Functions**

In this section, we use the Generalized Impulse Response Functions (GIRFs) as the main interpretation tool of our model, in order to deal with non-linear dynamic cross-relations. GIRFs are Impulse Response Functions generalized to a nonlinear framework, introduced in the seminal article of Koop et al. (1996). Ehrmann et al. (2003) transposed the GIRF to the specific case of Markov-Switching VARs. They consider an IRF conditional to the regime in which the shock occurs. However this IRF only captures the dynamics within a particular regime. It is assumed that there is no more change in the level of financial stress after the occurrence of the shock. Here we use the GIRF approach of Karamé (2010) because it generalizes Ehrmann et al. (2003) approach by taking into account the probabilities of occurrence of all future states, and thus solving the problem of state asymmetries in the GIRF.

Karamé (2015) shows that the GIRF is independent of both initial conditions and future innovations, so there is no need to draw random future shocks or random initial

conditions in the sample. We suppose that the regime is perfectly known at the time of the shock.

Let's define  $\Theta = \{A_0(s_t), A_+(s_t), \Xi(s_t)\}$  as the set of unknown parameters estimated through the Gibbs Sampling algorithm. Knowing the first regime and the values from the fixed transition probability matrix, all the probabilities associated to a particular chronology of regimes of financial (in-)stability up to horizon  $t + h$  can be computed as,

$$\forall h \geq 1, \quad P(s_{t+h}, s_{t+h-1}, \dots, s_{t+1} | s_t; \Theta) = p_{s_{t+h-1}, s_{t+h}} \times P(s_{t+h-1}, \dots, s_{t+1} | s_t; \Theta). \quad (3.8)$$

For an initial shock sequence  $\varepsilon_t$  and conditionally to each simulated trajectory for the latent variable, the optimal forecast for  $y_{t+h}$  can be calculated based on equation 3.1,

$$E[y_{t+h} | s_{t+h}, \dots, s_t, \varepsilon_t; \Theta] = z_t' C(s_t) + \sum_{l=1}^p E[y_{t+h-l} | s_{t+h-1}, \dots, s_t, \varepsilon_t; \Theta] A_l(s_t). \quad (3.9)$$

The “shocked trajectory” corresponds to the sum of all possible responses weighted by their own probability of occurrence. As a result, the computation of this trajectory should display exponentially increasing complexity as the prediction horizon  $h$  lengthens. But Karamé (2010) shows that collapsing techniques can be applied to the MS-SVAR framework so that they have the advantage of keeping the size of the problem constant.

$$E[y_{t+h} | s_{t+h}, \varepsilon_t; \Theta] = \sum_{s_{t+h}} \dots \sum_{s_{t+1}} E[y_{t+h} | s_{t+h}, \dots, s_t, \varepsilon_t; \Theta] \times P(s_{t+h}, \dots, s_{t+1} | s_t; \Theta). \quad (3.10)$$

The state-dependent IRF at the  $h$ -month horizon, conditional to an initial regime  $s_t$  and a shock  $\varepsilon_t$  is defined as the difference between the shocked trajectory and a benchmark non-shocked trajectory, that is,

$$IRF(h, s_t, \varepsilon_t; \Theta) = E[y_{t+h} | s_{t+h}, \varepsilon_t; \Theta] - E[y_{t+h} | s_{t+h}, \varepsilon_t; 0].$$

This allows one to check for state asymmetry in the macroeconomic effects of monetary policy actions.

## 5.2 Unconventional monetary policy - A new normal ?

We use GIRFs from Karamé (2010) in order to investigate the relative efficiency of unconventional monetary policies in periods of high (resp. low) stress index.

Figure 3.5 depicts the consequences of a positive structural shock on securities purchased by the ECB on inflation, real output, financial stress, and credit volume. Such an impulse can be viewed as part of the quantitative easing program. Two sets of GIRFs are produced under two distinct assumptions about the starting regime of high or low level of stress within the domestic financial system. The first row panel of Figure 3.5 displays GIRFs conditional to an initial regime of low stress (blue lines) and GIRFs conditional to an initial regime of high stress (red lines) in the same box. The collapsing technique implies that the probability of being in one particular regime is updated each period by the estimated transition matrix with constant probabilities. This assumption makes the two conditional GIRFs very close to one another after a limited number of periods, namely 7 months in most graphs of Figure 3.5. The mid row panel displays the GIRF for the low stress regime with confidence bands at 16% – 84%. The choice of a 68% confidence interval is standard in Bayesian time series analysis. Finally, the bottom row panel in Figure 3.5 displays only the GIRFs for the high stress regime with the same confidence interval.

Let us first look at the impact of securities purchases on real output. We can see in the first row of Figure 3.5 that ECB's quantitative easing measures seem to have a far more sizeable positive effect on GDP in the high stress regime than in the low stress regime. Furthermore, the mid and bottom row panels show that the expansionary effect on economic activity turns out to be significant only in periods of high stress. That positive impact quickly shrinks because of the increasing probability in each period for the economy to go back to the low stress regime.

Panels in Figures 3.5 that display the impacts of securities purchases on CISS and credit give us some insights to understand the channels through which quantitative easing impacts economic activity. First we see that quantitative easing has a positive impact

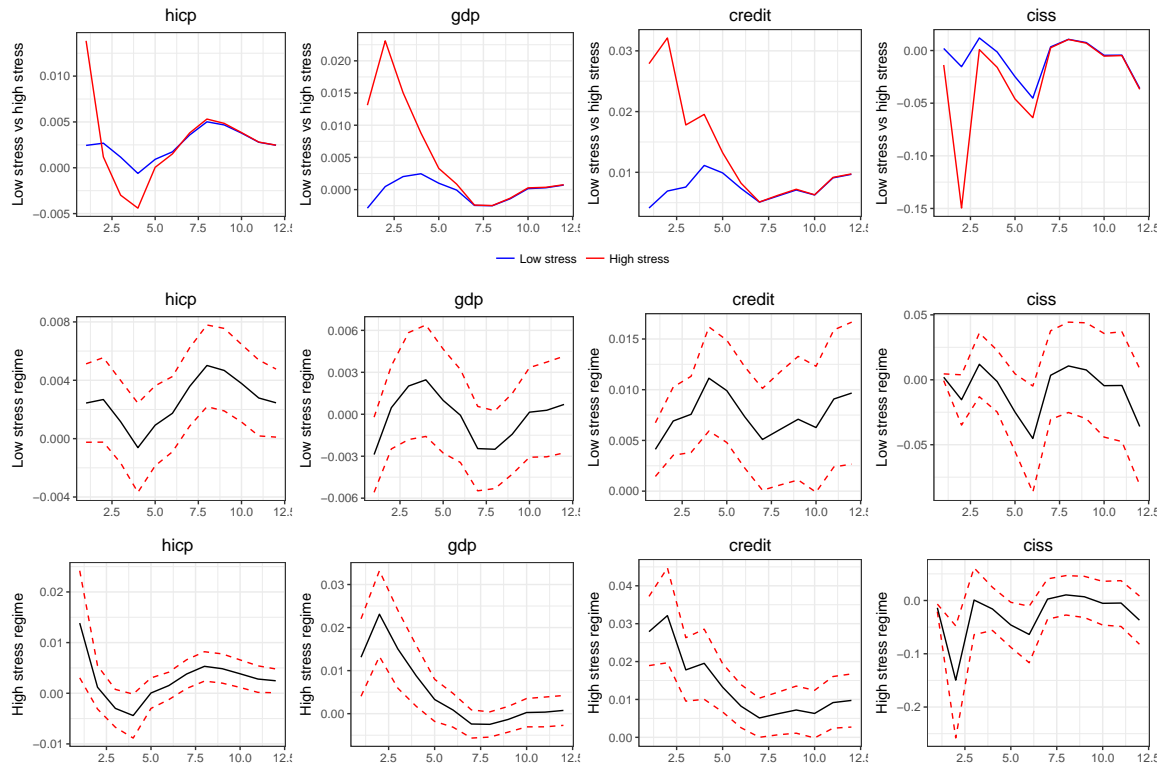


Figure 3.5: Generalized Impulse Response Functions to a 1% shock on securities purchases conditional to each starting regime.

on the quantity of loanable funds delivered by banks to non financial corporations. This impact is significant under the two identified regimes of low and high volatility in the domestic financial system. But the size of the effect is 6 times higher for the high stress regime in the first month after the monetary surprise.

This is in line with standard macroeconomic results. The central bank engages into large scale assets purchases to restore the financial soundness and liquidity of banks. If so, banks will have extended access to central liquidity at least temporarily. Benefiting from a looser liquidity constraint than before, credit institutions are prone to raise their loans to non financial corporations. In a period of financial disruption on the interbank market (high stress coefficient regime), banks are particularly subject to liquidity shortages, which forces them to dramatically reduce their loan supply. As the central bank gives

them access to liquidity, the loan supply can increase again to meet the loan demand. This effect is less important in times of low threats to the financial system. When banks are not particularly constrained to fulfill their liquidity requirements, their enlarged access to liquidity will have a moderate effect on loan supply, which already meets the loan demand for reasonable levels of loan interest rate.

Looking at the impact of securities purchases on the CISS, our results are consistent with the mechanism we highlighted before. Indeed, the effects of quantitative easing on the CISS are only significant for the high stress regime, with a very important decrease of the financial stress indicator: The CISS shrinks by 15% for a 1% increase in securities purchases in the first two months. When the central bank delivers liquidity to the banking system in the last resort, since banks face severe liquidity shortages, the level of financial stress proxied by the CISS strongly decreases, which allows banks to deliver more loans and the economy to recover.

Let us consider now the relative effectiveness of an increase in LTROs under both the high-stress and low-stress regimes. We are able to compare it with the impact of the increase in private securities purchases studied before. Figure 3.6 displays the dynamic adjustment paths of inflation, real output, financial instability and credit granted to commercial banks by the ECB. Like Figure 3.5 above, the 3 rows of Figure 3.6 display a set of GIRFs conditional to each starting regime with their respective confidence intervals. The top panels show the comparison between both conditional GIRFs. As for the securities purchases shock, the conditional GIRFs exhibit very contrasting features during the first 7 months after such an event, and then merge.

A first striking observation is that the new set of generalized responses is close to the one resulting from a positive shock to private securities purchases. A strong increase in real output can be noticed in response to this new unconventional monetary policy impulse. This expansionary effect is stronger under the high-stress regime than the low-stress one. Still, the impact on economic activity remains significant during both regimes and until the seventh month. The fact that there is a significant positive impact of LTROs on economic activity in times of low-financial stress, while this impact is insignificant for securities purchases, is a key result of our model. Gagnon (2016) insists on the fact

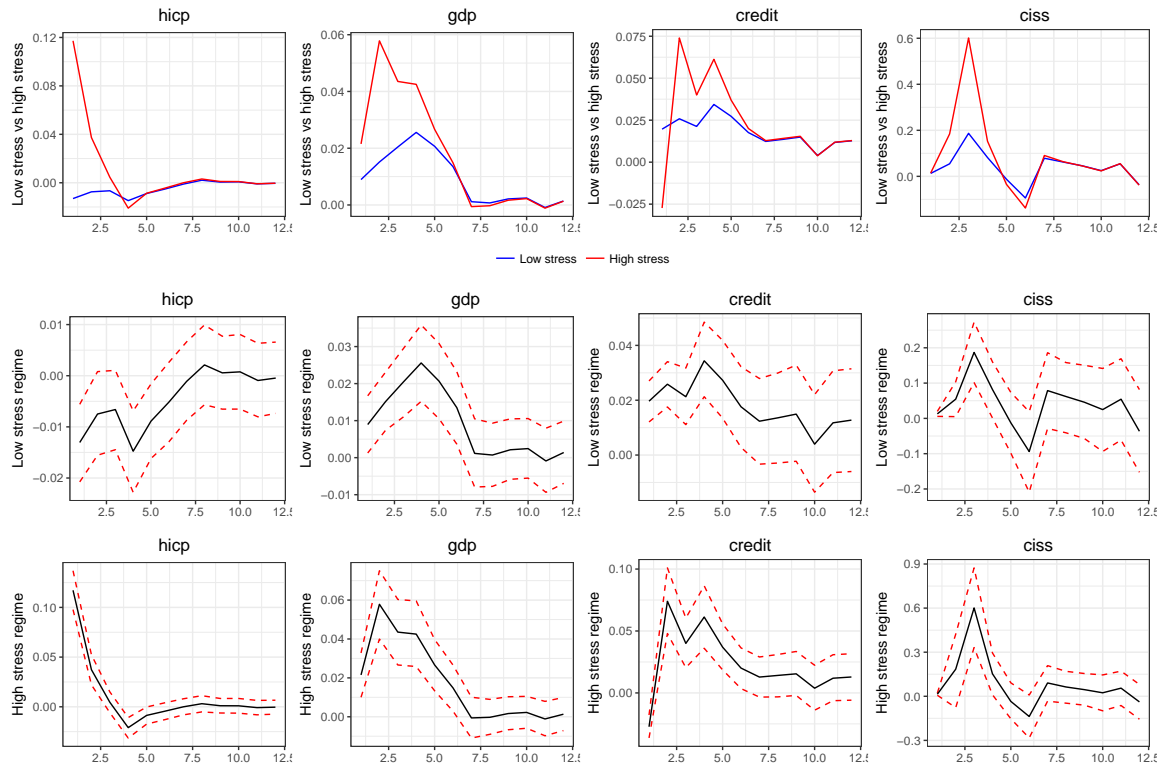


Figure 3.6: Generalized Impulse Response Functions to a 1% shock on Longer-Term Refinancing Operations, conditional to each starting regime

that there is still a room for quantitative easing in non-financial crisis times, because even though the Bank Funding Channel is not working anymore when the financial disruption is over (banks can have access to liquidity again through a well-functioning interbank market), the Portfolio Substitution Channel is still active (when the central bank buys long-term bonds, it creates a reduction of long-term yields, which decreases the cost of accessing credit for non-financial corporations, encouraging them to invest more). As LTROs are exclusively composed of long-term loans (3 or 4 years maturity), their effects on economic activity through the Portfolio Substitution Channel are more important than those of securities purchases, so they are still useful as monetary policy tools when financial crisis times are over, even if their overall effect is reduced.

When considering the magnitude of the effects, we can see that in the high stress



regime, the peak effect on domestic real output of a 1% rise in LTROs is more than twice the maximum impact of an increase in securities purchases of the same proportion (almost 0.06 against less than 0.025), probably because it works both through the Bank Funding Channel and through the Portfolio Substitution Channel.

The positive effects of monetary accommodation on inflation through an increase in LTROs in the high stress regime, has the same shape as the estimated inflation path in reaction to additional securities purchases by the ECB (see the bottom left panels of Fig. 5 and 6). However, given narrow confidence bands, emergency liquidity provision through LTROs has an immediate inflationary impact that is 5 to 6 times higher than what would happen after a new securities purchase program. This upward shift in domestic retail prices is not only more important, but it also lasts one more month when LTROs are preferred over securities purchases. The small, temporary, and rather unconvincing inflationary effect of securities repurchases by the central bank to restore confidence and liquidity of financial markets and intermediaries is in line with Gambacorta et al.'s (2014) main conclusion. However, the strong positive response of the euro area's price level to ECB's LTROs is more difficult to reconcile with the former authors' statement. Our GIRFs for the HICP variable gives support to Boeckx et al. (2017) and to Buriel and Galesi (2018). However, in the low stress regime, the effects on inflation of a LTROs increase are barely significant and slightly negative. Again monetary impulses by means of LTROs or securities purchases imply different responses of the consumer price index. Looking at the medium left panel of Figure 3.6, Longer-Term Refinancing Operations appear to have a much higher impact during episodes of extreme financial stress than they do in a context of sound financial conditions.

Looking at the two last columns of Figure 3.6, it appears that credit is the main channel of transmission of LTROs on economic activity and inflation. LTROs also seem more efficient than securities purchases in order to restore credit: Following an initial shock on LTROs, the estimated credit expansion two months later is more than twice the corresponding rise in response to a shock on securities purchases (despite a counterintuitive effect on the first period after the shock). This can be explained by the fact that while under securities purchases programs, banks need to have the specific type of security required by the central bank in their balance sheet to get access to liquidity, in the case of

LTROs, the collateral constraints to have access to loans from the central bank are much lighter (the ECB expanded since 2007 the range of assets eligible as collateral for refinancing operations). However, this higher increase in credit supply in the case of LTROs comes with an increase of financial stress, clearly significant in the third period after the shock. Indeed, as long-term interest rates are lowered and access to credit becomes easier, this raises concerns about over-optimism of agents in their borrowing and lending behavior, as has already been the case before the financial crisis of 2007. This result is also consistent with Jäger and Grigoriadis (2017), who explain the difference of aggregate effects between securities purchases and LTROs by a difference in distributional effects between crisis and non-crisis countries inside the Eurozone. Finally, as for the shock on securities purchases, we can see that the shock on LTROs has a much bigger effect on credit volumes under the high stress regime than under the low-stress one.

The transmission channels of LTROs on activity are pretty much the same as for assets purchases. Central banks deliver loans to commercial banks, with banks assets as collateral. These new loans give banks an easier access to liquidity, which allows them to sell new loans to the private sector. This mechanism of liquidity access for banks is particularly powerful in periods of liquidity shortages. However, we can point out two main differences.

First, as stated before, as LTROs are exclusively composed of long-term loans, their effects through the Portfolio Substitution Channel are far more important than those of securities purchases: The increase in the supply of long-term bonds creates a reduction of long-term yields, which decreases the cost of accessing credit for non-financial corporations, encouraging them to invest more. Furthermore, as this effect is active even in non-crisis times (in opposition to the effect on bank's liquidity, which is far less important when financial intermediaries are able to refinance themselves on the interbank market), LTROs still have an impact on macroeconomic conditions when financial disruption is over. This second channel of action also explains the higher efficiency of LTROs in increasing the amount of credit in the economy.

Second, in the case of assets purchases, the central bank engages into net purchases of certain types of assets on the primary or on the secondary market. The majority of these

assets are central government bonds or bonds issued by well-established public agencies, by regional or local governments, by international organizations and by multilateral development banks located in the euro area (82.62% of the APP in December 2017), which are purchased on the secondary market. Banks can have access to liquidity if they hold this type of assets in their balance sheet and are willing to sell it. In the case of LTROs, the variety of assets banks can use as collateral to have access to liquidity is much larger, and it was increased in December 2011, accepting Asset-Backed Securities with a second-best rating or even bank loans that comply with specific eligibility criteria. So it is easier for banks to have access to liquidity through LTROs. Furthermore, LTROs include Targeted Longer-Term Refinancing Operations (TLTROs), which are directly linked to banks loans to non-financial corporations and households. This two features help explain the stronger effect of LTROs on fighting recession.

Finally, according to Jäger and Grigoriadis (2017), the difference on the magnitude of effects between securities purchases and LTROs can also be explained by differences between distributional effects: While LTROs lowers bond yield spreads for both country groups, the securities purchases redistribute risk from countries subject to crisis to the entire Euro-area through the ECB balance sheet, which has opposite effects on bond yield spreads for the crisis and non-crisis countries, resulting in a less important effect on the whole Eurozone's spreads.

However, it shall be noticed that a shock in LTROs temporarily increases the CISS in both high-stress and low-stress regimes. The upward move in the systemic risk index is 4 times higher under the high stress regime than under the alternative. This is a sign of the potential risk that the possibility to have an easy access to liquidity with flexible collateral requirements can encourage risky behaviors for banks, and thus increase systemic risk. Moral hazard is a serious issue as illustrated by the GIRFs depicted in Figure 3.6.

## 6 Conclusion

In this chapter, we have built a Markov-Switching VAR model estimated on the Eurozone, incorporating financial variables, to assess the relative efficiency of unconventional monetary policy variables in high financial stress situations and in normal times. We

have used Generalized Impulse Response Functions as an analytical tool adapted to the Markov-Switching framework of the model. We have found that unconventional monetary policies are highly efficient in high financial stress situations, but we find ambiguous results regarding their effectiveness in normal times. Whereas securities purchases have no significant effect in low financial stress periods, LTROs have significant positive effects on economic activity and credit during both periods, even if those effects are clearly stronger in high financial stress periods. LTROs are also more efficient in high-stress periods than securities purchases in refueling activity and providing new loans. However, this is done at the cost of a higher financial stress in the economy.

This chapter complements the work from Hubrich and Tetlow (2015) who showed that conventional monetary policy was efficient in non-stressed times but weak in high financial stress situations. In terms of policy implications, this result highlights a trade-off between economic activity and financial risks, advising the ECB to carefully choose its unconventional monetary policy tools.

The possible explanations of the greater effectiveness of LTROs in refueling activity and providing credit to the economy and of its efficiency even in low-financial stress situations are threefold.

First, as LTROs are exclusively composed of long-term loans, their effects through the Portfolio Substitution Channel are far more important than those of securities purchases. According to Gagnon (2016), the Portfolio Substitution Channel is still active during low-stress episodes, in opposition to the Bank Funding Channel, which explains the effectiveness of LTROs and these situations.

Second, whereas in the case of securities purchases commercial banks need to hold in their balance sheet the specific type of assets required by the central bank to get access to liquidity, in the case of LTROs the range of assets that can be used as collateral to access credit is much broader.

Finally, according to Jäger and Grigoriadis (2017), the difference on the magnitude of effects between securities purchases and LTROs can also be explained by differences between distributional effects.

There are still a number of challenges ahead.

One may first question the relevance of the CISS as an indicator of financial stress. There are several competing indexes of financial stability from the available literature; As stressed by Kleisen et al. (2012), those indexes should be strongly and positively correlated with one another in theory, since they are intended to capture the same phenomenon, namely a financial system more or less seriously put under pressure. Still, the 13 indexes under Kleisen et al.'s (2012) review exhibit surprisingly low pair-wise correlation when applied to the US economy. But most of them are consistent with the empirical record of episodes of acute stress in the financial system. Borio and Drehmann (2009) are more skeptical about the capacity of FSI to send useful signals to monetary authorities in a timely way, namely at the onset of the systemic financial crisis or enough time before it to take preventive measures rather than to cure its subsequent financial and economic disorders.

Next, the proposed non-linear VAR framework has some limitations. This is why we would like to check for the robustness of our main findings in two directions. The first one concerns the identification scheme to isolate the structural shocks. Our GIRFs are based on a set of zero constraints on the instantaneous impact of some variables on others. Doing so, the factorized system implies a specific recursive system that may be irrelevant. Zero-constraints in the long-run may be helpful as they may discriminate among competing theories.

Finally, the proposed econometric strategy is, for now, unable to account for cross-border spillover effects of UMP measures. As suggested by Bluwstein and Canova (2016), it could be useful to further distinguish among a number of channels of international transmission that may be relevant for unconventional policies. Since UMP measures may influence the exchange rate, they influence net exports volumes and prices for the partner country. According to this exchange rate channel, the resulting adjustment of the currency spot rate affect foreign prices, production, and consumption. Therefore, substitution and income effects condition the size of the effects on foreign inflation and output.

As it stands, this first empirical investigation calls for further developments to address the above methodological and economic issues.

# General Conclusion

The financial crisis of 2007 has deeply altered the conduct of monetary policy in most developed countries. As conventional monetary policy tools were not sufficient anymore to stabilize the macroeconomy and to avoid a financial disruption, central banks extensively relied upon a wide set of unconventional monetary policy measures. Quantitative easing has been widely used. Over the last 10 years, the size of the ECB's balance sheet has been multiplied by 3, while the size of the Federal Reserve's balance sheet has been multiplied by 4. The success of quantitative easing in monetary policy triggered a need for more theoretical and empirical understandings of this tool. This has been filled over the years by a fast growing academic literature.

The aim of this thesis was to contribute to the understanding of quantitative easing programs and their macroeconomic effects by focusing on the non-linear nature of financial crises. Several questions, yet unanswered in the literature, have been addressed using this specific framework.

We built the three chapters of this thesis around three main questions. First, considering the transitory nature of financial crises, one question that naturally arises is the question of the impact of quantitative easing, not only on the magnitude of the financial crisis, but also on its duration. We tried to answer this question using a non-linear DSGE model with an occasionally binding credit constraint - accounting for the transitory nature of financial disruption events - where the crisis situation can be endogenously triggered by external financial shocks. Second, focusing on the specific challenges of monetary policy inside the Eurozone, we tried to determine which type of quantitative easing would be the most efficient one given the strong heterogeneities observed between the financial systems of Eurozone members. Thus we extended the non-linear DSGE model of

the first chapter to a two-country framework where the financial crisis can spread from one country to another, and we study the impact of different types of quantitative easing programs on this transmission effects. Third, as most central banks' balance sheet are still large despite the fact that the financial crisis is over and that macroeconomic variables slowly go back to their pre-crisis level, comes the question of the future of unconventional monetary policies: Should unconventional monetary policy be part of the new normal of monetary policy, or should central banks exit from this policy as soon as possible? We tried to answer this question empirically, using a Markov-Switching VAR estimated on the Eurozone with two regimes corresponding respectively to high financial stress situations and low financial stress situations.

The main results can be summarized as follows. The DSGE model presented in chapter 1 shows that while a credit policy (i.e a specific type of quantitative easing, where the central bank lends directly to the non-financial sector) always decreases the magnitude of the financial crisis, it also increases its duration. In order to quantify the net effects resulting from this trade-off, we proceed to an intertemporal analysis of the response of aggregate output to financial shocks, with and without credit policy. For reasonable values of the underlying parameters, we find that the intertemporal effects of conducting a credit policy are always positive. However, for extreme values of the underlying parameters, for example a high leverage ratio between entrepreneurs' net wealth and their borrowing capacities, these effects can become very weak.

The two-country DSGE model presented in chapter 2 provides us with a large set of results relative to the international transmission channels of the financial crisis and the efficiency of different types of credit policies. First we find that cross-border lending is the main transmission channel of financial crisis between countries. For realistic values of cross-border banking sector integration, a financial shock in the peripheral countries of the Eurozone may spread towards core countries. Cross-border lending has ambiguous effects on the Eurozone's macroeconomic variables, because on one side it creates a financial disruption on the countries that were not initially subject to the financial shock, while, on the other side, it lightens the credit constraint of the countries that were initially subject to the shock, because entrepreneurs are able to switch part of their loan demand towards other countries' banks. For realistic values of financial integration, in-

creasing cross-border lending would reduce the overall effects of financial shocks on the Eurozone. Noticeably, the optimal degree of financial integration, which minimizes the consequences of a negative financial shock on the aggregate output of the Eurozone, is not that far from what is observed in the data, making it a realistic policy target. Testing for different types of credit policies, we find that a homogeneous credit policy (ignoring country-specific factors) is always less efficient than a heterogeneous one (taking into account country-specific factors). However, while credit policies reduce inequalities between Eurozone's members for low degrees of financial integration, they increase inequalities for high degrees of financial integration.

The Markov-Switching VAR model presented in chapter 3 brings empirical evidence about the relevance of conducting unconventional monetary policies in normal times. We find that whereas securities purchases have no significant effect in low financial stress periods, LTROs have significant positive effects on economic activity and credit during both periods, even if those effects are clearly stronger in high financial stress periods. LTROs are also more efficient in high-stress periods than securities purchases in refueling activity and providing new loans. However, this is done at the cost of a higher financial stress in the economy.

In this thesis, we highlighted the importance of taking into account the inherently non-linear nature of the financial crisis when conducting unconventional monetary policy. However, there are still a number of challenges ahead.

The most important improvement would be to empirically estimate the DSGE models in chapters 1 and 2, using Bayesian techniques. However, the empirical estimation of non-linear DSGE models is quite challenging, and is currently not implemented in routines available under standard softwares such as dynare. For this reason, we have chosen to simulate this models, using parameters calibrated ex-ante.

We also believe that the Markov-Switching VAR model of chapter 3 can still be improved. In particular, further research about the identification of this model should be conducted, using a combination of zero restrictions and sign restrictions.

Finally, some efforts could be directed towards several points for further research. One interesting point that deserves further investigations according to us is the question of the way for the central banks to exit from quantitative easing programs. Should the



central bank favor a quick sell-off strategy, or a slow unwinding strategy? If a slow unwinding strategy is to be adopted, what should be the optimal unwinding rate? We believe this questions can be answered through an expansion of the non-linear DSGE model of chapter 1, by changing the credit policy rule or simulating credit policy using series of exogenous credit policy shocks directly fed into the model.

# Appendix A

## The distribution of risky projects

We follow closely Poutineau and Vermandel (2015) on the definition of the accelerator mechanism on the entrepreneurial sector. Each entrepreneur  $e \in [0, 1]$  conducts a mass of heterogeneous projects. Each project undertaken by the entrepreneur is risky. To model individual riskiness, we assume that the net return of each investment project is made of the aggregate return of projects  $R_t^k$  and a random value  $\omega \in [\omega^{\min}, +\infty)$  drawn from a Pareto law, so that the individual return of each risky project writes  $\omega R_t^k$ . The value of  $\omega$  is not known ex ante, neither by entrepreneurs nor by banks. Entrepreneurs finance their projects with their net wealth and loans from banks, so the net profit generated by the project  $\omega$  of entrepreneur  $e$  is,  $\omega R_t^k Q_{t-1} K_t(e, \omega) - R_{t-1}^L L_{t-1}^D(e, \omega)$ , with  $K_t(e, \omega)$

the amount of capital invested by the entrepreneur  $e$  on the realization of the project  $\omega$ , and  $L_{t-1}(e, \omega)$  the amount of loans subscribed by entrepreneur  $e$  in order to fund this specific project. From that expression, we define a threshold value  $\omega_t^C(e)$  of the random variable  $\omega$  that distinguishes profitable from non profitable projects. This threshold value is computed as,

$$\omega_t^C(e) R_t^k Q_{t-1} K_t(e, \omega_t^C) - R_{t-1}^L L_{t-1}^D(e, \omega_t^C) = 0. \quad (\text{A.1})$$

For a realization of  $\omega \geq \omega_t^C$ , the project is profitable; The entrepreneur pays back the bank from whom he borrowed for this specific project, and keeps the remaining profit.

For a realization of  $\omega < \omega_t^C$ , the project is non profitable; The entrepreneur does not pay back the bank, and makes no profit.

Entrepreneurs' projects individual profitability are drawn from a Pareto distribution:  $\omega \sim P(\kappa, \omega^{\min})$ , where  $\kappa$  is the shape parameter of the Pareto law and  $\omega^{\min}$  is the minimum realization of  $\omega$ . Aggregating the projects, we define the share of profitable projects as,  $\eta^E \equiv \Pr[\omega \geq \omega^C] = \int_{\omega^{\min}}^{\infty} f(\omega)d\omega = \left(\frac{\omega^{\min}}{\omega^C}\right)^\kappa$ . The conditional expectation of  $\omega$  when the project is profitable writes,  $\eta^E \bar{\omega} = \int_{\omega^C}^{\infty} \omega f(\omega)d\omega$ . From that we are able to define the conditional expectation of a profitable project as,  $\bar{\omega} \equiv E[\omega | \omega \geq \omega^C] = \int_{\omega^C}^{\infty} \omega f(\omega)d\omega / \int_{\omega^{\min}}^{\infty} f(\omega)d\omega = \frac{\kappa}{\kappa-1} \omega^C$ .

For each project with individual profitability  $\omega$  the entrepreneur pays back its loan and keeps the remaining profit with a probability  $\eta_t^E(\omega)$ , and does not make any profit and does not repay its loan with a probability  $(1 - \eta_t^E(\omega))$ . The aggregation of entrepreneurs projects  $\int_{\omega^{\min}}^{\infty} \omega R_{t+1}^k Q_t K_{t+1}(e) - R_t^L L_t^D(e)$ , gives the following expected profit,

$$\Pi_{t+1}^E = \left\{ \begin{array}{l} \bar{\omega}_{t+1} R_{t+1}^k Q_t K_{t+1}(e) - R_t^L L_t^D(e) \text{ with probability } \eta_{t+1}^E \\ 0 \text{ with probability } 1 - \eta_{t+1}^E \end{array} \right\}, \quad (\text{A.2})$$

so in the aggregate, the profit of an entrepreneur is,

$$\Pi_{t+1}^E = \eta_{t+1}^E (\bar{\omega}_{t+1} R_{t+1}^k Q_t K_{t+1}(e) - R_t^L L_t^D(e)).$$

To introduce an entrepreneur's accelerator mechanism, we assume that entrepreneurs' forecasts regarding the aggregate profitability of a given project  $\bar{\omega}_t$  are optimistic (*i.e.*, their expectations are biased upwards).<sup>1</sup> The perceived *ex ante* value of profitable projects

1. According to Puri and Robinson (2013), three main factors seem to characterize entrepreneurs as an economic group: (i) Entrepreneurs enjoy substantial non-pecuniary benefits from the autonomy and freedom associated with self-employment; (ii) Differences in risk tolerance have also been offered as a potential explanation for the puzzling choices entrepreneurs make; (iii) dispositional optimism, which is a personality trait, rather than a misperception about the probability of some future event occurring. Their main results clearly underline that entrepreneur are more optimistic, more willing to bear risk and more motivated by the non-pecuniary enjoyment of work than wage-earners.

is defined by the CES function,

$$g(\bar{\omega}_{t+1}) = \gamma (\bar{\omega}_{t+1})^{\frac{\varkappa^E}{\varkappa^E - 1}} \left( e^{\varepsilon_t^{opt}} \right)^{\frac{1}{\varkappa^E - 1}}, \quad (\text{A.3})$$

where  $\varkappa^E$  is the elasticity of the external finance premium and  $\gamma$  is a scale parameter.<sup>2</sup>

Thus, *ex ante* the entrepreneur chooses a capital amount  $K_{t+1}(e)$  that maximizes its expected profit defined as,

$$\max_{\{K_{t+1}(e)\}} \mathbb{E}_t \left\{ \eta_{t+1}^E \left[ g(\bar{\omega}_{t+1}) R_{t+1}^k Q_t K_{t+1}(e) - R_t^L L_t^D(e) \right] \right\}. \quad (\text{A.4})$$

Solving this program at the first order and using the expression of  $\bar{\omega}_{t+1}$ , we can express the expected spread required by the representative entrepreneur  $e$  to undertake the decision to finance firms (i.e. the external finance premium) as,

$$S_t(e) = \frac{\mathbb{E}_t [R_{t+1}^k]}{R_t^L} = \gamma^{\varkappa^E - 1} \left[ \frac{\kappa}{\kappa - 1} \left( 1 - \frac{N_t^E(e)}{Q_t K_{t+1}(e)} \right) \right]^{\varkappa^E} e^{\varepsilon_t^{opt}}. \quad (\text{A.5})$$

The size of the borrowing accelerator is determined by the elasticity of the external finance premium  $\varkappa^E$ . For  $\varkappa^E > 0$ , the external finance premium is a positive function of the leverage ratio,  $Q_t K_{t+1}(e) / N_{t+1}^E(e)$ , so that an increase in the share of entrepreneur's net wealth on the composition of the project funding induces a reduction of the external finance premium. This phenomenon disappears if  $\varkappa^E = 0$ .

Combining  $Q_t K_{t+1}(e) = \phi_t^E(e) N_t^E(e)$  and A.5 we can thus define,

$$\phi_t^E(e) \equiv \left[ 1 - \frac{\kappa - 1}{\kappa} \left( \frac{\mathbb{E}_t [R_{t+1}^k]}{R_t^L} \frac{\gamma^{1 - \varkappa^E}}{e^{\varepsilon_t^{opt}}} \right)^{\frac{1}{\varkappa^E}} \right]^{-1}. \quad (\text{A.6})$$

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The optimism of this group of agents has furthermore been investigated. As an example Dawson et al. (2013) report the accumulating evidence, that entrepreneurs hold distorted beliefs about their own ability and success probability. Those selecting self-employment may have an optimistic disposition, in which case they will also tend to overestimate their prospects in paid employment. Those who will enter self-employment display higher than average financial optimism while in paid employment and are even more optimistic when self-employed.

2. This parameter is needed to have correct anticipations at the steady-state such as  $g(\bar{\omega}) = \bar{\omega}$ , which implies  $\gamma = \bar{\omega}^{1/(1-\varkappa^E)}$ .



# Appendix B

## Bank's net wealth, interest rate setting and loan market tightness

### 1 The closed-economy case

Banks' marginal cost is determined by maximizing the profit equation with flexible interest rate, before taxation from the government,

$$\max_{\{B_{t+1}(b)\}} E_t [\Pi_{t+1}^B(b)] = E_t [\eta_{t+1}^E] MC_t^B(b) L_t^S(b) - R_t B_{t+1}(b), \quad (\text{B.1})$$

where  $L_t^S(b) = N_t^B(b) + B_{t+1}(b)$ . The amount of households savings at the bank ( $B_{t+1}(b)$ ) must ensure the validation of the credit constraint,

$$L_t^S(b) \leq L_t^{S \max}(b) = \phi_t^B(b) N_t^B(b). \quad (\text{B.2})$$

In order to solve this maximization problem under an occasionally binding constraint, we use Kuhn-Tucker conditions on the Lagrangian,

$$\max_{\{B_{t+1}(b)\}} L = \left\{ \begin{array}{l} E_t [\eta_{t+1}^E] MC_t^B(b) (N_t^B(b) + B_{t+1}(b)) - R_t B_{t+1}(b) \\ -\zeta_t [B_{t+1}(b) - N_t^B(b) (\phi_t^B(b) - 1)] \end{array} \right\}. \quad (\text{B.3})$$

First order conditions write,

$$E_t [\eta_{t+1}^E] MC_t^B(b) - R_t = \zeta_t, \quad (\text{B.4})$$

$$\zeta_t \geq 0, \quad (\text{B.5})$$

$$\zeta_t [B_{t+1}(b) - N_t^B(b)(\phi_t^B(b) - 1)] = 0, \quad (\text{B.6})$$

$$B_{t+1}(b) \leq N_t^B(b)(\phi_t^B(b) - 1). \quad (\text{B.7})$$

From this equation and inequation system, we get two possible regimes.

### 1.1 Normal times

The first situation corresponds to normal times. The crisis indicator variable is null,

$$\zeta_t = 0, \quad (\text{B.8})$$

so B.5 and B.6 are verified. The 2 remaining equations write,

$$B_{t+1}(b) < N_t^B(b)(\phi_t^B(b) - 1), \quad (\text{B.9})$$

for equation B.7 and,

$$MC_t^B(b) = \frac{R_t}{E_t [\eta_{t+1}^E]}, \quad (\text{B.10})$$

for equation B.4. In this regime, the credit constraint is not binding, and the marginal cost of loans (and so the interest rate on loans) is still determined by the banks for a given amount of loan demand from the entrepreneurs.

### 1.2 Crisis times

The second situation corresponds to crisis times. In this situations, the crisis indicator variable is positive,

$$\zeta_t > 0, \quad (\text{B.11})$$

so B.5 is verified. The 3 remaining equations write,

$$B_{t+1}(b) = N_t^B(b)(\phi_t^B(b) - 1), \quad (\text{B.12})$$

for equations B.6 and B.7 and,

$$MC_t^B(b) = \frac{R_t + \zeta_t}{E_t [\eta_{t+1}^E]}. \quad (\text{B.13})$$

for equation B.4. In this regime, the credit constraint is binding, and the marginal cost of loans (and so the interest rate on loans) becomes a jump variable determined by market conditions through the influence of  $\zeta_t$ , to ensure the equilibrium between loan demand and loan supply on the credit market.

## 2 The two-country case

We compute bankers' profits in the same way as Dedola et al. (2013). The representative core bank  $b$  generates profits by lending to both core entrepreneurs (an amount  $L_{h,h,t}^D(b)$ ) and peripheral entrepreneurs (an amount  $L_{f,h,t}^D(b)$ ) with the same interest rate  $R_{h,t}^L(b)$ , and  $L_{h,t}^S(b) = L_{h,h,t}^D(b) + L_{f,h,t}^D(b)$ . The representative bank for country  $h$  pays taxes, pays a riskless interest rate  $R_t$  on the deposits it gets from core households, and faces a probability of default on both core and peripheral entrepreneurs' loans. It creates loans  $L_{h,t}^S(b)$  from its net wealth  $N_{h,t}^B(b)$  and deposits from core households  $D_{h,t+1}(b)$ . Its profit writes,



$$\begin{aligned}
\Pi_{h,t+1}^B(b) &= (1 - \tau_h^B) R_{h,t}^L(b) (E_t [\eta_{h,t+1}^E] L_{h,h,t}^D(b) + E_t [\eta_{f,t+1}^E] L_{f,h,t}^D(b)) - R_t D_{h,t+1}(b), \\
&= (1 - \tau_h^B) R_{h,t}^L(b) \left[ \begin{aligned} &(E_t [\eta_{f,t+1}^E] - E_t [\eta_{h,t+1}^E]) L_{f,h,t}^D(b) \\ &+ E_t [\eta_{h,t+1}^E] (L_{h,h,t}^D(b) + L_{f,h,t}^D(b)) \end{aligned} \right] - R_t D_{h,t+1}(b), \\
&= (1 - \tau_h^B) R_{h,t}^L(b) [(E_t [\eta_{f,t+1}^E] - E_t [\eta_{h,t+1}^E]) L_{f,h,t}^D(b) + E_t [\eta_{h,t+1}^E] L_{h,t}^S(b)] \\
&\quad - R_t (L_{h,t}^S(b) - N_{h,t}^B(b)), \\
&= [(1 - \tau_h^B) E_t [\eta_{h,t+1}^E] R_{h,t}^L(b) - R_t] L_{h,t}^S(b) + R_t N_{h,t}^B(b) \\
&\quad + (1 - \tau_h^B) R_{h,t}^L(b) (E_t [\eta_{f,t+1}^E] - E_t [\eta_{h,t+1}^E]) L_{f,h,t}^D(b), \\
&= \left[ \begin{aligned} &((1 - \tau_h^B) E_t [\eta_{h,t+1}^E] R_{h,t}^L(b) - R_t) \\ &+ (1 - \tau_h^B) R_{h,t}^L(b) (E_t [\eta_{f,t+1}^E] - E_t [\eta_{h,t+1}^E]) \frac{L_{f,h,t}^D(b)}{L_{h,t}^S(b)} \end{aligned} \right] L_{h,t}^S(b) \\
&\quad + R_t N_{h,t}^B(b), \\
&= \left[ \begin{aligned} &((1 - \tau_h^B) E_t [\eta_{h,t+1}^E] R_{h,t}^L(b) - R_t) \\ &- (1 - \tau_h^B) R_{h,t}^L(b) (E_t [\eta_{h,t+1}^E] - E_t [\eta_{f,t+1}^E]) \Xi_{h,t} \end{aligned} \right] L_{h,t}^S(b) \\
&\quad + R_t N_{h,t}^B(b), \tag{B.14}
\end{aligned}$$

with  $\Xi_{h,t} \equiv \frac{L_{f,h,t}^D(b)}{L_{h,h,t}^D(b) + L_{f,h,t}^D(b)} = \left( \frac{1 - \alpha_h^L}{1 - \alpha_f^L} \left( \frac{P_{f,t}^L}{P_{h,t}^L} \frac{T_o T_{t+1}}{T_o T_t} \right)^{-\mu_h^L} \frac{Q_{h,t} K_{h,t+1} - N_{h,t}^E}{Q_{f,t} K_{f,t+1} - N_{f,t}^E} + 1 \right)^{-1}$  the share of loan demand from peripheral entrepreneurs in the total loan demand to the representative core bank  $b$ . Symmetrically, the profit of the representative peripheral bank  $b$  writes,

$$\begin{aligned}
\Pi_{f,t+1}^B(b) &= \left[ \begin{aligned} &((1 - \tau_f^B) E_t [\eta_{f,t+1}^E] R_{f,t}^L(b) - R_t) \\ &- (1 - \tau_f^B) R_{f,t}^L(b) (E_t [\eta_{f,t+1}^E] - E_t [\eta_{h,t+1}^E]) \Xi_{f,t} \end{aligned} \right] L_{f,t}^S(b) \\
&\quad + R_t N_{f,t}^B(b), \tag{B.15}
\end{aligned}$$

with  $\Xi_{f,t} \equiv \frac{L_{h,f,t}^D(b)}{L_{h,f,t}^D(b) + L_{f,f,t}^D(b)} = \left( \frac{\alpha_f^L}{\alpha_h^L} \left( \frac{P_{h,t}^L}{P_{f,t}^L} \frac{T_o T_t}{T_o T_{t+1}} \right)^{-\mu_h^L} \frac{Q_{f,t} K_{f,t+1} - N_{f,t}^E}{Q_{h,t} K_{h,t+1} - N_{h,t}^E} + 1 \right)^{-1}$  the share of loan demand from core entrepreneurs in the total loan demand to the representative

peripheral bank  $b$ .

So the net wealth of the representative bank  $b$  from core (resp. peripheral) countries is just its profit on the previous period subject to a normally distributed shock  $e^{\varepsilon_{h,t}^{NB}}$  (resp.  $e^{\varepsilon_{f,t}^{NB}}$ ),

$$N_{h,t}^B(b) = \left[ (1 - \tau_h^B) \left[ \begin{array}{c} \left( \eta_{h,t}^E R_{h,t-1}^L(b) - \frac{1}{1 - \tau_h^B} R_{t-1} \right) \\ - R_{h,t-1}^L(b) (\eta_{h,t}^E - \eta_{f,t}^E) \Xi_{h,t-1} \\ + R_{t-1} N_{h,t-1}^B(b) \end{array} \right] L_{h,t-1}^S(b) \right] / e^{\varepsilon_{h,t}^{NB}}, \quad (\text{B.16})$$

$$N_{f,t}^B(b) = \left[ (1 - \tau_f^B) \left[ \begin{array}{c} \left( \eta_{f,t}^E R_{f,t-1}^L(b) - \frac{1}{1 - \tau_f^B} R_{t-1} \right) \\ - R_{f,t-1}^L(b) (\eta_{f,t}^E - \eta_{h,t}^E) \Xi_{f,t-1} \\ + R_{t-1} N_{f,t-1}^B(b) \end{array} \right] L_{f,t-1}^S(b) \right] / e^{\varepsilon_{f,t}^{NB}}. \quad (\text{B.17})$$

The marginal cost of the representative core bank  $b$  from country  $h$  is determined by maximizing the profit equation with flexible interest rate,

$$\max_{\{D_{h,t+1}(b)\}} E_t [\Pi_{h,t+1}^B(b)] = \left[ \begin{array}{c} ((1 - \tau_h^B) E_t [\eta_{h,t+1}^E] MC_{h,t}^B(b) - R_t) \\ - (1 - \tau_h^B) MC_{h,t}^B(b) (E_t [\eta_{h,t+1}^E] - E_t [\eta_{f,t+1}^E]) \Xi_{h,t} \\ + R_t N_{h,t}^B(b), \end{array} \right] L_{h,t}^S(b) \quad (\text{B.18})$$

where  $L_{h,t}^S(b) = N_{h,t}^B(b) + D_{h,t+1}(b)$ . The amount of households savings at the bank ( $D_{h,t+1}(b)$ ) must ensure the respect of the credit constraint,

$$L_{h,t}^S(b) \leq L_{h,t}^{S,\max}(b) = \phi_{h,t}^B(b) N_{h,t}^B(b). \quad (\text{B.19})$$

In order to solve this maximization problem under an occasionally binding constraint, we use Kuhn-Tucker conditions on the Lagrangian,

$$\max_{\{D_{h,t+1}(b)\}} L = \left[ \begin{array}{c} ((1 - \tau_h^B) E_t [\eta_{h,t+1}^E] MC_{h,t}^B(b) - R_t) \\ - (1 - \tau_h^B) MC_{h,t}^B(b) (E_t [\eta_{h,t+1}^E] - E_t [\eta_{f,t+1}^E]) \Xi_{h,t} \\ + R_t N_{h,t}^B(b) - \zeta_{h,t} (D_{h,t+1}(b) - N_{h,t}^B(b) (\phi_{h,t}^B(b) - 1)). \end{array} \right] (N_{h,t}^B + D_{h,t+1}(b)) \quad (\text{B.20})$$

First order conditions write,

$$(1 - \tau_h^B) MC_{h,t}^B(b) (E_t [\eta_{h,t+1}^E] - (E_t [\eta_{h,t+1}^E] - E_t [\eta_{f,t+1}^E]) \Xi_{h,t}) - R_t = \zeta_{h,t}, \quad (\text{B.21})$$

$$\zeta_{h,t} \geq 0, \quad (\text{B.22})$$

$$\zeta_{h,t} (D_{h,t+1}(b) - N_{h,t}^B(b)(\phi_{h,t}^B(b) - 1)) = 0, \quad (\text{B.23})$$

$$D_{h,t+1}(b) \leq N_{h,t}^B(b)(\phi_{h,t}^B(b) - 1). \quad (\text{B.24})$$

From this equation and inequation system, we get two possible regimes.

## 2.1 Normal times

The first situation corresponds to normal times. The crisis indicator variable is null,

$$\zeta_{h,t} = 0, \quad (\text{B.25})$$

so B.22 and B.23 are verified. The 2 remaining equations write,

$$D_{h,t+1}(b) < N_{h,t}^B(b)(\phi_{h,t}^B(b) - 1), \quad (\text{B.26})$$

for equation B.24 and,

$$MC_{h,t}^B(b) = \frac{1}{1 - \tau_h^B} \frac{R_t}{(E_t [\eta_{h,t+1}^E] - (E_t [\eta_{h,t+1}^E] - E_t [\eta_{f,t+1}^E]) \Xi_{h,t})}, \quad (\text{B.27})$$

for equation B.21. In this regime, the credit constraint is not binding, and the marginal cost of loans (and so the interest rate on loans) is still determined by the banks for a given amount of loan demand from the entrepreneurs. Symmetrically, if the credit constraint is not binding for the representative peripheral bank  $b$ , its marginal cost writes,

$$MC_{f,t}^B(b) = \frac{1}{1 - \tau_f^B} \frac{R_t}{(E_t [\eta_{f,t+1}^E] - (E_t [\eta_{f,t+1}^E] - E_t [\eta_{h,t+1}^E]) \Xi_{f,t})}. \quad (\text{B.28})$$

## 2.2 Crisis times

This second situation corresponds to crisis times. In this situations, the crisis indicator variable is positive,

$$\zeta_{h,t} > 0, \quad (\text{B.29})$$

so B.22 is verified. The 3 remaining equations write,

$$D_{h,t+1}(b) = N_{h,t}^B(b)(\phi_{h,t}^B(b) - 1), \quad (\text{B.30})$$

for equations B.23 and B.24 and,

$$MC_{h,t}^B(b) = \frac{1}{1 - \tau_h^B} \frac{R_t + \zeta_{h,t}}{(E_t [\eta_{h,t+1}^E] - (E_t [\eta_{h,t+1}^E] - E_t [\eta_{f,t+1}^E]) \Xi_{h,t})}, \quad (\text{B.31})$$

for equation B.21. In this regime, the credit constraint is binding, and the marginal cost of loans (and so the interest rate on loans) becomes a jump variable determined by market conditions through the influence of  $\zeta_{h,t}$ , to ensure the equilibrium between loan demand and loan supply on the credit market. Symmetrically, if the credit constraint is binding for the representative peripheral bank  $b$ , its marginal cost writes,

$$MC_{f,t}^B(b) = \frac{1}{1 - \tau_f^B} \frac{R_t + \zeta_{f,t}}{(E_t [\eta_{f,t+1}^E] - (E_t [\eta_{f,t+1}^E] - E_t [\eta_{h,t+1}^E]) \Xi_{f,t})}. \quad (\text{B.32})$$



# Appendix C

## The model equations

### 1 The closed-economy DSGE model

In line with the methodology developed by Guerrieri and Iacoviello (2014), as the non-linearity of the model is supported by a single floating variable ( $\zeta_t$ ) equal to zero on the steady-state, we declare the model equations in exponential level, and let dynare perform a first-order linearization of the system. Variables in log-deviation are indicated with a hat. We have a system of 60 equations - 60 variables, with 53 endogenous variables  $\left[ \hat{y}_t, \hat{y}_t^S, \hat{c}_t, \hat{r}_t, \hat{u}_t, \hat{\Lambda}_{t-1,t}, \hat{\varrho}_t, \hat{w}_t, \hat{w}_t^S, \hat{r}_t^k, \hat{h}_t, \hat{h}_t^S, \hat{k}_t, \hat{u}_t^{\text{tayl}}, i\hat{n}v_t, \hat{I}n_t, \hat{m}c_t^E, \hat{q}_t, \hat{n}_t^E, \hat{r}_t^L, \hat{l}_t, \hat{l}_t^{S\max}, \hat{\eta}_t^E, \hat{\pi}_t^E, \hat{\pi}_t, \hat{D}_t, \hat{F}_t, \hat{Z}_t, \hat{\pi}_t^*, \hat{\omega}_t^C, \hat{\omega}_t, g(\hat{\omega}_t), \hat{m}c_t^B, \hat{\zeta}_t, \hat{n}_t^{EB}, \hat{n}_t^{NB}, \hat{n}_t^B, \hat{v}_t, \hat{\eta}_t, \hat{\phi}_t^B, \hat{z}_t, \hat{x}_t, \hat{\phi}_t^E, \hat{\lambda}_t, \hat{\psi}_t, \hat{D}_t^W, \hat{F}_t^W, \hat{Z}_t^W, \hat{\pi}_t^{W*}, \Phi(\hat{u}_t), \hat{z}_t^k, \hat{g}_t \right]$  distributed as follows: 4 equations in the households' block, 7 equations in the labor unions' block, 8 equations in the entrepreneurs' block, 12 equations in the firms' block, 3 equations in the capital supply decisions' block, 7 equations in the banks' block, 5 equations in the lending accelerator's block, 5 equations in the macroeconomic and policy variables' block, and 2 equations describing the non linear dynamics of the model, and 7 exogenous shock variables  $\left[ \hat{\varepsilon}_t^a, \hat{\varepsilon}_t^g, \hat{\varepsilon}_t^{\text{opt}}, \hat{\varepsilon}_t^{\text{cons}}, \hat{\varepsilon}_t^\lambda, \hat{\varepsilon}_t^i, \hat{\varepsilon}_t^{NB} \right]$ .

## 1.1 Households

Euler equation:

$$\beta \exp(\hat{\Lambda}_{t,t+1}) = \frac{1}{\exp(\hat{r}_t)}, \quad (\text{C.1})$$

with the marginal utility of consumption,

$$\exp(\hat{\varrho}_t) = \frac{\exp(\varepsilon_t^C)}{\exp(\hat{c}_t) - h \exp(\hat{c}_{t-1})} - \frac{\beta}{E_t[\exp(\hat{c}_{t+1})] - h \exp(\hat{c}_t)}, \quad (\text{C.2})$$

and the stochastic discount rate,

$$\exp(\hat{\Lambda}_{t-1,t}) \equiv \frac{\exp(\hat{\varrho}_t)}{\exp(\hat{\varrho}_{t-1})}. \quad (\text{C.3})$$

Non arbitrage relation between consumption and leisure:

$$\exp(\hat{\varrho}_t) \exp(\hat{w}_t^S) = \varkappa^C \exp(\hat{h}_t^S)^\varphi. \quad (\text{C.4})$$

Total welfare:

$$\exp(\hat{\Omega}_t) = \exp(\varepsilon_t^C) \ln(\exp(\hat{c}_t) - h \exp(\hat{c}_{t-1})) - \chi^C \frac{\exp(\hat{h}_t^S)^{1+\varphi}}{1+\varphi}. \quad (\text{C.5})$$

## 1.2 Labor Unions

From the aggregate wage index equation we get,

$$\exp(\hat{h}_t^S) = \exp(\hat{h}_t) \exp(\hat{D}_t^H). \quad (\text{C.6})$$

The staggered real wage equation combined with aggregate wage index equation gives the new Keynesian Phillips curve for wages, which in level is represented by a

6 equations system,

$$\begin{aligned} \exp(\hat{D}_t^H) &= \theta^W \exp(\hat{D}_{t-1}^H) \exp(\hat{\pi}_t^W)^{\varepsilon^W} \\ &+ (1 - \theta^W) \left( \frac{1 - \theta^W \exp(\hat{\pi}_t^W)^{\theta^W - 1}}{1 - \theta^W} \right)^{\frac{-\varepsilon^W}{1 - \theta^W}}, \end{aligned} \quad (C.7)$$

$$\exp(\hat{F}_t^H) = \exp(\hat{h}_t) \frac{\exp(\hat{w}_t^S)}{\exp(\hat{w}_t)} + \beta \theta^W E_t \left[ \exp(\hat{\Lambda}_{t,t+1}) \exp(\hat{\pi}_{t+1}^W)^{\varepsilon^W} \exp(\hat{F}_{t+1}^H) \right], \quad (C.8)$$

$$\exp(\hat{Z}_t^H) = \exp(\hat{h}_t) + \beta \theta^W E_t \left[ \exp(\hat{\Lambda}_{t,t+1}) \exp(\hat{\pi}_{t+1}^W)^{\varepsilon^W - 1} \exp(\hat{Z}_{t+1}^H) \right], \quad (C.9)$$

$$\exp(\hat{\pi}_t^{W*}) = \frac{\varepsilon^W}{(\varepsilon^W - 1)} \frac{\exp(\hat{F}_t^H)}{\exp(\hat{Z}_t^H)} \exp(\hat{\pi}_t^W), \quad (C.10)$$

$$\exp(\hat{\pi}_t^W)^{1 - \varepsilon^W} = \theta^W + (1 - \theta^W) \exp(\hat{\pi}_t^{W*})^{1 - \varepsilon^W}. \quad (C.11)$$

From that, we get the wage rate,

$$\exp(\hat{w}_t) = \exp(\hat{\pi}_t^W) \exp(\hat{w}_{t-1}). \quad (C.12)$$

### 1.3 Entrepreneurs

Loans' demand of entrepreneurs is determined by their balance sheet,

$$\exp(\hat{l}_t) = \exp(\hat{q}_t) \exp(\hat{k}_t) - \exp(\hat{n}_t^E). \quad (C.13)$$

From the Pareto distribution of the investment projects of entrepreneurs, we can deduce the share of profitable projects,

$$\exp(\hat{n}_t^E) = \left( \frac{\omega^{\min}}{\exp(\hat{\omega}_t^C)} \right)^\kappa. \quad (C.14)$$



The threshold value of a profitable project writes,

$$\exp(\hat{\omega}_t^C) = \frac{\exp(\hat{r}_{t-1}^L) \exp(\hat{l}_{t-1})}{\exp(\hat{r}_t^k) \exp(\hat{q}_{t-1}) \exp(\hat{k}_t)}, \quad (\text{C.15})$$

from which we deduce the entrepreneur's expectation of rentability for successful projects,

$$\exp(\hat{\omega}_t) = \frac{\kappa}{\kappa - 1} \exp(\hat{\omega}_t^C), \quad (\text{C.16})$$

entrepreneur bias,

$$\exp(g(\hat{\omega}_t)) = \gamma \exp(\hat{\omega}_t)^{\frac{\chi^E}{\chi^E - 1}} \exp(\varepsilon_t^{opt})^{\frac{1}{\chi^E - 1}}, \quad (\text{C.17})$$

and finally the external finance premium,

$$\frac{\exp(\hat{r}_{t+1}^k)}{\exp(\hat{r}_t^L)} = \frac{1}{\exp(g(\hat{\omega}_{t+1}))}. \quad (\text{C.18})$$

Entrepreneur's real profits writes,

$$\exp(\hat{\pi}_t^E) = \exp(\hat{\eta}_t^E) (\exp(\hat{\omega}_t) \exp(\hat{r}_t^k) \exp(\hat{q}_{t-1}) \exp(\hat{k}_t) - \exp(\hat{r}_{t-1}^L) \exp(\hat{l}_{t-1})), \quad (\text{C.19})$$

which after taxation gives his net wealth,

$$\exp(\hat{n}_t^E) = (1 - \tau^E) \exp(\hat{\pi}_t^E). \quad (\text{C.20})$$

## 1.4 Firms

Production function:

$$\exp(\hat{y}_t^S) = \exp(\varepsilon_t^a) (\exp(\hat{u}_t) \exp(\hat{k}_t))^\alpha \exp(\hat{h}_t)^{1-\alpha}. \quad (\text{C.21})$$

From the first order conditions on the maximization program of producer profit, we deduce the optimal utilization rate of capital,

$$\exp(\hat{m}c_t^E)\alpha\frac{\exp(\hat{y}_t^S)}{\exp(\hat{u}_t)} = \exp(\hat{z}_t^k)\exp(\hat{k}_t), \quad (\text{C.22})$$

labor demand,

$$\exp(\hat{m}c_t^E)(1 - \alpha)\frac{\exp(\hat{y}_t^S)}{\exp(\hat{h}_t)} = \exp(\hat{w}_t), \quad (\text{C.23})$$

return to capital,

$$\exp(\hat{r}_t^k) = \frac{\exp(\hat{m}c_t^E)\alpha\frac{\exp(\hat{y}_t^S)}{\exp(\hat{k}_t)} - \Phi(\hat{u}_t) + (1 - \delta_c)\exp(\hat{q}_t)}{\exp(\hat{q}_{t-1})}, \quad (\text{C.24})$$

with the utilization cost of capital,

$$\Phi(\hat{u}_t) = \frac{1 - \Psi}{\Psi}Z^k \left[ \exp\left(\frac{1 - \Psi}{\Psi}(\exp(\hat{u}_t) - 1)\right) - 1 \right], \quad (\text{C.25})$$

and marginal cost of using capital,

$$\exp(\hat{z}_t^k) = Z^k \exp\left[\left(\frac{\Psi}{1 - \Psi}\right)(\exp(\hat{u}_t) - 1)\right], \quad (\text{C.26})$$

with  $\hat{z}_t^k = \Phi'(\hat{u}_t)$ .

From the aggregate price index equation we get,

$$\exp(\hat{y}_t^S) = \exp(\hat{y}_t^d)\exp(\hat{D}_t). \quad (\text{C.27})$$

The staggered real wage equation gives the new Keynesian Phillips curve for prices, which in level is represented by a 6 equations system,

$$\begin{aligned} \exp(\hat{D}_t) &= \theta^E \exp(\hat{D}_{t-1}) \exp(\hat{\pi}_{t-1})^{-\gamma^{pe} \varepsilon^E} \exp(\hat{\pi}_t)^{\varepsilon^E} \\ &\quad + (1 - \theta^E) \left( \frac{1 - \theta^E \exp(\hat{\pi}_{t-1})^{\gamma^{pe}(1-\theta^E)} \exp(\hat{\pi}_t)^{\theta^E - 1}}{1 - \theta^E} \right)^{\frac{-\varepsilon^E}{1-\theta^E}}, \end{aligned} \quad (C.28)$$

$$\begin{aligned} \exp(\hat{F}_t) &= \exp(\hat{y}_t^d) \exp(\hat{m}c_t^E) \\ &\quad + \beta \theta^E E_t \left[ \exp(\hat{\Lambda}_{t,t+1}) \exp(\hat{\pi}_{t+1})^{\varepsilon^E} \exp(\hat{\pi}_t)^{-\gamma^{pe} \varepsilon^E} \exp(\hat{F}_{t+1}) \right], \end{aligned} \quad (C.29)$$

$$\begin{aligned} \exp(\hat{Z}_t) &= \exp(\hat{y}_t^d) \\ &\quad + \beta \theta^E E_t \left[ \exp(\hat{\Lambda}_{t,t+1}) \exp(\hat{\pi}_{t+1})^{\varepsilon^E - 1} \exp(\hat{\pi}_t)^{\gamma^{pe}(1-\varepsilon^E)} \exp(\hat{Z}_{t+1}^H) \right] \end{aligned} \quad (C.30)$$

$$\exp(\hat{\pi}_t^*) = \frac{\varepsilon^E}{(\varepsilon^E - 1)} \frac{\exp(\hat{F}_t)}{\exp(\hat{Z}_t)} \exp(\hat{\pi}_t). \quad (C.31)$$

From that, we get the inflation rate,

$$\exp(\hat{\pi}_t)^{1-\varepsilon^E} = \theta^E \exp(\hat{\pi}_{t-1})^{\gamma^{pe}(1-\varepsilon^E)} + (1 - \theta^E) \exp(\hat{\pi}_t^*)^{1-\varepsilon^E}. \quad (C.32)$$

## 1.5 Capital Supply decisions

Price of capital:

$$\begin{aligned} \exp(\hat{q}_t) &= 1 + \frac{\eta^I}{2} \left( \frac{\hat{I}n_t + INV}{\hat{I}n_{t-1} + INV} - 1 \right)^2 + \frac{\hat{I}n_t + INV}{\hat{I}n_{t-1} + INV} \eta^I \left( \frac{\hat{I}n_t + INV}{\hat{I}n_{t-1} + INV} - 1 \right) \\ &\quad - \beta E_t \left[ \exp(\hat{\Lambda}_{t,t+1}) \left( \frac{\hat{I}n_{t+1} + INV}{\hat{I}n_t + INV} \right)^2 \eta^I \left( \frac{\hat{I}n_{t+1} + INV}{\hat{I}n_t + INV} - 1 \right) \right], \end{aligned} \quad (C.33)$$

with new investment,

$$\hat{I}n_t = \exp(i\hat{n}v_t) - \delta_c \exp(\hat{k}_t). \quad (\text{C.34})$$

The capital law of motion writes,

$$\exp(\hat{k}_t) = \exp(\hat{k}_{t-1})(1 - \delta_c) + \exp(i\hat{n}v_t). \quad (\text{C.35})$$

## 1.6 Banks

From the maximization of bank's profit, we get the marginal cost of producing new loans,

$$\exp(\hat{m}c_t^B) = \frac{\exp(\hat{r}_t) + \zeta_t}{E_t[\exp(\hat{\eta}_{t+1}^E)]}, \quad (\text{C.36})$$

which, after taxation and monopolistic competition, gives us the interest rate on loans,

$$\exp(\hat{r}_t^L) = \frac{1}{1 - \tau^B} \frac{\varepsilon^B}{\varepsilon^B - 1} \exp(\hat{m}c_t^B). \quad (\text{C.37})$$

From the bank's profit equation, we can deduce the growth rate of banks' capital,

$$\exp(\hat{z}_t^B) = [(1 - \tau^B) \exp(\hat{\eta}_t^E) \exp(\hat{r}_{t-1}^L) - \exp(\hat{r}_{t-1})] \frac{\exp(\hat{l}_{t-1})}{\exp(\hat{n}_{t-1}^B)} + \exp(\hat{r}_{t-1}), \quad (\text{C.38})$$

and existing banks' net worth accumulation,

$$\exp(\hat{n}_t^{EB}) = \theta \exp(\hat{z}_t^B) \exp(\hat{n}_{t-1}^B) \exp(\varepsilon_t^{NB}). \quad (\text{C.39})$$

Banks' total net worth is the sum of existing banks' and new banks' net worth,

$$\exp(\hat{n}_t^B) = \exp(\hat{n}_t^{EB}) + \exp(\hat{n}_t^{NB}), \quad (\text{C.40})$$

with new banks' net worth,

$$\exp(\hat{n}_t^{NB}) = \omega(1 - \hat{\psi}_{t-1}) \exp(\hat{l}_{t-1}). \quad (\text{C.41})$$

Loan's maximal supply in the economy is a function of banks' total net worth and a lending accelerator,

$$\exp(\hat{l}_t^{S \max}) = \exp(\hat{n}_t^B) \exp(\hat{\phi}_t^B). \quad (\text{C.42})$$

## 1.7 Lending accelerator

Leverage ratio of banks writes,

$$\exp(\hat{\phi}_t^B) = \frac{1}{1 - \hat{\psi}_t} \frac{\exp(\hat{\eta}_t)}{\exp(\hat{\lambda}_t) - \exp(\hat{\nu}_t)}, \quad (\text{C.43})$$

By using Bellman's equation on the intertemporal value of bankers net wealth  $V_t$ , we can deduce the components of the lending accelerator: The value of banks' capital writes,

$$\begin{aligned} \exp(\hat{\nu}_t) = & (1 - \theta)\beta \exp(\hat{\Lambda}_{t,t+1}) [(1 - \tau^B) \exp(\hat{\eta}_{t+1}^E) \exp(\hat{r}_t^L) - \exp(\hat{r}_t)] \\ & + \beta E_t \left[ \exp(\hat{\Lambda}_{t,t+1}) \theta \exp(\hat{x}_{t+1}^B) \exp(\hat{\nu}_{t+1}) \right], \end{aligned} \quad (\text{C.44})$$

with the growth rate of banks' net wealth,

$$\exp(\hat{x}_t^B) = \frac{\exp(\hat{l}_t)}{\exp(\hat{l}_{t-1})}, \quad (\text{C.45})$$

and the value of banks' net wealth writes,

$$\exp(\hat{\eta}_t) = (1 - \theta) + \beta E_t \left[ \exp(\hat{\Lambda}_{t,t+1}) \theta \exp(\hat{z}_{t+1}^B) \exp(\hat{\eta}_{t+1}) \right]. \quad (\text{C.46})$$

The diversion parameter is stochastic in this model:

$$\exp(\hat{\lambda}_t) = \lambda \exp(\varepsilon_t^\lambda). \quad (\text{C.47})$$

## 1.8 Macroeconomic relations and policy variables

Aggregate resource constraint:

$$\begin{aligned} \exp(\hat{y}_t^d) &= \exp(\hat{c}_t) + \exp(i\hat{n}v_t) + \tau\hat{\psi}_t \exp(\hat{k}_{t+1}) \\ &\quad + \frac{\eta^I}{2} \left( \frac{\hat{I}n_t + INN}{\hat{I}n_{t-1} + INN} - 1 \right)^2 (\hat{I}n_t + INN) + \exp(\hat{g}_t). \end{aligned} \quad (C.48)$$

Fisher equation:

$$\exp(\hat{i}_t) = \exp(\hat{r}_t) \exp(\hat{\pi}_{t+1}). \quad (C.49)$$

Interest rate rule:

$$\exp(\hat{i}_t^{tayl}) = \frac{1}{\beta} \exp(\hat{\pi}_t)^{\phi_\pi} \left( \frac{1/\exp(\hat{m}c_t^E)}{\varepsilon^E/(\varepsilon^E - 1)} \right)^{\phi_{CM}} \exp(\varepsilon_t^i). \quad (C.50)$$

Public spending:

$$\exp(\hat{g}_t) = G \exp(\varepsilon_t^g). \quad (C.51)$$

Credit policy rule:

$$\hat{\psi}_t = v\hat{\zeta}_t. \quad (C.52)$$

## 1.9 Non linear dynamics

**Occasionally binding credit constraint** If the incentive constraint is not binding:

$$\hat{\zeta}_t = 0, \exp(\hat{l}_t) \leq \exp(\hat{l}_t^{S \max}). \quad (C.53)$$

If the incentive constraint is binding:

$$\hat{\zeta}_t > 0, \exp(\hat{l}_t) = \exp(\hat{l}_t^{S \max}). \quad (C.54)$$

**Zero Lower Bound constraint** If the Zero Lower Bound constraint is not binding:

$$\exp(\hat{i}_t) = \exp(\hat{i}_t^{taylor}). \quad (\text{C.55})$$

If the Zero Lower Bound constraint is binding:

$$\exp(\hat{i}_t) = \text{Zero Lower Bound}. \quad (\text{C.56})$$

## 1.10 Exogenous Shocks

- Shock on the diversion parameter:  $\varepsilon_t^\lambda = \rho^\lambda \varepsilon_{t-1}^\lambda + \eta_t^\lambda$  with  $\eta_t^\lambda \sim N(0, \sigma_{\eta^\lambda}^2)$ .
- Technology shock:  $\varepsilon_t^a = \rho^a \varepsilon_{t-1}^a + \eta_t^a$  with  $\eta_t^a \sim N(0, \sigma_{\eta^a}^2)$ .
- Government spending shock:  $\varepsilon_t^g = \rho^g \varepsilon_{t-1}^g + \eta_t^g$  with  $\eta_t^g \sim N(0, \sigma_{\eta^g}^2)$ .
- Optimism shock:  $\varepsilon_t^{opt} = \rho^{opt} \varepsilon_{t-1}^{opt} + \eta_t^{opt}$  with  $\eta_t^{opt} \sim N(0, \sigma_{\eta^{opt}}^2)$ .
- Consumption shock:  $\varepsilon_t^{cons} = \rho^{cons} \varepsilon_{t-1}^{cons} + \eta_t^{cons}$  with  $\eta_t^{cons} \sim N(0, \sigma_{\eta^{cons}}^2)$ .
- Bank net wealth shock:  $\varepsilon_t^{NB}$  with  $\varepsilon_t^{NB} \sim N(0, \sigma_{\varepsilon^{NB}}^2)$ .
- Interest rate shock:  $\varepsilon_t^i$  with  $\varepsilon_t^i \sim N(0, \sigma_{\varepsilon^i}^2)$ .

## 2 The two-country DSGE model

In line with the methodology developed by Guerrieri and Iacoviello (2014), as the non-linearity of the model is supported by a couple of floating variables ( $\zeta_{i,t}$  for  $i \in \{h, f\}$ ) equal to zero on the steady-state, we declare the model equations in exponential level, and let dynare perform a first-order linearization of the system. Variables in log-deviation are indicated with a hat. We have a system of 139 equations - 139 variables, with 60 endogenous variables for each country's block:  $\left[ \hat{c}_{i,t}, \hat{c}_{i,h,t}, \hat{c}_{i,f,t}, \hat{\Lambda}_{i,t-1,t}, \hat{q}_{i,t}, \hat{h}_{i,t}^S, \hat{w}_{i,t}^S, \hat{D}_{i,t}^W, \hat{F}_{i,t}^W, \hat{Z}_{i,t}^W, \hat{\pi}_{i,t}^{W*}, \hat{\pi}_{i,t}^W, \hat{h}_{i,t}, \hat{w}_{i,t}^C, \hat{w}_{i,t}, g(\hat{w}_{i,t}), \hat{\eta}_{i,t}^E, \hat{n}_{i,t}^E, \hat{\pi}_{i,t}^E, \hat{l}_{i,t}^d, \hat{r}_{i,t}^k, \hat{k}_{i,t}, \hat{w}_{i,t}, \hat{y}_{i,t}^S, \Phi(\hat{u}_{i,t}), \hat{u}_{i,t}, \hat{z}_{i,t}^k, \hat{m}c_{i,t}^E, \hat{D}_{i,t}, \hat{F}_{i,t}, \hat{Z}_{i,t}, \hat{\pi}_{i,t}^*, \hat{\pi}_{i,t}, \hat{\pi}_{i,t}^C, \hat{inv}_{i,t}, \hat{inv}_{i,h,t}, \hat{inv}_{i,f,t}, \hat{I}n_{i,t}, \hat{q}_{i,t}, \hat{r}_{i,t}^L, \hat{p}_{i,t}^L, \hat{l}_{i,t}^S, \hat{l}_{i,h,t}^d, \hat{l}_{i,f,t}^d \right]$

$\hat{l}_{i,t}^{S \max}, \hat{m}_{i,t}^B, \hat{\Xi}_{i,t}, \hat{n}_{i,t}^{EB}, \hat{n}_{i,t}^{NB}, \hat{n}_{i,t}^B, \hat{z}_{i,t}, \hat{\nu}_{i,t}, \hat{\eta}_{i,t}, \hat{\phi}_{i,t}^B, \hat{x}_{i,t}, \hat{\lambda}_{i,t}, \hat{y}_{i,t}^d, \hat{\psi}_{i,t}, \hat{g}_{i,t}, \hat{\zeta}_{i,t}$  ] with  $i \in \{h, f\}$ , distributed as follows: 6 equations in the households' block, 7 equations in the labor unions' block, 8 equations in the entrepreneurs' block, 13 equations in the firms' block, 5 equations in the capital supply decisions' block, 12 equations in the banks' block, 5 equations in the lending accelerator's block, 3 equation in the macroeconomic and policy variables' block, and 1 equations describing the non linear dynamics of the model. We also have 6 international variables:  $[\hat{r}_t, \hat{tot}_t, \hat{ca}_t, \hat{b}_t, \hat{y}_t^{zone}, \hat{l}_t^{zone}]$ , and 13 exogenous shock variables:  $[\hat{\varepsilon}_{h,t}^a, \hat{\varepsilon}_{f,t}^a, \hat{\varepsilon}_{h,t}^g, \hat{\varepsilon}_{f,t}^g, \hat{\varepsilon}_{h,t}^{opt}, \hat{\varepsilon}_{f,t}^{opt}, \hat{\varepsilon}_{h,t}^{cons}, \hat{\varepsilon}_{f,t}^{cons}, \hat{\varepsilon}_{h,t}^\lambda, \hat{\varepsilon}_{f,t}^\lambda, \hat{\varepsilon}_{h,t}^{NB}, \hat{\varepsilon}_{f,t}^{NB}, \hat{\varepsilon}_t^r]$ .

## 2.1 Households

Euler equation:

$$\beta_i E_t \left[ \exp(\hat{\Lambda}_{i,t,t+1}) \right] = E_t \exp \left[ (\hat{\pi}_{i,t,t+1}^C) \right] \frac{1 + \varkappa_i^B \left( E_t \left[ \hat{b}_{i,t+1} \right] - b_i \right)}{\exp(\hat{r}_t)}, \quad (\text{C.57})$$

with the marginal utility of consumption,

$$\exp(\hat{\varrho}_{i,t}) = \frac{\exp(\varepsilon_{i,t}^C)}{\exp(\hat{c}_{i,t}) - h_i \exp(\hat{c}_{i,t-1})} - \frac{\beta_i}{E_t [\exp(\hat{c}_{i,t+1})] - h_i \exp(\hat{c}_{i,t})}, \quad (\text{C.58})$$

and the stochastic discount rate,

$$\exp(\hat{\Lambda}_{i,t-1,t}) \equiv \frac{\exp(\hat{\varrho}_{i,t})}{\exp(\hat{\varrho}_{i,t-1})}. \quad (\text{C.59})$$

Non arbitrage relation between consumption and leisure:

$$\exp(\hat{\varrho}_{i,t}) \exp(\hat{w}_{i,t}^S) = \varkappa_i^C \exp(\hat{h}_{i,t}^S)^{\varphi_i}. \quad (\text{C.60})$$



## 2.2 Labor Unions

From the aggregate wage index equation we get,

$$\exp(\hat{h}_{i,t}^S) = \exp(\hat{h}_{i,t}) \exp(\hat{D}_{i,t}^H). \quad (\text{C.61})$$

The staggered real wage equation combined with aggregate wage index equation gives the new Keynesian Phillips curve for wages, which in level is represented by a 6 equations system,

$$\begin{aligned} \exp(\hat{D}_{i,t}^H) &= \theta_i^W \exp(\hat{D}_{i,t-1}^H) \exp(\hat{\pi}_{i,t}^W)^{\varepsilon_i^W} \\ &+ (1 - \theta_i^W) \left( \frac{1 - \theta_i^W \exp(\hat{\pi}_{i,t}^W)^{\theta_i^W - 1}}{1 - \theta_i^W} \right)^{\frac{-\varepsilon_i^W}{1 - \theta_i^W}}, \end{aligned} \quad (\text{C.62})$$

$$\exp(\hat{F}_{i,t}^H) = \exp(\hat{h}_{i,t}) \frac{\exp(\hat{w}_{i,t}^S)}{\exp(\hat{w}_{i,t})} \quad (\text{C.63})$$

$$+ \beta_i \theta_i^W E_t \left[ \exp(\hat{\Lambda}_{i,t,t+1}) \exp(\hat{\pi}_{i,t+1}^W)^{\varepsilon_i^W} \exp(\hat{F}_{i,t+1}^H) \right], \quad (\text{C.64})$$

$$\exp(\hat{Z}_{i,t}^H) = \exp(\hat{h}_{i,t}) + \beta_i \theta_i^W E_t \left[ \exp(\hat{\Lambda}_{i,t,t+1}) \exp(\hat{\pi}_{i,t+1}^W)^{\varepsilon_i^W - 1} \exp(\hat{Z}_{i,t+1}^H) \right], \quad (\text{C.65})$$

$$\exp(\hat{\pi}_{i,t}^{W*}) = \frac{\varepsilon_i^W}{(\varepsilon_i^W - 1)} \frac{\exp(\hat{F}_{i,t}^H)}{\exp(\hat{Z}_{i,t}^H)} \exp(\hat{\pi}_{i,t}^W), \quad (\text{C.66})$$

$$\exp(\hat{\pi}_{i,t}^W)^{1 - \varepsilon_i^W} = \theta_i^W + (1 - \theta_i^W) \exp(\hat{\pi}_{i,t}^{W*})^{1 - \varepsilon_i^W}. \quad (\text{C.67})$$

From that, we get the wage rate,

$$\exp(\hat{w}_{i,t}) = \exp(\hat{\pi}_{i,t}^W) \exp(\hat{w}_{i,t-1}). \quad (\text{C.68})$$

### 2.3 Entrepreneurs

Loans' demand of entrepreneurs is determined by their balance sheet,

$$\exp(\hat{l}_{i,t}^d) = \exp(\hat{q}_{i,t}) \exp(\hat{k}_{i,t}) - \exp(\hat{n}_{i,t}^E). \quad (\text{C.69})$$

From the Pareto distribution of the investment projects of entrepreneurs, we can deduce the share of profitable projects,

$$\exp(\hat{\eta}_{i,t}^E) = \left( \frac{\omega_i^{\min}}{\exp(\hat{\omega}_{i,t}^C)} \right)^{\kappa_i}. \quad (\text{C.70})$$

The threshold value of a profitable project writes,

$$\exp(\hat{\omega}_{i,t}^C) = \frac{\exp(\hat{p}_{i,t-1}^L) \exp(\hat{l}_{i,t-1}^d)}{\exp(\hat{r}_{i,t}^k) \exp(\hat{q}_{i,t-1}) \exp(\hat{k}_{i,t})}, \quad (\text{C.71})$$

from which we deduce the entrepreneur's expectation of profitability for successful projects,

$$\exp(\hat{\omega}_{i,t}) = \frac{\kappa_i}{\kappa_i - 1} \exp(\hat{\omega}_{i,t}^C), \quad (\text{C.72})$$

entrepreneur bias,

$$\exp(g(\hat{\omega}_{i,t})) = \gamma_i \exp(\hat{\omega}_{i,t})^{\frac{\chi_i^E}{\chi_i^E - 1}} \exp(\varepsilon_{i,t}^{opt})^{\frac{1}{\chi_i^E - 1}}, \quad (\text{C.73})$$

and finally the external finance premium,

$$\frac{E_t [\exp(\hat{r}_{i,t+1}^k)]}{\exp(\hat{p}_{i,t}^L)} = E_t \left[ \frac{1}{\exp(g(\hat{\omega}_{i,t+1}))} \right]. \quad (\text{C.74})$$

Entrepreneur's real profits writes,

$$\exp(\hat{\pi}_{i,t}^E) = \exp(\hat{\eta}_{i,t}^E) (\exp(\hat{\omega}_{i,t}) \exp(\hat{r}_{i,t}^k) \exp(\hat{q}_{i,t-1}) \exp(\hat{k}_{i,t}) \quad (\text{C.75})$$

$$- \exp(\hat{p}_{i,t-1}^L) \exp(\hat{l}_{i,t-1}^d)), \quad (\text{C.76})$$

which after taxation gives his net wealth,

$$\exp(\hat{n}_{i,t}^E) = (1 - \tau_i^E) \exp(\hat{\pi}_{i,t}^E). \quad (\text{C.77})$$

## 2.4 Firms

Production function:

$$\exp(\hat{y}_{i,t}^S) = \exp(\varepsilon_{i,t}^a) (\exp(\hat{u}_{i,t}) \exp(\hat{k}_{i,t}))^{\alpha_i} \exp(\hat{h}_{i,t})^{1-\alpha_i}. \quad (\text{C.78})$$

From the first order conditions on the maximization program of producer profit, we deduce the optimal capacity utilization rate,

$$\exp(\hat{m}c_{i,t}^E) \alpha_i \frac{\exp(\hat{y}_{i,t}^S)}{\exp(\hat{u}_{i,t})} = \exp(\hat{z}_{i,t}^k) \exp(\hat{k}_{i,t}), \quad (\text{C.79})$$

labor demand,

$$\exp(\hat{m}c_{i,t}^E) (1 - \alpha_i) \frac{\exp(\hat{y}_{i,t}^S)}{\exp(\hat{h}_{i,t})} = \exp(\hat{w}_{i,t}), \quad (\text{C.80})$$

return to capital,

$$\frac{\exp(\hat{r}_{i,t}^k)}{1 + \varkappa_i^B \left( E_t \left[ \hat{b}_{i,t+1} \right] - b_i \right)} = \frac{\exp(\hat{m}c_{i,t}^E) \alpha_i \frac{\exp(\hat{y}_{i,t}^S)}{\exp(\hat{k}_{i,t})}}{-\Phi(\hat{u}_{i,t}) + (1 - \delta_{i,c}) \exp(\hat{q}_{i,t})}, \quad (\text{C.81})$$

with the utilization cost of capital,

$$\Phi(\hat{u}_{i,t}) = \frac{1 - \Psi_i}{\Psi_i} Z_i^k \left[ \exp\left(\frac{1 - \Psi_i}{\Psi_i} (\exp(\hat{u}_{i,t}) - 1)\right) - 1 \right], \quad (\text{C.82})$$

marginal cost of using capital,

$$\exp(\hat{z}_{i,t}^k) = Z_i^k \exp \left[ \left( \frac{\Psi_i}{1 - \Psi_i} \right) (\exp(\hat{u}_{i,t}) - 1) \right]. \quad (\text{C.83})$$

From the aggregate price index equation we get,

$$\exp(\hat{y}_{i,t}^S) = \exp(\hat{y}_{i,t}^d) \exp(\hat{D}_{i,t}). \quad (\text{C.84})$$

The staggered real wage equation gives the new Keynesian Phillips curve for prices, which in level is represented by a 6 equations system,

$$\begin{aligned} \exp(\hat{D}_{i,t}) &= \theta_i^E \exp(\hat{D}_{i,t-1}) \exp(\hat{\pi}_{i,t-1})^{-\gamma_i^{pe} \varepsilon_i^E} \exp(\hat{\pi}_{i,t})^{\varepsilon_i^E} \\ &+ (1 - \theta_i^E) \left( \frac{1 - \theta_i^E \exp(\hat{\pi}_{i,t-1})^{\gamma_i^{pe} (1 - \theta_i^E)} \exp(\hat{\pi}_{i,t})^{\theta_i^E - 1}}{1 - \theta_i^E} \right)^{\frac{-\varepsilon_i^E}{1 - \theta_i^E}} \end{aligned} \quad (\text{C.85})$$

$$\begin{aligned} \exp(\hat{F}_{i,t}) &= \exp(\hat{y}_{i,t}^d) \exp(\hat{m}c_{i,t}^E) + \\ &\beta_i \theta_i^E E_t \left[ \exp(\hat{\Lambda}_{i,t,t+1}) \exp(\hat{\pi}_{i,t+1})^{\varepsilon_i^E} \exp(\hat{\pi}_{i,t})^{-\gamma_i^{pe} \varepsilon_i^E} \exp(\hat{F}_{i,t+1}) \right] \end{aligned} \quad (\text{C.86})$$

$$\begin{aligned} \exp(\hat{Z}_{i,t}) &= \exp(\hat{y}_{i,t}^d) + \\ &\beta_i \theta_i^E E_t \left[ \exp(\hat{\Lambda}_{i,t,t+1}) \exp(\hat{\pi}_{i,t+1})^{\varepsilon_i^E - 1} \exp(\hat{\pi}_{i,t})^{\gamma_i^{pe} (1 - \varepsilon_i^E)} \exp(\hat{Z}_{i,t+1}^H) \right] \end{aligned} \quad (\text{C.87})$$

$$\exp(\hat{\pi}_{i,t}^*) = \frac{\varepsilon_i^E}{(\varepsilon_i^E - 1)} \frac{\exp(\hat{F}_{i,t})}{\exp(\hat{Z}_{i,t})} \exp(\hat{\pi}_{i,t}). \quad (\text{C.88})$$

From that, we get the production price index,

$$\exp(\hat{\pi}_{i,t})^{1 - \varepsilon_i^E} = \theta_i^E \exp(\hat{\pi}_{i,t-1})^{\gamma_i^{pe} (1 - \varepsilon_i^E)} + (1 - \theta_i^E) \exp(\hat{\pi}_{i,t}^*)^{1 - \varepsilon_i^E}, \quad (\text{C.89})$$

which is used to deduce domestic inflation,

$$\exp(\hat{\pi}_{h,t}^C) = \exp(\hat{\pi}_{h,t}) \left[ \frac{(1 - \alpha_h^C) + \alpha_h^C \exp(\hat{t}o\hat{t}_t)^{1 - \mu_h^C}}{(1 - \alpha_h^C) + \alpha_h^C \exp(\hat{t}o\hat{t}_{t-1})^{1 - \mu_h^C}} \right]^{\frac{1}{1 - \mu_h^C}}, \quad (\text{C.90})$$

and foreign inflation,

$$\exp(\hat{\pi}_{f,t}^C) = \exp(\hat{\pi}_{f,t}) \left[ \frac{\alpha_f^C + (1 - \alpha_f^C) / \exp(t\hat{\omega}_t)^{1-\mu_f^C}}{\alpha_f^C + (1 - \alpha_f^C) / \exp(t\hat{\omega}_{t-1})^{1-\mu_f^C}} \right]^{\frac{1}{1-\mu_f^C}}. \quad (\text{C.91})$$

## 2.5 Capital Supply decisions

Price of capital:

$$\begin{aligned} \exp(\hat{q}_{i,t}) = & 1 + \frac{\eta_i^I}{2} \left( \frac{\hat{I}n_{i,t} + INV_i}{\hat{I}n_{i,t-1} + INV_i} - 1 \right)^2 + \frac{\hat{I}n_{i,t} + INV_i}{\hat{I}n_{i,t-1} + INV_i} \eta_i^I \left( \frac{\hat{I}n_{i,t} + INV_i}{\hat{I}n_{i,t-1} + INV_i} - 1 \right) \\ & - \beta_i E_t \left[ \exp(\hat{\Lambda}_{i,t,t+1}) \left( \frac{\hat{I}n_{i,t+1} + INV_i}{\hat{I}n_{i,t} + INV_i} \right)^2 \eta_i^I \left( \frac{\hat{I}n_{i,t+1} + INV_i}{\hat{I}n_{i,t} + INV_i} - 1 \right) \right], \end{aligned} \quad (\text{C.92})$$

with new investment,

$$\hat{I}n_{i,t} = \exp(\hat{i}nv_{i,t}) - \delta_{i,c} \exp(\hat{k}_{i,t}). \quad (\text{C.93})$$

Capital law of motion writes,

$$\exp(\hat{k}_{i,t}) = \exp(\hat{k}_{i,t-1})(1 - \delta_{i,c}) + \exp(\hat{i}nv_{i,t}). \quad (\text{C.94})$$

## 2.6 Banks

From the maximization of bank's profit, we get the marginal cost of producing new loans,

$$\exp(\hat{m}c_{h,t}^B) = \frac{1}{1 - \tau_h^B} \frac{\exp(\hat{r}_t) + \hat{\zeta}_{h,t}}{E_t[\exp(\hat{\eta}_{h,t+1}^E)] - (E_t[\exp(\hat{\eta}_{h,t+1}^E)] - E_t[\exp(\hat{\eta}_{f,t+1}^E)]) \exp(\hat{\Xi}_{h,t})}, \quad (\text{C.95})$$

$$\exp(\hat{m}c_{f,t}^B) = \frac{1}{1 - \tau_f^B} \frac{\exp(\hat{r}_t) + \hat{\zeta}_{f,t}}{E_t[\exp(\hat{\eta}_{f,t+1}^E)] - (E_t[\exp(\hat{\eta}_{f,t+1}^E)] - E_t[\exp(\hat{\eta}_{h,t+1}^E)]) \exp(\hat{\Xi}_{f,t})}, \quad (\text{C.96})$$

which, taking into account monopolistic competition, gives us the interest rate on loans,

$$\exp(\hat{r}_{i,t}^L) = \frac{\varepsilon_i^B}{\varepsilon_i^B - 1} \exp(\hat{m}c_{i,t}^B). \quad (\text{C.97})$$

From the bank's profit equation, we can deduce the growth rate of banks' capital,

$$\exp(\hat{z}_{h,t}^B) = \left[ \begin{array}{l} (1 - \tau_h^B) \exp(\hat{\eta}_{h,t}^E) \exp(\hat{r}_{h,t-1}^L) - \exp(\hat{r}_{t-1}) - \\ (1 - \tau_h^B) \exp(\hat{r}_{h,t-1}^L) (\exp(\hat{\eta}_{h,t}^E) - \exp(\hat{\eta}_{f,t}^E)) \exp(\hat{\Xi}_{h,t-1}) \end{array} \right] \frac{\exp(\hat{l}_{h,t-1}^S)}{\exp(\hat{n}_{h,t-1}^B)} + \exp(\hat{r}_{t-1}), \quad (\text{C.98})$$

$$\exp(\hat{z}_{f,t}^B) = \left[ \begin{array}{l} (1 - \tau_f^B) \exp(\hat{\eta}_{f,t}^E) \exp(\hat{r}_{f,t-1}^L) - \exp(\hat{r}_{t-1}) - \\ (1 - \tau_f^B) \exp(\hat{r}_{f,t-1}^L) (\exp(\hat{\eta}_{f,t}^E) - \exp(\hat{\eta}_{h,t}^E)) \exp(\hat{\Xi}_{f,t-1}) \end{array} \right] \frac{\exp(\hat{l}_{f,t-1}^S)}{\exp(\hat{n}_{f,t-1}^B)} + \exp(\hat{r}_{t-1}), \quad (\text{C.99})$$

with the share of loan demand from peripheral entrepreneurs to core banks on the total loan demand to core banks,

$$\exp(\hat{\Xi}_{h,t}) \equiv \left( \frac{\frac{1 - \alpha_h^L}{1 - \alpha_f^L} \left( \frac{\exp(\hat{p}_{f,t}^L) E_t[\exp(\hat{t}o\hat{t}_{t+1})]}{\exp(\hat{p}_{h,t}^L) E_t[\exp(\hat{t}o\hat{t}_t)]} \right)^{-\mu_h^L} *}{\frac{\exp(\hat{q}_{h,t}) E_t[\exp(\hat{k}_{h,t+1})] - \exp(\hat{n}_{h,t}^E)}{\exp(\hat{q}_{f,t}) E_t[\exp(\hat{k}_{f,t+1})] - \exp(\hat{n}_{f,t}^E)} + 1} \right)^{-1}, \quad (\text{C.100})$$

the share of loan demand from core entrepreneurs to peripheral banks on the total loan demand to peripheral banks,

$$\exp(\hat{\Xi}_{f,t}) \equiv \left( \frac{\frac{\alpha_f^L}{\alpha_h^L} \left( \frac{\exp(\hat{p}_{h,t}^L) \exp(\hat{t}o\hat{t}_t)}{\exp(\hat{p}_{f,t}^L) E_t[\exp(\hat{t}o\hat{t}_{t+1})]} \right)^{-\mu_f^L} *}{\frac{\exp(\hat{q}_{f,t}) E_t[\exp(\hat{k}_{f,t+1})] - \exp(\hat{n}_{f,t}^E)}{\exp(\hat{q}_{h,t}) E_t[\exp(\hat{k}_{h,t+1})] - \exp(\hat{n}_{h,t}^E)} + 1} \right)^{-1}, \quad (\text{C.101})$$

and existing banks' net worth accumulation,

$$\exp(\hat{n}_{i,t}^{EB}) = \theta_i \exp(\hat{z}_{i,t}^B) \exp(\hat{n}_{i,t-1}^B) \exp(-\varepsilon_{i,t}^{NB}). \quad (\text{C.102})$$

Banks' total net worth is the sum of existing banks' and new banks' net worth,

$$\exp(\hat{n}_{i,t}^B) = \exp(\hat{n}_{i,t}^{EB}) + \exp(\hat{n}_{i,t}^{NB}), \quad (\text{C.103})$$

with new banks' net worth,

$$\exp(\hat{n}_{i,t}^{NB}) = \omega_i(1 - \hat{\psi}_{i,t-1}) \exp(\hat{l}_{i,t-1}^S). \quad (\text{C.104})$$

Loan's maximal supply in the economy is a function of banks' total net worth and a lending accelerator,

$$\exp(\hat{l}_{i,t}^{S \max}) = \exp(\hat{n}_{i,t}^B) \exp(\hat{\phi}_{i,t}^B). \quad (\text{C.105})$$

Each country's banks supply loans to both core and peripheral entrepreneurs,

$$\exp(\hat{l}_{i,t}^S) = \exp(\hat{l}_{h,i,t}^d) + \exp(\hat{l}_{f,i,t}^d), \quad (\text{C.106})$$

with loan demand from core entrepreneurs to core banks,

$$\exp(\hat{l}_{h,h,t}^d) = (1 - \alpha_h^L) \left[ \frac{\exp(\hat{r}_{h,t}^L)}{\exp(\hat{p}_{h,t}^L)} \right]^{-\mu_h^L} \exp(\hat{l}_{h,t}^d), \quad (\text{C.107})$$

loan demand form peripheral entrepreneurs to core banks,

$$\exp(\hat{l}_{f,h,t}^d) = (1 - \alpha_f^L) \left[ \frac{\frac{\exp(\hat{t} \hat{t}_t)}{E_t[\exp(\hat{t} \hat{t}_{t+1})]} \exp(\hat{r}_{h,t}^L)}{\exp(\hat{p}_{f,t}^L)} \right]^{-\mu_f^L} \exp(\hat{l}_{f,t}^d), \quad (\text{C.108})$$

loan demand from core entrepreneurs to peripheral banks,

$$\exp(\hat{l}_{h,f,t}^d) = \alpha_h^L \left[ \frac{\frac{E_t[\exp(\hat{t} \hat{t}_{t+1})]}{\exp(\hat{t} \hat{t}_t)} \exp(\hat{r}_{f,t}^L)}{\exp(\hat{p}_{h,t}^L)} \right]^{-\mu_h^L} \exp(\hat{l}_{h,t}^d), \quad (\text{C.109})$$

loan demand from peripheral entrepreneurs to peripheral banks,

$$\exp(\hat{l}_{f,f,t}^d) = \alpha_f^L \left[ \frac{\exp(\hat{r}_{f,t}^L)}{\exp(\hat{p}_{f,t}^L)} \right]^{-\mu_f^L} \exp(\hat{l}_{f,t}^d). \quad (\text{C.110})$$

The price of loans in each country is a bundle of each country's banks interest rate on loans,

$$\exp(\hat{p}_{h,t}^L) = \left[ \begin{array}{c} (1 - \alpha_h^L) \exp(\hat{r}_{h,t}^L)^{1-\mu_h^L} \\ + \alpha_h^L \left( \frac{E_t[\exp(\hat{t}o\hat{t}_{t+1})]}{\exp(\hat{t}o\hat{t}_t)} \exp(\hat{r}_{f,t}^L) \right)^{1-\mu_h^L} \end{array} \right]^{\frac{1}{1-\mu_h^L}}, \quad (\text{C.111})$$

$$\exp(\hat{p}_{f,t}^L) = \left[ \begin{array}{c} (1 - \alpha_f^L) \left( \frac{\exp(\hat{t}o\hat{t}_t)}{E_t[\exp(\hat{t}o\hat{t}_{t+1})]} \exp(\hat{r}_{h,t}^L) \right)^{1-\mu_f^L} \\ + \alpha_f^L \exp(\hat{r}_{f,t}^L)^{1-\mu_f^L} \end{array} \right]^{\frac{1}{1-\mu_f^L}}. \quad (\text{C.112})$$

## 2.7 Lending accelerator

Leverage ratio of banks writes,

$$\exp(\hat{\phi}_{i,t}^B) = \frac{1}{1 - \hat{\psi}_{i,t}} \frac{\exp(\hat{\eta}_{i,t})}{\exp(\hat{\lambda}_{i,t}) - \exp(\hat{\nu}_{i,t})}, \quad (\text{C.113})$$

By using Bellman's equation on the intertemporal value of bankers net wealth  $V_t$ , we can deduce the components of the lending accelerator: Value of banks' capital writes,

$$\begin{aligned} \exp(\hat{\nu}_{h,t}) &= (1 - \theta_h) \beta_h E_t \left\{ \exp(\hat{\Lambda}_{h,t,t+1}) \left[ \begin{array}{c} (1 - \tau_h^B) \exp(\hat{\eta}_{h,t+1}^E) \exp(\hat{r}_{h,t}^L) - \exp(\hat{r}_t) \\ - (1 - \tau_h^B) \exp(\hat{r}_{h,t}^L) (\exp(\hat{\eta}_{h,t+1}^E) - \exp(\hat{\eta}_{f,t+1}^E)) \exp(\hat{\Xi}_{h,t}) \end{array} \right] \right\} \\ &\quad + \beta_h E_t \left[ \exp(\hat{\Lambda}_{h,t,t+1}) \theta_h \exp(\hat{x}_{h,t+1}^B) \exp(\hat{\nu}_{h,t+1}) \right], \end{aligned} \quad (\text{C.114})$$

$$\begin{aligned} \exp(\hat{\nu}_{f,t}) &= (1 - \theta_f) \beta_f E_t \left\{ \exp(\hat{\Lambda}_{f,t,t+1}) \left[ \begin{array}{c} (1 - \tau_f^B) \exp(\hat{\eta}_{f,t+1}^E) \exp(\hat{r}_{f,t}^L) - \exp(\hat{r}_t) \\ - (1 - \tau_f^B) \exp(\hat{r}_{f,t}^L) (\exp(\hat{\eta}_{f,t+1}^E) - \exp(\hat{\eta}_{h,t+1}^E)) \exp(\hat{\Xi}_{f,t}) \end{array} \right] \right\} \\ &\quad + \beta_f E_t \left[ \exp(\hat{\Lambda}_{f,t,t+1}) \theta_f \exp(\hat{x}_{f,t+1}^B) \exp(\hat{\nu}_{f,t+1}) \right], \end{aligned} \quad (\text{C.115})$$



with the growth rate of banks' net wealth,

$$\exp(\hat{x}_{i,t}^B) = \frac{\exp(\hat{l}_{i,t}^S)}{\exp(\hat{l}_{i,t-1}^S)}, \quad (\text{C.116})$$

and value of banks' net wealth writes,

$$\exp(\hat{\eta}_{i,t}) = (1 - \theta_i) + \beta E_t \left[ \exp(\hat{\Lambda}_{i,t,t+1}) \theta_i \exp(\hat{z}_{i,t+1}^B) \exp(\hat{\eta}_{i,t+1}) \right]. \quad (\text{C.117})$$

Diversion parameter is stochastic in this model:

$$\exp(\hat{\lambda}_{i,t}) = \lambda_i \exp(\varepsilon_{i,t}^\lambda). \quad (\text{C.118})$$

## 2.8 Macroeconomic relations and policy variables

Aggregate resource constraint for core countries:

$$\begin{aligned} \exp(\hat{y}_{h,t}^d) &= \exp(\hat{c}_{h,h,t}) + \exp(\hat{c}_{f,h,t}) + \exp(\hat{i}n v_{h,h,t}) + \exp(\hat{i}n v_{f,h,t}) + \tau_h \hat{\psi}_{h,t} E_t \left[ \exp(\hat{k}_{h,t+1}) \right] \\ &\quad + \frac{\eta_h^I}{2} \left( \frac{\hat{I}n_{h,t} + INV_h}{\hat{I}n_{h,t-1} + INV_h} - 1 \right)^2 (\hat{I}n_{h,t} + INV_h) + \exp(\hat{g}_{h,t}), \end{aligned} \quad (\text{C.119})$$

with core countries' consumption of core countries goods,

$$\exp(\hat{c}_{h,h,t}) = (1 - \alpha_h^C) \exp(\hat{c}_{h,t}) \left( (1 - \alpha_h^C) + \alpha_h^C \exp(\hat{t}o t_t) \right)^{1 - \mu_h^C} \frac{\mu_h^C}{1 - \mu_h^C}, \quad (\text{C.120})$$

foreign countries' consumption of core countries goods,

$$\exp(\hat{c}_{f,h,t}) = (1 - \alpha_f^C) \exp(\hat{c}_{f,t}) \left( (1 - \alpha_f^C) + \alpha_f^C \exp(\hat{t}o t_t) \right)^{1 - \mu_f^C} \frac{\mu_f^C}{1 - \mu_f^C}, \quad (\text{C.121})$$

core countries' investment with core countries goods,

$$\exp(i\hat{n}v_{h,h,t}) = (1 - \alpha_h^I) \exp(i\hat{n}v_{h,t}) \left( (1 - \alpha_h^I) + \alpha_h^I \exp(t\hat{o}t_t)^{1-\mu_h^I} \right)^{\frac{\mu_h^I}{1-\mu_h^I}}, \quad (\text{C.122})$$

and foreign countries' investment with core countries goods,

$$\exp(i\hat{n}v_{f,h,t}) = (1 - \alpha_f^I) \exp(i\hat{n}v_{f,t}) \left( (1 - \alpha_f^I) + \alpha_f^I \exp(t\hat{o}t_t)^{1-\mu_f^I} \right)^{\frac{\mu_f^I}{1-\mu_f^I}}. \quad (\text{C.123})$$

Aggregate resource constraint for foreign countries:

$$\begin{aligned} \exp(\hat{y}_{f,t}^d) &= \exp(\hat{c}_{h,f,t}) + \exp(\hat{c}_{f,f,t}) + \exp(i\hat{n}v_{h,f,t}) + \exp(i\hat{n}v_{f,f,t}) + \tau_f \hat{\psi}_{f,t} \exp(\hat{k}_{f,t+1}) \\ &\quad + \frac{\eta_f^I}{2} \left( \frac{\hat{I}n_{f,t} + INV_f}{\hat{I}n_{f,t-1} + INV_f} - 1 \right)^2 (\hat{I}n_{f,t} + INV_f) + \exp(\hat{g}_{f,t}), \end{aligned} \quad (\text{C.124})$$

with foreign countries' consumption of foreign countries goods,

$$\exp(\hat{c}_{f,f,t}) = \alpha_f^C \exp(\hat{c}_{h,t}) \left( \frac{1 - \alpha_f^C}{\exp(t\hat{o}t_t)^{1-\mu_f^C}} + \alpha_f^C \right)^{\frac{\mu_f^C}{1-\mu_f^C}}, \quad (\text{C.125})$$

core countries' consumption of core countries goods,

$$\exp(\hat{c}_{h,f,t}) = \alpha_h^C \exp(\hat{c}_{h,t}) \left( \frac{1 - \alpha_h^C}{\exp(t\hat{o}t_t)^{1-\mu_h^C}} + \alpha_h^C \right)^{\frac{\mu_h^C}{1-\mu_h^C}}, \quad (\text{C.126})$$

foreign countries' investment with foreign countries goods,

$$\exp(i\hat{n}v_{f,f,t}) = \alpha_f^I \exp(i\hat{n}v_{h,t}) \left( \frac{1 - \alpha_f^I}{\exp(t\hat{o}t_t)^{1-\mu_f^I}} + \alpha_f^I \right)^{\frac{\mu_f^I}{1-\mu_f^I}}, \quad (\text{C.127})$$

and core countries' investment with core countries goods,

$$\exp(\hat{inv}_{h,f,t}) = \alpha_h^I \exp(\hat{inv}_{h,t}) \left( \frac{1 - \alpha_h^I}{\exp(\hat{tot}_t)^{1-\mu_h^I}} + \alpha_h^I \right)^{\frac{\mu_h^I}{1-\mu_h^I}}. \quad (\text{C.128})$$

Interest rate rule:

$$\exp(\hat{r}_t) = \frac{1}{\beta} [\exp(\hat{\pi}_{h,t}^C) \exp(\hat{\pi}_{f,t}^C)]^{\phi_\pi} \left[ \frac{\exp(\hat{y}_{h,t}^d) \exp(\hat{y}_{f,t}^d)}{\exp(\hat{y}_{h,t-1}^d) \exp(\hat{y}_{f,t-1}^d)} \right]^{\phi_y} \exp(\varepsilon_t^r). \quad (\text{C.129})$$

Public spending:

$$\exp(\hat{g}_{i,t}) = G_i \varepsilon_{i,t}^g. \quad (\text{C.130})$$

Credit policy rule:

$$\hat{\psi}_{i,t} = v_i \hat{\zeta}_{i,t}. \quad (\text{C.131})$$

## 2.9 International variables

The terms of trade write,

$$\frac{\exp(\hat{tot}_t)}{\exp(\hat{tot}_{t-1})} = \frac{\exp(\hat{\pi}_{f,t})}{\exp(\hat{\pi}_{h,t})}. \quad (\text{C.132})$$

Current account (defined for core countries) is the difference between core exports of consumption and investment goods and core imports of consumption and investment goods,

$$\hat{ca}_t = \exp(\hat{c}_{h,f,t}) + \exp(\hat{inv}_{h,f,t}) - \exp(\hat{c}_{f,h,t}) - \exp(\hat{inv}_{f,h,t}). \quad (\text{C.133})$$

Internationally traded bonds:

$$\hat{b}_{t+1} = \exp(\hat{r}_t) \hat{b}_t + \exp(\hat{c}_{f,h,t}) - \exp(\hat{c}_{h,f,t}) + \exp(\hat{inv}_{f,h,t}) - \exp(\hat{inv}_{h,f,t}). \quad (\text{C.134})$$

Overall production in the monetary union is simply defined as,

$$\exp(\hat{y}_t^{zone}) = \exp(\hat{y}_{h,t}^d) + \exp(\hat{y}_{f,t}^d), \quad (\text{C.135})$$

and overall quantity of loans in the monetary union writes,

$$\exp(\hat{l}_t^{zone}) = \exp(\hat{l}_{h,t}^d) + \exp(\hat{l}_{f,t}^d). \quad (\text{C.136})$$

## 2.10 Non linear dynamics

**Occasionally binding credit constraint** If the incentive constraint is not binding:

$$\hat{\zeta}_{i,t} = 0, \exp(\hat{l}_{i,t}^S) \leq \exp(\hat{l}_{i,t}^{S \max}). \quad (\text{C.137})$$

If the incentive constraint is binding:

$$\hat{\zeta}_{i,t} > 0, \exp(\hat{l}_{i,t}^S) = \exp(\hat{l}_{i,t}^{S \max}). \quad (\text{C.138})$$

## 2.11 Exogenous Shocks

- Shock on the diversion parameter:  $\varepsilon_{i,t}^\lambda = \rho_i^\lambda \varepsilon_{i,t-1}^\lambda + \eta_{i,t}^\lambda$  with  $\eta_{i,t}^\lambda \sim N(0, \sigma_{\eta_i^\lambda}^2)$ .
- Technology shock:  $\varepsilon_{i,t}^a = \rho_i^a \varepsilon_{i,t-1}^a + \eta_{i,t}^a$  with  $\eta_{i,t}^a \sim N(0, \sigma_{\eta_i^a}^2)$ .
- Government spending shock:  $\varepsilon_{i,t}^g = \rho_i^g \varepsilon_{i,t-1}^g + \eta_{i,t}^g$  with  $\eta_{i,t}^g \sim N(0, \sigma_{\eta_i^g}^2)$ .
- Optimism shock:  $\varepsilon_{i,t}^{opt} = \rho_i^{opt} \varepsilon_{i,t-1}^{opt} + \eta_{i,t}^{opt}$  with  $\eta_{i,t}^{opt} \sim N(0, \sigma_{\eta_i^{opt}}^2)$ .
- Consumption shock:  $\varepsilon_{i,t}^{cons} = \rho_i^{cons} \varepsilon_{i,t-1}^{cons} + \eta_{i,t}^{cons}$  with  $\eta_{i,t}^{cons} \sim N(0, \sigma_{\eta_i^{cons}}^2)$ .
- Bank net wealth shock:  $\varepsilon_{i,t}^{NB}$  with  $\varepsilon_{i,t}^{NB} \sim N(0, \sigma_{\varepsilon_i^{NB}}^2)$ .
- Interest rate shock:  $\varepsilon_t^r$  with  $\varepsilon_t^r \sim N(0, \sigma_{\varepsilon^r}^2)$ .



## Appendix D

### Coefficients, transition probabilities and complete sets of GIRFs

	Low(t+1)	High(t+1)
Low(t)	93.677	0.063
High(t)	0.559	0.441

Table D.1: Transition matrix of the MS-SVAR (full sample average, %)

	HICP	GDP	CREDIT	CISS	MRO	LTRO	SEC
HICP(-1)	0.57576***	0.87184***	1.0998***	-2.4573	3.0045***	40.9808**	-13.6328*
GDP(-1)	0.077123	0.73404***	0.91617***	11.2187***	0.92978**	31.5107*	49.7594***
CREDIT(-1)	-0.34258***	0.79421***	1.0554***	-13.0132***	0.07672	-4.6375	-27.0461***
CISS(-1)	-0.0023087	-0.0039737	0.029208***	0.96134***	-0.033169**	0.093479	0.84021***
MRO(-1)	0.018795	0.013436	0.13068*	1.0412*	0.83708***	8.4365*	-6.6214**
LTRO(-1)	-0.0055513***	-0.0020808*	0.0021038*	-0.040377*	-0.0092585***	0.21546*	0.11674*
SEC(-1)	0.0046619***	-0.0076422***	-0.01502***	0.044149*	-0.015235***	0.16925	0.37517***
HICP(-2)	0.3201*	-1.2194***	-2.2815***	19.9222***	-1.4038**	8.2441	-45.0682***
GDP(-2)	0.11267	0.44824***	-0.90502**	-11.0872***	1.0969**	-15.1361	-65.0382***
CREDIT(-2)	-0.00055037	-0.63468***	-0.58839**	11.2233***	-0.75987**	43.0704***	5.8113
CISS(-2)	0.00055848	-0.00052089	-0.013979	0.02722	-0.019681	0.17622	-0.9429**
MRO(-2)	-0.00072726	0.043371	-0.25919*	-2.1163*	-0.24222*	-20.1745**	9.2272**
LTRO(-2)	0.0021778*	8.1708e-05	-0.0030529*	-0.025918*	0.0068126***	0.16835*	0.0030046
SEC(-2)	-0.0049091**	0.0063434***	0.011496**	-0.12558***	0.002627	-0.3667*	-0.10962
HICP(-3)	0.008762	0.27641*	1.611***	-12.2917***	-0.4108	-15.6678	46.3044***
GDP(-3)	-0.046078	-0.35483***	0.282*	2.924*	-1.6557***	-10.4379	41.7927***
CREDIT(-3)	0.28072***	-0.17335*	0.61008***	5.0648**	1.5825***	-30.0244**	31.0754***
CISS(-3)	0.0055063*	0.0075133**	-0.012848*	-0.030664	-0.015165*	1.2666***	-0.17306
MRO(-3)	0.002002	-0.058474*	0.077766*	0.11531	-0.086631*	7.8274*	-6.5309***
LTRO(-3)	0.00037254	0.00059304	-0.00020895	-0.016302*	0.0032172*	0.012842	0.048917
SEC(-3)	0.0020256*	0.0052386**	-0.0012646	-0.048521*	-0.0088504*	0.5618***	0.1223*
Constant	-0.0046118*	0.0015141	0.00078596	0.13608*	0.089122***	-0.63513*	1.2773***

Note: \*\*\* signif. at 1% level of risk, \*\* signif. at 5%, \* signif. at 10%.

Table D.2: VAR coefficient estimates and significance - HIGH stress regime

	HICP	GDP	CREDIT	CISS	MRO	LTRO	SEC
HICP(-1)	1.1048***	0.0046223	0.071154	-0.12161	0.60295**	19.0244***	2.5329*
GDP(-1)	-0.012767	1.0208***	0.21527*	0.7094	0.21276*	7.3487**	-0.62742
CREDIT(-1)	0.058051*	0.040702*	0.97655***	0.88652	0.3424***	0.38589	0.77226*
CISS(-1)	0.0018726	-0.0067006***	-0.01014*	0.66619***	-0.0025389	0.073656	0.085267*
MRO(-1)	0.014749	-0.060281**	-0.12417**	1.0922*	1.3461***	-1.2089*	1.1853***
LTRO(-1)	0.00077146	-0.00142*	-0.003447*	0.050807*	-0.0031741*	1.031***	-0.0045346
SEC(-2)	-0.0022733	0.0054892*	-0.0053066	0.043376	-0.010078*	0.1814*	1.089***
HICP(-2)	-0.18836*	-0.071603	0.45052*	0.23137	-0.37091	-24.6193***	-3.8353*
GDP(-2)	0.068823	0.086933	0.0050434	-1.8483	-0.095505	-7.8698*	0.42146
CREDIT(-2)	-0.0079674	-0.013672	-0.033656	0.54905	-0.29907*	-1.6276	-1.3109*
CISS(-2)	0.0023663	0.0043373*	0.0058805	0.091283*	-0.0020872	-0.024159	-0.035497
MRO(-2)	-0.026673	0.15116***	0.25186***	-0.87034	-0.33804***	0.14263	-1.8615***
LTRO(-2)	0.00045684	-0.0013802	0.00078089	-0.0099548	0.00093252	-0.053499	-0.0024413
SEC(-2)	0.00083773	0.00044995	0.007162	0.033704	0.014463*	-0.19653	-0.036827
HICP(-3)	-0.003036	0.021174	-0.25712*	-0.8547	-0.039232	6.7598*	-1.3981
GDP(-3)	-0.055262*	-0.2014***	-0.11185	0.96838	-0.10014	0.12964	-0.34091
CREDIT(-3)	-0.050948*	-0.017636	0.072206	-1.57*	0.030699	2.2578*	0.56567
CISS(-3)	0.00058933	-0.008017***	-0.0040703	0.16951**	0.0018635	-0.19581*	0.013426
MRO(-3)	0.018194	-0.091079***	-0.15496***	-0.073889	-0.042242	0.8038	0.78958*
LTRO(-3)	-0.0012*	0.0028739***	0.0011611	-0.032457*	0.0025695	-0.049022*	-0.0083056
SEC(-3)	0.0026251*	-0.0060196*	-0.0025973	-0.075444	-0.0074984	0.069555	-0.10281**
Constant	-0.0015378*	0.00576***	0.0015419	0.021249	0.002278	0.055445*	0.024746*

Note: \*\*\* signif. at 1% level of risk, \*\* signif. at 5%, \* signif. at 10%.

Table D.3: VAR coefficient estimates and significativity - LOW stress regime



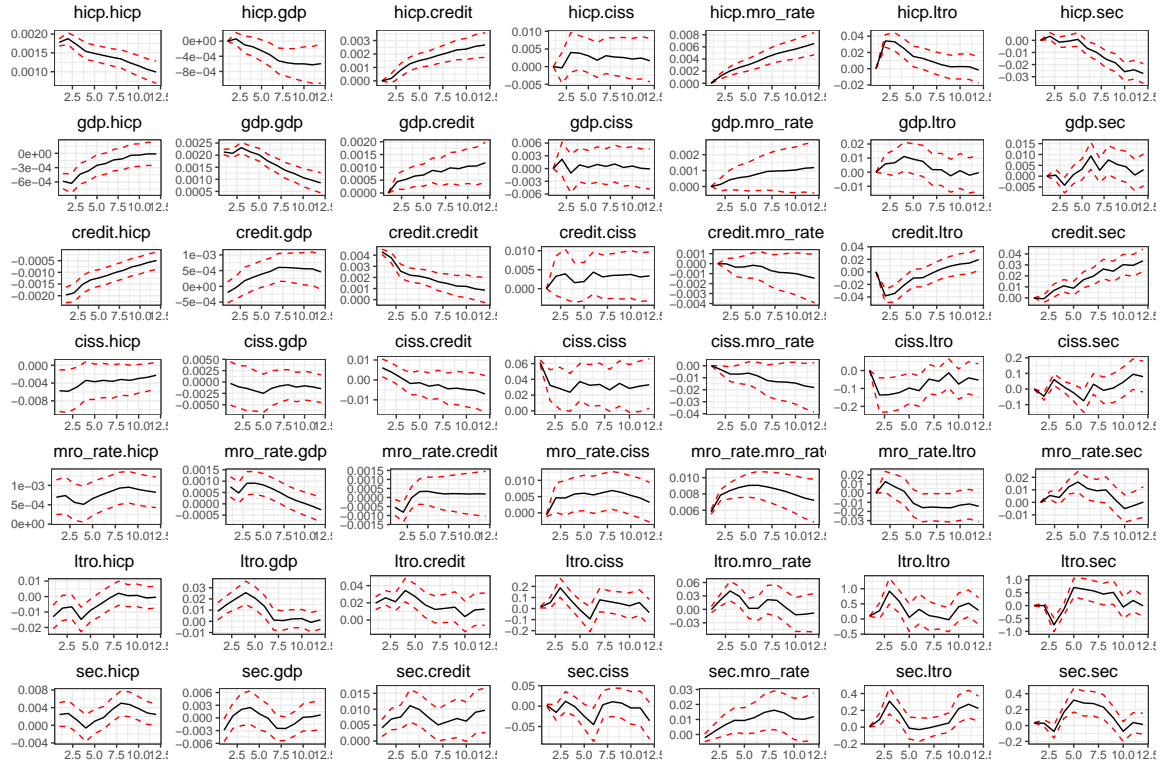


Figure D.1: Full Generalized Impulse Response Functions with [16%, 84%] confidence band, LOW stress regime

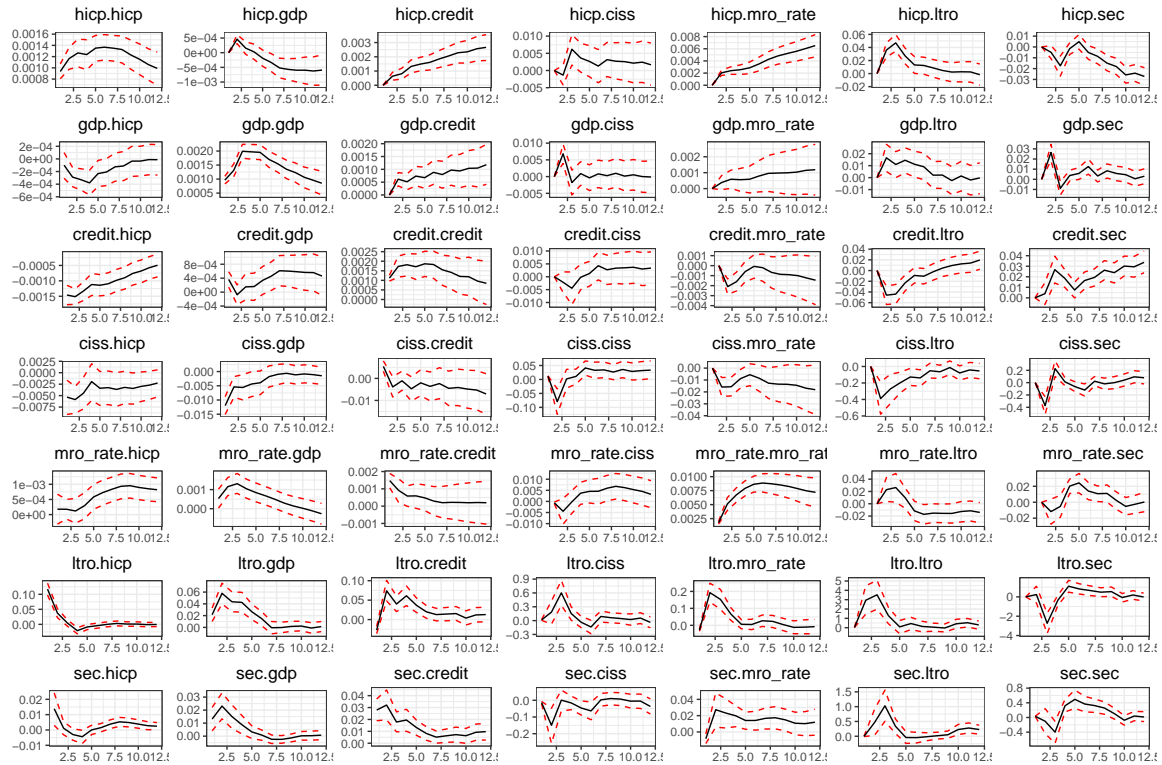


Figure D.2: Full Generalized Impulse Response Functions with [16%, 84%] confidence band, HIGH stress regime

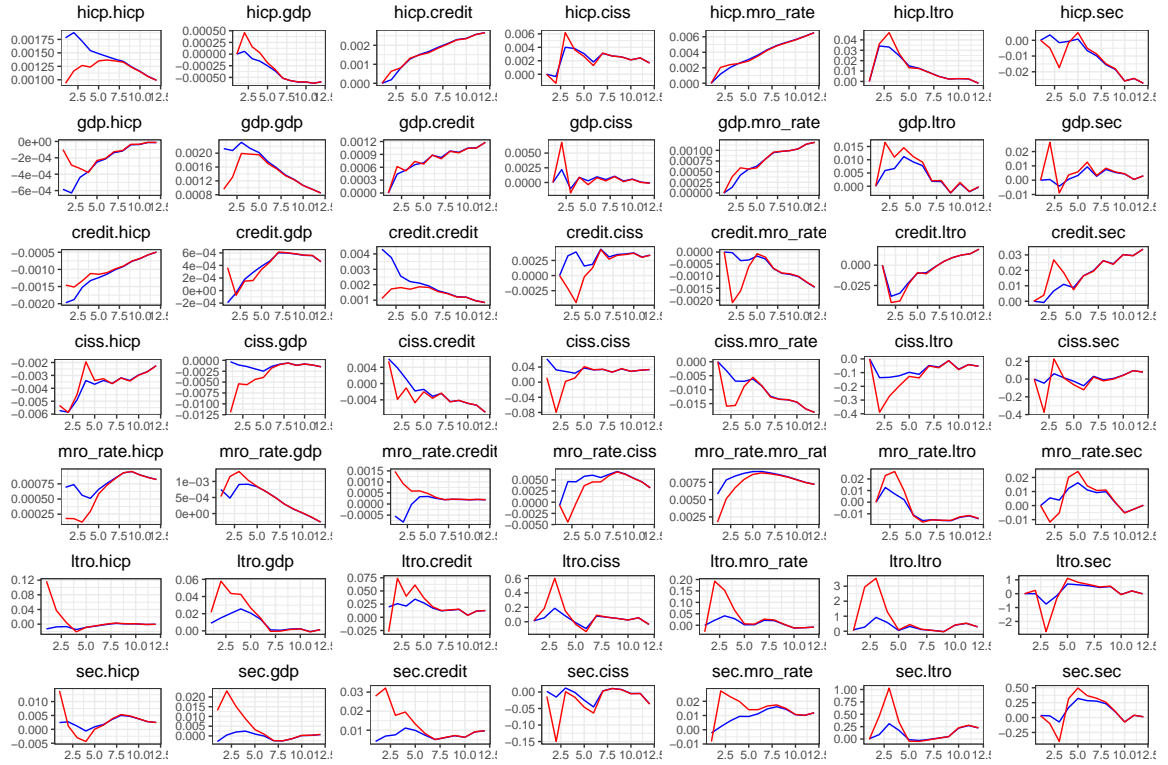


Figure D.3: Full Generalized Impulse Response Functions, mean values, LOW (blue) vs HIGH (red) stress regimes

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VU :  
**Le Directeur de Thèse**  
(Nom et Prénom)

VU :  
**Le Responsable de l'École Doctorale**

**VU pour autorisation de soutenance**

**Rennes, le**

**Le Président de l'Université de Rennes 1**

**David ALIS**

**VU après soutenance pour autorisation de publication :**

**Le Président de Jury,**  
(Nom et Prénom)



## **Politique Monétaire en Période de Crise : Trois Essais sur l'Assouplissement Quantitatif dans un Contexte Financier Non-Linéaire**

Suite à la crise financière de 2007, les outils de politique monétaire conventionnelle se sont avérés insuffisants pour stabiliser l'économie et empêcher la diffusion de la crise financière. Les banques centrales ont de fait mis en place des politiques monétaires non conventionnelles. L'objectif de cette thèse est de participer à la compréhension théorique et empirique des politiques monétaires non conventionnelles en concentrant nos efforts de modélisation sur la nature non-linéaire de la crise financière. Les deux premiers chapitres de cette thèse développent des modèles DSGE incorporant des contraintes de crédit occasionnellement saturées de manière à capturer la nature transitoire des phénomènes de crise. Dans le premier chapitre - obtenu dans un cadre d'économie fermée - un résultat notable est que les politiques d'assouplissement quantitatif diminuent bien l'amplitude de la crise, mais augmentent sa durée. Dans le deuxième chapitre, lorsque l'on implémente des programmes d'assouplissement quantitatif au niveau d'une union monétaire hétérogène constituée de deux pays, se pose le problème des hétérogénéités entre les pays membres de cette union. Nous trouvons qu'il est toujours plus intéressant pour la banque centrale de concentrer ses achats de titres dans les pays de l'union les plus touchés par la crise financière. De plus, un niveau intermédiaire d'intégration financière permet de minimiser les conséquences de la crise au niveau de l'union monétaire dans son ensemble. Dans le troisième chapitre, nous utilisons un modèle Markov-Switching VAR Bayésien pour comparer l'efficacité des politiques d'assouplissement quantitatif en période de crise et en période normale. Alors que les programmes d'assouplissement quantitatif sont particulièrement efficaces en période de crise, nous ne trouvons aucun effet significatif de ces programmes sur les variables macroéconomiques lorsque l'économie retourne à son état initial.

**Mots clés:** Macroéconomie; Zone Euro; Modèles DSGE; Markov-Switching VAR; Politique Monétaire; Assouplissement Quantitatif; Système Financier; Non-Linéarités.

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### **Monetary Policy in Troubled Times: Three Essays on Quantitative Easing in a Non-Linear Financial Environment**

Following the 2007 financial crisis, conventional monetary policy tools proved insufficient to stabilize the macroeconomy and to avoid a financial disruption. As a consequence, central banks relied more heavily on unconventional monetary policy tools. This thesis aims at contributing to the understanding of unconventional monetary policy tools, focusing on the inherently non-linear nature of financial crises. In the first two chapters, we use DSGE models with occasionally binding credit constraints to account for the transitory nature of financial disruption events. In chapter one, in the case of a closed economy, we find that quantitative easing decreases the magnitude of the crisis but increases its duration. Still, when looking for intertemporal effects of quantitative easing programs, it appears that they are always welfare improving. In chapter two, when implementing quantitative easing on a two country monetary union, comes the question of how to deal with heterogeneities between members. We find that it is always better to implement nationally tailored quantitative easing programs. Finally, an intermediate degree of financial integration proves optimal to dampen the macroeconomic consequences of the financial crisis on the overall monetary union. In the third chapter, we use a Markov-Switching Bayesian VAR model to compare the efficiency of quantitative easing in normal times versus financial crisis times. While quantitative easing programs are highly efficient during financial crisis times, we find no significant effect of these programs when the economy goes back to normal times.

**Keywords:** Macroeconomics; Eurozone; DSGE Models; Markov-Switching VAR; Monetary Policy; Quantitative Easing; Financial System; Non-Linearities.