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THÈSE

CRISES, FRICTIONS FINANCIÈRES ET MODÉLISATION MACROÉCONOMIQUE

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A Mes Parents,

Mes Soeurs,

Leurs Enfants ...

Résumé

L'interaction sphère financière/sphère réelle a longtemps été délaissée dans les modèles macroéconomiques, postulant généralement la neutralité de la première. La récente crise financière dite des *subprime* démontre qu'il en est autrement. Cette thèse propose trois essais sur le rôle du secteur financier et plus particulièrement bancaire à l'aune de la dernière crise.

Le premier consiste à donner un cadre formel à la nature exceptionnelle de la crise en abandonnant l'hypothèse de normalité des 'événements résiduels'. Nos résultats réfutent le caractère 'normal' de la crise mais, aussi et surtout, soulignent les biais en termes de diagnostics économiques à la considérer comme telle.

Par ailleurs, un des effets exceptionnels de cette crise a été le recours à des politiques monétaires non conventionnelles. La deuxième partie de la thèse suggère à ce titre l'incertitude sur les marchés interbancaires comme une raison probable de l'inefficacité des politiques monétaires conventionnelles. Une politique monétaire équilibrée entre lutte contre l'inflation et soutien à l'économie réelle serait néanmoins plus à même de réduire les effets de cette incertitude sur le cycle économique.

Enfin, le troisième volet de la thèse propose une étude d'impact de la nouvelle réglementation Bâle III sur le secteur réel. L'absence d'externalités positives entre la mise en oeuvre de la contrainte de capitalisation et celle du LCR accentue davantage l'écart de production entre PME et grandes entreprises, induisant un impact récessif global encore plus sensible. Une mise en oeuvre plus lente et parfaitement anticipée des nouvelles normes réglementaires pourrait néanmoins nuancer ces effets.

Mots Clefs: Modèles DSGE, Frictions Financières, Politique Monétaire.

Abstract

Until recently, most macroeconomic models have ignored the interaction between financial and real sectors, postulating the neutrality of the former. However, the last financial crisis, also known as subprime crisis, rejected this assumption. In this thesis we propose three essays where we try to shed light on the role of the financial and more particularly the banking sector during the last crisis.

The first essay provides a formal assessment of the exceptional nature of the crisis by challenging the usual 'normality' assumption of the innovations. Our results refute the 'normality' assumption for the crisis, but also and more importantly, they put forward possible biases from using this assumption in macroeconometric models.

The exceptional features of the crisis can also be seen in the use of unconventional monetary policy. The second chapter of the thesis shows how higher volatility in the interbank market impedes the standard monetary policy effects. However, a central bank with a more balanced monetary policy, reacting both to inflation pressures and to GDP variations, would be in a better situation to dampen the effects of interbank volatility shocks on the economic cycle.

The last chapter deals with the impact on the real sector of the new Basel III regulatory requirements. The fulfillment of the new capital ratio has no positive spill-over effects on the Liquidity Coverage Ratio which magnifies the output discrepancy between SMEs and corporate firms. This, in turn, generates a greater recessionary impact on the overall economy. A more progressive implementation of the new regulation combined with perfect expectations should however decrease such adverse effects.

Key Words: DSGE Models, Financial Frictions, Monetary Policy.

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Avertissement

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Introduction

La récente crise financière commencée en 2007 a remis en cause un certain nombre de préceptes des sciences économiques modernes. Ainsi, un changement de paradigme s'est opéré dans la modélisation macro-économique en général et, plus particulièrement, dans les modèles dits d'équilibre général intertemporel et stochastique (ou DSGE dans la suite - pour Dynamic Stochastic General Equilibrium-). Ces modèles, issus de la nouvelle synthèse néoclassique, s'étaient déjà largement imposés avant la crise comme outils de référence pour l'analyse, voire la prévision, dans les milieux académiques et dans les banques centrales. Cependant, les modèles DSGE, à l'instar d'autres outils d'analyse macro-économétriques n'ont été capables ni d'anticiper les fluctuations des variables d'intérêt elles-mêmes (PIB, inflation, prix des actifs, taux d'intérêt etc.), ni même leur ampleur, soulevant ainsi plusieurs questions quant à leur pertinence et l'étendue de leurs limites. Loin de remettre en cause l'ensemble de l'innovation que représente le cadre des DSGE, ce sont plutôt les hypothèses sous-jacentes à ces modèles qui ont concentré l'essentiel des critiques. Ainsi, Buiter[1] dénonce particulièrement l'hypothèse, communément admise dans ce type de modèles, de marchés complets et efficients, ainsi que celle d'agent représentatif. Solow le rejoint sur ce deuxième point [2] et concentre également ses critiques sur l'hypothèse d'anticipations rationnelles et sur les conséquences en termes de comportement des agents qui en découlent. Enfin, dans un registre plus spécifique, Curdia and Woodford [16], ainsi que Goodhart [41] et Dib [19], dénoncent l'absence de frictions financières dans les modèles DSGE ; cette carence induit par conséquent une neutralité parfaite des intermédiaires financiers, qui se retrouvent ainsi absents de la plupart des modèles d'équilibre général élaboré avant la crise.
Face à ces critiques, les modèles DSGE ont dû peu à peu intégrer des frictions financières, abandonnant notamment les hypothèses d'absence d'asymétrie d'information ou d'absence d'hétérogénéités des comportements (cf. les deux modèles cadres de Kiyotaki and Moore [48] et de Bernanke et al. [5]) qui les caractérisaient auparavant. Par ailleurs, les modélisateurs ont cherché à intégrer une description plus fine du secteur bancaire, lui-même contraint par des frictions financières, et à s'intéresser de façon plus précise non seulement au cadre opérationnel de la politique monétaire mais aussi à la réglementation

[1] Buiter, Willem, " The unfortunate uselessness of most 'state of the art' academic monetary economics ", 03-03-2009, Financial Times.

[2] Robert Solow, " Building a Science of Economics for the real world ", 20-07-2010, The House Committee on Science and Technology.

bancaire et financière.

Ces innovations récentes ont renforcé l'intérêt des institutions en charge des politiques économiques et notamment les banquiers centraux pour les modèles d'équilibre général. D'une part, la nouvelle mouture des modèles DSGE a légitimement été appelée à réexaminer les conclusions relatives à l'efficacité des politiques économiques en temps de crise, notamment dans le cadre du débat sur l'efficacité des politiques monétaires accommodantes et non-conventionnelles adoptées par les banques centrales des pays avancés en réponse à la crise. De nombreux travaux ont ainsi procédé à l'évaluation de l'efficacité de la politique monétaire sous la contrainte de taux plancher ou à la substitution de la politique d'assouplissement monétaire (ou de prêteur en dernier ressort) à la politique conventionnelle de fixation de taux directeurs. Enfin, sous l'impulsion des travaux de Fernández-Villaverde et al. [27, 28, 29], un nouvel axe de recherche s'est développé autour de l'analyse, à l'aide des modèles d'équilibre général, de l'impact de l'incertitude qui entoure les politiques économiques (budgétaire comme monétaire) en temps de crise.

D'autre part, l'ajout du secteur bancaire avec frictions financières, conjugué au caractère très adapté des modèles DSGE à l'analyse contrefactuelle, a fait de ces nouveaux modèles un outil puissant et, de ce fait, fréquemment utilisé pour l'évaluation des mesures élaborées en réponse à la dernière crise financière. Ainsi, afin d'évaluer l'impact des réformes prudentielles touchant le secteur bancaire, dites de Bâle III, le groupe de travail Macroeconomic Assessment Group (MAG dans la suite) souligne le caractère essentiel des micro-fondements théoriques des modèles DSGE et leur aptitude à prendre en compte les effets de report pouvant exister entre les différents marchés. De manière similaire, Angelini et al. [1] mobilisent dix modèles DSGE de la dernière génération, afin d'établir l'impact de long terme des mesures de Bâle III.

Notre thèse s'intègre dans l'ensemble des problématiques développées ci-dessus. Le premier chapitre propose ainsi une caractérisation de la dernière crise financière, en tentant de déterminer si les événements ayant eu lieu sont des événements connus, dont la probabilité d'occurrence est faible, ou s'il s'agit d'événements de caractéristiques non identifiées jusqu'à présent.

Une fois la nature de la crise mieux identifiée, nous procédons, dans un deuxième chapitre, à l'analyse des effets de cette crise sur la transmission de la politique monétaire en période de forte incertitude sur le marché interbancaire. L'objectif est double : il s'agit de proposer, d'une part, une explication à certains faits stylisés observés durant les cinq dernières années et, d'autre part, de mieux identifier l'une des causes de l'insuffisance de la politique monétaire conventionnelle durant cette même période.

Enfin, le troisième chapitre propose une évaluation des réformes prudentielles de Bâle III en reprenant le cadre méthodologique adopté par le groupe de travail MAG, mais en poursuivant l'analyse notamment en tenant compte des hétérogénéités entre petites et moyennes entreprises (PME dans la suite) et grandes entreprises et en s'appuyant sur une spécification de la nouvelle contrainte de liquidité introduite par Bâle III, plus fidèle à sa définition officielle, en sus des contraintes de solvabilité.

Plus précisément, dans le premier chapitre, nous proposons un cadre formel à l'identification de la crise financière de 2007-2008. En effet, s'il existe un quasi-consensus pour décrire la Grande Récession comme la résultante de chocs d'une amplitude exceptionnelle, aucune étude ne fournit à notre connaissance de cadre formel à une telle assertion. La réponse à une telle question revêt une importance qui dépasse le simple fait statistique, puisqu'elle joue également un rôle important dans l'analyse inférentielle des modèles.

Ainsi, nous procédons à l'étude d'un modèle VAR, dont les innovations ne suivent plus une loi normale, comme il est de coutume, mais une loi t de Student, qui se caractérise justement par des queues de distribution relativement plus épaisses. Le modèle est estimé selon l'approche bayésienne, en utilisant un échantillonneur de Gibbs. Par ailleurs, la théorie économique nous fournit une méthodologie simple permettant de recouvrer les chocs structurels à partir des modèles à forme réduite. Cette matrice de passage présente dans notre cas l'avantage de se confondre avec celle que nous aurions obtenue dans l'hypothèse de la normalité des chocs lorsque le degré de liberté de la loi t de Student est élevé. De plus, nous montrons que l'écart entre les réponses impulsionnelles issues d'un modèle 'normal' et celles obtenues à partir de notre modèle est inversement proportionnel au nombre de degrés de liberté.

Nous nous focalisons ensuite sur la transmission des chocs de risque de contrepartie (modélisé par le spread Euribor-OIS[3]) dans la zone euro en mobilisant tant des variables financières (taux d'intérêt débiteurs des banques et le volume de crédit bancaire), que des variables réelles (taux de chômage et taux directeur). Nous identifions, par ailleurs, les chocs structurels selon une décomposition de Cholesky, en supposant que le choc de risque de crédit est susceptible d'impacter instantanément les variables financières mais non les variables réelles. Nous montrons ainsi que la différence entre modèle normal et modèle suivant une loi t de Student n'est pas très significative durant la période antérieure à la crise. En revanche, il en va autrement lorsque l'on tient compte de la dynamique des variables macro-économiques durant la crise. Ce premier résultat milite ainsi en faveur de l'hypothèse de l'avènement de chocs rares pour définir la dernière crise financière. Nous montrons, par ailleurs, que l'utilisation de modèles reposant sur l'hypothèse de normalité des innovations est susceptible d'aboutir à des réponses impulsionnelles, sinon économiquement contre-intuitives, au moins imprécises, notamment en ce qui concerne l'identification de chocs d'offre de crédit. Ce résultat ne se retrouve pas lorsque l'on se fonde sur l'hypothèse de non-normalité des chocs, dont les réponses impulsionnelles se caractérisent pas une grande stabilité vis-à-vis de la période d'estimation.

Le deuxième chapitre se propose d'évaluer l'efficacité des intermédiaires financiers

[3]Le spread entre l'Euribor et l'*Overnight Index Swap* constitue un indicateur du risque sur le marché interbancaire.

dans la transmission de la politique monétaire, durant les périodes où des événements rares identifiés dans la première partie sont susceptibles de se produire. Nous nous intéressons plus particulièrement à l'étude des *pass-through* des taux d'intérêt, c'est-à-dire de transmission des variations des taux directeurs aux taux d'intérêt débiteurs en période de forte volatilité sur le marché interbancaire. En effet, si la question du niveau de *pass-through* a longtemps été débattue dans la littérature, notamment empirique, peu de travaux sont consacrés à l'impact des chocs de volatilité sur ces *pass-through* en particulier et à l'efficacité de la politique monétaire en général.
Par ailleurs, bien que la littérature théorique ne soit pas d'un apport significatif pour la détermination des valeurs des *pass-through*, elle n'en demeure pas moins essentielle pour la compréhension des principaux déterminants et implications de tels résultats. Ainsi, en mobilisant des modèles macro-économiques néo-keynésiens, Kwapil and Scharler [52] et Darracq Pariès et al. [17] ont récemment montré que le caractère incomplet des *pass-through* réduit l'efficacité de la politique monétaire, voire l'ensemble du bien-être social Kobayashi [50]. Notre travail s'inscrit également dans ce cadre d'étude, puisque nous proposons une explication de l'abaissement constaté du *pass-through* durant la crise (IMF [47], Čihák et al. [13], Hristov et al. [44]), en nous aidant d'un modèle néo-keynésien micro-fondé inspiré des travaux de Iacoviello [46] et de Gerali et al. (2010).
Nous montrons ainsi comment la présence d'une forte volatilité sur le marché interbancaire incite les banques à moins répercuter les variations de taux directeurs sur leurs propres taux débiteurs. Ainsi, une politique monétaire accommodante est moins susceptible d'être transmise à l'économie réelle en période de forte volatilité sur le marché interbancaire. En période de fortes incertitudes, une baisse des taux directeurs se traduira essentiellement par une augmentation des marges des intermédiaires financiers, ce qui leur permettra de dégager davantage de bénéfices et d'augmenter par la suite leurs fonds propres. Cette situation est similaire à ce qui a été observé durant la dernière crise financière, la majorité des banques ayant pu, dans un délai relativement court, recouvrer leurs fonds propres et rembourser *in fine* les dettes contractées au plus haut de la crise.
En outre, nous proposons dans notre étude quelques intuitions économiques pour expliquer l'origine de ce phénomène. Cette explication vient ainsi compléter celle proposée par Fernández-Villaverde et al. [27], cette dernière ne semblant pas être adaptée à tout type de modèle.
Enfin, nous analysons quel comportement de la banque centrale serait le plus à même de juguler les effets négatifs de l'incertitude sur les principaux agrégats macro-économiques.

Le troisième chapitre s'intéresse à l'évaluation d'une des réponses apportées à la récente crise financière, à savoir les réformes prudentielles dites de Bâle III. Pour ce faire, comme indiqué déjà, nous suivons la procédure méthodologique adoptée par le groupe de travail MAG Macroeconomic Assessment Group [55, 54] pour les besoins d'un exercice similaire au nôtre. Notre apport est d'articuler notre étude autour de deux problématiques : une analyse comparative de l'impact du ratio de capitalisation bancaire par rapport à celui du nouveau ratio de liquidité (LCR dans la suite), puis l'étude de l'effet du calendrier de mise en oeuvre, en distinguant entre une mise en oeuvre rapide (deux années) et une mise en oeuvre lente (huit années). Nous élaborons pour cela un modèle DSGE de taille relativement importante, avec un secteur réel complet, mais en enrichissant les modèles standard, d'abord par la prise en compte d'actifs de maturité supérieure à une période suivant l'approche adoptée par Benes and Lees [4], ensuite par la distinction entre PME et grandes entreprises (GE par la suite). Cette distinction nous conduit à intégrer une dimension importante en matière de financement des entreprises en zone euro, à savoir la part croissante d'émissions de titres obligataires par les entreprises non financière. Dans notre modèle nous intégrons la capacité des GE à posséder une alternative entre financement bancaire et financement de marché, tandis que les PME restent essentiellement tributaires des crédits bancaires pour leurs besoins de financement.

Nous mettons ainsi en lumière le différentiel d'impact des nouvelles exigences réglementaires sur les productions respectives des PME et des GE. Ces dernières bénéficient d'un effet de substituabilité entre les deux sources de financement, et peuvent ainsi faire face à un éventuel rationnement de crédit, comme en témoignent les évolutions récentes du taux d'endettement obligataire des sociétés non-financières. Cet effet de substituabilité est en outre accentué par l'incitation des banques à détenir davantage d'obligations *corporate*. Cependant, si les deux contraintes réglementaires de capitalisation et de liquidité ont des effets similaires sur l'écart de production des deux types d'entrepreneurs, nous montrons comment ces contraintes ont globalement des effets sensiblement différents sur certaines autres variables, notamment celles ayant trait au secteur bancaire (taux débiteurs, volume de crédits, niveau du *leverage* etc.). Ces différences expliquent les faibles externalités positives que l'on pourrait attendre de la mise en oeuvre simultanée des réformes prudentielles.

Enfin, nous montrons comment une mise en oeuvre des réformes lente et parfaitement anticipée par les agents permettrait d'éviter les effets récessifs transitoires des réformes prudentielles, l'hypothèse d'anticipations parfaites y jouant un rôle primordial. Outre la capacité du modèle à reproduire certains faits stylisés de l'économie de la zone euro, notre modèle fournit une quantification robuste de ces effets, permettant éventuellement de tester différentes spécifications des reformes en cours et de leurs effets sur l'économie réelle.

Chapter 1

Structural VAR, Rare Events and the transmission of credit risk in the Euro Area

1.1 Introduction

The Great Recession, the global downturn of late 2000, is considered to be an unprecedented severe recession.[1] The crisis originated in the US financial markets in 2007, quickly propagated to the US domestic real activity and soon a worldwide turmoil. The lowest depth in the euro zone was reached at the beginning of 2009, where the drop of GDP growth at quarterly frequencies was three times larger than the average downturns since 1980. The Great Recession was a disproportionate and of high impact event. This statement is largely agreed both among central banks or policy institutions[2] and among academic circles.[3] While there exists an informal agreement on the subject, a formal assessment of this statement is lacking, and it is legitimate to wonder whether normality is a safe assumption in this context.

In this paper, we study whether distributions with thicker tails help to better characterize the European experience and hence whether the Great Recession can be treated as a 'rare event' for the Euro zone as a whole. We then revisit the transmission mechanism of credit risk shocks accounting for the occurrence of unfrequent and non-normal events. Consequently, in our setup structural shocks do not necessary follow a normal distribution but they are allowed to be described as multivariate student-t distributions. To capture the dynamics of the data, we consider a structural VAR where the parameters of the model are recovered using a Gibbs Sampler, extending the Geweke [37]'s work on univariate times series to the multivariate setting. We show that the distribution assumptions

[1]This chapter is based on joint work with Filippo Ferroni

[2]In an interview with Bloomberg Television in 05/26/10 A. Greenspan said "It is very evident to me that the underlying crisis was caused by what is clearly a once-in-a-century event. We have had almost no instances of short-term credit being withdrawn on a global basis the way it happened right after the Lehman bankruptcy. All of the individual evidence here is that this is a very rare occasion."

[3]In a conference Discussing Future of the Global Economy at CERAWeek 2009 K. Rogoff described the late 2000 current recession as "a once in a 50-year event."

about the shock is not only important from a statistical viewpoint, but they also play an important role for structural inference. Economic theory typically provides us with a discipline to recover the structural innovation form the reduced form shock. This discipline involves putting short or long run restrictions (i.e. zeros or signs) on the contemporaneous impact matrix. Such a matrix is identical under the normal and student-t case only if the parameter measuring the degrees of freedom is 'large', that is when the likelihood of rare event is low. With small enough degrees of freedom, the impulse responses of structural shocks depend on the distribution assumptions. We show clearly this point analytically and under controlled simulation experiments. This implies that a formal statement of whether the financial turmoil was a rare event is not only statistically important but also economically meaningful since it can change our conclusions about the propagation mechanism of structural shocks. In particular, much of the current attention is devoted on the measurement and the amplification mechanism of interbank credit risk shocks as a possible source of credit crunch. As a proxy for that, many commentators and policy-makers have been closely monitoring the spread between the rates on unsecured interbank loans (the EURIBORs in the euro area) and their risk-free counterparts, proxied by the Overnight Indexed Swap rate (OIS) [4]. This spread is considered as a crucial indicator at the very core of the financial crisis: it reveals not only banks' concerns regarding the credit risk of their counterparts, but also their own liquidity needs. It can be then thought as a credit risk indicator.

Our study aims at measuring the impact of variations in the credit risk to bank lending rates and volumes and to the real activity (measured ad the rate of unemployment) allowing the importance and the impact of this shock to change over time. We study the propagation mechanism using a VAR under the different distribution assumptions of the structural shocks. To identify credit risk shock we employ a Cholesky recursive ordering where real variables are ordered first and the credit risk is allowed to impact contemporaneously the spread, bank loans volumes and lending rates. In particular, we ask if the transmission channels changes if we allow the credit risk to have unfrequent but stronger impact. And if so, we ask if the the recent recession episode could be considered as a rare unfrequent event.

Our findings suggest that data favors a specification where the distribution of the structural shocks is student-t distributed and the degree of freedom parameter that controls the thickness of the tails of the distribution is estimated to be around 3 or 4. Moreover, we find that the distribution assumptions matter for the empirical response of bank lending rates and loans volumes to an increase in credit risk. In a normal setting an increase in the credit risk induces an immediate (statistically positive) increase in loans followed by subsequent decline and has no contemporaneous impact on bank lending. This set of result is difficult to square with the economic insight of what an increase in credit spread should generate in terms of credit supply and possibly credit crunch. In the student-t setting we are more likely to have a positive response of bank lending rates and negative response of loans. Finally, we contrast the transmission mechanisms pre-2008 under normal and student-t distribution assumptions. We find that there is moderate evidence for non-normality and there are negligible difference in the transmission mechanisms of

[4] See [Gonzales-Paramo]

credit risk shocks. This suggests that the recent recession episodes can be considered as rare events.

In this paper we exploit the fact that a multivariate Student-t can be represented as a mixture of normals scaled by a gamma distribution. To some extent, we allow the volatility of the shocks to be heteroskedastic. However, we do not assume a slow moving process that captures low frequency movement of volatility or changes in the propagation mechanism. Slow moving time variations were appropriately used in the context of the study of the Great Moderation in the US, as in Primiceri [62] or Cogley and Sargent [14], where the available data embraces the postwar period until mid 2000 and low frequency data (quarterly). Focusing on Euro Area data, we face short sample size constraints, making it difficult to use pre-sample information to calibrate the priors of the time varying processes. Moreover, many of these credit risk spread measures all share the same peculiar feature of displaying volatility 'jumps', so that they appear very little volatile in good times and occasionally more volatile in bad times. While such variation in volatility could be modeled with stochastic volatility models, the assumption of thicker tails distributions appears more appealing in this context. These considerations make time variations unpalatable for the European experience. Moreover, while the estimation with time variations entails very densely parameterized structures, with Student-t shocks we are adding an extra degree of freedom relative to the plain vanilla OLS estimation of the VAR, making our set up parsimonious in the dimension of parameter space. Discrete changes in volatility (as in Sims and Zha [72] or Sims et al. [71]) seem more appealing to use in this context. However, we wanted to study what a less parameterized and computationally less intensive framework could tell us about the European experience. While there exists papers exploring the implication of Student-t errors in general equilibrium framework (see Chib and Ramamurthy [12] or Curdia et al. [15]), less evidence is available for the structural VARs. Ni and Sun [58] propose a bayesian VAR model with student-t shocks. However, they do not stress the implications for structural inference nor they bring the student-t errors VAR to the actual data.

This paper is organized as follows. Section 2 presents the econometric framework. In Section 3 we show the consequences of distribution assumptions for structural analysis. Section 4 studies the transmission mechanism of credit risk shock in the Euro Area using the VAR with thick tails. Section 5 concludes.

1.2 Econometric framework

This section extends the work of Geweke [37] to a vector of autoregressions. Let y_t be a $N \times 1$ vector of time series for $t = 1, ..., T$ and let

$$y_t = \beta_0 + \beta_1 y_{t-1} + \cdots + \beta_m y_{t-m} + \varepsilon_t \tag{1.1}$$

We assume that the error term is independent and identically Student-t distributed, that is $\varepsilon_t \sim MT(0, \Sigma, n)$ where MT stands for a multivariate t-student distribution, Σ is a $N \times N$ symmetric positive semi-definite scaling matrix and n represents the degrees of freedom (see appendix for details on the distributions). For exposition purposes we rewrite

(1.1) stacking the lags, i.e.

$$\begin{aligned} y_t &= x_t B + \varepsilon_t \\ \varepsilon_t &\sim MT(0, \Sigma, n) \end{aligned} \tag{1.2}$$

where $x_t = (1, y'_{t-1}, \ldots, y'_{t-m})$ is a $k \times 1$ vector where $k = mN + 1$ and B is a suitable $N \times k$ matrix. The likelihood of y^T is given by

$$L(y^T|x^T; B, \Sigma, n) = c^T |\Sigma|^{-T/2} \prod_{t=1}^{T} \left\{1 + \frac{1}{n}(y_t - Bx_t)'\Sigma^{-1}(y_t - Bx_t)\right\}^{-\frac{N+n}{2}} \tag{1.3}$$

where $c = (n\pi)^{-N/2} \frac{\Gamma((n+N)/2)}{\Gamma(n/2)}$.

Consider now the following system :

$$\begin{aligned} y_t &= x_t B + \eta_t \\ \eta_t &\sim MN(0, \omega_t^{-1}\Sigma) \\ \omega_t &\sim \Gamma(a, b) \end{aligned} \tag{1.4}$$

where $\{\eta_t\}_{t=1}^T$ follow independent multivariate normal distributions, i.e. $\eta_t \sim MN(0, \Sigma)$ and MN stands for a multivariate normal distribution, Σ is the $N \times N$ variance covariance matrix, and $\{\omega_t\}_{t=1}^T$ are independent identically distributed random variables with a Gamma distribution pdf, i.e. $\omega_t \sim \Gamma(a, b)$.
Conditional on ω^T The likelihood of y^T is

$$L(y^T|x^T, \omega^T; B, \Sigma, n) = (2\pi)^{-Tp/2} |\Sigma|^{-T/2} \prod_{t=1}^{T} \omega_t^{1/2} \exp\left\{-\frac{1}{2}(y_t - Bx_t)'\Sigma^{-1}(y_t - Bx_t)\omega_t\right\} \tag{1.5}$$

It can be shown that (1.3) is equal to (1.5) with $a = \frac{n}{2}$ and $b = \frac{2}{n}$ (see appendix A).

Let $p(B, \Sigma, n) = p(B, \Sigma)p(n)$ be the priors for the coefficients and the scaling matrix and the degrees of freedom, the posterior distribution of B and Σ conditional on n is given by

$$\begin{aligned} p(B, \Sigma, n|y^T, x^T) &\propto p(B, \Sigma) \times L(y^T|x^T; B, \Sigma, n) \\ &\propto \int_{\omega^T > 0} p(B, \Sigma) \times L(y^T|x^T, \omega^T; B, \Sigma, n) \times p(\omega^T|n) \times p(n)\ d\omega^T \end{aligned}$$

The full analytical posterior distribution is quite intractable. However, conditional on knowing blocks of parameters the conditional distributions are of known forms [5], i.e.

- Conditional on n, B and Σ,

$$\omega_t \mid (y^T, x^T; B, \Sigma, n) \sim \Gamma\left(\frac{N+n}{2}, \frac{2}{\psi_t + n}\right)$$

  where Γ stands for the gamma distribution and $\psi_t = (y_t - Bx_t)'\Sigma^{-1}(y_t - Bx_t)$.

[5] See the appendix C for details using a Jeffreys uninformative prior and conjugate Gaussian-Inverse Wishart distributions.

- Conditional on n, B and $\Omega = diag(\omega_1, ..., \omega_T)$,

$$\Sigma \mid (y^T, x^T; \Omega, B, n) \sim IW(S, \nu)$$

where IW stands for the inverse Wishart, S is the matrix of the residual sum of the squares and ν are the degrees of freedom which are equal to T for flat priors.

- Conditional on B, Σ and Ω,

$$B \mid (y^T, x^T; \Omega, \Sigma, n) \sim MN(\widehat{B}, \Sigma_B)$$

where $\widehat{B}$ is the OLS estimator reweighted by the draws form the Gamma distribution and adjusted by the priors assumption distribution and Σ_B is the corresponding covariance matrix.

- Conditional on Ω, B and Σ, the posterior of n does not follow a non standard distribution, but is a log concave function. Hence, the adaptive rejection sampling algorithms proposed by Gilks (1992)[6] can be implemented and allows us to sample from it.

A Gibbs sampler can be implemented starting from the OLS estimates of B_{ols} and S_{ols}. In the next section, we show that accounting for fat tails does not only matter for statistical inference but it also plays a role for structural inference. We show this point first using simulated data and then with actual data for the euro area.

1.3 Structural inference with thick tails Distributions

In VAR analysis, it is customary to decompose the original VAR shocks into a set of uncorrelated components, called innovations, and compute the consequences for the observables of a unit impulse in the innovations. Economic theory and hence structural inference enter typically in the way we orthogonalize the original shocks. More precisely, assume that

$$\eta_t = Au_t$$

where η_t and u_t are normal i.i.d. vectors with variance covariance matrix Σ and identity matrix, respectively. We have that

$$Q_\eta \equiv E(\eta_t \eta_t') = \Sigma$$

It follows from the assumptions that $Q_\eta = AA'$. Absent any further assumptions there exists multiple factorizations of the matrix Q_η since for any non singular orthogonal matrix P, we have

$$\Sigma = APP'A'$$

Economic theory provides us with a discipline to pin down the matrix P. Popular ways to recover the impact matrix are the Cholesky decomposition, sign restrictions (see Canova

[6]For our exercices, we actually use the approach proposed by Robert and Casella (2004).

and de Nicolo [9] or Uhlig [74] among others) or long run restrictions (see Blanchard and Quah [7], Galí [31] among others). For the remainder of this section, we consider only Cholesky factorization, but the conclusions apply to any type of restrictions.

While in the normal case we retrieve orthogonal innovations using the covariance matrix of the shocks, Q_ε, with Student-t distributed errors we orthogonalize the shocks with the scaling matrix[7]

$$\varepsilon_t = A\iota_t$$

where ε_t and ι_t are normal t-student vectors with n degrees of freedom and scaling matrix Σ and I respectively, i.e. $\varepsilon_t \sim MT(0, \Sigma, n)$ and $\iota_t \sim MT(0, I, n)$, and $\Sigma = A'A$. It is important to notice that for $n > 2$ the scaling matrix is proportional to the covariance matrix, i.e.

$$Q_\varepsilon = E(\varepsilon_t \varepsilon_t') = \frac{n}{n-2}\Sigma$$

In the limit, $n \to \infty$, the scaling matrix coincides with covariance matrix. However, for finite degrees of freedom, the two matrices are different. Non normal distribution assumptions (as long as shocks have finite variance) do not corrupt the estimate of Q_ε using classical or bayesian methods[8]. However, with student-t shocks we need an estimate of the scaling matrix in order to recover the orthogonalized shocks and hence distribution assumptions are crucial for structural inference.

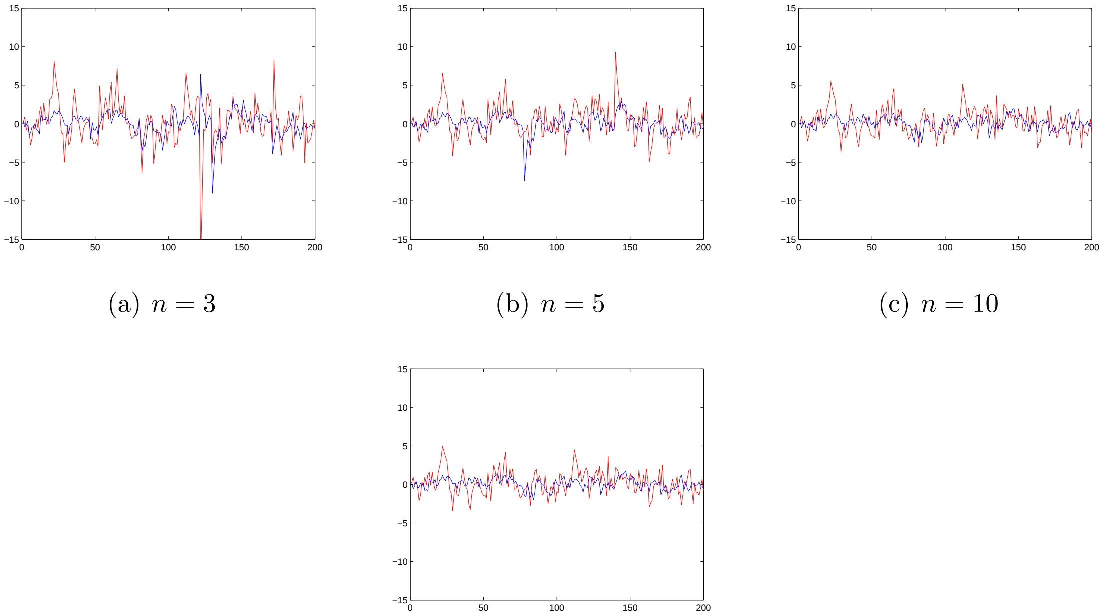
The next subsection tries to provide insights on how many degrees of freedom make the structural inference with fat tails important. While we focus the analysis on the impulse response function, the conclusions apply to different types of structural inference, such as variance or historical decomposition.

1.3.1 Impulse responses in a controlled experiment

We have generated data from a bivariate VAR(1) where $\beta_0 = (0.1, 0.1)$ and $\beta_1 = \begin{pmatrix} 0.6 & 0.1 \\ 0.05 & 0.6 \end{pmatrix}$. The structural matrix is given by $A = \begin{pmatrix} 1.2 & 0.2 \\ 0 & 0.5 \end{pmatrix}$. We simulate data using different degrees of freedom, such as $n = 3, 5, 10, 30$. Figure 1.1 reports 200 data point simulations with the same random generator seeds generated by a student-t with 3, 5, 10 and 30 degrees of freedom in red and by a normal distribution in blue. Both the overall amplitude of fluctuations and the single peaks and trough depend on the magnitude of parameter measuring the degrees of freedom. With three degrees of freedom, the smallest integer value that guarantees a finite variance of the errors, the fluctuations are more pronounced and within two hundreds of observations it is possible to observe a 'rare event', meaning an observation which appears to deviate markedly form the other members of the sample in which it occurs. For larger values of the degrees of freedom, the overall volatility diminishes as well as the occurrence of rare events. Finally, as the value of the degrees of freedom increases the difference between a student-t and normal process

[7] See the appendix for details.

[8] See Chapter 8 of Hamilton [43] for a tractation in terms of consistency and bias from a classical perspective



(a) $n = 3$ (b) $n = 5$ (c) $n = 10$

(d) $n = 30$

Figure 1.1: Data generated from a bivariate VAR(1) by with a t-student with different degrees of freedom

vanishes. To what extent accounting for infrequently large events affects our structural inference is the focus of this section.

Table 1.1 reports the mean estimates of the impact matrix A under the normality and t-student distribution assumptions. While with 100 degrees of freedom the difference between normality and non-normality assumption is undistinguishable, the magnitude of the bias is important for degrees of freedom smaller then 10. If with small enough degree of freedom the impact matrix is estimated differently with normal and non-normal shock, it is then possible that our structural inference with the wrong assumption about the distribution of the innovation can dramatically change.

A	n=3	n=5	n=10	n=30	true
normal VAR	$\begin{pmatrix} 2.57 & 0.03 \\ 0 & 1.19 \end{pmatrix}$	$\begin{pmatrix} 1.79 & 0.24 \\ 0 & 0.77 \end{pmatrix}$	$\begin{pmatrix} 1.43 & 0.14 \\ 0 & 0.58 \end{pmatrix}$	$\begin{pmatrix} 1.32 & 0.11 \\ 0 & 0.52 \end{pmatrix}$	$\begin{pmatrix} 1.2 & 0.2 \\ 0 & 0.5 \end{pmatrix}$
Student-t VAR	$\begin{pmatrix} 1.41 & 0.13 \\ 0 & 0.54 \end{pmatrix}$	$\begin{pmatrix} 1.42 & 0.16 \\ 0 & 0.53 \end{pmatrix}$	$\begin{pmatrix} 1.32 & 0.12 \\ 0 & 0.52 \end{pmatrix}$	$\begin{pmatrix} 1.28 & 0.11 \\ 0 & 0.50 \end{pmatrix}$	$\begin{pmatrix} 1.2 & 0.2 \\ 0 & 0.5 \end{pmatrix}$
Student-t VAR(unknown dF)	$\begin{pmatrix} 1.38 & 0.12 \\ 0 & 0.52 \end{pmatrix}$	$\begin{pmatrix} 1.44 & 0.16 \\ 0 & 0.53 \end{pmatrix}$	$\begin{pmatrix} 1.35 & 0.12 \\ 0 & 0.53 \end{pmatrix}$	$\begin{pmatrix} 1.28 & 0.11 \\ 0 & 0.50 \end{pmatrix}$	$\begin{pmatrix} 1.2 & 0.2 \\ 0 & 0.5 \end{pmatrix}$

Table 1.1: Mean posterior estimates of the impact matrix A under different degrees of freedom.

In Figure 1.2 we report the 95% credible sets of the impulse responses under normality or student-t distribution and the true impulse response generated by a VAR(1) with a

Student-t with 3 degrees of freedom. The impulse response obtained under normality assumptions are different from the true transmission mechanism. In particular, we obtain that the impact of of the first (second) variable to the first (second) shock are typically overestimated and it does not include the true impulse response. This is somehow intuitive if we think that the degree of freedom is going to scale up the impact matrix A by a factor of $n/n-2$; hence, the smaller the degree of freedom the larger the distortion. However, not only our inference on the elements on the main diagonal is distorted, but also the impact on the off-diagonal elements can be poorly estimated. In fact, while the response of the first variable to the second shock is estimated to be zero in the normal setting, the true response is positive and the student-t framework captures this fact by having the 95% of positive trajectories. Finally, bands are typically much larger implying a non-negligible loss in efficiency. All in all, the non-normality distribution assumption of orthogonal innovations has important implications in terms of transmission mechanism and precision, and neglecting it might result in uncorrect inference. This bias vanishes as

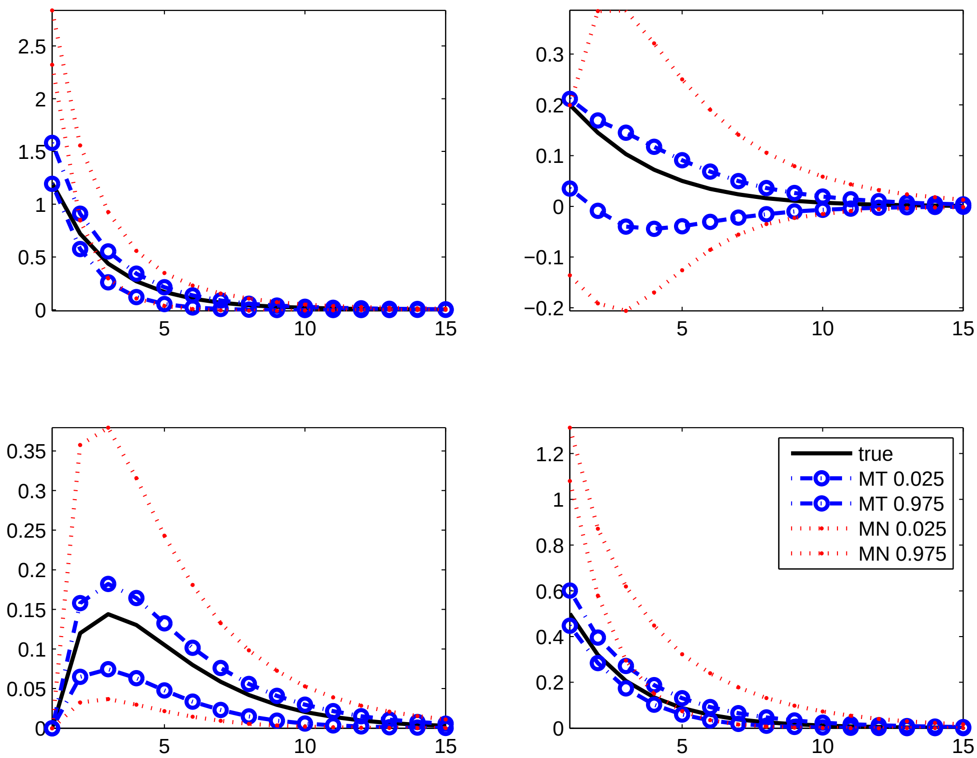


Figure 1.2: Impulse response of a VAR(1) with 3 degrees of freedom. In black the true response, in blue circles the 95% credible set of Multivariate Student-T VAR, and in red dots the 95% credible set of the normal VAR

the degree of freedom increases. In our controlled experiment, we find that with already ten degrees of freedom the difference between the two settings is not significant. In figure 1.3 we report the 95% credible sets of the impulse responses under normality or student-t distribution and the true impulse response generated by a VAR(1) with a Student-t with 3 degrees of freedom. The confidence sets obtained under the normality and non normality assumptions are almost indistinguishable.

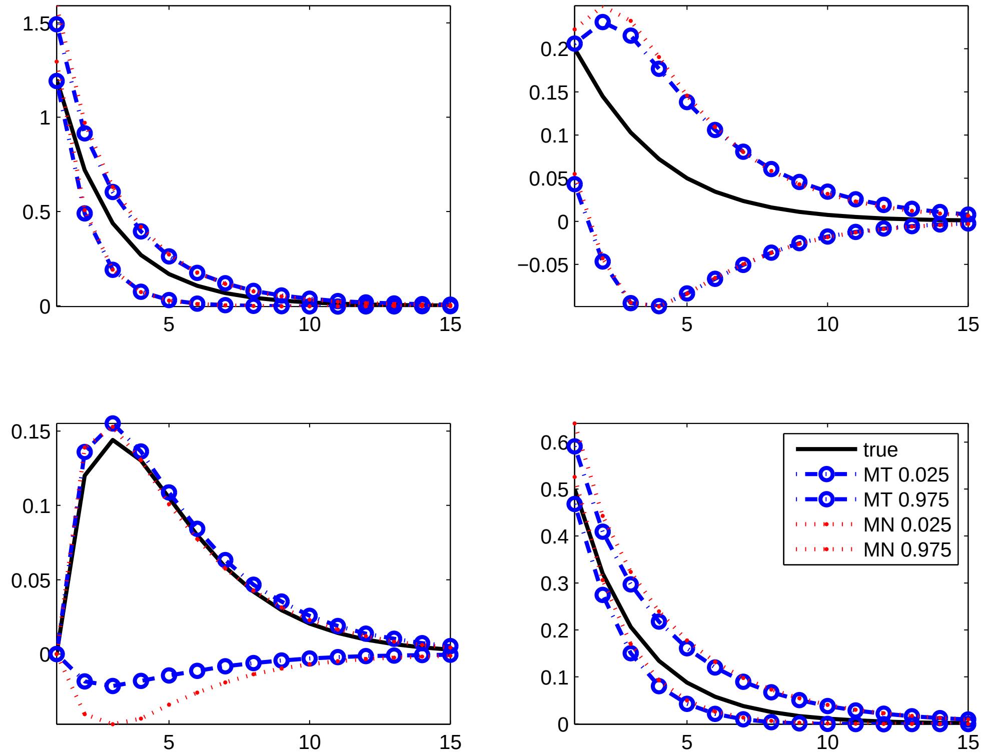


Figure 1.3: Impulse response of a VAR(1) with 10 degrees of freedom. In black the true response, in blue circles the 95% credible set of Multivariate Student-T VAR, and in red dots the 95% credible set of the normal VAR

It is legitimate to wonder how many degrees of freedom one should use in practical applications. Besides imposing a prior on the degrees of freedom parameter, one could treat the degree of freedom as an hyperparameter and compute the marginal likelihood for different values of n. Assuming proper priors, one could use the output of the Gibbs Sampler and approximate the marginal likelihood of the data using the quantity proposed by Gelfand and Dey [33], i.e.

$$\widehat{m} = \left\{ \frac{1}{G} \sum_{g=1}^{G} \left(\frac{p(\vartheta^{(g)})}{p(y^T|\vartheta^{(g)}, n)p(\vartheta^{(g)}, n)} \right) \right\}^{-1}$$

where $\vartheta^{(g)} = [B^{(g)}, \Sigma^{(g)}]$ is a draw from the posterior density and $p(\vartheta^{(g)})$ is a distribution with thin tails. Alternatively, one could compute the integrating constant of the full conditional distributions in the Gibbs sampler and use the quantity proposed by Chib [11]. Table 1.2 presents the results in terms of the marginal likelihoods of different estimation settings. A loose but proper priors for B, Σ was imposed; in particular, we postulated a normal-inverse Wishart distributions centered on the OLS estimators for the parameters.[9] We analyze both the case of known as well as unknown degrees of freedom. According to Table 1.2 figures, the use of the normality of innovations hypothesis can involve a relatively large loss of information, the the more frequently 'rare events' take place, the

[9]Similar results are obtained with Jeffreys priors.

estimated/true n	3	5	10	30	unknown n	Normal
3	-660	-666	-585	$-\infty$	-658 (2.7)	$-\infty$
5	-596	-591	-596	-609	-595 (5.5)	-636
10	-543	-534	-531	-530	-532 (13.0)	-533
30	-514	-502	-498	-495	-496 (30.7)	-495

Table 1.2: Log Marginal Likelihoods

higher is this loss. Indeed, we note that the marginal likelihood relative to a normality assumption is much lower than the non-normal assumption, the difference being inversely proportional to the true degree of freedom. As noted already, with a degree of freedom larger than 10, the difference between normality and non-normality assumptions results becomes undistinguishable. Furthermore, we also note that we are able to recover the underlying degree of freedom with mild accuracy.

1.4 Transmission of credit risk in Euro Area

The recent recession episodes in Europe have been characterized by large swings in loan fluctuations both in terms of interest rates and in terms of volumes, and the economists largely agree that such fluctuations had significant amplification mechanism to the real economy. To better understand the recent economic turmoil it is then important to correctly identify the impact of changes in the credit/lending conditions and measure their dynamic transmission to loan volumes and interest rates and on the real economy. Since the onset of the financial crisis, many economic commentators and policy-makers have been closely monitoring the interbank indicators, measured typically as the difference between some reference risk-free rate and a measure of lending rate. In this paper, we focus on the difference between the rates on unsecured interbank loans (EURIBOR) and the Overnight Indexed Swap rate (OIS). While many measure of credit risk spread can be constructed and considered, many of these measures all share the same peculiar feature of displaying volatility 'jumps', so that they appear not very volatile in good times and occasionally more volatile in bad times. Such variation in volatility could be modeled with stochastic volatility models, as in Primiceri [62] or Cogley and Sargent [14]. However, with short sample (the data span covers the first decade of 2000s) and high frequency data (monthly) slow moving time variations are difficult to capture. Moreover, even if slow moving time varying volatility process are technically implementable, the assumption of thicker tails distributions appears more appealing in this context.

Our study aims at measuring the impact and propagation mechanism of innovations to the credit risk on bank lending rates, bank lending volumes and the real activity (measured as the rate of unemployment) under the different distribution assumptions of the structural shocks. In particular, we ask whether the transmission channels changes if we allow the credit risk to have unfrequent but stronger impact over time. And if so, we ask if the recent European experience could be better characterized by a normal process or by a process with events rare but of larger magnitude.

1.4.1 Data specification and Identification structure

We consider monthly data form 2003:m2 until 2013:m4 at the Euro Area aggreagation level. Our information set includes changes in seasonally adjusted unemployment rate, bank lending rates and the growth rate of loan volumes. We define the measure of the credit spread as the difference between the EURIBOR and the Overnight Indexed Swap. The Euro Interbank Offered Rate (EURIBOR) provides a measure of the interest rate at which banks can raise unsecured funds from other financial institutions. The EURIBOR is the interest for unsecured interbank loans, i.e. the lending bank does not receive collateral as protection against default by the borrowing bank. Hence, these rates carry some compensation for solvency risks that might arise in bad states. The OIS is a fixed-for-floating interest rate swap with a floating rate leg indexed on overnight interbank rates, the EONIA in the euro-area case. OIS have become especially popular hedging and positioning vehicles in euro financial markets and grew significantly in importance during the financial turmoil of the last few years. The OIS curve is more and more seen by market participants as a proxy of the risk-free interbank yield curve (see e.g. Joyce, Lasaosa, Stevens, and Tong (2011)). As no principal is exchanged, the OIS requires nearly no immobilization of capital. This spread is considered as an important indicator as it reveals banks' concerns regarding the credit risk of their counterparts and their own liquidity needs. In general, it proxy the credit and liquidity risk of the banking system.

Times series are plotted in figure 1.4 with grey area representing the CEPR recessions episodes[10]. From top left to bottom right we have first differences in the unemployment rate as well as in the EURIBOR, the credit risk spread and changes in bank lending rates when the last graph represent the yoy growth rate of the real bank loans to the private sector[11] which is almost I(0).[12]

Visual inspection of the data suggests that times series are embedded with occasional volatility jumps and not surprisingly they tend to coincide with recession periods.

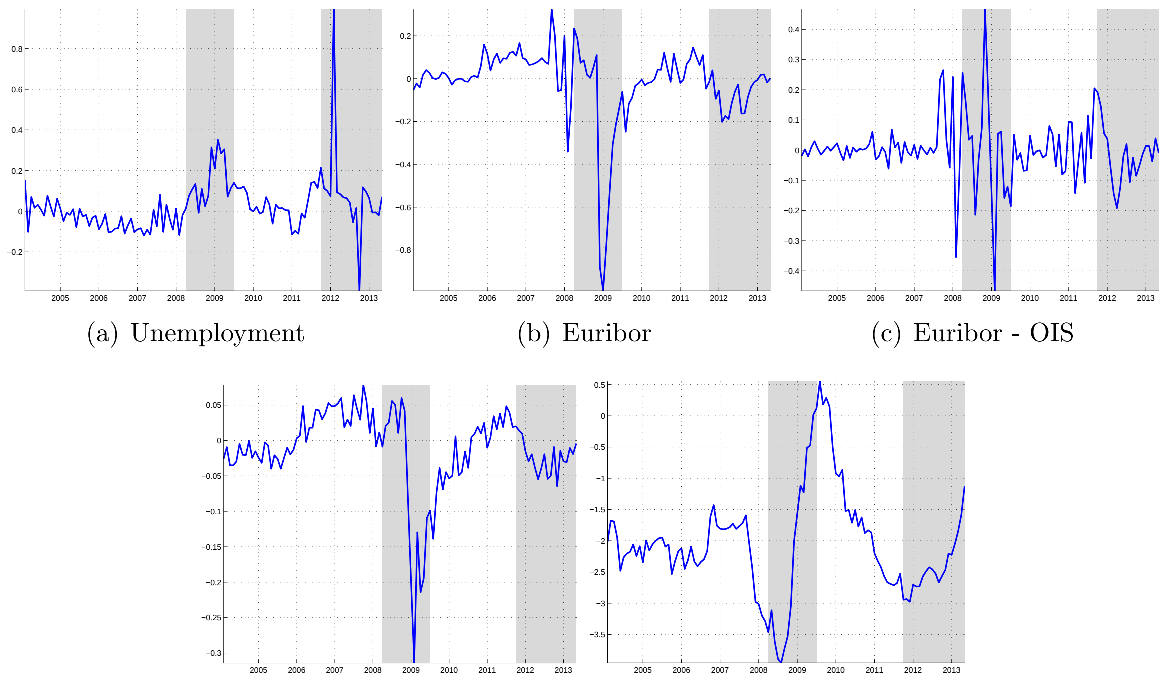
We identify credit risk shock on the basis of a Cholesky recursive ordering, which assumes a recursive exogeneity structure. We place unemployment first in the ordering of the variables, followed by inflation and interest rates. This initial sequence is fairly

[10]The Committee met in Paris on 9 October 2013. The decision of the Committee to convene was prompted by positive news stemming from a variety of sources (the European Commission, statistical agencies, forecasting institutions, international organizations, NowCasting.com) about economic activity in the euro area. The objective of this meeting was to determine whether there was enough evidence that the decline in economic activity that started after third quarter of 2011 had ended. The Committee decided that, while it is possible that the recession ended, neither the length nor the strength of the recovery is sufficient, as of 9 October 2013, to declare that the euro area has come out of recession.

[11]This refers to the credit growth indicator suggested by Biggs et al. [6].

[12]Both ADF and KPSS tests indicate that all the variables except the yoy growth rate of the real bank loans to the private sector are non stationary in level and stationary in first difference.

standard in the literature going back to Christiano et al. (1999). The financial variables are placed lower in the ordering. Assenmacher-Wesche and Gerlach (2008) argue that they should follow interest rates because monetary policy only reacts to asset price movements if these are prolonged, while asset prices react immediately to changes in monetary policy. We place the leverage indicators last among the financial variables as do Adalid and Detken (2007), Goodhart and Hofmann (2008) and Musso, Neri and Stracca (2010). They argue that this implies a conservative approach to the endogeneity of money and credit growth, allowing these variables to react contemporaneously to shocks in all the other endogenous variables. Hence, the ordering of the variables in the VAR is unemployment, EURIBOR, the credit risk spread, bank lending rates and the loans growth rate. We set the lag length to 1 [13] and assume Minnesota priors on the coefficients of the VAR favoring an a-priori unit root process for individual series.[14] We use for each estimation 100000 simulations for the Gibbs sampler.



(a) Unemployment (b) Euribor (c) Euribor - OIS

(d) BLR (e) Loans

Figure 1.4: Euro Area data. Grey shaded area CEPR recession periods

[13]The choice of the number of lags is based on Hannan-Quinn (1979) and Schwarz (1978) information criteria.

[14]Following Canova (2007) pag 358, we set $\phi_0 = 0.2$, $\phi_1 = 0.5$, $\phi_2 = 10^5$ and $\phi_3 = 2$. Else one could treat them as hyper-parameters and estimate them as in Giannone, Lenza and Primiceri (2012)

1.4.2 Empirical Results

We estimate the VAR model with normality and student-t assumption with different degree of freedom. The result in terms of in-sample-fit are reported in table 1.3. The table reports the marginal likelihood of the multivariate normal and student-t with different known and unknown degrees of freedom using different estimators of the marginal likelihood as proposed in Gelfand and Dey (1994), Geweke(1996) and Newton (1992).

n	Gelfand and Dey (1994)	Geweke(1996)	Newton (1992)
3	264.4	260.4	357.8
4	287.0	261.4	312.6
5	257.8	253.8	343.8
6	279.1	215.9	323.2
7	206.3	202.3	303.7
8	261.3	239.8	309.8
9	234.3	230.3	322.9
12	234.4	186.2	311.1
15	236.5	204.1	321.8
18	213.1	178.9	297.7
20	217.2	172.5	287.2
25	179.9	175.9	287.6
30	211.8	199.7	296.4
unknown dF (3.5)	251.1	235.2	367.8
Normal	148.3	108.7	183.8

Table 1.3: The log marginal likelihood of the multivariate normal and student-t using Gelfand and Dey, Geweke and Newton estimators - Full sample

Table 1.3 indicates that data favors a specification with non-normal distributed errors regardless of the specification. Moreover, it seems that the three estimators of the marginal likelihood point at similar values of the degrees of freedom and suggest that data are best described with 3/4 degrees of freedom. Same conclusions can be reached in the setting where the degree of freedom is treated as an unknown estimated parameters. Interestingly, the estimated degree of freedom for the Euro Area is smaller than the one found by Curdia et al. [15] for US data which is around six. However, there are important differences that might explain this difference. They use quarterly data and they employ a different structure, a dynamics stochastic general equilibrium model.

Given this sharp clear cut between the normal and student-t setting, we expect to draw different conclusions in terms of transmission mechanism of credit risk shocks. Figure 1.5

reports the 68% bands of the two structures, the multivariate normal (red dotted) and the multivariate student-t (blue dash dotted). While the impact of credit risk shocks on

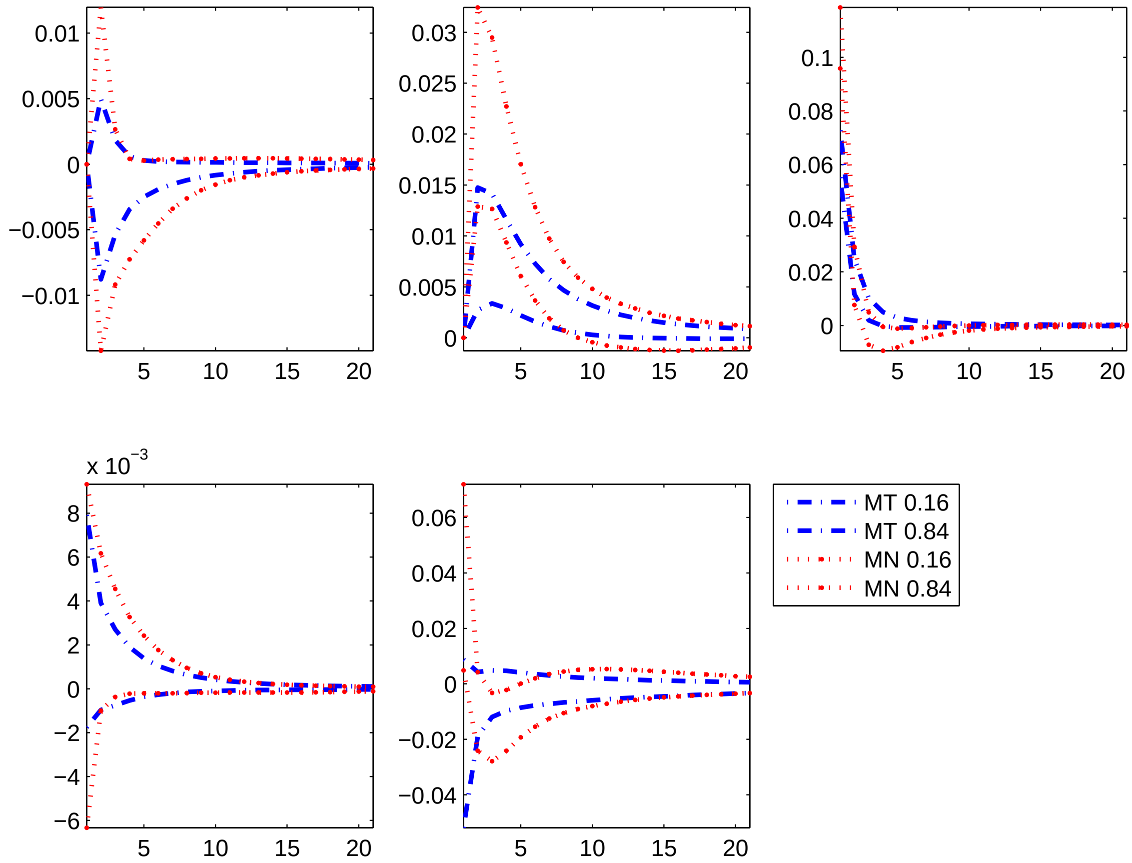


Figure 1.5: Impulse responses 68% bands to a credit risk shock. From top left to bottom right, unemployment, EURIBOR, credit risk spread, bank lending rates and loans

unemployment is similar under the two settings, the responses of the other variables is distinct for each distribution assumptions. Following a credit risk shock EURIBOR increases in both settings however the magnitude is different. More importantly, the response of bank lending rates and loans volumes are statistically and economically different. In a normal setting an increase in the credit risk induces an immediate (statistically positive) increase in loans followed by subsequent decline and has no contemporaneous impact on bank lending. This set of result is difficult to square with the economic insight of what a increase in credit spread should generate. In the student-t setting we are more likely to have a positive response of bank lending rates and a negative response of loans. It is interesting also to see how the last financial crisis contribute to the transmission of interbank credit risk. For this purpose, we estimate the same model than previously up to 2007m5 in order to exclude potential information about the subprime crisis. Table 1.4 reports the marginal likelihood of the multivariate normal and student-t specifications.

We note that even if the marginal likelihood criteria still are in favor of non-normality specification, the difference with student-t model recedes dramatically comparing to what got previously taking into account the last recession period. The estimated degree of

n	Gelfand and Dey (1994)	Geweke(1996)	Newton (1992)
3	13.5	9.5	71.0
4	17.7	13.7	65.5
5	30.6	26.7	77.9
6	31.5	27.5	55.1
7	-2.6	-6.6	57.1
8	35.6	31.6	62.8
9	-9.8	-13.8	65.3
12	17.8	13.8	56.5
15	24.9	19.1	39.5
18	15.4	11.4	44.4
20	18.0	14.0	53.7
25	-0.8	-4.8	31.4
30	18.1	7.4	49.1
unknown dF (6.8)	8.2	4.2	61.5
Normal	13.6	9.6	39

Table 1.4: The log marginal likelihood of the multivariate normal and student-t using Gelfand and Dey, Geweke and Newton estimators - pre 2007m5 sample

freedom parameter that controls the thickness of the tails of the student-t distribution moves from 3/4 with the post crisis estimation to 5/7 in the pre subprime period. This indicates that the last recession periods contributed in a consistent manner in the change of behavior to non-normality for main variables. We come to the same conclusion when we look at the transmission mechanism of credit risk shocks excluding the recession episodes. Figure 1.6 reports the 68% bands of the two structures, the multivariate normal (red dotted) and the multivariate student-t (blue dash dotted). If we exclude the recession period we obtain a more similar patter of impulse responses under the two settings, in the normal and student-t shocks. Signs are similar and bands tend to overlap. This suggests that the recession episodes contribute significantly to change the transmission mechanism of credit risk shocks and they can be consistently identified as rare event episodes.

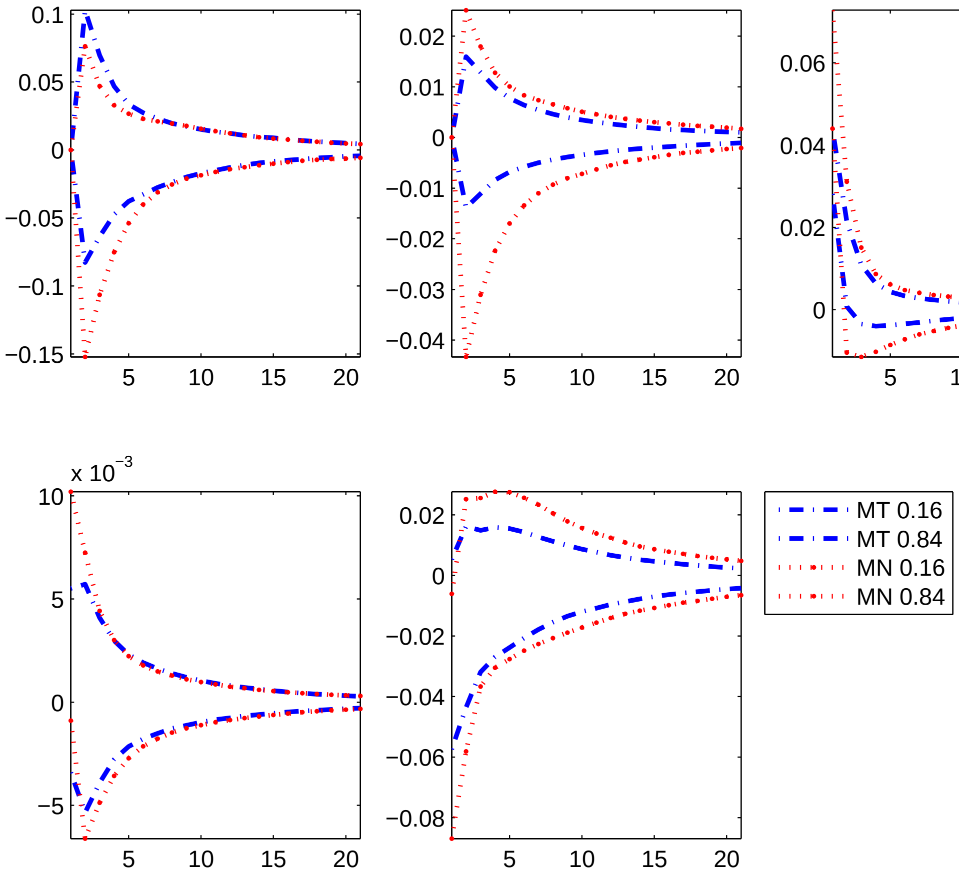


Figure 1.6: Impulse responses 68% bands to a credit risk shock using data up to 2007m5. From top left to bottom right, unemployment, EURIBOR, credit risk spread, bank lending rates and loans

1.5 Conclusion

The last recessionary episodes in the Euro Area confronted us with the idea that not all the recessions are alike and some might be 'non-normal' downturn. We formally test this hypothesis by studying whether shock distributions with thicker tails help to better characterize the European experience. We revisit the impact of variations in the credit risk to bank lending rates and volumes and to the real activity (measured ad the rate of unemployment) allowing the importance and the impact of this shock to change over time. We study the propagation mechanism using a VAR under the different distribution assumptions of the structural shocks. To identify interbank credit risk shocks we employ a Cholesky recursive ordering where real variables are ordered first and the credit risk is allowed to impact contemporaneously the spread, loans volumes and rates. In particular, we ask whether the transmission channels changes if we allow the credit risk to have unfrequent but stronger impact. And if so, we ask if the the recent recession episode could be considered as a rare and unfrequent event.

Our findings suggest that data favors a specification where the distribution of the structural shocks is student-t distributed and the degree of freedom parameter that controls the thickness of the tails of the distribution is estimated to be around 3 and 4. Moreover, we find that the distribution assumptions matter for the empirical response of bank lending rates and loans volumes to an increase in credit risk. In a normal setting an increase in the credit risk induces an immediate (statistically positive) increase in loans followed by subsequent decline and has no contemporaneous impact on bank lending. This set of result is difficult to square with the economic insight of what a increase in credit spread should generate. In the student-t setting we are more likely to have a positive response of bank lending rates and negative response of loans. Finally, we contrast the transmission mechanisms pre-2008 under normal and student-t distribution assumptions. We find that pre-2008 there is little evidence for non-normality and there are negligible difference in the transmission mechanisms of credit risk shocks. This suggests that the recent recession episodes can be considered as rare events.

There are a number of ways in which our analysis can be extended. While in this paper we focus on recursive Cholesky identification, it is possible to bridge this framework to sign restrictions or long run identification schemes. The study of the implication of distribution assumptions can be analyzed in the context of data rich environments and study the distribution of the lower data dimension fundamental factors driving the economy.

Appendices

A Distributions

In this section we provide the analytical form of the distributions used in the paper.

- The random $N \times 1$ vector, x, follows a Multivariate T-Student if: $x \sim MT(\mu, \Sigma, n)$

$$f(x; \mu, \Sigma, n) = c|\Sigma|^{-\frac{1}{2}} \left\{1 + \frac{1}{n}(x-\mu)'\Sigma^{-1}(x-\mu)\right\}^{-\frac{n+N}{2}}$$

where $c = (n\pi)^{-\frac{N}{2}} \frac{\Gamma((n+N)/2)}{\Gamma(n/2)}$

- The random $N \times 1$ vector, x, follows a Multivariate Normal if: $x \sim MN(\mu, \Sigma)$

$$f(x; \mu, \Sigma, n) = (2\pi)^{-\frac{N}{2}} |\Sigma|^{-\frac{1}{2}} \exp\left\{-\frac{1}{2}(x-\mu)'\Sigma(x-\mu)\right\}$$

- The random variables, x, follows Gamma Distribution if: $x \sim \Gamma(k, \theta)$

$$f(x; k, \theta) = \frac{(1/\theta)^k}{\Gamma(k)} x^{k-1} \exp\{-1/\theta\ x\}$$

- The random $N \times N$ matrix, W, follows an Inverse Wishart Distribution if: $S \sim IW(\Psi, d)$

$$f(W; \Psi, d) = c|W|^{-\frac{d+N+1}{2}} |\Psi|^{\frac{d}{2}} \exp\left\{-\frac{1}{2}\operatorname{Tr}(W^{-1}\Psi)\right\}$$

where $c = (2)^{-\frac{dp}{2}}/\Gamma(d/2)$

B Miscellanea

Proposition 1. *The system in* (1.2) *is equal to* (1.4) *under assumption* $a = \frac{n}{2}$ *and* $b = 2/n$.

Proof. Let $\omega_t \sim \Gamma(a, b)$ so that

$$p(\omega^T) = \prod_{t=1}^{T} \frac{\omega_t^{a-1} \exp^{-\omega_t/b}}{\Gamma(a) b^a}$$

$$L(y^T | x^T; B, \Sigma, n) = \int_{\omega^T > 0} L(y^T | x^T, \omega^T; B, \Sigma, n) p(\omega^T | n) d\omega^T$$

$$= \int_{w_t} (2\pi)^{-NT/2} |\Sigma|^{-T/2} \prod_{t=1}^{T} \omega_t^{N/2} \exp\left\{-\frac{\omega_t}{2} \underbrace{(Y-BX)'\Sigma^{-1}(Y-BX)}_{\Psi}\right\} \times \prod_{t=1}^{T} \frac{\omega_t^{a-1} \exp^{-\omega_t/b}}{\Gamma(a) b^a} d\omega_t$$

Let $k = a + \frac{N}{2}$ and $\theta = \frac{1}{\frac{1}{b}+\frac{\Psi}{2}}$ so that

$$=(2\pi)^{-NT/2}|\Sigma|^{-T/2}\left[\frac{\Gamma\left(1+\frac{N}{2}\right)}{\Gamma\left(a\right)b^{a}}\right]^{T}\prod_{t=1}^{T}\left[\frac{1}{b}+\frac{\Psi}{2}\right]^{-(a+N/2)}\underbrace{\int_{w_t}\underbrace{\frac{w_t^{k-1}\exp-\frac{w_t}{\theta}}{\Gamma(k)\theta^{k}}}_{\Longleftrightarrow w_t\sim\Gamma(k,\theta)}d\omega_t}_{=1}$$

notice that the last term is equal to one since it is the integral the Gamma pdf distribution with parameters k and θ.

$$\begin{aligned}
=&(2\pi)^{-NT/2}|\Sigma|^{-T/2}\left[\frac{\Gamma\left(a+\frac{N}{2}\right)}{\Gamma\left(a\right)b^{a}}\right]^{T}\prod_{t=1}^{T}\left[\frac{1}{b}+\frac{\Psi}{2}\right]^{-(a+N/2)}\\
=&(2\pi)^{-NT/2}|\Sigma|^{-T/2}\left[\frac{\Gamma\left(a+\frac{N}{2}\right)}{\Gamma\left(a\right)}\right]^{T}\prod_{t=1}^{T}\left[b^{\frac{a}{a+\frac{p}{2}}-1}+\frac{b^{\frac{a}{a+\frac{p}{2}}}}{2}\Psi\right]^{-(a+N/2)}
\end{aligned}$$

By factorizing with $b^{\frac{a}{a+\frac{p}{2}}-1}$ and using the term in the Gamma function, we can easily show that the last formula is identical to (1.3) when $a = \frac{n}{2}$ and $b = \frac{2}{n}$. □

Proposition 2. *Let ε be a $N\times 1$ random vector and let $\varepsilon \sim MT(\mu,\Sigma,n)$. Then*

$$\varepsilon = \mu + A\ \iota$$

where $\iota \sim MT(0, I, n)$ and A is a $N \times N$ invertible matrix such that $A'A = \Sigma$

Proof.

$$\begin{aligned}
f_x(x) =&\frac{1}{|A|}f_\iota(A^{-1}(x-\mu)) =\\
=&c\frac{1}{|A^{\frac{1}{2}}A^{\frac{1}{2}}|}\left[1+\frac{1}{n}(A^{-1}(x-\mu))'A^{-1}(x-\mu)\right]^{-\frac{n+N}{2}}\\
=&c\frac{1}{|A'A|^{\frac{1}{2}}}\left[1+\frac{1}{n}(x-\mu)'(A'A)^{-1}(x-\mu)\right]^{-\frac{n+N}{2}}\\
=&c|\Sigma|^{-\frac{1}{2}}\left[1+\frac{1}{n}(x-\mu)'(\Sigma)^{-1}(x-\mu)\right]^{-\frac{n+N}{2}}
\end{aligned}$$

where the first equivalence stems from the properties of a linear function of an absolutely continuous random vector. □

C Gibbs Sampler with Jeffreys and conjugate priors

C.1 The Likelihood Function

Consider the following VAR model with a standard notation :

$$Y = C + Y_{-1}A_1 + .. + Y_{-q}A_q + E \qquad E_t \sim M\mathcal{N}(0, w_t^{-1}\Sigma) \tag{6}$$

Y and E are a T×N matrices where C is a row vector with N columns and A_l are square NxN matrices.
We note Ω a T×T diagonal matrix where each element $w_t \sim \Gamma(n/2, 2/n)$, n being the degree of freedom of the T Student innovations.

We can rewrite the VAR in two alternative formats :

$$Y = XA + E \tag{7}$$

which leads to the vectorized notation : (la variance de ε est à confirmer bien qu'elle semble être bonne)

$$y = (I_N \otimes X)\,\alpha + \varepsilon \qquad \varepsilon \sim M\mathcal{N}(0, \Sigma \otimes \Omega^{-1}) \tag{8}$$

where X and A are T×k (with $k = Nq + 1$) and k×N matrices respectively. Also, for each capital letters $L = (Y, A, E)$ corresponds its vectorized vector $l = vec(L) = (y, \alpha, \varepsilon)$.

We can easily write the likelihood function as :

$$\mathcal{L}(\alpha, \Sigma, \Omega) = (2\pi)^{-NT/2} \underbrace{\left|\Sigma \otimes \Omega^{-1}\right|^{-1/2}}_{=|\Sigma|^{-T/2}|\Omega|^{N/2}} exp\left\{-\frac{1}{2}\left[y - (I_N \otimes X)\,\alpha\right]' \left(\Sigma^{-1} \otimes \Omega\right)\left[y - (I_N \otimes X)\,\alpha\right]\right\} \tag{9}$$

C.2 Gibbs sampling

C.2.1 Non-informative priors

Assuming :
- Flat (constant) prior for α
- Jeffrey's prior for Σ : $\Sigma \propto |\Sigma|^{-\frac{N+1}{2}}$
- Gamma distribution for $n/2$: $n/2 \sim \Gamma(k, \theta)$

The posterior distribution kernel can thus be written as :

$$\mathcal{D}(\alpha, \Sigma, \Omega/y, x, k, \theta) \propto |\Sigma|^{-\frac{N+T+1}{2}} |\Omega|^{N/2} exp\left\{-\frac{1}{2}\left[y - (I_N \otimes X)\,\alpha\right]' \left(\Sigma^{-1} \otimes \Omega\right)\left[y - (I_N \otimes X)\,\alpha\right]\right\}$$
$$\underbrace{\frac{|\Omega|^{\frac{n}{2}-1}}{\Gamma_T\left(\frac{n}{2}\right)\left(\frac{2}{n}\right)^{\frac{n}{2}}} exp\left\{-\frac{n}{2}\operatorname{Tr}(\Omega)\right\}}_{P(\Omega)} \underbrace{\frac{\left(\frac{n}{2}\right)^{k-1}}{\Gamma(k)\,\theta^k} exp\left\{-\frac{n/2}{\theta}\right\}}_{P\left(\frac{n}{2}\right)} \tag{10}$$

The marginal distributions

- Conditional on α, Σ and n :

$$p\left(w_t/....|\Sigma,\Omega\right) \propto exp\left\{-\frac{1}{2}\left[y-\left(I_N\otimes X\right)\alpha\right]'\left(\Sigma^{-1}\otimes\Omega\right)\left[y-\left(I_N\otimes X\right)\alpha\right]\right\} \quad (11)$$
$$\frac{|\Omega|^{\frac{n+N}{2}-1}}{\Gamma_T\left(\frac{n}{2}\right)\left(\frac{2}{n}\right)^{\frac{n}{2}}} exp\left\{-\frac{n}{2}\operatorname{Tr}\left(\Omega\right)\right\}$$

Using the two following properties :

$$vec(A)'\left(D\otimes B\right)vec(C)=\operatorname{Tr}\left(A'BCD'\right)$$
$$\left(C'\otimes A\right)vec(B)=vec(ABC)$$

we can write that :

$$\begin{aligned} p\left(w_t/....|\Sigma,\Omega\right) &\propto |\Omega|^{-\frac{n-1}{2}}\, exp\left\{-\frac{1}{2}\operatorname{Tr}\left(\left[Y-XA\right]'\Omega\left[Y-XA\right]\Sigma^{-1}+n\Omega\right)\right\} \\ &\propto |\Omega|^{-\frac{n-1}{2}}\, exp\left\{-\frac{1}{2}\operatorname{Tr}\left(\left\{\left[Y-XA\right]\Sigma^{-1}\left[Y-XA\right]'+n\right\}\Omega\right)\right\} \end{aligned} \quad (12)$$

Hence :

$$\omega_t \sim \Gamma\left(\frac{n+N}{2},\frac{2}{\psi(t,t)+n}\right)$$

or equivalently :

$$\Omega \sim M\Gamma_T\left(\frac{n+N+T-1}{2},\frac{2}{\psi+n},I_T\right)$$

where :

$$\psi=\left[Y-XA\right]\Sigma^{-1}\left[Y-XA\right]'$$

- Conditional on Ω, Σ and n :

$$p\left(\alpha_t/....|\Sigma,\Omega\right) \propto exp\left\{-\frac{1}{2}\left[y-\left(I_N\otimes X\right)\alpha\right]'\left(\Sigma^{-1}\otimes\Omega\right)\left[y-\left(I_N\otimes X\right)\alpha\right]\right\} \quad (13)$$

That can be rewritten as[15]

$$\begin{aligned} p\left(\alpha_t/....|\Sigma,\Omega\right) \propto exp\Bigg\{-\frac{1}{2}\underbrace{\left[\left(\Sigma^{-1/2}\otimes\Omega^{1/2}\right)y-\left(\Sigma^{-1/2}\otimes\Omega^{1/2}X\right)\alpha\right]'}_{=G_1} \\ \left[\Sigma^{-1/2}\otimes\Omega^{1/2}y-\left(\Sigma^{-1/2}\otimes\Omega^{1/2}X\right)\alpha\right]\Bigg\} \end{aligned} \quad (14)$$

[15]Using :

$$\left(\Sigma^{-1}\otimes\Omega\right)=\left(\Sigma^{-1/2}\otimes\Omega^{1/2}\right)\left(\Sigma^{-1/2}\otimes\Omega^{1/2}\right)$$

and :

$$\left(\Sigma^{-1/2}\otimes\Omega^{1/2}\right)'=\left(\Sigma^{-1/2}\otimes\Omega^{1/2}\right)$$

By introducing a constant α_{OLS}, we can write G_1 as :

$$G_1 = \underbrace{\left(\Sigma^{-1/2} \otimes \Omega^{1/2}\right) y - \left(\Sigma^{-1/2} \otimes \Omega^{1/2} X\right) \alpha_{OLS}}_{=G_2} + \underbrace{\left(\Sigma^{-1/2} \otimes \Omega^{1/2} X\right) (\alpha_{OLS} - \alpha)}_{=G_3} \quad (15)$$

Thus :

$$p\left(\alpha_t/....|\Sigma, \Omega\right) \propto exp\left\{-\frac{1}{2} G_2' G_2 + G_3' G_3 + G_2' G_3 + G_3' G_2\right\} \quad (16)$$

Note that :
G_2 doesn't depend on α and using the fact that $\alpha_{OLS} = \left(I_N \otimes (X'\Omega X)^{-1} (\Omega X)'\right) y$, we can easily show that $G_2' G_3 = G_3' G_2 = 0$.

As a consequence, we can write :

$$\begin{aligned} p\left(\alpha_t/....|\Sigma, \Omega\right) &\propto exp\left\{-\frac{1}{2}\left[\left(\Sigma^{-1/2} \otimes \Omega^{1/2} X\right) (\alpha_{OLS} - \alpha)\right]' \left[\left(\Sigma^{-1/2} \otimes \Omega^{1/2} X\right) (\alpha_{OLS} - \alpha)\right]\right\} \\ &\propto exp\left\{-\frac{1}{2}\left[(\alpha - \alpha_{OLS})' \left(\Sigma^{-1} \otimes X'\Omega X\right) (\alpha - \alpha_{OLS})\right]\right\} \end{aligned} \quad (17)$$

Thus :

$$p\left(\alpha_t/....|\Sigma, \Omega\right) \sim M\mathcal{N}\left(\alpha_{OLS}, \left(\Sigma \otimes (X'\Omega X)^{-1}\right)\right) \quad (18)$$

- Conditional on Ω, α and n :

$$p\left(\Sigma/....|\Omega\right) \propto |\Sigma|^{-\frac{N+T+1}{2}} exp\left\{-\frac{1}{2}\left[y - (I_N \otimes X)\alpha\right]' \left(\Sigma^{-1} \otimes \Omega\right) \left[y - (I_N \otimes X)\alpha\right]\right\} \quad (19)$$

Using the relation (...) we can assess that the previous relation is equivalent to :

$$p\left(\Sigma/....|\Omega\right) \propto |\Sigma|^{-\frac{N+T+1}{2}} exp\left\{-\frac{1}{2} \mathrm{Tr}\left[Y - XA\right]' \Omega \left[Y - XA\right] \Sigma^{-1}\right\} \quad (20)$$

We can thus set that :

$$p\left(\Sigma/....|\Omega\right) \sim IW\left(\left[Y - XA\right]' \Omega \left[Y - XA\right], T\right) \quad (21)$$

- Conditional on Ω, α and Σ :

$$p\left(n/....|\Omega\right) \propto \frac{|\Omega|^{-\frac{N+n-1}{2}}}{\Gamma_T\left(\frac{n}{2}\right)\left(\frac{2}{n}\right)^{\frac{n}{2}}} exp\left\{-\frac{n}{2} \mathrm{Tr}\left(\Omega\right)\right\} \frac{\left(\frac{n}{2}\right)^{k-1}}{\Gamma(k)\,\theta^k} exp\left\{-\frac{n/2}{\theta}\right\} \quad (22)$$

We do not recognize a standard distribution, we thus use the Adaptive Rejection Sampling algorithm to generate n (see "Monte-Carlo Statisctical Methods", C.P. Robert, et G. Casella, 2004)

C.2.2 Conjugate priors

Assuming :
- Conjugate prior for α : $\alpha \sim M\mathcal{N}(a, \Lambda)$
- Conjugate prior for Σ : $\Sigma \sim IW(\Phi, d)$
- Gamma distribution for ${}^{n}\!/_{2}$: ${}^{n}\!/_{2} \sim \Gamma(k, \theta)$

The posterior distribution kernel can thus be written as :

$$\begin{aligned}\mathcal{D}(\alpha, \Sigma, \Omega / y, x, k, \theta) \propto |\Sigma|^{-\frac{T}{2}} |\Omega|^{N/2} exp\left\{-\frac{1}{2}\left[y-(I_N \otimes X)\alpha\right]' \left(\Sigma^{-1} \otimes \Omega\right)\left[y-(I_N \otimes X)\alpha\right]\right\} \\ \frac{|\Omega|^{\frac{n}{2}-1}}{\Gamma_T\left(\frac{n}{2}\right)\left(\frac{2}{n}\right)^{\frac{n}{2}}} exp\left\{-\frac{n}{2}\operatorname{Tr}(\Omega)\right\} \frac{\left(\frac{n}{2}\right)^{k-1}}{\Gamma(k)\,\theta^k} exp\left\{-\frac{n/2}{\theta}\right\} \\ \underbrace{exp\left\{-\frac{1}{2}[\alpha-a]' \Lambda^{-1}[\alpha-a]\right\}}_{\propto P(\alpha)} \underbrace{|\Sigma|^{-d+N+1/2} exp\left\{-\frac{1}{2}\operatorname{Tr}\left(\Phi\Sigma^{-1}\right)\right\}}_{\propto P(\Sigma)}\end{aligned} \tag{23}$$

The marginal distributions

- Since the Hyper parameters do not depend on ω_t, the marginal distribution of ω_t doesn't change. Hence :

$$\omega_t \sim \Gamma\left(\frac{n+N}{2}, \frac{2}{\psi(t,t)+n}\right)$$

or equivalently (à démontrer):

$$\Omega \sim M\Gamma_T\left(\frac{n+N+T-1}{2}, \frac{2}{\psi+n}, I_T\right)$$

where :

$$\psi = [Y - XA]\,\Sigma^{-1}\,[Y - XA]'$$

- Conditional on Ω, Σ and n :

$$\begin{aligned}p(\alpha_t/....|\Sigma, \Omega) \propto exp\left\{-\frac{1}{2}\left[y-(I_N \otimes X)\alpha\right]' \left(\Sigma^{-1} \otimes \Omega\right)\left[y-(I_N \otimes X)\alpha\right]\right\} \\ exp\left\{-\frac{1}{2}[\alpha-a]' \Lambda^{-1}[\alpha-a]\right\}\end{aligned} \tag{24}$$

That can be rewritten as :

$$p(\alpha_t/....|\Sigma, \Omega) \propto exp\left\{-\frac{1}{2}\left[\underbrace{(\alpha-\alpha_{OLS})' \left(\Sigma^{-1} \otimes X'\Omega X\right)(\alpha-\alpha_{OLS}) + (\alpha-a)' \Lambda^{-1}(\alpha-a)}_{G_4}\right]\right\} \tag{25}$$

We can show that[16] :

$$G_4 = (\alpha - \hat{\alpha})' \Sigma_{\alpha}^{-1} (\alpha - \hat{\alpha})$$

with :

$$\hat{\alpha} = \left[\Lambda^{-1} + \Sigma^{-1} \otimes X'\Omega X\right]^{-1} \left[\Lambda^{-1} a + \left(\Sigma^{-1} \otimes X'\Omega X\right) \alpha_{OLS}\right]$$

$$\Sigma_{\alpha} = \left[\Lambda^{-1} + \Sigma^{-1} \otimes X'\Omega X\right]^{-1}$$

As a consequence, we can assess that :

$$p(\alpha_t/....|\Sigma, \Omega) \sim M\mathcal{N}(\hat{\alpha}, \Sigma_{\alpha}) \tag{26}$$

Note that using a prior centered on α_{OLS} we would have $\hat{\alpha} = \alpha_{OLS}$. Thus, the marginal density of α is as :

$$p(\alpha_t/....|\Sigma, \Omega) \sim M\mathcal{N}(\alpha_{OLS}, \Sigma_{\alpha}) \tag{27}$$

This relation would not be useful especially when we note that it would change the marginal density of Ω which would complicate the mathematics with ne real improvement.

- Conditional on Ω, α and n :

$$\begin{aligned} p(\Sigma/....|\Omega) \propto |\Sigma|^{-\frac{T}{2}} exp\left\{-\frac{1}{2}[y - (I_N \otimes X)\alpha]' \left(\Sigma^{-1} \otimes \Omega\right)[y - (I_N \otimes X)\alpha]\right\} \\ |\Sigma|^{-\frac{d+N+1}{2}} exp\left\{-\frac{1}{2}\operatorname{Tr}\left(\Phi\Sigma^{-1}\right)\right\} \end{aligned} \tag{28}$$

That can be rewritten as :

$$\begin{aligned} p(\Sigma/....|\Omega) &\propto |\Sigma|^{-\frac{T}{2}} exp\left\{-\frac{1}{2}\operatorname{Tr}[Y - XA]'\Omega[Y - XA]\Sigma^{-1}\right\} |\Sigma|^{-\frac{d+N+1}{2}} exp\left\{-\frac{1}{2}\operatorname{Tr}\left(\Phi\Sigma^{-1}\right)\right\} \\ &\propto |\Sigma|^{-\frac{T+d+N+1}{2}} exp\left\{-\frac{1}{2}\operatorname{Tr}\left\{\left([Y - XA]'\Omega[Y - XA] + \Phi\right)\Sigma^{-1}\right\}\right\} \end{aligned} \tag{29}$$

Hence, we can deduce that :

$$p(\Sigma/....|\Omega) \sim IW\left([Y - XA]'\Omega[Y - XA] + \Phi, T + d\right) \tag{30}$$

- Since the Hyper parameters do not depend on n, the marginal distribution of n doesn't change. Hence :

$$p(n/....|\Omega) \propto \frac{|\Omega|^{-\frac{N+n-1}{2}}}{\Gamma_T\left(\frac{n}{2}\right)\left(\frac{2}{n}\right)^{\frac{n}{2}}} exp\left\{-\frac{n}{2}\operatorname{Tr}(\Omega)\right\} \frac{\left(\frac{n}{2}\right)^{k-1}}{\Gamma(k)\theta^k} exp\left\{-\frac{n/2}{\theta}\right\} \tag{31}$$

[16]See A. Zellner "An Introduction to Bayesian Inference in Econometrics", p. 240, Wiley Classics Library, 1996.

Chapter 2

Interest rate pass-through and interbank rate volatility shocks: a DSGE perspective

2.1 Introduction

Would there be something more to say about the interest rate pass-through?[1]
Indeed, the pass-through from the monetary policy rate to retail interest rates has been widely investigated in the empirical literature. Results emphasize short-term stickiness in bank interest rates as well as differences across countries and over time. The understanding of these differences matters particularly for central banks since they need to assess the transmission mechanisms of monetary policy shocks. Furthermore, the empirical literature on the interest rate pass-through does not focus on a single measure of the stickiness in retail interest rates but provides rather a wide range of results. First, numerous retail interest rates are considered both on loans and on deposits.[2] Second, the pass-through to retail interest rates can be measured against a money market rate or against a market rate of comparable maturity. The former proxies the monetary policy rate and then focuses on monetary policy transmission. The latter proxies bank's cost of funds and then highlights the role of competition and market structure (Sander and Kleimeier [68]). Third, empirical studies can estimate both short-term and long-term interest rate pass-through. As a result, all these measures provide complementary insights on banks' price-setting behavior.

The theoretical literature on the interest rate pass-through is rather scarce. It is however essential to understand the main determinants and implications of the sluggishness of retail interest rates. For example, structural approaches, based on the New Keynesian framework, show that the stickiness of retail interest rates and an incomplete interest rate pass-through weaken the monetary policy efficiency (Kwapil and Scharler [52], Darracq

[1] This chapter is based on joint work with Vincent Bouvatier

[2] See for example de Bondt [18] which provides a literature review and reports empirical estimates of the interest rate pass-through in euro area countries for 6 market segments: short-term loans to firms, long-term loans to firms, consumer credit, mortgages, savings deposits and time deposits.

Pariès et al. [17]), mitigate the strength of the cost channel of monetary policy (Hülsewig et al. [45]) and reduce social welfare (Kobayashi [50]). Our paper falls within this category of studies, we also adopt a New Keynesian framework mainly drawn from Iacoviello [46] and Gerali et al. [34] and we provide in particular an explanation of the slowdown in the interest rate pass-through identified during the 2007-2008 financial crisis (IMF [47], Čihák et al. [13], Aristei and Gallo [3], Hristov et al. [44]).

The paper has three main contributions. First, we analyze the impact of an interbank rate volatility shock on the interest rate pass-through. Second, we provide a complementary explanation of the stagflationary effect generated by volatility shocks to the one presented by Fernández-Villaverde et al. [27]. Third, we evaluate how the central bank can mitigate the impact of an interbank rate volatility shock on retail interest rates. The main finding is that the transmission of a monetary policy easing to retail interest rates is impeded when an interbank rate volatility shock occurs at the same time as the decrease in the policy rate. In addition, we also show that, conversely, the impact of a restrictive monetary policy can be amplified in times of high interbank volatility corresponding to times where the pass-through is likely to exceed the unit value. Finally, we find that a central bank putting more weight on the GDP stabilization objective in the monetary policy rule and increasing the policy rate smoothing can reduce the consequences of the interbank rate volatility shock.

The rest of the paper is organized as follows. Section 2 is devoted to the literature review and the presentation of stylized facts. Sections 3 and 4 present respectively the theoretical model and its calibration. Impulse response functions are analyzed in Section 5. The transmission of the monetary policy in time of interbank uncertainty is analyzed in section 6. Section 7 concludes the article.

2.2 Literature review and stylized fact

2.2.1 Literature review on interest rate pass-through

The euro area creation gave rise to a large volume of empirical research on the interest rate pass-through for two main reasons. First, the euro area merges heterogeneous banking sectors. The single monetary policy can then affect differently national banking sectors, which is a major concern for the European Central Bank (ECB). Second, the financial integration between members countries increased since the euro area creation until the Great Financial Crisis. This has the potential to increase, which can modify the monetary policy transmission process over time. Based on country level data, Sander and Kleimeier [68] find that the pass-through from the monetary policy rate to lending rates increased and became more homogeneous across euro area countries. Angeloni and Ehrmann [2], Vajanne [75] and Nakajima and Teranishi [57] reach similar conclusions. The remaining heterogeneity can be explained by differences in macroeconomic performances and in banking sector characteristics as the degree of competition (Kok Sørensen and Werner [51], Kleimeier and Sander [49], Gropp et al. [42] and van Leuvensteijn et al. [76]).

Empirical studies suggest further that the interest rate pass-through is lower to deposit rates than to lending rates and that the long-run pass-through is usually incomplete for most retail interest rates. Considering euro area as a whole, de Bondt [18] investigates both the pass-through from the monetary policy rate to market rates (i.e. bank's cost of fund) and the pass-through from market rates to retail bank interest rates. He finds that short-run pass-throughs are around 50% while long-run pass-throughs are nearly complete for market rates and lending rates.

The empirical literature is however not only devoted to the euro area. Differences in the strength and in the speed of the transmission process across many countries have already been investigated. For example, Panagopoulos et al. [59] make comparison between the US, UK, Canada and Eurozone; Sander and Kleimeier [69] and Égert et al. [23] focus on transition economies in Central and Eastern Europe; Wang [78] on Asian countries; and Gigineishvili [39] adopts a wider approach considering seventy countries.

The stability of the relationships between retail interest rates and the monetary policy rate has logically been questioned during and following the 2007-2008 financial crisis. In this regard, IMF [47] underlines that financial intermediation changed over the last decade with a larger part of financial intermediation provided by "near-bank" financial institutions while short term financing became more important in banks' liabilities. IMF [47] documents two main implications of these structural changes. First, tightening in credit market during the financial crisis occurred mainly by downward quantity adjustments rather than lending rates increases. Second, the pass-through of policy rates to short-term lending rates have been impeded by the financial turmoil in the US, and to a lesser extent in the euro area. Čihák et al. [13], Aristei and Gallo [3] and Hristov et al. [44] reach similar conclusions for the euro area and find that the pass-through to market rates has slowed down during the crisis. Empirical evidences from ECB [21] are more in line with the stability of the pass-through and suggest that the linkages between retail interest rates and market rates in the euro area since mid-2007 do not differ markedly from past patterns.

Several theoretical studies investigate the reasons behind the slowdown in the interest rate pass-through identified during the 2007-2008 financial crisis. Based on simulations of a DSGE model, Hristov et al. [44] put forward that an increase in the frictions characterizing the banking sector, as for example tighter collateral requirements, dampens the interest rate pass-through. Roelands [65], in a partial equilibrium framework, shows that binding capital or liquidity constraints, more frequently observed during monetary policy easing, slow down the interest rate pass-through while Ritz [64] shows that a rise in funding uncertainty dampens the interest rate pass-through from the monetary policy rate to market interest rates.

The last argument putting forward the role of money market uncertainty and its impact on retail rate has also been investigated in the literature, especially the empirical one since the theoretical literature has long relied on the assumption of homoscedastic stochastic process. Raunig and Scharler [63] study the transmission of money market volatility to retail rates in 10 OECD countries. They find that the volatility of money market rates has a limited impact on the volatility of retail interest rates, except in the US. They conclude that banks smooth shocks and then contribute to macroeconomic stability. However, Raunig and Scharler [63] use a simplistic approach to assess the retail interest rates volatility. In addition, the volatility transmission could be magnified during periods of financial crisis. Wang and Lee [79] and [78; 77] paid a particular attention in modeling the retail interest rates volatility to estimate retail interest rate pass-through in 9 Asian countries and in the US. They do not address the issue of volatility transmission but they clearly identify volatility shocks in retail interest rates.

2.2.2 Identification of volatility shocks

Focusing on the euro area, we illustrate the presence of uncertainty (i.e. volatility shocks) in the money market interest rate and in the lending rates. We proceed in two step to model the fluctuations in interest rates in the spirit of Wang and Lee [79]. In the first step, we identify the long-run dynamics of the money market and of the lending rates with cointegration relations. In a second step, the short-run dynamics are assessed with an error correction specification including a multivariate GARCH process. Three variables are used in the model. We use the Eonia rate ($Eonia_t$) as the monetary policy rate, the 1-year Euribor rate ($Euribor_t^{1Y}$) as the money market rate and the short term lending rate to non-financial corporations (r_t^L) as the retail rate.[3] We consider the January 1997-April 2012 period and all the data come from the ECB databases. The Dickey and Fuller [20], Elliott et al. [24], Perron [60] and Kwiatkowski et al. [53]) tests indicate that the 3 variables are non stationary in level and stationary in first difference.

First, we estimate the two following long-run relations to evaluate the pass-through from the policy rate to the money market rate and from the money market rate to the retail rate:

$$Euribor_t^{1Y} = b_{10} + b_{11} Eonia_t + \varepsilon_{1,t} \tag{2.1}$$
$$r_t^L = b_{20} + b_{21} Euribor_t^{1Y} + \varepsilon_{2,t} \tag{2.2}$$

Equations (2.1) and (2.2) are estimated by Fully Modified Least Squares (FMOLS) and results are reported in Table A.1. The Phillips and Ouliaris [61] cointegration tests confirm that Equations (2.1) and (2.2) can be considered as long-run relations and $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ represent therefore long-run error terms. The pass-through from the policy rate to the money market rate (b_{11}) is 0.82 while the one from the money market rate to the retail rate (b_{21}) is 0.84. Both coefficients are significant at the 1% level and also significantly different from 1 at the 1% level, suggesting an incomplete pass-through in the long-run.[4]

Second, we identify volatility shocks with the following short-run specification:

$$\Delta Euribor_t^{1Y} = k_{10} + k_{11} \Delta Euribor_{t-1}^{1Y} + k_{12} \Delta Eonia_{t-1} + k_{13} \hat{\varepsilon}_{1,t-1} + u_{1,t} \tag{2.3}$$
$$\Delta r_t^L = k_{20} + k_{21} \Delta r_{t-1}^L + k_{22} \Delta Euribor_{t-1}^{1Y} + k_{23} \hat{\varepsilon}_{2,t-1} + u_{2,t} \tag{2.4}$$

with

$$u_t = (u_{1,t}, u_{2,t})' \sim N(0, H_t)$$

[3]The Euribor rates with shorter maturities have also been considered to represent the money market rate. We decided to retain the Euribor rate which exhibits the stronger cointegration relationship with the retail rate, based on the Phillips and Ouliaris [61] cointegration tests. Similarly, alternative retail rates could have been considered but our empirical illustration does not seek to be exhaustive.

[4]Note that a complete long-run pass-through from the policy rate to the money market rate is obtained if the 1-month or 3-month Euribor rates are used instead of the 1-year Euribor rate.

where H_t, corresponding to the variance-covariance matrix, is represented by a diagonal BEKK specification (Engle and Kroner [26]).[5] More precisely:

$$H_t = C'C + A'u_{t-1}u'_{t-1}A + G'H_{t-1}G \tag{2.5}$$

where C is a 2x2 triangular matrix of constants, A and G are 2x2 diagonal matrix. Matrix A measures the effects of shocks on the elements of H_t and matrix G introduces the volatility persistence. According to the diagonal parametrization, the variances depend on their own past squared residual and on their own past value while the covariance depend on the product of residuals and on its own past value.

The bivariate diagonal BEKK model, made up of equations (2.3), (2.4) and (2.5), is estimated by maximum likelihood. A multivariate normal distribution is used and the Bollerslev-Wooldridge standard errors are considered. The results are reported in Table A.2. Regarding the mean equations, all the parameters (except the intercepts) are significant at the 1% or 5% levels. Money market rate and lending rate variations positively depend on their own past value, suggesting smooth adjustments. In addition money market rate variations depend on past variations in the policy rate while lending rate variations depend on on past variations in the money market rate. Finally, short term fluctuations are characterized by an error correction mechanism. Variables $\hat{\varepsilon}_{1,t-1}$ and $\hat{\varepsilon}_{2,t-1}$ affect negatively respectively the money market and the lending rates.[6] Concerning the variance-covariance equations, parameters from matrix A and G are significant at the 1% level suggesting respectively the presence of ARCH effects and volatility persistence. Figure 2.1 represents conditional standard deviations and correlation obtained from the BEKK model. The dynamics of the money market and lending rates have been affected by volatility shocks, particularly during the financial crisis. Before 2008, volatility in the lending rate was weaker and more stable than the one in the money market rate, suggesting that banks provide insurance against interest rates shocks (Raunig and Scharler [63]). However, this behavior was challenged during the financial crisis and uncertainty increased both in the money market and in the lending rates. In addition, Figure 2.1 shows that conditional correlation in shocks increased during the financial crisis, reinforcing the fact that volatility shocks are not restricted to the money market. As a result, we conclude from the BEKK model that during a financial crisis, banks cannot absorb the increasing uncertainty in the money market rate. Retail interest rates are then also affected. To the best of our knowledge, consequences of these volatility shocks on the interest rate pass-through has never been investigated. The model developed in the following section allows to fill this research gap.

[5] The BEKK specification ensure that the estimated covariance matrix will be positive semi-definite, which guarantee non-negative estimated variances. Furthermore, two alternative specifications have been considered for robustness check. First, we used a DCC-GARCH model (Engle [25]. Second, we used a trivariate diagonal BEKK model; including a third equation to represent $\Delta Eonia_t$ as an autoregressive process. Similar conclusions have been reached with these two alternative specifications.

[6] Additional exogenous variables could have been introduced, as variations in long-term interest rate for example, but we prefer a parsimonious specification in this empirical illustration.

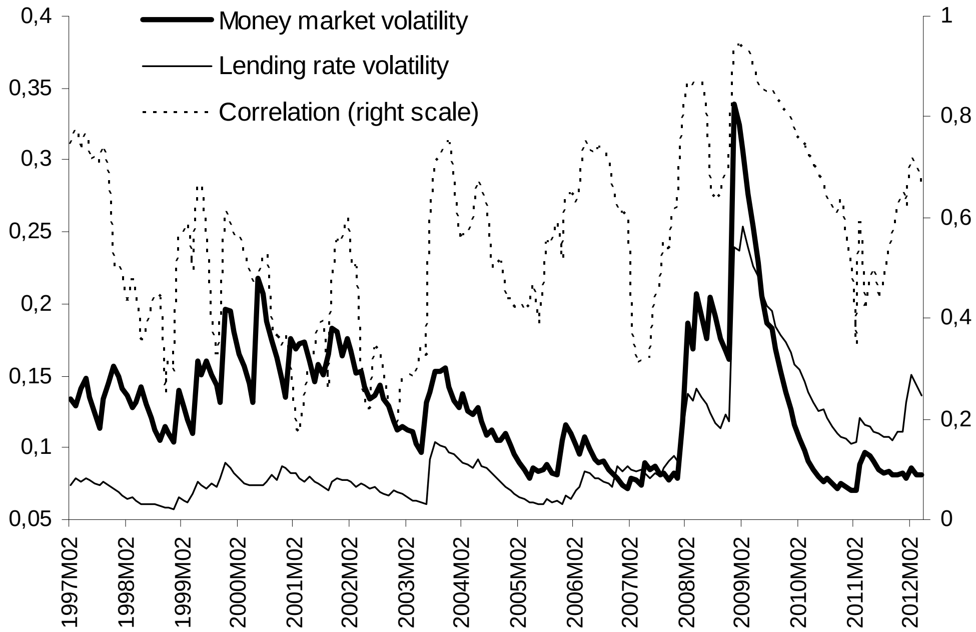


Figure 2.1: Conditional standard deviations and correlation from the BEKK model

2.3 The model

Our benchmark model is mainly drawn from Iacoviello [46] and Gerali et al. [34]. To focus on the main questions of our paper, we limit our description of the model to its standard features in order to fix notation.

2.3.1 Households

The economy is populated by two types of households. Both types of households consume, work and enjoy housing services. When the first type of households (called patient, indexed by P) are net lenders in the sense that, in each period, they can save some of their revenue in the form of banks deposits, the second type of households (called impatient, indexed by I) are net borrowers in our economy.

For each type of households $m = \{I, P\}$, an infinitely-lived representative household $i \in [0, 1]$ maximizes in each period its intertemporal utility function which is assumed to be of the form:

$$\mathcal{W}_t^{m,i} = \mathbb{E}_t \left[\sum_{j=0}^{\infty} \beta_{w,m}^j \left\{ \frac{1-\eta^m}{1-\sigma_c^m} \left(\frac{C_{t+j}^{m,i} - \eta^m \overline{C}_{t+j-1}^m}{1-\eta^m} \right)^{1-\sigma_c^m} + \frac{\left(h_{t+k}^{m,i}\right)^{1-\sigma_h^m}}{1-\sigma_h^m} - \frac{(N_{t+j}^i)^{1-\sigma_n^m}}{1-\sigma_n^m} \right\} \right]$$

where $C_t^{m,i}$, $h_t^{m,i}$ and $N_t^{m,i}$ represent respectively the household m's consumption, housing demand and labor, when the parameters σ_c^m, σ_h^m and σ_n^m are the corresponding intertemporal elasticity of substitution. η^m measures the degree of external habit formation in consumption.

Each period, the households maximize their utility function with respect to a budget constraint. For patient households, the budget constraint is written (in real terms) as:

$$C_t^{P,i} + D_t^{P,i} + q_t^h \left(h_t^{P,i} - h_{t-1}^{P,i}\right) = \frac{W_t^{P,i}}{P_t} N_t^{P,i} + \frac{(1+R_{t-1}^D)D_{t-1}^i}{\pi_t} + \mathscr{D}_t^{P,i} + \mathscr{T}_t^{P,i} \tag{2.6}$$

Their resources are composed of wage earnings $\frac{W_t^i}{P_t}N_t^{P,i}$, gross interest income on last period deposits $\frac{1+R_{t-1}^D}{\pi_t}D_{t-1}^{w,h}$ as well as some lump-sum transfers $\mathscr{T}_t^{P,i}$ and dividends $\mathscr{D}_t^{w,h}$ from the different types of firms that all belong to them. Their flow of expenses includes, in addition of their current consumption C_t^i and the accumulation of housing $h_t^{P,i}$, the amount of revenue they decide to save in the current period D_t^i.

For impatient households, the budget constraint is written (in real terms) as:

$$C_t^{I,i} + \frac{(1+R_{t-1}^{L,I})L_{t-1}^{I,i}}{\pi_t} + q_t^h \left(h_t^{I,i} - h_{t-1}^{I,i}\right) = \frac{W_t^{I,i}}{P_t} N_t^{I,i} + L_t^{I,i} + \mathscr{T}_t^{I,i} \tag{2.7}$$

The impatient household are not able to save. Quite the reverse, to fund their housing demand, they have to negotiate a banking loan $L_t^{I,i}$ at a nominal interest rate $R_t^{L,I}$. The amount of period 't' fund they can borrow is limited by the expecting value in 't+1' of their housing stock that is required to guarantee repayment of the principal as well as the interests. This collateral constraint à la Kiyotaki and Moore [48] is written as:

$$(1+R_t^{L,I})L_t^{I,i} \leqslant \mathbb{E}_t \left(\theta^I \left[q_{t+1}^i \pi_{t+1} h_t^{I,i}\right]\right) \tag{2.8}$$

where θ_t^I is the loan-to-value ratio (LTV) required from households, it's assumed to be constant.

2.3.2 Labor Market

The labor market is mainely composed of two unions, one for patient households and one for the impatient ones. Unions differentiate the aggregate level of labor issued by the corresponding type of households and sell its services in a monopolistically competitive market to a perfectly competitive firm which, using a CES technology function, transforms it into an aggregate labor input:

$$N_t^m = \left(\int_0^1 (N_t^{m,\iota})^{\frac{\nu_w - 1}{\nu_w}} d\iota\right)^{\frac{\nu_w}{\nu_w - 1}}$$

where $N_t^{m,\iota}$ is the differentiated type of labor brought by union $\iota \in [0,1]$ and ν_w is the elasticity of substitution between differentiated labor services.

In addition, unions set their wages on a staggered basis à la Rotemberg [67] in the sense that, at each period, every union faces quadratic adjustment costs when changing their wages. Each type of union has the following optimization program:

$$\max_{N_t^{m,\iota}, W_t^{m,\iota}} \mathbb{E}_t \sum_{k=0}^{\infty} \beta_m^k \left\{ \lambda_{t+k}^m \left(\frac{W_{t+k}^{m,\iota}}{P_{t+k}} N_{t+k}^{m,\iota} - \frac{\kappa_w}{2} \left(\frac{W_{t+k}^{m,\iota}}{W_{t+k-1}^{m,\iota}} - \pi_{t+k-1}^{\gamma_w} \overline{\pi}^{1-\gamma_w} \right)^2 \frac{W_{t+k}^m}{P_{t+k}} \right) - \frac{\left(N_{t+k}^m\right)^{1+\sigma_n^m}}{1+\sigma_n^m} \right\}$$

subject to the following demand constraint:

$$N_t^{m,\iota} = \left(\frac{W_t^{m,\iota}}{W_t^m}\right)^{-\nu_w} N_t^m$$

where W_t^m and N_t^m represent the aggregate nominal wage and labor level for each type of households.

2.3.3 Production

2.3.3.1 Entrepreneurs

In the economy there is a continuum $j \in [0,1]$ of entrepreneurs. Each of them maximizes its own consumption $C_t^{E,j}$ by optimizing its utility function which is of the form:

$$\mathcal{W}_t^{E,j} = \mathbb{E}_t \left[\sum_{k=0}^{\infty} \beta_E^k \left(\frac{C_{t+k}^{E,j} - \eta^E \overline{C}_{t+k-1}^{E,j}}{1-\eta^E} \right)^{1-\sigma_c^E} \frac{1-\eta^E}{1-\sigma_c^E} \right]$$

and under the following budget constraint:

$$\frac{P_t^{E,j}}{P_t} Y_t^{E,j} + L_t^{E,j} + q_t^k K_{t-1}^j (1-\delta) = C_t^{E,j} + w_t^P N_t^{P,j} + w_t^I N_t^{I,j} + \frac{(1+R_{t-1}^{L,E}) L_{t-1}^{E,j}}{\pi_t} + q_t^k K_t^j + \psi(z_t^j) K_{t-1}^j \tag{2.9}$$

Each entrepreneur chooses the optimal stock of physical capital K_t^j - as well as its utilization rate z_t^j facing an adjustment cost $\psi(z_t^j)$ - and the desired amount of labor inputs $N_t^{P,j}$ and $N_t^{I,j}$ that are combined to produce an intermediate output $Y^{E,j}$ according to a Cobb-Douglas production function:

$$Y^{E,j} = \left(K_{t-1}^{E,j} z_t^j\right)^{\alpha} \left((N_t^{P,j})^{\gamma_n} (N_t^{I,j})^{1-\gamma_n}\right)^{1-\alpha} \tag{2.10}$$

$L_t^{E,j}$ is the amount of firms' external financing borrowed from banks. Similarly to the constrained households, this amount of bank lending is limited by the expected value of their undepreciated physical capital. This collateral constraint is thus written as:

$$(1+R_t^{L,E}) L_t^{E,j} \leqslant \mathbb{E}_t \theta_t^E \left[q_{t+1}^k \pi_{t+1} K_t^j (1-\delta) \right] \tag{2.11}$$

2.3.3.2 Capital Producers

The main objective behind introducing the capital producers is to determine quite clearly the price of the physical capital. The physical capital market is composed by a capital producer evolving in a competitive market framework. At the beginning of each period, capital producer buy back the aggregated level of the undepreciated capital stocks $K_{t-1}(1-\delta)$ at real prices (in terms of consumption goods) $q_t^{K,p}$. Then it augments this stock using investment goods but facing adjustment costs. The augmented stock is sold back to entrepreneurs at the end of the period at the same price. Thus, the decision problem of capital producer is given by:

$$\max_{K_t, I_t} \mathbb{E}_t \sum_{i=0}^{\infty} \beta_e^i \lambda_{t+i}^e \left\{ \left(q_{t+i}^k K_{t+i} - q_{t+i-1}^k K_{t+i-1}(1-\delta) - I_{t+i} \right) \right\}$$

taking into account the following cumulative technology function:

$$K_t = (1-\delta)K_{t-1} + \left(1 - \Gamma_I \left(\frac{I_t}{I_{t-1}}\right)\right) I_t \tag{2.12}$$

where $\Gamma_I \left(\frac{I_t}{I_{t-1}}\right)$ represent the standard quadratic adjustment costs when varying investment I_t:

$$\Gamma_I(x) = \frac{\phi}{2}(x-1)^2 \tag{2.13}$$

2.3.3.3 Retail Market

The retail market is assumed to be monopolistically competitive. Retailers' prices are sticky and are indexed to a combination of past and steady-state inflation, with relative weights parameterized by γ^p. In addition, if retailers want to change their price beyond what indexation allows, they face a quadratic adjustment cost parameterized by κ^p. Each firm $f \in [0,1]$ chooses its sell price P_t^f so as to maximize its market value:

$$\max_{Y_t^f, P_{f,t}} \mathbb{E}_t \sum_{k=0}^{\infty} (\beta_p)^k \lambda_{p,t+k} \left\{ \left(P_t^f - P_{t+i}^e\right) Y_{f,t+i} - \frac{\kappa_g}{2} \left(\frac{P_t^{j-1}}{P_{t-1}^{j-1}} - \pi_{t+k-1}^{\gamma_p} \overline{\pi}^{1-\gamma_p} \right)^2 P_{t+k} Y_{t+k} \right\}$$

subject to the demand derived from consumers' maximization program à la Dixit-Stiglitz:

$$Y_{f,t} = \left(\frac{P^{f,t}}{P_t}\right)^{-\nu_g} Y_t$$

where ν_g is the demand price elasticity which is supposed to be constant.

In a symmetric equilibrium, the optimal choice for each retailer will be given by the (non-linear) Phillips curve:

$$\kappa_g \left(\pi_t - \pi_{t-1}^{\gamma_p} \overline{\pi}^{1-\gamma_p}\right) \pi_t = 1 - \nu_p + \nu_p p_t^e + \beta_p \frac{\lambda_{t+1}^p}{\lambda_t^p} \kappa_g \left(\pi_{t+1} - \pi_t^{\gamma_p} \overline{\pi}^{1-\gamma_p}\right) \pi_{t+1} \frac{Y_{t+1}}{Y_t} \tag{2.14}$$

2.3.4 Banking Sector

According to Gerali et al. [34] modeling framework, there are infinitely-lived representative banks $i \in [0,1]$, each is composed of two main branches, namely a wholesale branch and a retail one. The last is itself composed of two subbranches that we will mention to as deposit and loan branches.

2.3.4.1 The wholesale branch

Each wholesale branch has in charge the management of the balance sheet structure of the bank it belongs to. Indeed, the wholesale unit combines the savers deposit D_t with cumulative bank capital K_t^b to issue loans B_t to the loan branch. The total amount of these assets B_t is lent at a nominal rate R_t^b when the deposits are borrowed from the deposit branch at a rate R_t^{IB}. R_t^{IB} represents the interbank interest rate. Indeed, we suppose that the wholesale branch has an infinitely access to the money market funds where the main interest rate is the interbank rate. Moreover, we consider that interbank rate equal to the policy rate but, contrary to the latter, the interbank rate may be subject to an idiosyncratic shock characterized by a stochastic volatility.

$$1 + R_t^{IB} = (1 + R_t)\,\varepsilon_t^{IB} \tag{2.15}$$

when R_t is the policy rate and ε_t^{IB} is an iid variable in the sense that :

$$log\left(\varepsilon^{IB,t}\right) = \sigma_t^{\varepsilon^{IB}} \nu_t^{IB} \text{ where } \nu_t^{IB} \sim \mathcal{N}(0,1) \tag{2.16}$$

with $\sigma^{\varepsilon_t^{IB}}$ is the standard deviation of the log of the interbank shock and is indexed by t. This means that the dispersion of the interbank shock changes over time. More precisely, we assume that $\sigma_t^{\varepsilon^{IB}}$ evolves over time as an auto-regressive process with the form:

$$log\left(\frac{\sigma_t^{\varepsilon^{IB}}}{\overline{\sigma^{\varepsilon^{IB}}}}\right) = \rho_\sigma log\left(\frac{\sigma_{t-1}^{\varepsilon^{IB}}}{\overline{\sigma^{\varepsilon^{IB}}}}\right) + \eta^\sigma \nu_t^\sigma \text{ where } \nu_t^\sigma \sim \mathcal{N}(0,1) \tag{2.17}$$

where $\overline{\sigma^{\varepsilon^{IB}}}$ is the steady-state value of the volatility $\sigma_t^{\varepsilon^{IB}}$, ρ_σ represents the autoregressive coefficient of the log standard deviation and η^σ the standard deviation of the innovations to volatility ν_t^σ.

Furthermore, the structure of each bank balance sheet is subject to a regulatory constraint which states that the capital to assets ratio $K_t^b/B_t = k_{B,t}$ shall be not less than a given target value ν^b. So, in its optimization program, each wholesale branch has to pay a cost $f(k_{B,t})$ whenever the actual capital to assets ratio is different from ν^b. The wholesale branch objective is then:

$$\max_{D_t,B_t} \mathbb{E}_t \sum_{i=0}^{\infty} \beta_{w,P}^i \lambda_{t+i}^P \left\{ R_{t+i}^b B_{t+i} - R_{t+i} D_{t+i} - f\left(\frac{K_{t+i}^b}{B_{t+i}}\right) K_{t+i}^b \right\} \tag{2.18}$$

under the accounting identity:

$$B_t = D_t + K_t^b \tag{2.19}$$

Note that when Gerali et al. [34] chose a quadratic cost function for f, we rather prefer a more sophisticated function at least for two reasons. First, we choose to model a more realistic cost function with a positive cost when the capital to assets ratio is below the regulatory threshold and a negative cost when it is above the threshold. Indeed, by holding more capital, banks reduces potential bankruptcy costs (Warner [80]). However, getting large amount of capital represent also an opportunity cost that makes finally the cost function not monotonic. Second, and using the non-monotonicity of the cost function, we are also able to model an endogenous capital buffer. According to all these reasons, we choose f to be of the form:

$$f(k_{B,t}) = \kappa_b \left\{ \gamma_b \left[(k_{B,t})^{-1/\xi_b} - (\nu^b)^{-1/\xi_b} \right] + \left(k_{B,t} - \nu^b \right)^2 \right\} \qquad (\kappa_b, \xi_b, \gamma_b) \in \left(\mathbf{R}^{+,*} \right)^3 \tag{2.20}$$

Solving the wholesale branch program, the FOC results in an equation linking the spread $\left(R_t^b - R_t^{IB} \right)$ to the leverage ratio $k_{B,t}$:

$$R_t^b - R_t^{IB} = \kappa^b k_{B,t}^2 \left\{ \frac{\gamma_b}{\xi_b} (k_{B,t})^{-1/\xi_b - 1} - 2 \left(k_{B,t} - \nu^b \right) \right\} \tag{2.21}$$

At the steady state, the right hand of the previous equation is equal to 0 which induces a steady-state bank capital to assets ratio as:

$$\overline{k_B} = \nu^b + \underbrace{\frac{\gamma_b}{2\xi_b} \left(\overline{k_B} \right)^{-1/\xi_b - 1}}_{\text{Capital Buffer}} \tag{2.22}$$

Merging equation (2.22) with equation (2.21), we can assess the following relation :

$$R_t^b - R_t^{IB} = \kappa^b k_{B,t}^2 \left\{ \frac{\gamma_b}{\xi_b} (k_{B,t})^{-1/\xi_b - 1} - \frac{\gamma_b}{\xi_b} \left(\overline{k_B} \right)^{-1/\xi_b - 1} - 2 \left(k_{B,t} - \overline{k_B} \right) \right\} \tag{2.23}$$

This equation is similar to what Gerali et al. [34] found with a quadratic cost function. However, we allow in our specification asymmetric costs around the steady-state when quadratic costs do not. Indeed, if γ_b controls for the steady-state value of the capital buffer (see eq. (2.22), the parameter ξ_b affects the degree of asymmetry around the steady-state level. With this new specification, banks are less depressed when their capitalization ratio rises than when it decreases with a same amount.[7] This behavior is of particular interest when dealing with uncertainty shocks as we analyze later.[8]

Finally, the law of motion of bank capital is of the form:

$$\pi_t K_t^b = (1 - \delta^b) K_{t-1}^b + J_{t-1}^b \tag{2.24}$$

where δ^b represents the proportion of last period bank capital used in managing the bank capital and J_t^b the overall profits made by the wholesale unit as well as the retail one with its two subbranches.

2.3.4.2 The retail branch

The retail branch is composed of a unit mass of banks $j \in [0, 1]$ which evolve in a monopolistic market framework with nominal rigidities à la Rotemberg. Their

[7] According to our baseline calibration, a decrease in capital ratio by 0.5% (in level) generates a 18% larger response in the interbank rate than what does an increase of the capital ratio by 0.5%

[8] Note also that since the resolution method requires a third order approximation, this asymmetry is still present.

main activity consists in offering financial services to both households and firms (entrepreneurs). These services are of two types : collecting deposits from savers (deposit branch) and lending funds to both impatient households and entrepreneurs (loan branch).

The deposit branch

The retail deposit branch of bank i raises deposits from patient households and remunerate them at $R_t^{d,j}$. As mentioned in the previous section, all these collected deposits are lent to the wholesale branch at a nominal rate r_t. Exploiting its market power, the deposit branch chooses the optimal interest rate $R_t^{d,j}$ that maximizes its profit taking into account a finite elasticity of deposit supply. The deposit branch decision program boils down to:

$$\max_{D^j_{t+k},R^{D,j}_{t+k}} \mathbb{E}_t \sum_{k=0}^{\infty} \beta_b^k \lambda_{t+k}^p \left\{ \left(R_{t+k}^{IB} - R_{t+k}^{D,j}\right) D_{t+k}^j - \frac{\kappa_d}{2}\left(\frac{R_{t+k}^{D,j}}{R_{t+k-1}^{D,j}} - 1\right)^2 R_{t+k}^D D_{t+k} \right\} \tag{2.25}$$

D_t^j represent the part of the aggregated deposit supply D_t raised by bank j which is also a solution of the following equation:

$$D_t^j = \left(\frac{R_t^{D,j}}{R_t^D}\right)^{-\nu_D} D_t \tag{2.26}$$

where ν_D is the constant supply price elasticity.
The solution of the deposit branch programme involves the choice of a deposit rate which is of the form:

$$\begin{aligned} R_t^D = & -\frac{\nu_D}{1-\nu_D} R_t^{IB} \\ & - \left\{ \kappa^D \left(\frac{R_t^D}{R_{t-1}^D} - 1\right) \frac{R_t^D}{R_{t-1}^D} - \frac{\lambda_{t+1}^p}{\lambda_t^p} \beta_p \left(\frac{R_{t+1}^D}{R_t^D} - 1\right) \left(\frac{R_{t+1}^D}{R_t^D}\right)^2 \frac{D_{t+1}}{D_t} \right\} R_t^D \end{aligned} \tag{2.27}$$

The loan branch

Similarly, the loan branch of bank j borrows funds from the wholesale branch at R_t^b in order to lend them to households and firms. Thus, the corresponding optimization program can be written as:

$$\begin{aligned} \max_{L^{I,j}_{t+k},R^{L,I}_{t+k},L^{E,j}_{t+k},R^{L,E}_{t+k}} \mathbb{E}_t \sum_{k=0}^{\infty} \beta_p^k \lambda_{t+k}^p \Big\{ & R_{t+k}^{L,I,j} L_{t+k}^{I,j} + R_{t+k}^{L,E,j} L_{t+k}^{E,j} - R_{t+k}^b B_{t+k}^j \\ & - \frac{\kappa_{li}}{2}\left(\frac{R_{t+k}^{L,I,j}}{R_{t+k-1}^{L,I,j}} - 1\right)^2 R_{t+k}^{L,I,j} L_{t+k}^I - \frac{\kappa_{le}}{2}\left(\frac{R_{t+k}^{L,E,j}}{R_{t+k-1}^{L,E,j}} - 1\right)^2 R_{t+k}^{L,E,j} L_{t+k}^E \Big\} \end{aligned} \tag{2.28}$$

under the accounting identity:

$$B_t^j = L_t^{E,j} + L_t^{I,j} \tag{2.29}$$

as well as the demand equations from impatient households and entrepreneurs:

$$L_t^{I,j} = \left(\frac{R_t^{L,I,j}}{R_t^{L,I}}\right)^{-\nu_{L,I}} L_t^I \tag{2.30}$$

$$L_t^{E,j} = \left(\frac{R_t^{L,E,j}}{R_t^{L,E}} \right)^{-\nu_{L,E}} L_t^E \tag{2.31}$$

where $\nu_{L,I}$ and $\nu_{L,E}$ are respectively the households and entrepreneurs demand price elasticities. For each type of asset $A = \{I, E\}$, the interest rates' law of motion is in a symmetric equilibrium of the form:

$$\begin{aligned} R_t^A =& \frac{\nu_A}{\nu_A - 1} R_t^B \\ & - \left\{ \kappa^A \left(\frac{R_t^A}{R_{t-1}^A} - 1 \right) \frac{R_t^A}{R_{t-1}^A} - \frac{\lambda_{t+1}^p}{\lambda_t^p} \beta_p \left(\frac{R_{t+1}^A}{R_t^A} - 1 \right) \left(\frac{R_{t+1}^A}{R_t^A} \right)^2 \frac{L_{t+1}^A}{L_t^A} \right\} R_t^A \end{aligned} \tag{2.32}$$

2.3.5 Monetary Policy & Market clearing conditions

Monetary policy is specified in terms of an interest rate rule targeting inflation, its first difference as well as the first difference in output. The Taylor interest rate rule used has the following form:

$$1 + R_t = (1 + R_{t-1})^{\rho_R} \left[\left(1 + \overline{R} \right) \left(\frac{\pi_t}{\overline{\pi}} \right)^{r_\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{r_{\Delta Y}} \right]^{1-\rho_R} \varepsilon_{R,t} \tag{2.33}$$

where r_π is the weight assigned to inflation and ΔY that assigned to output growth. $\overline{R}$ is the steady-state policy rate and $\varepsilon_{R,t}$ is the monetary policy shocks. The law of motion of $\varepsilon_{R,t}$ is assumed to be as:

$$log\left(\varepsilon_{R,t}\right) = \sigma^\varepsilon \nu_t^r \text{ where } \nu_t^r \sim \mathcal{N}(0,1) \tag{2.34}$$

σ^ε is the standard deviation of the log monetary policy shocks which is considered as constant.

Aggregating all the agents's budget constraints, we set the following market clearing condition in goods market:

$$C_t^P + C_t^I + C_t^E + Q_t^k I_t \left(1 - \Gamma \left(\frac{I_t}{I_{t-1}} \right) \right) + \psi(z_t) K_{t-1} + \delta^b \frac{K_{t-1}^b}{\pi_t} + Adj_t^{NB} + Adj_t^B = Y_t \tag{2.35}$$

where Adj_t^B and Adj_t^{NB} include all adjustment costs in banking and non-banking sectors.

2.4 Calibration

Table A.3 summarizes our calibration choices. We fix several parameters to values in the range suggested by Gerali et al. [34] estimation or calibration. Thus, with respect to households inter-temporal elasticities, we set $\sigma_c^m = 1$, $\sigma_h^m = 1$ and $\sigma_n^m = 1$ for both patient and impatient households $m = P, I$. The same applies for the parameters related to nominal rigidities as well as all other Phillips curve parameters for both good and labor market. Finally, the share of the impatient households $(1 - \gamma_n)$ was set at 0.2 in accordance with Gerali et al. [34] calibration.

For some other parameters, we chose to set their values in order to pin down the steady-state values of some variables. We computed the steady-state values as the mean of the variable of interest on the sample starting from the beginning of 2003 until the mid of 2008, this choice of the sample is subject, on the one hand, to data availability and, on the other hand, to our willingness not to take into account the post Lehman Brothers collapse that triggered unusual variations in most financial variables. Using this strategy, we calibrate several parameters including some fundamental parameters such as the LTV ratios for households and entrepreneurs (θ^h and θ^e), as well as the households discount factor parameter β_p or the elasticities of the loans demand (resp. deposit supply) to the corresponding bank lending rates (resp. deposit rate). Moreover, we set the required level of banks capitalization ratio ν^b at 4.5% which corresponds to the Basel III "minimum common equity capital" ratio final objective, when the regulatory cost function parameters ξ_b and γ_b were fixed at 1 and 0.0013 respectively, which corresponds to a steady-state capital ratio 10.5% in line with the Basel III "minimum total capital plus conservation buffer" ratio.

For other parameters such as the weights of bank rates rigidities (κ_d, κ_{le} and κ_{li}) for which the calibration is more problematic, our calibration scheme was oriented towards the empirical literature. Therefore, we set the values of the previously mentioned parameters in a way that is consistent with the shape of the impulse response function of bank deposit/lending rates to a market interest rate shock which had been obtained from a SVAR using euro area data in de Bondt [18].

Concerning the volatility shocks parameters, we set the auto-regression coefficient ρ_σ at 0.95 when the steady-state value of σ_t^ε is equal to 0.125% which means that a one standard deviation shock on ν_t^r corresponds to a 50 bp rise in the annual policy rate. Finally, we put η^σ at 0.1 which means that starting at the steady-state interbank rate (3% in annual term), a simultaneous one-standard-deviation innovation to the rate with a one std shock to its volatility, the interbank rate jumps by about 56 bp rather than by 50 bp in the absence of volatility shocks.

2.5 Impulse response functions analysis

2.5.1 Level shock

Figure 2.2 shows the impulse response functions (IRFs) to a monetary policy shock, more precisely, an unanticipated 50 bp (on annual basis) increase in the monetary policy rate. The responses of interest rates, interest rate spreads and inflation are expressed in percentage points from their ergodic means while the responses of other variables are expressed in percent deviation from their ergodic means. The main objective of Figure 2.2 is to highlight that the calibrated model replicates standard stylized facts concerning the monetary policy transmission and more particularly concerning the interest rate pass-through.

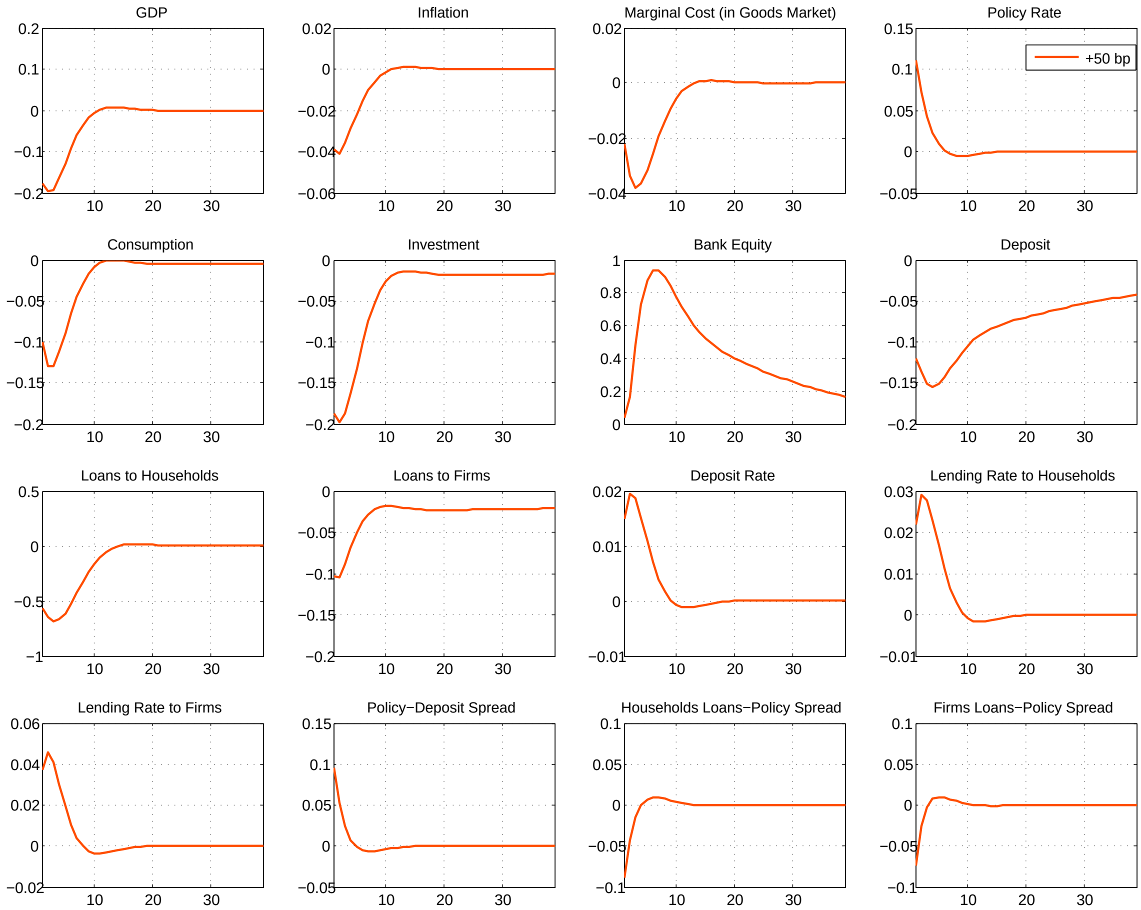


Figure 2.2: IRFs after a 50 bp rise in the monetary policy shock
All rates are shown as absolute deviations from steady state, expressed in percentage points. All other variables are percentage deviations from steady state.

First, we observe that banks' depositors receive a higher remuneration while banks' borrowers face more costly credit terms following the shock. The immediate pass-through from the policy rate to the retail rates are nevertheless incomplete. Furthermore, according to the calibration, rigidities are stronger on the deposit rate than on the loan rates. The policy rate increases by about 12 bp (in quarterly basis) when the shock occurs and leads to a 1.5 bp increase in the deposit rate while the loan rates increase respectively by 2.2 bp for households and by 3.7 percentage point for firms. As a result the immediate interest rate pass-through is around 13% for the deposit rate, 20% for the loan rate to households and 33% for the loan rate to firms. The size of these immediate adjustments in the retail rates is in line with the empirical literature (Mojon [56], de Bondt [18]).[9] During the following periods, the policy rate returns quickly to its ergodic mean when,

[9]Note that in the model, there is no difference between the policy rate and the money market rate at the equilibrium. In addition, the long run pass-through is given by the steady state equations. The long run pass-through is then different from 1 but depends on the mark-ups for the loan rates and depends on the mark-down for the deposit rate.

conversely, the retail rates still increase during one more period and then progressively turn down to their ergodic means, which highlights the sluggishness in the retail rates adjustments. For example, the impulse response of the lending rate to firms rise to 4.7 bp one period following the shock while impulse response of the policy rate is reduced to 7.3 bp. These differences are highlighted by the IRF of the firms loans-policy spread on Figure 2.2. This spread is negatively affected by the shock due to the incomplete immediate pass-through but turns slightly positive four periods following the shock due to the central bank's reaction and to the rigidities in bank interest rates. Considering banks' activities as a whole, Figure 2.2 shows a contraction in the credit and deposit volumes but the loan-deposit margins increase. Banks' profits and thus banks' equities increase following the shock. Second, price stickiness implies that impatient households and entrepreneurs face higher real borrowing costs. Consequently, the user costs of capital and housing rise; the demands for these assets fall and then asset prices decline. This downward movements in asset prices reinforces the credit constraints which lead therefore to a drop in banks lending and then to a downward adjustment in consumption and investment. In turn, patient households receive a higher real deposit rate. However, they reduce their deposit holdings as well as their consumptions, mainly due to intertemporal substitution effects. As a result, the monetary policy shock generates a drop in GDP that reaches a trough about 0.18% three periods after the shock. This value is quite lower than what we can find with standard new keynesian models even if they lack the amplification mechanism à la K&M. Indeed and as pointed out by Gerali et al. [34], the sluggishness of loan rates reduces the contraction of real variables since the transmission to the real sector of the contractionary monetary policy is smoothed across periods.

2.5.2 Volatility shock

The introduction of stochastic volatility in a New Keynesian framework has been considered notably by Fernández-Villaverde and Rubio-Ramírez [30] who highlight the importance of time-variant volatilities to account for macroeconomic fluctuations. Fernández-Villaverde et al. [29] and Fernández-Villaverde et al. [27] have more particularly focused their studies on the country spread and of fiscal volatility shocks. In this paper, we focus on an interbank rate volatility shock as well as on its implications for the interest rate pass-through.

Figure 2.3 represents the impact of a two-standard deviation uncertainty shock to the interbank lending rate.[10] Focusing on the differences between the IRFs for the three scenarios considered, we can see how the second and third order terms induce strong non-linearities in the responses with the latter increasing more than proportionally to the size of the shock. We remark also the non negligible impact of financial uncertainty

[10] For a matter of comparison, we also show the impulse responses of 4 and 7 standard deviations shocks to ν^{σ}. Starting from the steady-state value, an eventual 2 standard deviations change in the interbank rate would then represent a ± 0.62% when 4 and 7 std shocks would respectively represent around ± 0.75% and ± 1.0% variation of the interbank rate.

on the key real variables. Indeed, rational agents in the model react to the fact that future shocks will be drawn from a larger distribution and this will be true for many periods according to the high volatility shocks persistency. As a consequence, they react in a way that makes the potentially large shock as painless as possible. Indeed, a two standard-deviation interbank volatility shock triggers a drop in the overall output that reaches a low about -0.5% six quarters after the shock. This drop is equally driven by the decline in consumption and investment, each dropping by around 0.5%. Born and Pfeifer [8] found that a shock to the policy rate volatility has a contractionary effect on output that is mostly driven by the collapse in investment when consumption reacts sluggishly. Their model lacks however financial frictions that play a key role in the transmission mechanism of shocks. Indeed, in times of high volatility, households adopt a precautionary behavior that consists in diminishing their demand for consumption goods as well as their ability to invest in residential goods. This induces a drop in housing prices which in turn affects the ability of borrowing households to get funds from banks. The collateral constraint will thus play an amplification role that accentuate the positive correlation between house prices (or bank loans) and consumption. A similar mechanism arises for firms that witness tighter bank lending conditions through the decline in capital prices. Thus, we note that for the 2std shock, the bank loans to both households and firms decline by about 0.53% and 0.2% respectively when in the same time the corresponding interest rates go up. Indeed, a key result of an interbank rate volatility shock is the stagflationary effect that we note in most of the models' market. This result is similar to the one obtained by Fernández-Villaverde et al. [27] using fiscal volatility shocks. According to the contractionnary effect of uncertainty shocks, we would legitimately expect a downward pressure on prices. However, the impulse responses on Figure 2.3 indicate an upward trend in most of the prices in the economy, including the banking markets. Indeed, we observe from the impulse responses of interest rates spreads that the mark-up policy chosen by banks changes from what we would expect and also from what we have seen for a standard monetary policy shock. Focusing on this point, it should be noted that the increase in the bank lending rates spreads indicates that the pass-through from the policy rate to the bank lending rates are larger than unity. The monetary policy rate slightly increases following the volatility shock due to the stagflationary situation inducing a rise in firms lending rate. However, the spreads also increases and reach its maximum of 0.2 bp bp 1.5 year following the shock.

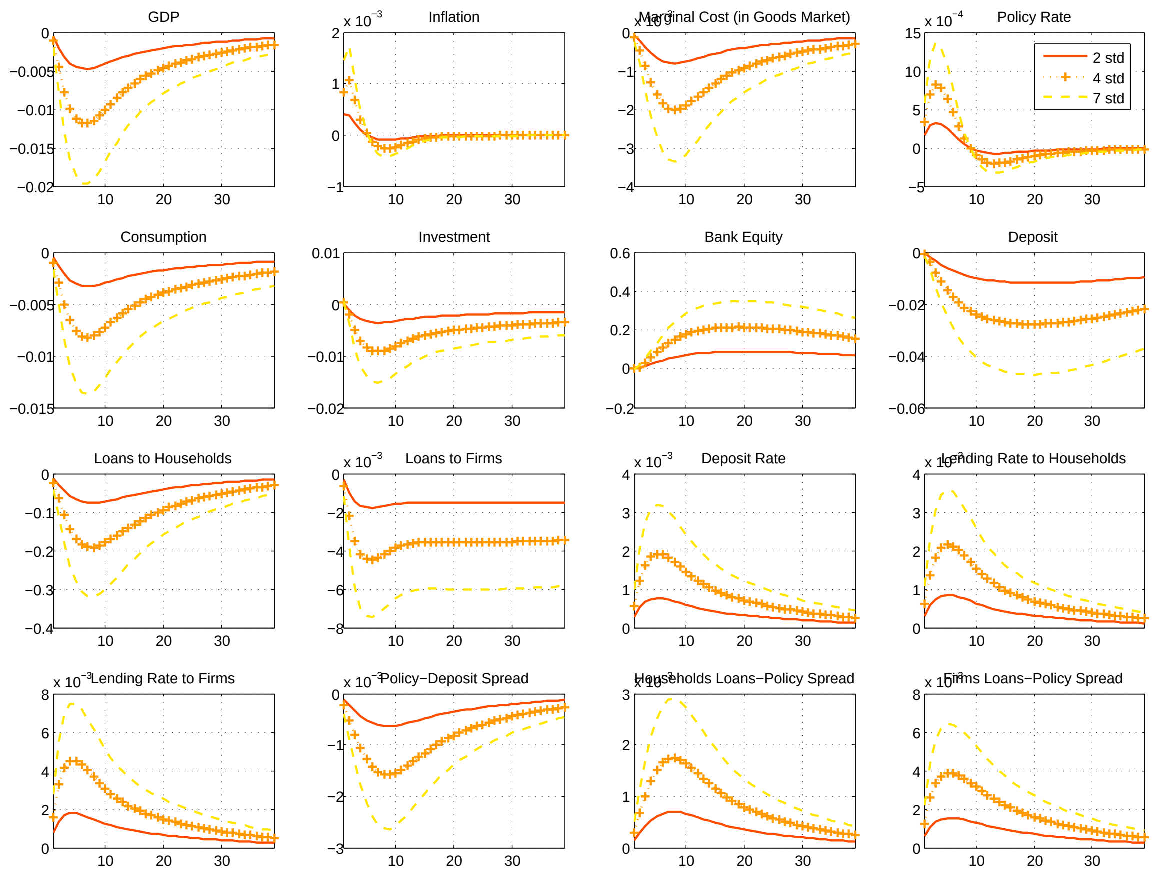


Figure 2.3: IRFs after a rise in interbank rate volatility
All rates are shown as absolute deviations from steady state, expressed in percentage points. All other variables are percentage deviations from steady state.

Fernández-Villaverde et al. [27] define an upward pricing bias channel to explain this upward trend in prices and corollary the stagflation situation. This channel, based on nominal rigidities, gives a particular importance to adjustment costs. Indeed, according to Fernández-Villaverde et al. [27], under uncertainty, profits are less impacted in terms of adjustment costs if prices are too high than if prices are too low. Goods retailers increase therefore their mark-up following the shock and inflation goes up. However, according to the impulse responses, we also found an upward pricing bias for the deposit branch of the banking sector when these "marginal cost makers[11]" are supposed to lower their marginal cost according to Fernández-Villaverde et al. [27] explanation. In this paper, we propose an alternative explanation to the change in mark-ups policy which is not necessary upward. As Fernández-Villaverde et al. [27] claimed, the upward trend in prices

[11]The deposit rate is not strictly speaking the marginal cost of the deposit brunch. We nevertheless will abusively use the "marginal cost maker" expression for a matter of simplicity.

is totally due to the presence of adjustments costs. Indeed, fearing to be hit by a large shock and factoring into that each price change will be costly, the optimizing agents decide to react in order to make the adjustment costs as low as possible. Moreover with the nominal rigidity à la Rotemberg, which considers adjustment costs to be proportional to the prices growth rate, to reach an optimal price it will be less costly to start from a high level of price than the inverse since with the same growth rate, then at the same cost, an optimizing agent would reach a closer price to the optimal one if he starts at a high level than at a low one. In Appendix B, we give more insights on the intuition behind this result. Still, it is important to note that this upward pricing pressures are not systematic, they seem depending on the specification of the nominal rigidity process that one chooses. However, testing different types of nominal rigidities specifications, we found that most of them generate this upward pressure on prices which in consequence should not alter the conclusions of our paper nor those of Fernández-Villaverde et al. [29] and Fernández-Villaverde et al. [27].

2.6 The transmission of the monetary policy in time of interbank uncertainty

2.6.1 A standard calibration

In this section, we assess the impact of the interbank market uncertainty on the transmission of the monetary policy. For that purpose, we generate the IRFs to two simultaneous shocks; the first one on the policy rate level and the second one on the volatility of the interbank rate.

The choice of the size of the shocks matters because we are dealing with a third order approximation (and thus non-linear) form of our model. In the baseline calibration, the standard deviation of the monetary market rate was set to a low level in line with the degree of volatility observed up to 2007. We represent therefore the increase in the interbank market uncertainty by a 7 standard deviations shock in the innovations of the standard deviation of the interbank rate (ν^{σ}). This value seems high when actually it means that a potential one std interbank change would correspond to $\pm$ 1% variation which has been witnessed several times in the last 2 decades. Concerning the shock on the policy rate, we consider an accommodative monetary policy that we define as a 50 basis point decrease in the interest rate. The impulse response functions are reported on Figure 3.4. To make the interpretation easier, we also report on Figure 3.4 the impulse response functions obtained following a 50 basis point decrease in the interest rate without any shock on the interbank rate volatility.

We note the transmission of the monetary policy to the real economy is initially not affected by the rise in the interbank uncertainty. However, except for the first period, Figure 3.4 shows some discrepancies between the impulse responses due to the inclusion, or not, of the volatility shock. We also note that the financial variables are those that are the most affected by the interbank volatility when the real variables carry much less of the volatility shock. This means that the banking sector filter the volatility shocks as it does with policy ones. This result is also in line with our finding in section 2.2.2 as well as Scharler [70] conclusions.

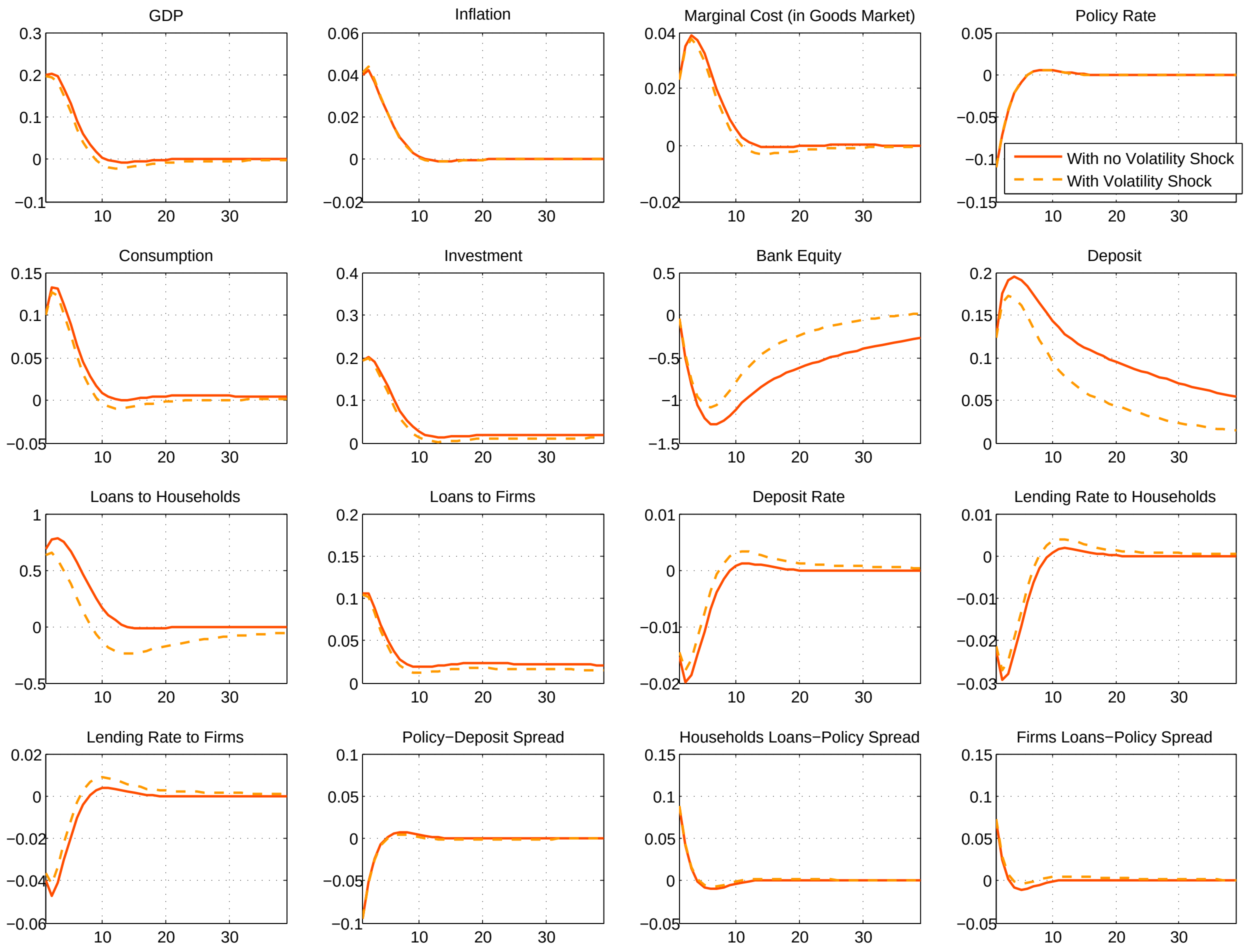


Figure 2.4: The transmission of monetary policy in time of interbank volatility
All rates are shown as absolute deviations from steady state, expressed in percentage points. All other variables are percentage deviations from steady state.

Concerning the interest rate pass-through, the deposit rate and the loan rates for households and firms decrease respectively by 0.015, 0.021 and 0.038 percentage point following the 0.11 percentage point reduction in the policy rate when the two shocks occur simultaneously. The immediate interest rate pass-through is then around 12.5% for the deposit rate, 19% for the loan rate to households and 31.5% for the loan rate to firms, which is slightly lower than the immediate interest rate pass-through observed when the interbank rate uncertainty remain at a low level. In addition, the differences between the IRFs for the retails interest rates increase during the periods 2 and 3. The transmission of the expansionary monetary policy to the retail interest rates is therefore noticeably reduced by the rise in the interbank rate volatility. The slow down in the interest rate pass-through identified during the 2007-2008 financial crisis (IMF [47], Čihák et al. [13], Aristei and Gallo [3] and Hristov et al. [44]) can therefore be explained by an interbank rate volatility shock occurring simultaneously with the monetary policy easing. Finally, due to the persistence in the interbank rate volatility shock and due to the stagflationary effects generated by this kind of shock, the IRFs of retail interest rate turn positive six periods following the shocks when the effects of the monetary policy easing are lessening.

As a consequence, we can see from the IRFs for spreads on Figure 3.4 that the lending margins increase while the deposit margins decreases. The upward pressures on prices generated by the volatility shock moderate therefore the drop in banks profits. Banks can rebuild their capital positions in relatively few quarters after the shocks. However, this resumption in banks benefits comes with a drop in deposits and lending activities. All of these evolutions were observed in the euro area following the financial crisis (ECB [22]).

2.6.2 The impact of structural parameters

In the previous subsection, we showed that for a standard set of parameters calibration, the transmission of the monetary policy to the real economy is affected by the degree of volatility in the interbank market. More precisely, the expansionary effect of a monetary policy easing and the interest rate pass through are weakened by a rise in the interbank rate volatility. In this subsection, we proceed to a sensitive analysis and we focus more particularly on the central bank behavior. The main objective is to evaluate if the disruption in monetary policy transmission generated by the volatility shock is reduced when the central bank behaves differently.

However, changes in structural parameters affect the effects both of the monetary policy easing and of the interbank volatility increase. As a result, to disentangle the effects generated by the change in the standard deviation from the effects generated by the change in the level, we use the following approach. First, we set different values for a structural parameter. Second, for each calibration, we compute the IRFs relatively to the two scenarios described in the previous subsection, i.e. the IRFs of an accommodative monetary policy with or without a modification of the interbank rate volatility. Third, we compute the relative difference in percentage between the two impulse responses.[12] This relative difference highlight to which extent the interbank volatility shock disrupts the effect of an accommodative monetary policy. More precisely, a positive value means that the volatility shock amplifies the monetary policy easing while a negative value indicates that the monetary policy easing is mitigated. In addition, a negative value lower that -100% indicates a sign inversion in the impulse response generated by the volatility shock.

2.6.2.1 Weight on inflation in the Taylor rule

The central bank could have the incentive to modify its reaction function if these modifications could improve the stabilizing powers of monetary policy. The interbank rate volatility shock is characterized by upward pressures on prices. We start therefore to con-

[12] For a given calibration, if $IRF_{X,t}^{level+volat}$ is the IRF for variable X in period t when the shocks on level and volatility occur simultaneously and $IRF_{X,t}^{level}$ is the IRF when only the level shock is considered, then we compute $(IRF_{X,t}^{level+volat}$-$IRF_{X,t}^{level})$*100/$IRF_{X,t}^{level}$.

sider a modification in the Taylor rule coefficient on inflation. The results are reported on Figure A.1. More precisely, the relative differences are reported for the baseline calibration (r_π=2) and for calibrations with a lower (r_π=1.5) and a higher (r_π=3 or 5) weight on inflation. Furthermore, we do not report the IRFs for all the variables but we rather focus on the situations of firms in order to save space.[13] We find that a more conservative strategy of the monetary authority, *ceteris paribus*, strengthens the disrupting effect of the interbank rate volatility shock on the real economy. Figure A.1 shows that the relative differences for loans to firms, investment and GDP, obtained with a more conservative central bank, are negative and below the ones obtained in the baseline calibration. Conversely, these relative differences are above the baseline situation when a less conservative central bank is considered. Indeed, as volatility shocks trigger inflation pressures in the economy, a central bank that mainly focuses on inflation will have more incentives to minimize its accommodative policy and will likely raise the policy rate more quickly. This will in turn put an additional upward pressure on bank lending rates, leading to a higher drop in bank loans and, at the end, investment and production. The main implication is that the volatility shock disrupts in a higher extent the interest rate pass-through as we can remark it to the graph relative to the loan to firms-policy rates spread on Figure A.1. Finally, Figure A.1 shows that the more conservative central bank get the inflation pressures generated by the volatility shock under control. The relative differences for inflation are closer to 0 and turn even negative when the weight on inflation in the Taylor rule is set to 3 or 5.
In conclusion, the degree of interest pass through is less resilient to the presence of volatility shock when the central bank is more conservative. In turn, the real economy benefit in a lower extent of the accommodative monetary policy shock.

2.6.2.2 Weight on GDP in the Taylor rule

In the baseline calibration, the central bank does not react to the GDP growth rate. The GDP weight is set to 0 in the Taylor rule. We can therefore investigate the consequences of a more balanced monetary policy including both GDP and inflation stabilization objectives. Figure A.2 shows the results corresponding to different calibrations of the weight of the output variation in the Taylor rule ($r_{\Delta Y}$): the relative differences are reported for the baseline calibration ($r_{\Delta Y}$=0) and for calibrations with a positive weight on GDP ($r_{\Delta Y}$ = 1, 2 or 5). The key result is that the impact of the financial uncertainty is very sensitive to the (semi) elasticity of policy rate to GDP. However, this relationship is not intuitive especially in the case of an accommodative monetary policy. Indeed, recall that the volatility shocks are stagflationnary, which means that a pure volatility shock has an ambiguous impact on the policy rate depending on the elasticity of policy rate to GDP. On the one hand, with a large elasticity, the monetary authority will be induced to decrease its rate after a volatility shock. This general equilibrium mechanism dampens largely the volatility shock effect. On the other hand, with a small elasticity to GDP growth, the policy rate initially increases after a pure volatility shocks which

[13]The conclusions can however be generalized to loans to households and to deposits activities. The whole set of IRFs is available upon request.

induces a larger negative impact on GDP. Thus, in time of accommodative monetary policy, a higher negative impact on GDP will reduce the GDP growth initially which in turn generates a smaller response from monetary authority according to its sensitivity to GDP. When in case of high elasticity, the lower negative effects of a pure volatility shocks combined to the large elasticity to GDP will induce a larger initial cut-off in interest rates. In consequence, larger the sensitivity of policy rate to GDP larger will be the amplification effects of volatility shocks initially (see. Fig. A.2). In the second half of our simulation period, the contribution of the volatility shocks starts increasing which induces negative pressure on the GDP and, in turn, gives incentives to monetary authority to ease its policy comparatively to what it would do in the absence of GDP sensitivity. The monetary authority moderates again the amplitude of most variables variations, the moderation degree being again very sensitive to the change in the policy rate and thus in to the general equilibrium channel. Fig. A.2 shows how a more balanced monetary policy is less affected by volatility shocks which, in turn, limits the amplification of volatility shocks.

2.6.2.3 Smoothing parameter in the Taylor rule

The central bank behavior is also characterized by the monetary policy smoothing parameter. In particular, an important feature following the monetary policy easing in 2007-2008 was the tendency initiated by the Federal Reserve of smoothing its monetary policy for a long period in order to keep the policy rate at a low level. We thus calibrate the policy-rate auto-correlation coefficient to different values (ρ_R=0.1, 0.5, 0.8 and 0.98) and we implement the same exercise as previously. Figure A.3 shows that a more pronounced smoothing by the central bank can reduce the disrupting effect of the interbank rate volatility shock on the real economy. The relative difference for a smoothing parameter fixed at 0.98 is above the relative difference of the baseline calibration for loans to firms and for GDP. Indeed, following the monetary policy easing, agents expect that the policy rate will be adjusted upward very progressively. The expansionary effect on the real economy is then magnified which offset the consequences of the change in the interbank rate volatility. However, the persistence in the policy rate and the evolution of aggregate demand lead to an amplification of the inflationary pressures. Figure A.3 shows that the relative difference for inflation is positive and above the baseline calibration when the smoothing parameter is high. These difficulties to keep inflation under control are the costs inherent in stabilizing the real sector.

2.7 Conclusion

Several empirical papers conclude that the interest rate pass through slowed down during the 2007-2008 financial crisis (IMF [47], Čihák et al. [13], Aristei and Gallo [3] and Hristov et al. [44]). However, very few structural approaches have been developed to explain these empirical findings. Only Hristov et al. [44] show that a modification in the frictions characterizing the banking sector, as for example tighter collateral requirements, can dampen the interest rate pass-through. In this paper, we rather focus on the interbank volatility. We point out that, during a financial crisis, banks cannot mute the consequences of an interbank rate volatility shock. As a results, retail interest rates and more generally the real economy can be affected by the time-variant interbank rate volatility.

We find that an interbank rate volatility shock has a stagflationary effect. Considering fiscal volatility shocks, Fernández-Villaverde et al. [27] already showed that volatility shocks can have a stagflationary effect. However, we provide an alternative explanation to the upward pressure on prices generated by a volatility shock. Our approach points out to the role of nominal rigidities specification in the interpretation of agents behavior.

Concerning the interest rate pass-through, we show that an interbank rate volatility shock disrupts the effect of a monetary policy easing. More precisely, following the cut of the policy rate, the downward adjustments of the retail interest rates are dampened because the rise in the interbank rate volatility generate upward pressures on all the prices in the economy. In addition, we show that a more conservative central bank would not perform better. The upward pressures on prices would be more aggressively managed, the degree of interest rate pass-through would be less stable, and the economic slowdown would be larger. A central bank with a more balanced monetary policy, reacting both to inflation pressures and to GDP variations, would be then in a better situation to deal with the consequences of an interbank rate volatility shock.

Appendices

A Tables & graphs

	Dependent variable	
	$Euribor_t^{1Y}$	r_t^L
b_{10}	0.9852*** (0.1811)	
b_{11}	0.8216*** (0.0600)	
b_{20}		1.3898*** (0.1676)
b_{21}		0.8397*** (0.0491)
R^2	0.89	0.89
Phillips-Ouliaris *tau*-stat	-3.07*	-4.14***
Phillips-Ouliaris z-stat	-18.05*	-21.16**

Note: ***, ** and * indicate significance respectively at the 1%, 5% and 10% levels. Standard errors are in brackets.

Table A.1: Long-run relationships

Mean equations

	Dependent variable	
	$\Delta Euribor_t^{1Y}$	Δr_t^L
k_{10}	-0.0005 (0.0075)	
k_{11}	0.5717*** (0.0610)	
k_{12}	0.1123** (0.0569)	
k_{13}	-0.0474** (0.0195)	
k_{20}		-0.0087 (0.0054)
k_{21}		0.2927*** (0.0667)
k_{22}		0.2058*** (0.0391)
k_{23}		-0.0845*** (0.0148)
R^2	0.47	0.49

Note: ***, ** and * indicate significance respectively at the 1%, 5% and 10% levels. Standard errors are in brackets.

Variance-covariance equations

	Coefficients	Std. Error
c_{11}	0.0005	0.0003
c_{12}	0.0002	0.0001
c_{22}	0.0002	0.0001
a_{11}	0.4271***	0.0636
a_{22}	0.3358***	0.0668
g_{11}	0.8938***	0.0284
g_{22}	0.9418***	0.0152

Table A.2: Short-run specification

Parameter	Description	Value
Households		
σ_c^P	Inter-temporal elasticity of substitution of patient households consumption	1
σ_c^I	Inter-temporal elasticity of substitution of impatient households consumption	1
η^P	Habit in patient households consumption coefficient	0.6
η^I	Habit in impatient households consumption coefficient	0.6
σ_n^P	Inverse of the Frisch elasticity for patient households	1
σ_n^I	Inverse of the Frisch elasticity for patient households	1
σ_h^P	Inter-temporal elasticity of substitution of patient households housing demand	1
σ_h^I	Inter-temporal elasticity of substitution of impatient households housing demand	1
θ^I	The LTV ratio for impatient households	0.1
Labor Market		
γ_w	Wage indexation on last period inflation rate	0.3
κ_w	Wage adjustment cost	70
Production		
σ_c^E	Inter-temporal elasticity of substitution of entrepreneurs consumption	1
η^E	Habit in entrepreneurs consumption coefficient	0.6
θ^E	The LTV ratio for entrepreneurs	0.075
α	Capital share in the production function	0.33
γ_n	the share of the impatient households	.8
δ	Capital depreciation rate	0.025
ϕ	Capital producers investment adjustment cost	1
ξ_2	Parameter of adjustment cost for capacity utilization	.00478
ν_g	$\frac{\nu_g}{\nu_g-1}$ is the mark-up in the good market	6
γ_p	Price indexation on last period inflation rate	0.15
κ_g	Price adjustment cost	30
Banking Sector		
κ_b	The weight of the regulatory cost	0.04
γ_b	The regulatory cost function	0.0013
ξ_b	The regulatory cost function	1
ν^b	The regulatory capital to total assets ratio	0.045
κ_d	Savers'deposits interest rate adjustment cost	70
ν_d	$\frac{\nu_d}{\nu_d-1}$ is the mark-down on deposit rate	-8
κ_{lh}	Households loan interest rate adjustment cost	20
$\nu_{L,i}$	$\frac{\nu_{L,i}}{\nu_{L,i}-1}$ is the mark-up on impatient households loan rate	3.2
κ_{le}	entrepreneur loan interest rate adjustment cost	10
$\nu_{L,e}$	$\frac{\nu_{L,e}}{\nu_{L,e}-1}$ is the mark-up on entrepreneur loan rate	3.7
Monetary Policy		
ρ_R	Policy rate persistency	0.8
r_π	Taylor rule coefficient on inflation	2
$r_{\Delta Y}$	Taylor rule coefficient on output growth	0
$\overline{R}$	Steady-state value of nominal policy rate	0.0075
$\overline{\pi}$	Target value of Inflation rate	0.005
Shocks		
$\overline{\sigma^{\varepsilon}}$	The steady state value of the stochastic policy rate volatility	0.00125
$\overline{\sigma^{\varepsilon^1}}$	The steady state value of the stochastic policy rate volatility	0.00125
ρ_σ	The AR coefficient of the stochastic policy rate volatility	0.95
η^σ	The standard deviation of $log(\sigma_t^{\varepsilon})$	0.1

Table A.3: Calibration

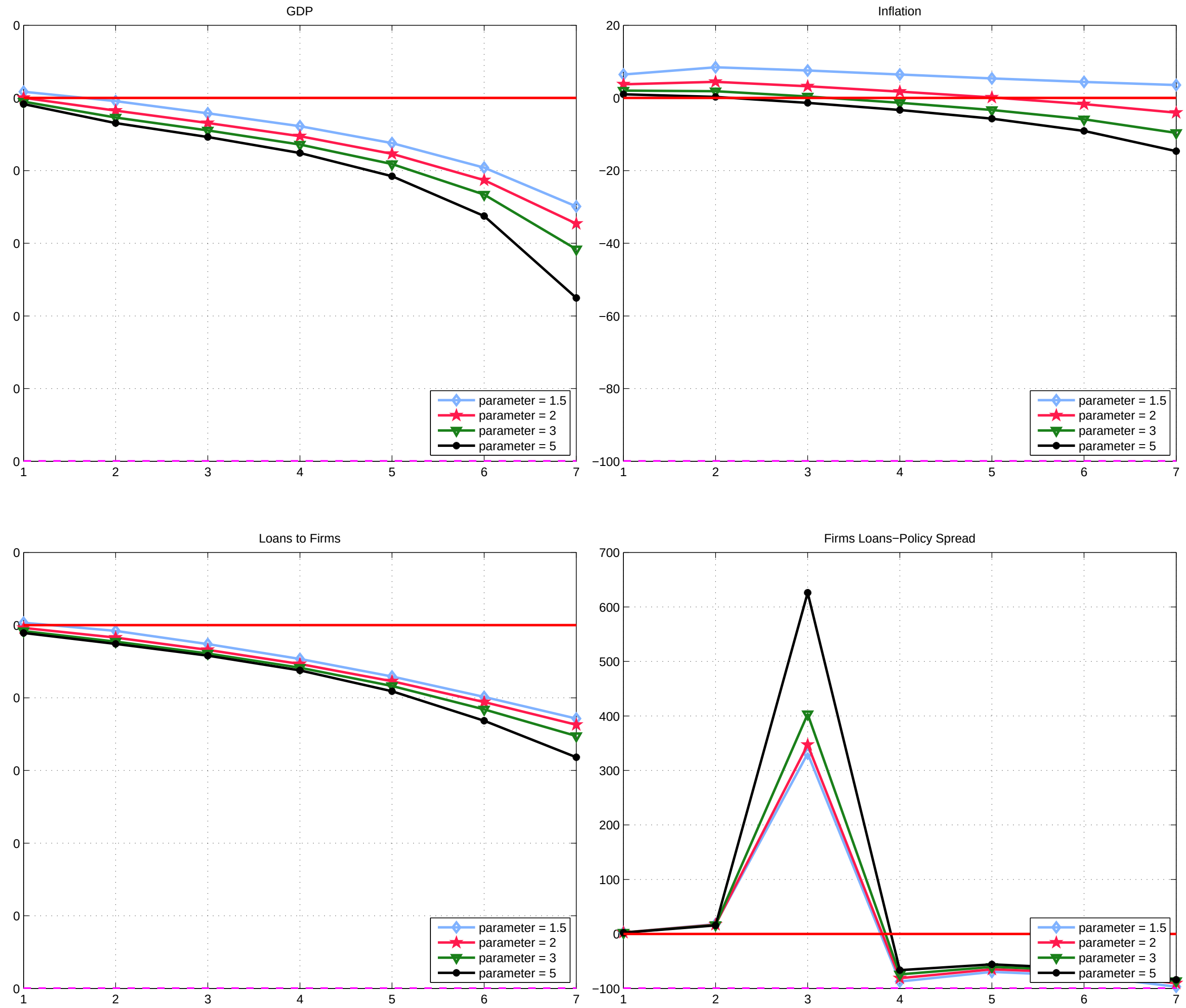


Figure A.1: The impact of the Taylor rule coefficient on inflation r_π

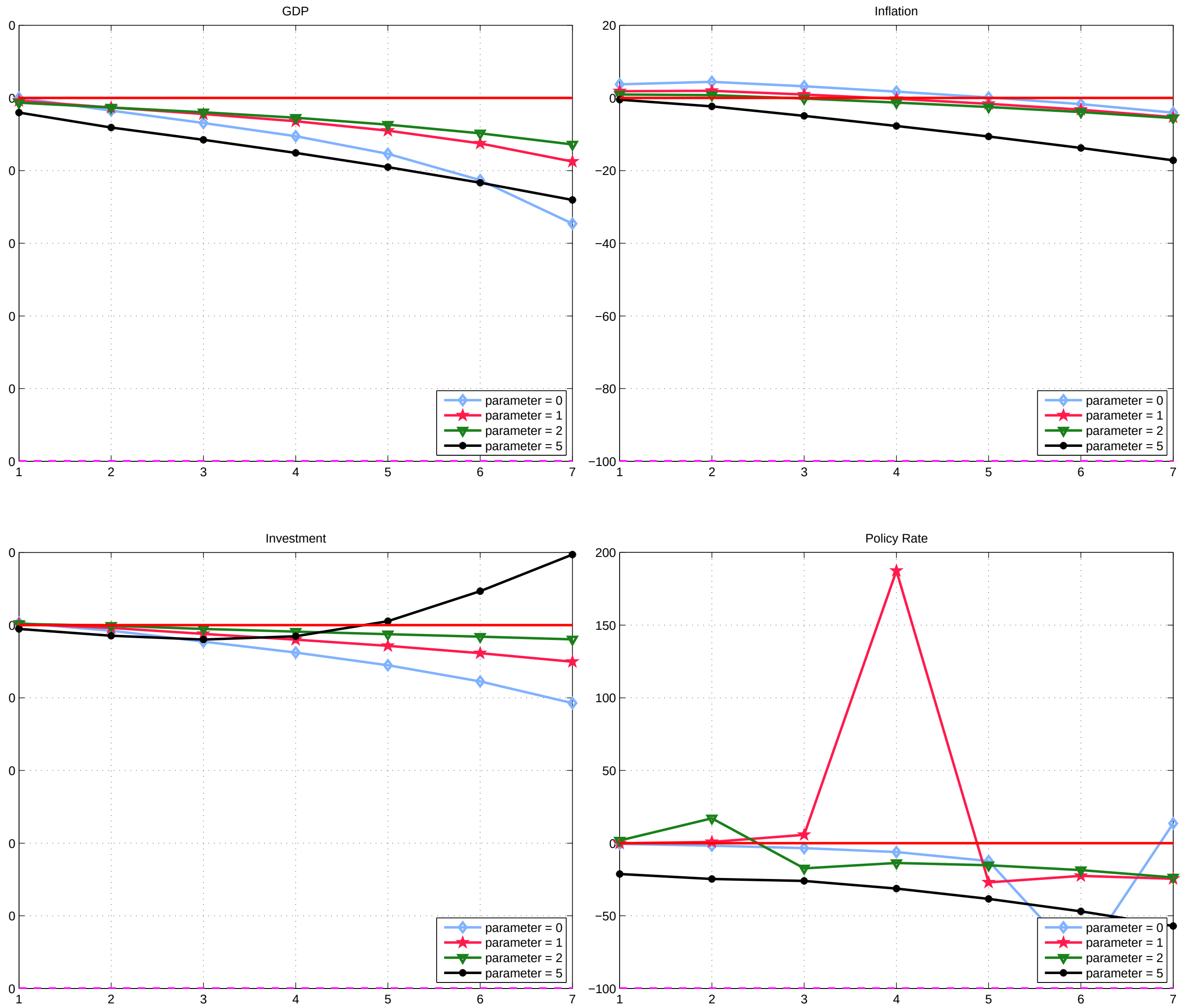


Figure A.2: The impact of the Taylor rule coefficient on output growth $r_{\delta Y}$

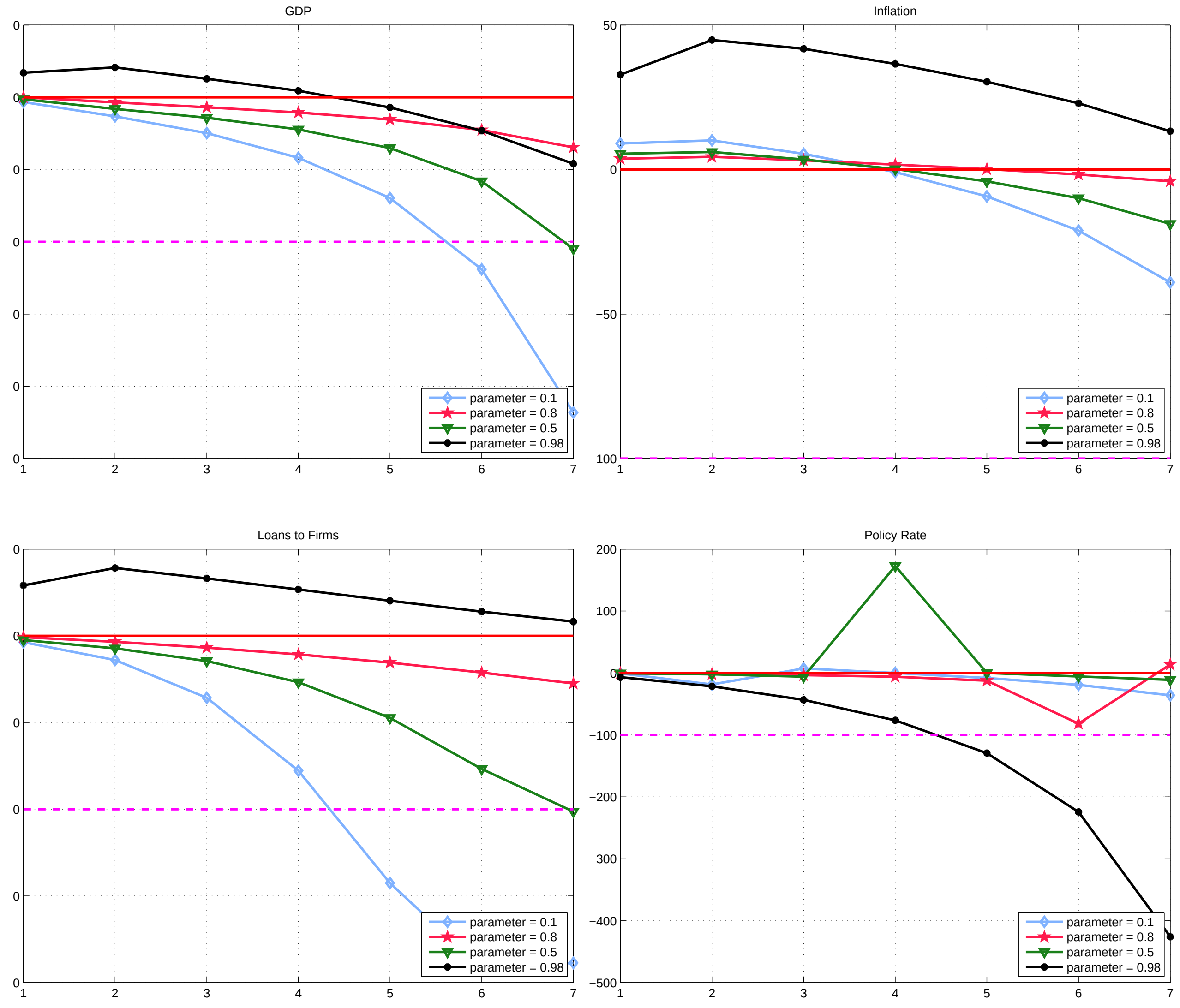


Figure A.3: The impact of the persistence in the policy rate ρ_R

B The upward pricing bias and The Rigidity à la Rotemberg

In the paper, we noticed that a volatility shock induce an upward pressure on prices in all the markets provided that they are set by optimizing agents. Thus, even the deposit branch who choose the level of the interest rate they will remunerate with the depositors increases its deposit rate when facing higher uncertainty on its selling interest rate. As it has been assessed by Fernández-Villaverde et al. [27], this upward pressure is due to the presence of nominal rigidities. However, in this section, we show that this upward pressure is not systematic and has more to do with nominal rigidities specification than the nominal rigidities themselves.
For this purpose, we developed a partial equilibrium model with a banking system à la Gerali et al. (i.e. with the 3 branches) but where we shut down the regulatory constraint, all the remaining variables being exogenous except the interest rates (both lending rates and deposit rate[14]. By doing so, we are able to disentangle the pure volatility shock from any other noisy effects such as the general equilibrium effect or the volume one. Fig. B.1 shows the results of a 2 std volatility shock on the bank rates.

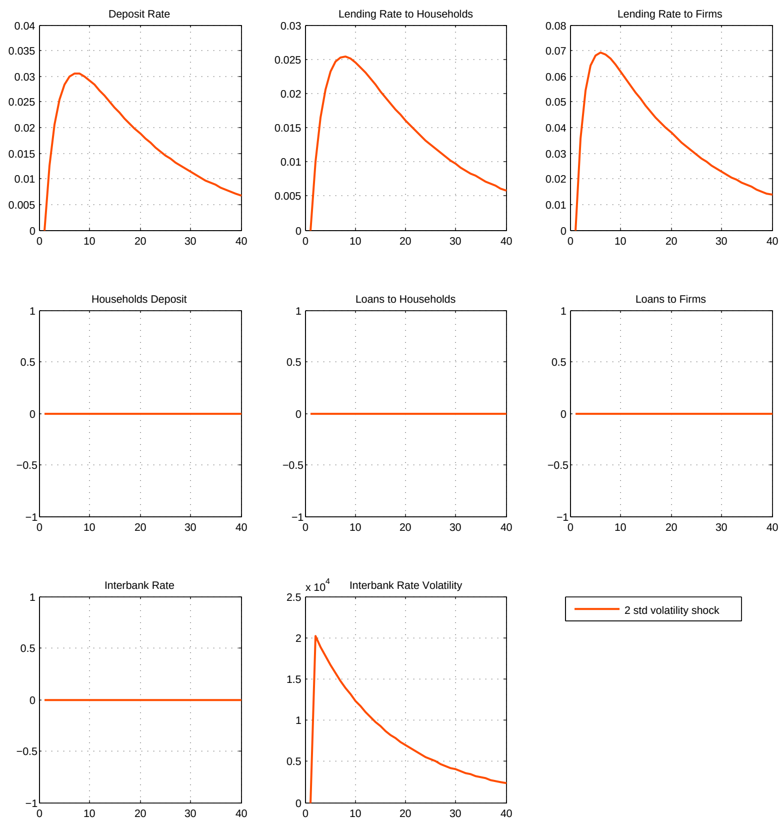


Figure B.1: Impulse responses after a 2 std volatility shock - baseline calibration

[14] We keep the same calibration than the baseline one.

This figure confirms the fact that the volatility shock has in this model an upward pressure on all the interest rates when the corresponding volumes do not move. As it has been suggested above, the intuition behind this result is as follows. In the optimizing agent point of view, a higher volatility is able to come with a high level of its marginal cost (or its selling price) which means also that he will, in this case, have to adjust its price at a level far from what it is set at the current period. In absence of adjustment costs, this will no reaction from the optimizing agent since he will set its price at the optimal one in each period and with no constraint. However, in the presence of adjustment costs, the optimizing agent knows that in the case he will have to reach a new optimal price, he will face costs that will force him to do it gradually and (probably) in many periods. In consequence and in order to avoid high adjustment costs, the optimizing agent will react in a way that it will minimize a potential cost that he would have to bear. Still, as the adjustment costs are proportional to the (squared) prices growth rates, the best way to minimize future potential costs is to be at a high starting point. This is especially the case when the processus needs different periods to be achieved, indeed with a same adjustment cost the price would be closer to the optimal one when we start from a high starting point than from a lower one. Thus, in order to minimize this future potential costs, optimizing agents will rise their prices, would them be selling price or marginal costs. The key point is that they are the prices involved in the adjustments costs.

In this section, we implement the same partial equilibrium model than above but we change the adjustment costs specification in a way that makes them more sensitive to the inverse growth rates than to the growth rates.
The adjustment costs relative to interest rates R^x will be of the form :

$$\frac{\kappa}{2}\left(\frac{R^x_{t-1}}{R^x_t} - 1\right)^2$$

In this case, more the prices growth rate is high, lower the costs are. We would in consequence expect that the optimizing agent would rather prefer to decrease their prices after a volatility shock. Fig. B.2 shows the results of such a specification that confirm our intuition.

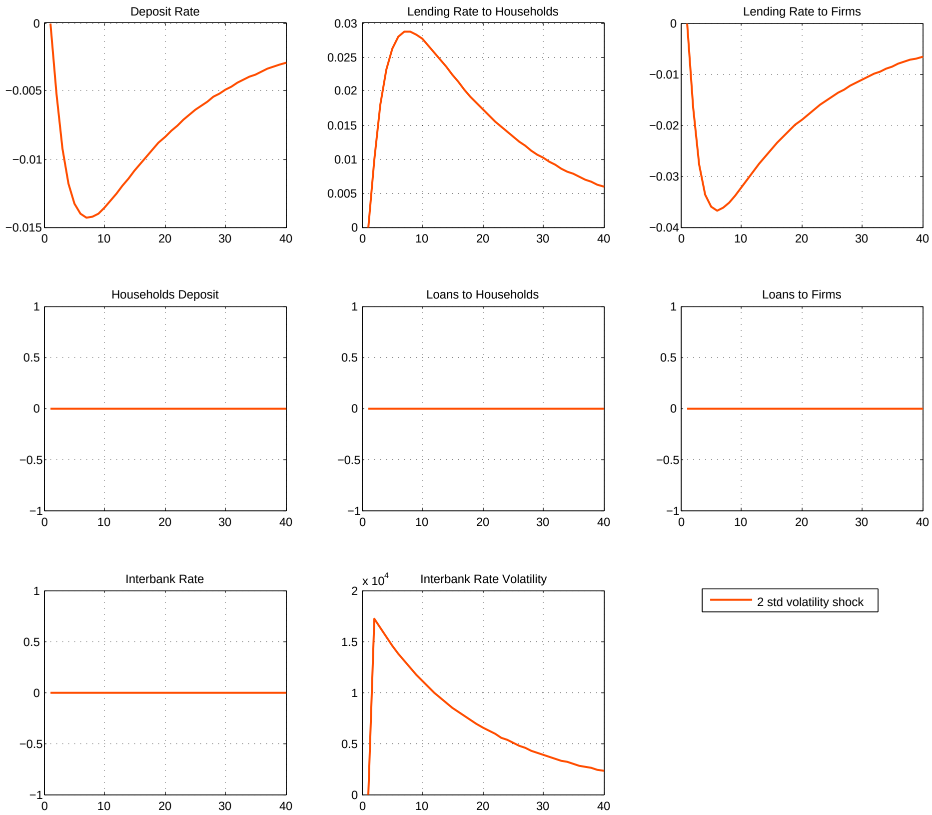


Figure B.2: Impulse responses after a 2 std volatility shock - inverse growth rate

The last simulation consists in making the adjustment costs no more sensitive to growth rates and than to the starting point. In this case, we would expect that the optimizing agent would not move its prices.
For this purpose, we consider the following adjustment costs :

$$\frac{\kappa}{2}\left(\frac{R_t^x}{\overline{R_t^x}} - 1\right)^2$$

Fig. B.3 below represents the results of a such specification that confirm our intuition.

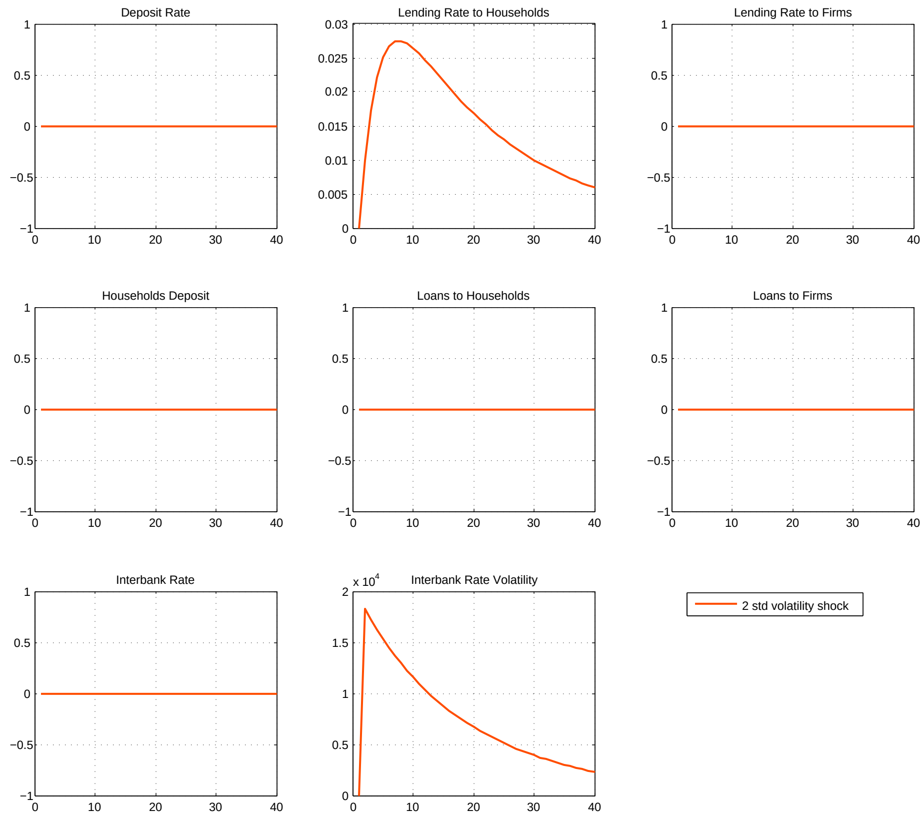


Figure B.3: Impulse responses after a 2 std volatility shock - no growth rate

Chapter 3

A DSGE model to assess the post crisis regulation of universal banks

3.1 Introduction

Following the Great Financial Crisis that started in 2007 a general consensus emerged to conclude that the previous regulatory framework had largely failed to detect and prevent the build-up of excessive risk-taking in the financial sector.[1] As a consequence a new regulatory agenda has been put in place including several dimensions, regarding banks' solvency and -substantial innovation- liquidity, as well on banks' business models.

The regulatory agenda is still very dense and while the contours of solvency regulation in Basel III are broadly defined, liquidity regulation is still under discussion. This includes the exact calibration of the Liquidity Coverage Ratio and the Net Stable Funding Ratio (NSFR). In particular under article 509 (1) of the Capital Requirement Regulation, that applied to the European Union, the EBA is requested to investigate annually whether "the general liquidity coverage regulation [...] is likely to have a material detrimental [...] on the economy and the stability of the supply of credit, with a particular focus on lending to SMEs [...]".

While in the long run, a tighter solvency and liquidity regulation helps increase the resilience of the banking sector, hence the financing of the economy, policy makers face a dilemma in the short run, as on the one hand restraining banks' leveraging and increasing liquidity helps reduce banking instability, but on the other hand, it may endanger the continuous flow of credit to the real economy

State of the art macroeconomic model, namely DSGE models including a fully fledged banking sector should be the appropriate tool to answer such a question, more generally to assess the consistency of the regulatory changes and their effects on the real economy, as well as to point out to the relevant tradeoffs.

However, while major progress has been made towards that goal, available macro models are still unsatisfactory.

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[1]This chapter is based on joint work with Olivier de Bandt

Indeed, the new Basel III requirements triggered a large set of studies that mainly focused on the overall impact of the new regulatory constraints on the real economy. The Macroeconomic Assessment Group (MAG Macroeconomic Assessment Group [55] and MAG Macroeconomic Assessment Group [54]) conducted in this regard two studies on the economic benefits and costs of stronger capital and liquidity regulation in terms of their impact on output. Angelini et al. [1] implemented 13 different models in order to analyze the long-term economic costs of the new rules putting forward the potential increase in banks margins as well as the subsequent drop in production, however most of the models were not fully consistent general equilibrium models. On the other hand, Gerali et al. [34] as well Darracq Pariès et al. [17] build DSGE model with a detailed banking sector including a wholesale and a retail branch. However, they concentrate on the effect of the solvency ratio, without considering liquidity regulation. In addition, the phasing in of the regulation is not investigated while it seems quite crucial for the effect on lending. One of the aims of this paper is to check how relevant these assumptions are.

For this purpose, we develop a large scale DSGE model of the euro area with a banking sector and credit frictions a la Iacoviello [46] and Gerali et al. [34]. However, the European banking system is dominated by the universal banking model, as in many European countries, where few banks represent a very large part of total assets in the system as well as of provision of financial services. Therefore, we propose to model both investment and retail branches of a bank unlike what is common in the literature, which focuses instead on the distinction between wholesale and retail branches, hence omitting a possible link with the real economy.

Indeed, investment banking in our modele comes with the introduction of a (corporate) bond market. We find it relevant to match the increasing share of securities issuance in Europe. Debt issuance can be seen as a substitute to bank loans for large corporations. In that respect Europe is getting closer to the US. This is also a way of to investigate further the role of investment banking in the crisis, as its failure (in particular Bear Sterns and Lehman Brothers) played a crucial role. We thus introduce a corporate bond market where large firms are able to issue bonds to fund a part of their expenses. A source of credit that is not available to small and medium size enterprizes (SMEs hereafter). We introduce this heterogeneity in the production sector in line with studies by Gertler and Gilchrist [35], Gilchrist et al. [40] among many others. Indeed, one key feature in the study of financial interaction with the real economy relies on the ability of borrowers to have access to different alternative sources of credit, or more specifically, to the degree of substitutability between (private) bank borrowing and public funding. Still, the fixed costs of issuance of bonds as well as the disclosure requirements are among others the reasons behind the fact that only large firms have access to the corporate market. Thus, conditions in financial and credit markets would have different impacts depending on the economy structure. Giesecke et al. [38] argues that "the Great Depression collapse of credit hit small and medium sized firms particularly hard since they did not have the same access to alternative forms of credit that a larger firm might". This result is consistent with the findings of Gertler and Gilchrist [35] as well as Chari and Kehoe [10].

Moreover and to assess the macroeconomic effects of the new banking regulatory constraints, we mainly focus on the Basel Committee's proposed capital and liquidity reforms that are incarnated in the capital to weighted assets ratio as well as the new liquidity ratios (Liquidity Coverage Ratio (LCR) and the Net Stable funding Ratio (NSFR)). However, if the last financial turmoil led to a wide range of studies on the macroprudential regulation, only few of them have investigated the issue of liquidity requirements. Indeed, liquidity presents more data and modeling challenges than capital, its impact is addressed by fewer models. The main contributions are, in our knowledge, those mentioned above namely both MAG studies as well as Angelini et al. [1]. Still, not all of the models used in those studies feature bank liquidity. Moreover, even those that incorporate liquidity requirements adopt very simple definitions of the liquidity constraint which mainly takes the form of a liquid to total assets ratio, the former being generally represented by sovereign bonds, a definition that is "quite distant from the complex measures introduced by the new rules" as attested in Angelini et al. [1] report. Indeed, liquidity matter comes along with assets maturity concerns. Yet, standard General Equilibrium Models, which represent the suited and thus mainely used framework to assess the macroprudential regulation effects, use the standard one period maturity assumption. An hypothesis that is consistent neither with the economic concept of liquidity, nor with its Basel III definitions. Thus, neglecting the maturity mismatches in the liquidity constraints definition, one may run the risk of omitting a large part of the dynamics of macroeconomic variables. For this reason, we made the choice to develop an economy where most of the assets have more than a one period maturity, using for this purpose the Benes and Lees [4] framework which incorporate differences in assets maturity at the cost of few additional state variables.

The main finding of the paper is that the impact of the capital ratio differs from what will induce the implementation of the new LCR requirement. First, the implementation of liquidity regulation, which affects private consumption, has a more persistent effect than solvency regulation that affects loan distribution as well as investment. Second, implementing both regulations simultaneously has compounded macroeconomic effects. Third, the model allows to quantify to what extent a more progressive implementation of the regulatory changes affects the mix between deleveraging and increasing profit margins in favour of the latter strategy. A more progressive implementation also has less adverse effects on SMEs that would suffer much less from the new regulatory requirements.

The paper is structured as follows. Section 3.2 provides an overview of the theoretical model where we mainely present each agent's objective function and the corresponding constraints when we develop the details in the technical appendix. Section 3.3 deals with the calibration matter of the model when Section 3.4 presents simulation results, drawing comparisons between the different types of Basel III implementation shapes. Section 3.5 concludes and describes several directions for future research.

3.2 The model

The economy[2] is mainly populated by households and two types of entrepreneurs[3]. Households consume, work and accumulate saving in the form of banking deposits, while entrepreneurs produce intermediate good using capital bought from specific capital-good producers and labor supplied by households. Entrepreneurs differ regarding their ability to have access to the bond market, large firms can issue corporate bonds, along with banking loans, to finance their activity when SMEs are limited to the banking loans.
As it is standard in the DSGE literature, there is a monopolistic competition at the workers' and unions' level. But firms use an homogeneous labor input. More formally, workers supply their differentiated labor services through a set of unions which operates in a monopolistic competitive market. Unions differentiate the aggregated level of labor issued by households and sell their services to a competitive labor packer which supplies a single labor input to firms.
The intermediate goods produced by entrepreneurs are aggregated by a perfectly competitive retailer to transform them to an homogeneous good which will be offered to final consumers through distributors. The latter evolve in a monopolistic competitive market.
The economy is also characterized by the presence of a financial intermediary represented by a continuum of universal banks. Each bank collects households' deposits and interbank funds which form, together with its accumulated own capital, the total liabilities. On the asset side, banks supply loans to both kinds of entrepreneurs and purchase corporate bonds. The banking system faces three classes of frictions. First, banks faces quadratic adjustment costs when changing their nominal interest rates, this degree of nominal rigidity generates some imperfect pass-through of policy rate to bank deposit, lending and bond interest rates. Second, they operates in a monopolistic competitive market which can amplify/attenuate the impact of some of their decisions. Third, banks face capital requirements as well as liquidity ones represented by the Basel III LCR.
The question of the new Basel III requirements implementation has been recently investigated in the literature (Roger [66], Gambacorta [32] among others). However, as it was stated Angelini et al. [1] report, most of the model featuring bank liquidity generally "adopt very simple definitions (e.g. the ratio of cash and government bonds to total assets) for the bank liquidity, that are quite distant from the complex measures introduced by the new rules". One reason behind this simplification is the use of DSGE models standards that are all based on one period maturity assets when the notion of liquidity - and more specifically both Basel III liquidity constraints (NSFR and LCR) - intrinsically presupposes a maturity mismatch between and within assets. One key feature of our model is that we develop an economy where most of the assets have more than a one period maturity. This allows us to asses much better the impact of the new

[2]The scheme in the end of this paper sums up the model and the main interactions between the different agents.

[3]Thereafter, the variables and parameters corresponding to households are indexed with 'w' (for workers), when those for entrepreneurs are indexed with 'e', for some variables and parameters we add a 'p' for SMEs and a 'g' for large firms. Finally, 'f' is used for final goods producers and distributors.

Basel III liquidity constraints (and more specifically the LCR) taking into account the maturity mismatch between the assets coupled with the heterogeneity in the productive sector as well as the different frictions in the model.

3.2.1 Households

There is a continuum $h \in [0,1]$ of infinitely-lived households, each representative household h maximizes its intertemporal utility function which is assumed to be of the form :

$$\mathcal{W}_t^{w,h} = \mathbb{E}_t \left[\sum_{i=0}^{\infty} \beta_w^i \left(\frac{1-\eta^w}{1-\sigma_c^w} \left(\frac{C_{t+i}^{w,h} - \eta^w \overline{C}_{t+i-1}^w}{1-\eta^w} \right)^{1-\sigma_c^w} - \frac{(N_{t+i}^h)^{1-\sigma_n}}{1-\sigma_n} \right) \right]$$

This utility function depends on consumption $C_t^{w,h}$ and hours worked N_t^h. The parameter σ_c represents the inter-temporal elasticity of substitution and η^w measures the degree of external habit formation in consumption[4]. Each period, the representative household have to optimize his utility function under the following budget constraint (in real terms) :

$$C_t^{w,h} + D_t^{w,h} + T_t^{w,h} = \frac{W_t^h}{P_t} N_t^h + \frac{J_{t-1}^{D^w,h}}{\pi_t} + \frac{J_{t-1}^{T^w,h}}{\pi_t} - BC_t^{w,h} + \mathscr{D}_t^{w,h} \tag{3.1}$$

The flow of expenses includes current consumption $C_t^{w,h}$ and the new deposit flow $D_t^{w,h}$. Resources include wage earnings $\frac{W_t^h}{P_t} N_t^h$, dividends $\mathscr{D}_t^{w,h}$ from the different types of firms that all belong to households and gross interest income on last periods deposits $\frac{J_{t-1}^{D,h}}{\pi_t}$ as well as on their financial investment in corporate bonds $\frac{J_{t-1}^{T^w,h}}{\pi_t}$.
Indeed, we consider a multi-period assets framework as in Benes and Lees [4]. The letter J_t^X refers to interests and (partial) principal repayments on all the assets X_{t-k} that households invested in k periods ago ($k \geqslant 0$). Thus, at time t, household "h" holds a stock of deposits and corporate bonds noted SD_t^h and $ST_t^{w,h}$ respectively.
Adopting the Benes and Lees [4] multi-period fixed-rate assets framework, we assume that the capital repayment required at each period is a constant proportion $(1-\delta^X) \in [0,1]$ of the residual outstanding amount SX_t of the asset X. Moreover, the interest payments are also due on this residual outstanding amount of the debt. This two assumptions involve a geometric repayments scheme that has two major practical advantages : First, the geometric distribution allows for simple recursive equations for most of the variables of interests. Second, the average maturity of an asset can be calibrated using only one parameter, namely the parameter δ^X. For example, we can easily show that according to the Macaulay's duration definition, the average maturity "d^X" of the asset X is (at the steady-state) of the form $d^X = \frac{R}{R-\delta^X}$ where R is the discounting interest rate. Thus, choosing the adequate calibration for the parameters "R" and "δ^X", we can set different maturities values for the different assets in the economy.

[4] Since C_t^w is the aggregate level consumption at period t

More practically, the sum of all repayments (in real terms) related to $X = (D, T^w)$ due at time 't' can be assessed as :

$$J_{t-1} = \sum_{k=1}^{\infty} (\underbrace{1-\delta^X}_{\text{capital repayment part}} + \underbrace{R_{t-k}^X}_{\text{interest repayment part}}) \underbrace{\left(\delta^X\right)^{k-1} X_{t-k}}_{\text{Residual amount in 't' of the asset bought in 't-k'}} \frac{P_{t-k}}{P_{t-1}}$$

which can be rewritten recursively as :

$$J_t^X = \frac{\delta^X}{\pi_t} J_{t-1}^X + (1 - \delta^X + R_t^X) X_t$$

As well, the stock of assets hold at time t is of the form :

$$SX_t = \sum_{k=0}^{\infty} \left(\delta^X\right)^k X_{t-k} \frac{P_{t-k}}{P_t} \Longleftrightarrow SX_t = \frac{\delta^X}{\pi_t} SX_{t-1} + X_t$$

According to this framework, one saving unit will afford resources not only in the next period but in the periods that come afterwards. Furthermore, the optimality condition assess that the current period marginal utility of consumption (noted λ_t, see the left hand of equation (3.2)) must equal the discounted values of one unit saving benefits (the right hand). We can thus write :

$$\begin{aligned}\Lambda_t &= \mathbb{E}_t \left\{ \beta_w \Lambda_{t+1} \left(1 - \delta^D + R_t^D\right) + \beta_w^2 \Lambda_{t+2} \left(1 - \delta^D + R_t^D\right) \delta^D + \beta_w^2 \Lambda_{t+2} \left(1 - \delta^D + R_t^D\right) \left(\delta^D\right)^2 + ... \right\} \\ &= \beta_w \left(1 - \delta^D + R_t^D\right) \mathbb{E}_t \underbrace{\sum_{j=1}^{\infty} \left[\Lambda_{t+j} \left(\beta_w \delta^D\right)^{j-1} \right]}_{=K_t}\end{aligned} \tag{3.2}$$

K_t can be written recursively as $K_t = \Lambda_{t+1} + \beta_w \delta^D K_{t+1}$.
Also, and using the optimality condition equation (3.2)), we know that $\Lambda_{t+1} = \beta_w \left(1 - \delta^D + R_{t+1}^D\right) K_{t+1}$.
Merging the two equations gives :

$$\mathbb{E}_t \left(\frac{\Lambda_t}{\Lambda_{t+1}} \frac{1}{\beta_w} \right) = \left(1 - \delta^D + R_t^D\right) \mathbb{E}_t \left(1 + \frac{\delta^D}{1 - \delta^D + R_{t+1}^D} \right)$$

The last equation represent modified version of the standard Euler equation which indicates that the consumption growth path depends not only on the current period deposit rate but also on the next period expected value.

Going back to the households program, we suppose that households have access to bond market in the sense that, in each period, the representative households is able to hold corporate bonds $T_t^{w,h}$ that pays a nominal interest rate R_t^T that is usually larger than the deposit rate $> R_t^D$. However, the households can not operate in the bond market directly, they have to turn to some intermediaries services who require in return costs $BC_t^{w,h}$ which are of two kinds : costs for managing the bond portfolio proportional to the portfolio contemporaneous gains and transaction costs which are proportional to the change within a period in the outstanding amount of assets[5]. Indeed, we suppose $BC_t^{w,h}$ to be as :

$$BC_t^{w,h} = (1-\mu_t^w)\frac{J_{t-1}^{T^w,h}}{\pi_t} + \frac{\kappa^w}{2}\left(\frac{ST_t^{w,h}}{ST_{t-1}^{w,h}}\pi_t - 1\right)^2 ST_t^w \tag{3.3}$$

3.2.2 Labor Market

In the labor market, there is a continuum of unions $\iota \in [0,1]$, each of which represents a certain type of labor. Unions differentiate the aggregated level of labor issued by households ($N_t^H = \int_0^1 N_t^h dh$) and sell its services in a monopolistically competitive market to a perfectly competitive firm which transforms it into an aggregate labor input using a CES technology function :

$$N_t = \left(\int_0^1 (N_t^\iota)^{\frac{\nu_w - 1}{\nu_w}} d\iota\right)^{\frac{\nu_w}{\nu_w - 1}}$$

where ν_w is the elasticity of substitution between differentiated labor services.
As a consequence, the unions face a labor demand curve with constant elasticity of substitution which is in the form :

$$N_t^\iota = \left(\frac{W_t^{e,\iota}}{W_t^e}\right)^{-\nu_w} N_t \tag{3.4}$$

$W_t^e = \left(\int_0^1 (W_t^{e,\iota})^{1-\nu_w} d\iota\right)^{\frac{1}{1-\nu_w}}$ is the aggregate wage the entrepreneurs have to pay.

In addition, unions set their wages on a staggered basis ? la Rotemberg [67] in the sense that, at each period, every union faces quadratic adjustment costs with indexation to a weighted average of lagged and steady-state inflation.
Each union thus maximizes :

$$\max_{N_t^\iota, W_t^{e,\iota}} \mathbb{E}_t \sum_{k=0}^{\infty} \beta^k \lambda_{t+k}^w \left\{ \frac{W_{t+k}^{e,\iota}}{P_{t+k}} N_{t+k}^\iota - \frac{\kappa_w}{2}\left(\frac{W_{t+k}^{e,\iota}}{W_{t+k-1}^{e,\iota}} - \pi_{t+k-1}^{\gamma_w}\overline{\pi}^{1-\gamma_w}\right)^2 \frac{W_{t+k}^e}{P_{t+k}} N_{t+k} - \frac{W_{t+k}^\iota}{P_{t+k}} N_{t+k}^\iota \right\}$$

subject to the demand constraint (3.4).

In a symmetric equilibrium, the labor choice for each single union in the economy will be given by the (non-linear) wage-Phillips curve :

$$\begin{aligned}\kappa_w \left(\frac{w_t^e}{w_{t-1}^e}\pi_t - \pi_{t-1}^{\gamma_w}\overline{\pi}^{1-\gamma_w}\right)\frac{w_t^e}{w_{t-1}^e}\pi_t \\ = 1 - \nu_w\left(1 - \frac{w_t}{w_t^e}\right) + \beta_w \frac{\lambda_{t+1}^w}{\lambda_t^w}\kappa_w\left(\frac{w_{t+1}^e}{w_t^e}\pi_{t+1} - \pi_t^{\gamma_w}\overline{\pi}^{1-\gamma_w}\right)\frac{w_{t+1}^e}{w_t^e}\pi_{t+1}\frac{N_{t+1}}{N_t}\end{aligned} \tag{3.5}$$

[5]Indeed, we choose to keep the definition of transaction costs as costs on the change in the outstanding amount rather than on new purchased asset in order to model the incentives offered by financial intermediaries in order to keep a minimum level of households investment in bonds.

With $w_t = \frac{W_t}{P_t}$ the wage received by households in real terms.

Since we make the assumption that workers have the ability to choose costlessly to work for small or large companies, the aggregate labor rate faced by each of these companies is unique (equal to w_t^e).

3.2.3 Production

Small Entrepreneurs (SMEs)

In the economy there is a continuum $i \in [0,1]$ of small entrepreneurs (indexed by "p") that have to maximize their specific consumption $C_t^{i,p}$ according to the following utility function :

$$\max \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \beta_p^j \frac{1-\eta^p}{1-\sigma_c^p} \left[\frac{C_{t+j}^{i,p} - \eta^p \overline{C}_{t+j-1}^i}{1-\eta^p} \right]^{1-\sigma_c^p} \right\} \tag{3.6}$$

Since small entrepreneurs are net borrowers in the model, the correspondent discount factor β_p is assumed to be strictly lower than β_w.

Each small entrepreneurs chooses the optimal stock of physical capital $K_t^{i,e,p}$ and the desired amount of labor input $N_t^{i,e,p}$ that are combined to produce an intermediate output $Y_t^{i,e,p}$ according to a Cobb-Douglas production function[6].

$$Y_t^{i,e,p} = A_t A_t^p (K_t^{i,p})^{\alpha} (N_t^{i,p})^{1-\alpha} \tag{3.7}$$

A_t and A_t^p represent total factor productivity shocks, the first is supposed to be common to both small and large companies when the second is specific to the small ones. Both of the shocks are supposed to be AR(1) processes.

Moreover small entrepreneurs maximize their own utility functions subject to an infinite sequence of real budget constraints :

$$C_t^{i,p} + \frac{J_{t-1}^{L^p,i}}{\pi_t} + w_t N_t^{i,p} + q_t^K K_t^{i,p} = (1-\delta) q_t^K K_{t-1}^{i,p} + p_t^{i,e,p} Y_t^{i,e,p} + L_t^{i,p} \tag{3.8}$$

δ is the capital depreciation rate while $L_t^{i,p}$ represents the amounts of new loans that the whole banking sector is willing to lend to entrepreneur i at a nominal interest rate $R^{L,p}$ assumed to be common to all small entrepreneurs.
The debt service charges the representative SME has to pay can thus be written recursively as :

$$J_t^{L^p,i} = \frac{\delta^{L^p}}{\pi_t} J_{t-1}^{L^p,i} + \left(1 - \delta^{L^p} + R_t^{L^p}\right) L_t^{p,i} \tag{3.9}$$

In addition, the entrepreneur faces a borrowing constraint is the sense that the expected value of its collateralizable (physical) capital stock at period t must be sufficient

[6]Since there is one kind of capital and labor we drop the index "e" in both variables.

to guarantee lenders of debt repayment. Indeed, in order to insure themselves against a potential credit event, banks require a part of borrowers' resalable capital as a collateral. Moreover, they also require that this collateral has to be large enough to cover not only the amount of debt services of the current time t but also all of those of the next periods. Doing so, banks ensure the repayment of both contracted interests and principal.
The collateral constraint is then written as :

$$FJ_t^{L^p,i} \leqslant \theta_t^p \left(q_{t+1}^{K,p} \pi_{t+1} \iota^p K_t^{i,p} (1-\delta) \right) \tag{3.10}$$

Given default, bankers would take over all the resalable bankrupted firm's capital at a proportional cost, this coefficient of proportionality is here represented by $(1-\theta_t^p)$. θ_t^p is also called the (stochastic) loan-to-value ratio (LTV). The variations in the LTV can be interpreted as outright shocks to bank's loan standards and, ceteris paribus, loan supply.

ι^p is the part of the SMEs' capital that can be considered as resalable. One can consider it as the value of bankrupted firm's building and heavy machinery that could find a buyer in the second hand market.
$FJ_t^{L^p,i}$ represents the residual value of interests and principal that the SME has to pay on his banks credit borrowed until time t. $FJ_t^{L^p,i}$ can be written recursively as :

$$FJ_t^{L^p,i} = \frac{\delta^{L^p}}{\pi_t} FJ_{t-1}^{L^p,i} + \left(1 + \frac{R_t^{L^p}}{1-\delta^{L^p}} \right) L_t^{p,i} \tag{3.11}$$

Corporate Firms

Symmetrically with respect to small entrepreneurs, large entrepreneurs (indexed by "g") form a continuum $i \in [0,1]$ where each member has to optimize its specific utility function facing similar production and loan constraints than small entrepreneurs.
Except the calibration matter, large firms differ also from the small ones in their ability to rely on a second type of debt contract. Indeed, large firms can enter the financial market and issue bonds which offer to them an alternative source of financing when small and medium sized firms are still bank dependant because of the relatively high fixed costs of issuance as well as the disclosure costs.

Indeed, to finance investment projects and their running expenditures, large firms use a combination of internal and external funds when we assume here that the latter refers exclusively to direct debt security that they issue in bond market. This external funds are however costly to issue because of the agency costs associated with default. To draw the bond pricing program, we follow Gilchrist et al. [40] framework based on the presence of idiosyncratic shocks hitting firms' production that are, if to low, able to make firm's manager decide to default. We thus assume that, each period, an idiosyncratic shock hits not the production of large firms but their equity value. One can consider this shock as a sudden movement in large firms equity value. However and since there is no accumulated equity in our model, we also make the assumption that the large firms equity is equal to their contemporaneous realized profits from which we drop the repayments related to the debt securities.

Indeed, according to an investor point of view, the net-worth of a large firm is defined as :

$$N_t = z_{t-1}\left[p_t^{e,g}Y_t^{e,g} - \left(w_t N_t^g + \frac{J_{t-1}^{L^g}}{\pi_t}\right)\right] - \frac{J_{t-1}^{T^g}}{\pi_t} + \iota^g\left(1-\theta^g\right)q_t^K K_{t-1}^G\left(1-\delta\right) \tag{3.12}$$

where $\iota^g\left(1-\theta^g\right)q_t^K K_{t-1}^G\left(1-\delta\right)$ is the resale value of installed capital. We note that the resale capital for bond buyer represent the value of defaulted firm's capital net of the collateralized part that would belong to the bank in case of credit event, the banks loans being of a higher degree of seniority than bonds. This would also induce a potential substitution effect between banking loans and market financing are also consistent with the results found by Gertler and Gilchrist [35] and Chari and Kehoe [10] among many others. Note also that since both current period as future loans banks repayments are entirely collateralized, banks are insured against any eventual default that could occur at the end of the period. They are thus not affected by the realizations of the shock z_t^i.

z_t^i indeed represents a persistent idiosyncratic shock which we assume evolving as an auto-regressive process :

$$log\left(z_t^i\right) = \rho_z log\left(z_{t-1}^i\right) + \varepsilon_{z,t}^i \text{ where } \varepsilon_{z,t}^i \sim \mathcal{N}\left(-\frac{\sigma_t^2}{2}, \sigma_t^2\right) \tag{3.13}$$

The firm purchases capital using this debt-financing coupled with other source of funds. In the next period, after observing the realization of shocks, the firm decides whether or not to fulfill the debt obligation. If the firm decides not to default, it pays the time "t" interests and principal parts on all the previous issued bonds (namely J_t^d) as it has been contracted and optimizes its program for the next period and the process continues. If the firm does default, it enters a debt renegotiation process with the bond market investors that would ultimately try to get the residual value of the bankrupted firm's net worth. For the structure of the renegotiation process, we adopt Gilchrist et al. [40] framework by assuming that there is a lower bound to the net-worth of the firm, $\overline{N}$, below which the firm cannot guarantee the repayment of its debt obligation.
Thus, given the price of capital, the amounts of capital and debt, the firm defaults if and only if the realized equity shock is lower than the threshold level, which is defined as the level that makes the firm's net-worth equal to the default boundary[7] :

$$\overline{N_t} = \overline{z_{t-1}}\underbrace{\left[p_t^{e,g}Y_t^{e,g} - \left(w_t N_t^g + \frac{J_{t-1}^{L^g}}{\pi_t}\right)\right]}_{\mathbb{B}_t} - \frac{J_{t-1}^{T^g}}{\pi_t} + \iota^g\left(1-\theta^g\right)q_t^K K_{t-1}^G\left(1-\delta\right) \tag{3.14}$$

with :

$$log\left(\overline{z_t^i}\right) = \rho_z log\left(z_{t-1}^i\right) + \varepsilon_{z,t}^i \text{ where } \overline{\varepsilon_{z,t}^i} \tag{3.15}$$

Moreover, we assume a costly state verification framework Townsend [73] where investors have to pay an irreversible disclosure cost in order to eliminate losses from the

[7]Hereafter and for a matter of simplicity, we assume $\overline{N} = 0$.

moral hazard of the bond issuer. We assume this cost to be proportional to the net worth value of the firm with "μ" being the factor of proportionality.

Thus, in the investor point of view, the average profit made on the credit allocation is given by :

$$\mathbb{P}_t = \int_{-\infty}^{\overline{\varepsilon_z}} (1-\mu)\left[z_t \pi_{t+1} + \iota^g \left(1-\theta_{t+1}^g\right) q_{t+1}^K K_t^G (1-\delta)\right] d\mathcal{F}(\varepsilon_z) + \int_{\overline{\varepsilon_z}}^{+\infty} \frac{J_t^G}{\pi_{t+1}} d\mathcal{F}(\varepsilon_z) \tag{3.16}$$

$\mathcal{F}$ representing the cumulative distribution function of normal distribution.
The investor has also access to a riskless debt security that is characterized by a larger maturity and also lower interest rates payments than a corporate bond.
The trade-off equation for the investor can be written as :

$$\mathbb{P}_t = \frac{J_t^S + \left(1 - \delta^{T,g} + R_t^T\right)}{\pi_{t+1}} \tag{3.17}$$

J_t^S represents the sum of all repayments the investor is expected to receive from sovereign debtors at time "t", J_t^S is written as :

$$J_t^S = \frac{\delta^S}{\pi_t} J_{t-1}^S + (1 - \delta^S + R_t) T_t^S$$

Since there is no active government in this our economy, we suppose T_t^S following an AR(1) process. We also assume the risk-less bond yield to be equal to the short term rate R_t when we suppose its maturity to be larger than the corporate bond one.

Furthermore and in order to be able to use a representative agent framework while maintaining the intuition of the default rule above, we adopt Darracq Pariès et al. [17] framework by assuming that borrowers belong to a large family that can pool their assets and diversify away the risk related to large firms after bond repayments are made. By pooling the large firms' resources, the representative family has the following aggregate repayments and defaults on its outstanding bonds :

$$\mathbb{H}_t = \int_{-\infty}^{\overline{\varepsilon_z}} \left[z_t \mathbb{B}_{t+1} + \iota^g \left(1-\theta_{t+1}^g\right) q_{t+1}^K K_t^G (1-\delta)\right] d\mathcal{F}(\varepsilon_z) + \int_{\overline{\varepsilon_z}}^{+\infty} \frac{J_t^G}{\pi_{t+1}} dF(\varepsilon_z) \tag{3.18}$$

Overall, each large entrepreneur optimizes its utility function :

$$\max_{C_t^{i,g}, Y_t^{i,e,g}, K_t^{i,g}, N_t^{i,g}, L_t^{i,g}, \overline{\varepsilon_{z,t}}} \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \beta_g^j \frac{1-\eta^g}{1-\sigma_c^g} \left[\frac{C_{t+j}^{i,g} - \eta^g \overline{C}_{t+j-1}^i}{1-\eta^g} \right]^{1-\sigma_c^g} \right\} \tag{3.19}$$

subject to an infinite sequence of real budget constraints [8]:

$$C_t^{i,g}+\frac{J_{t-1}^{L^g,i}}{\pi_t}+\left(1-\mathcal{F}\left(\frac{\overline{\varepsilon_{z,t-1}}+\sigma^2/2}{\sigma}\right)\right)\frac{J_{t-1}^{T^g,i}}{\pi_t}+\mathcal{F}\left(\frac{\overline{\varepsilon_{z,t-1}}-\sigma^2/2}{\sigma}\right)z_{t-2}^{\rho_z}\mathbb{B}_t+$$
$$\mathcal{F}\left(\frac{\overline{\varepsilon_{z,t-1}}+\sigma^2/2}{\sigma}\right)\iota^g\left(1-\theta_t^g\right)q_t^K K_{t-1}^G\left(1-\delta\right)+q_t^K K_t^{i,g}=(1-\delta)q_t^K K_{t-1}^{i,g}+\mathbb{B}_t+L_t^{i,g}+T_t^{i,g} \tag{3.20}$$

and the investor trad-off equation discussed above as well as the production function and collateral constraint that are similar to those of their small counterpart (namely eq. (3.7) and (3.10)).

Capital Producers

At the beginning of each period, capital producers buy back the undepreciated capital stocks $(K_{t-1}^p+K_{t-1}^g)(1-\delta)=K_{t-1}(1-\delta)$ at real prices (in terms of consumption goods) q_t^K. Then they augment this stock using investment goods and facing adjustment costs. The augmented stock is sold back to entrepreneurs at the end of the period at the same price. The decision problem of capital stock producers is given by :

$$\max_{K_t,I_t}\mathbb{E}_t\left\{\sum_{j=0}^{\infty}\beta_p^j\lambda_{1,t+j}^p\left[(K_t-K_{t-1}(1-\delta))q_t^K-I_t\right]\right\} \tag{3.21}$$

under the production function technology :

$$K_t=K_{t-1}(1-\delta)+\left(1-\frac{\phi^p}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right)I_t \tag{3.22}$$

The first order conditions determine the capital producers' optimal real price of capital q_t^K which is as :

$$q_t^K\left(1-\frac{\phi^p}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2-\phi^p\left(\frac{I_t}{I_{t-1}}-1\right)\frac{I_t}{I_{t-1}}\right)+\frac{\lambda_{1,t+1}^p}{\lambda_{1,t}^p}\beta_p q_{t+1}^K\left[\phi^p\left(\frac{I_{t+1}}{I_t}-1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right]$$
$$=1 \tag{3.23}$$

Retailer

There is a representative retailer who acts under perfect competition. First, the retailer aggregates intermediate goods from both small and large firms using a CES technology

[8]Using the probability density function of normal a normal distribution, we can easily show that

$$\int_a^b z_t dF\left(\varepsilon_z\right)=z_{t-1}^{\rho^z}\left[\mathcal{F}\left(\frac{b-\sigma^2}{\sigma}\right)-\mathcal{F}\left(\frac{a-\sigma^2}{\sigma}\right)\right]$$

$\mathcal{F}$ stands for the normal cumulative distribution, centered and standardized.

function[9]. Afterward, it sells its output to a monopolistic competitive distribution sector which is in charge to make the different goods accessible to final consumers.

The decision problem of the representative retailer is :

$$\max_{Y_t^e, Y_t^{e,p}, Y_t^{e,g}} [p^e Y_t^e - p^{e,p} Y_t^{e,p} - p^{e,g} Y_t^{e,g}] \tag{3.24}$$

subject the aggregation technology function :

$$Y_t^e = \left(\nu_t^{y\xi^y} Y_t^{e,p1-\xi^y} + 1 - \nu_t^{y\xi^y} Y_t^{e,g1-\xi^y}\right)^{\frac{1}{1-\xi^y}} \tag{3.25}$$

The first order conditions determines the optimal demand addressed to each of intermediate goods' produces.

$$Y_t^{e,p} = \nu_t^y Y_t^e \left(\frac{p^{e,p}}{p^e}\right)^{\frac{1}{\xi_y}} \tag{3.26}$$

$$Y_t^{e,g} = (1 - \nu_t^y) Y_t^e \left(\frac{p^{e,g}}{p^e}\right)^{\frac{1}{\xi_y}} \tag{3.27}$$

where the aggregate intermediate price (in terms of consumption price) can be set using the previous FOCs and the aggregation technology function (3.25) :

$$P_t^e = \left(\nu_t^y (Y_t^{e,p})^{\frac{\xi^y - 1}{\xi^y}} + (1 - \nu_t^y)(Y_t^{e,g})^{\frac{\xi^y - 1}{\xi^y}}\right)^{\frac{\xi^y}{\xi^y - 1}} \tag{3.28}$$

Distribution Sector

The distribution market is assumed to be monopolistically competitive. Distributors' prices are sticky and are indexed to a combination of past and steady-state inflation, with relative weights parameterized by γ^p. In addition, if retailers want to change their price beyond what indexation allows, they face a quadratic adjustment cost parameterized by κ^p.

Each firm f choose its sell price p_t^f (in terms of consumption goods) so as to maximize its market value :

$$\max_{p_{f,t}} \mathbb{E}_t \sum_{i=0}^{\infty} {\beta_w}^i \lambda_{w,t+i} \left\{ \left(p_{t+i}^f - p_{t+i}^e\right) Y_{t+i}^f - \frac{\kappa^f}{2} \left(\frac{p_t^f}{p_{t-1}^f} \frac{1}{\pi_t} - \pi_{t-1}^{\gamma^p} \overline{\pi}^{1-\gamma^p} \right)^2 Y_{t+i} \right\} \tag{3.29}$$

subject to the demand derived from consumers' maximization :

$$Y_t^f = (p^f)^{-\nu^f} Y_t \tag{3.30}$$

ν^f is the demand price elasticity which is supposed to be constant.

[9]The fact that intermediate goods are not perfect substitutes allows for defining different levels of intermediate goods' prices according to wether they are produced by small or large firms.

3.2.4 Banking Sector

The banking sector is represented by a continuum $n \in [0,1]$ of universal banks evolving in a monopolistic competition framework. We enrich our banking sector modeling by assuming different types of assets and liabilities. Indeed, each bank n has three types of liabilities : its own capital $(K_t^{b,n})$, savers-deposits (D_t^n) and interbank funds (IB_t^n). On the assets side, it can invest on three types of assets : loans to SMEs $(L_t^{p,n})$, loans to corporate firms $(L_t^{g,n})$ and corporate bonds $(T_t^{g,n})$.

Assets	Liabilities
Loans to Small Firms $(SL_t^{p,n})$	Bank Equity (K_t^n)
Loans to Large Firms $(SL_t^{g,n})$	Households deposits (SD_t^n)
Large Corporate Bonds $(ST_t^{g,n})$	Interbank Funds (IB_t^n)

Like the universal banks model, each bank n is composed of two main branches, namely retail branch and investment branch. The retail branch of bank n optimizes the discounted value of its contemporaneous and future flow of funds. For this purpose, it sets the optimal amount of the different types of liabilities and assets (except for its capital) as well as their correspondent interest rates (except for the interbank interest rate which is supposed equal to the policy rate R_t).
The investment branch of the bank is in charge of dealing with assets in the bond market and choose the optimal amount of corporate bond holding according to the relative yield of such asset as wall as the regulatory constraints.

Indeed,each bank faces two kinds of costs descending from the Basel III macroprudential requirements. The first cost is related to the bank's capital position whenever its solvency - measured by its capital-to-weighted assets ratio - moves away from a target value $RCAP$, the second one has more to do with its balance-sheet liquidity standard and more specifically its short term liquidity coverage ratio (LCR).

Since we use multi-period assets, we are able to model the LCR in a more suitable way than what it is usually done in the literature. In our paper, we enrich the LCR modeling through different perspectives. First, contrary to a one period asset's maturity, we can make a distinction between short term and long term incoming and outgoing cash flows and, second, using different kind of assets, we are able to take into account different weight of liquidity of each type of assets following the Basel III implementation.

The optimization program for the universal bank n is then of the form :

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} {\beta_w}^i \lambda_{w,t} \{ \frac{J_{t-1}^{L^p,n}}{\pi_t} + \frac{J_{t-1}^{L^p,n}}{\pi_t} \frac{J_{t-1}^{T^B,n}}{\pi_t} - L_t^P - L_t^G - T_t^{B,n}$$
$$- \frac{J_{t-1}^{D,n}}{\pi_t} - \frac{1+R_{t-1}}{\pi_t} IB_t^n + D_t^n + IB_t^n$$
$$- \frac{\kappa^p}{2} \left(\frac{R_t^{P,n}}{R_{t-1}^{P,n}} - 1 \right)^2 R_t^P L_t^G - \frac{\kappa^g}{2} \left(\frac{R_t^{G,n}}{R_{t-1}^{G,n}} - 1 \right)^2 R_t^G L_t^G - \frac{\kappa^d}{2} \left(\frac{R_t^{D,n}}{R_{t-1}^{D,n}} - 1 \right)^2 R_t^D L_t^D$$
$$- \frac{\kappa^K}{2} \left(BCAP_t^n - RCAP_t \right)^2 SK_t^B - \frac{\kappa^L}{2} \left(BLCR_t^n - RLCR_t \right)^2 SK_t^B \Big\} \tag{3.31}$$

Where $BCAP_t^n$ and $RCAP_t$ stand for the capital to risk weighted assets ratio for bank n as well as its regulatory level. $BLCR_t^n$ and $RLCR_t$ are the equivalent for the liquidity to assets ratio.

$$BCAP_t^n = \frac{SK_t^{B,n}}{\gamma_t^{L^P} SL_t^{P,n} + \gamma_t^{L^G} SL_t^{G,n} + \gamma_t^{T^G} ST_t^{G,n}} \tag{3.32}$$

$$BLCR_t^n = \frac{\mu^{NT^g} ST_t^{T^g,n}}{\underbrace{\mu^D SD_t^n + \mu^{JD} J_t^D + \mu^{IB} (1+R_t) IB_t^n - \left(\mu^{L^p} J^{L^P,n} + \mu^{L^g} J^{L^G,n} + \mu^{T^g} J^{T^G,n} \right)}_{BLCRD}} \tag{3.33}$$

Which represent respectively the capital and the liquidity regulatory costs. γ_t^x and μ_t^x are the weights used when defining the Basel regulatory ratios.

Evolving in a monopolistic competitive framework, each bank n faces the following new borrowing (deposit) demand (supply) equations, namely for deposits and the banking loans :

$$D_t^n = \left(\frac{R_t^{D,n}}{R_t^D} \right)^{-\nu^D} D_t \tag{3.34}$$

$$L_t^{G,n} = \left(\frac{R_t^{L^P,n}}{R_t^{L^P}} \right)^{-\nu^{L^P}} L_t^P \tag{3.35}$$

$$L_t^{G,n} = \left(\frac{R_t^{L^G,n}}{R_t^{L^G}} \right)^{-\nu^{L^G}} L_t^G \tag{3.36}$$

The previous equations derive from an optimization program similar to the one described in the labor market.
For a matter of simplicity, we assume in what follows that $\nu^{L,P} = \infty$ (perfect competitive framework) and $\kappa^p = 0$ (flexible rates). In this case, the maximization of banks profits function with respect to the default threshold $J_t^{L,P}$, L_t^P, SL_t^P and IB_t results in the

following first order conditions[10] :

$$\lambda_{1,t} + \kappa^L \left(BLCR_t - RLCR_t\right) BLCR \frac{SK_t^B}{BLCRD_t} \mu^{L^p} = \frac{\lambda_{w,t+1}}{\lambda w, t} \frac{\beta_w}{\pi_{t+1}} \left(1 + \lambda_{1,t+1} \delta^{L,P}\right) \quad (3.37)$$

$$-1 + \lambda_{1,t}\left(1 - \delta^{L,P} + R_t^{LP}\right) + \lambda_{2,t} = 0 \quad (3.38)$$

$$\kappa^K \left(BCAP_t - RCAP_t\right) BCAP_t^2 \gamma^{L^P} - \lambda_{3,t} - \lambda_{2,t} + \frac{\lambda_{w,t+1}}{\lambda_{w,t}} \frac{\beta_w}{\pi_{t+1}} \lambda_{2,t+1} \delta^{L,P} = 0 \quad (3.39)$$

$$\lambda_{3,t} = 1 - (1 + R_t)\left[\frac{\lambda_{w,t+1}}{\lambda_{w,t}} \frac{\beta_w}{\pi_{t+1}} - \kappa^L \left(BLCR_t - RLCR_t\right) BLCR \frac{SK_t^B}{BLCRD_t} \mu^{IB}\right] \quad (3.40)$$

By putting all $\delta^{LP} = 0$ we find the standard FOCs in a one period maturity framework. We can thus identify $-\lambda_{2_t}$ as the marginal cost for a bank that considers lending to SMEs. Indeed, our banking sector modeling differs slightly from Gerali et al. [34] in that we allow for different marginal costs for the bank depending on the identity of borrower since the regulatory constraints take into account the heterogeneity of borrowers. However, with $\delta^{LP} = 0$, we find similar result to Gerali et al. [34] with regulatory constraints increasing the marginal cost $-\lambda_{2_t}$ when the Banks ratios are below the regulatory ones and decreasing it when they above the thresholds. Moreover, eq. (3.38) refers to the standard equilibrium equation linking the marginal cost $-\lambda_{2_t}$ to the "selling price" R_t^{LP}.
Still, the introduction of long term maturities modifies the values of the marginal costs and prices as considered at time ’t’. Since, the lending decision matters for all the future periods, the marginal costs have to take into account next periods values of the interbank rate R_t when the future marginal profits induced by the lending decision in the current period have to be discounted by a specific discount factor λ_{1_t} which would be equal to the households discount factor in the absence of the liquidity constraint. However, the LCR as it has been defined depends among others on the bank lending rates, this liquidity constraint enters thus the banks optimal decision by affecting their discount factor. This is a key feature that a standard representation of the LCR constraints lacks. To assess the impact of the liquidity constraints, the MAG examined the impact of a 25% increase in the ratio of liquid assets to total assets, Gambacorta [32] in a VECM framework considers the liquidity as the sum of cash and government bonds, a very crude assumption as argued by Angelini et al. [1]. We can then legitimately wonder whether these studies on the impact of the LCR on bank lending spreads may create biased results as the liquidity constraint has an ambiguous impact on bank lending rate as they reinforce the banks marginal cost and at the same time lessen the bank lending rate (see section 3.4.1.1).

[10] $\lambda_{i=1..4}$ are lagrangian coefficients related to the accounting equation for the banks as well as for the definitions of $J_t^{L,P}$ and SL_t^P.

3.2.5 Monetary Policy

Monetary policy is specified in terms of an interest rate rule targeting inflation, its first difference as well as the first difference in output. The Taylor interest rate rule used has the following form :

$$R_t = R_{t-1}^{\rho_R} \left[R^\star \left(\frac{\pi_t}{\bar{\pi}} \right)^{r_\pi} \left(\frac{\pi_t}{\pi_{t-1}} \right)^{r_{\Delta\pi}} \left(\frac{Y_t}{Y_{t-1}} \right)^{r_{\Delta Y}} \right]^{1-\rho_R} \varepsilon_{R,t} \tag{3.41}$$

where r_π is the weight assigned to inflation and $\Delta\pi$ and ΔY those assigned to inflation and output growth. $R^\star$ is the steady-state policy rate, and $\varepsilon_{R,t}$ is the white noise monetary policy shock.

3.2.6 Market clearing conditions

Aggregating the entrepreneurs' budget constraints (3.8) and (3.20) and using the zero-profit conditions for competitive capital producers we can set the following aggregated entrepreneurs' budget constraints :

$$C_t^p + \frac{1 + R_{t-1}^{L,p}}{\pi_t} L_{t-1}^p + w_t N_t^p + I_t^p = p_t^{e,p} Y_t^{e,p} + L_t^p \tag{3.42}$$

$$C_t^g + \frac{1 + R_{t-1}^{L,g}}{\pi_t} L_{t-1}^g + \frac{1 + R_{t-1}^{T,g}}{\pi_t} T_{t-1}^g + w_t N_t^g + I_t^g = p_t^{e,g} Y_t^{e,g} + L_t^g + T_t^g \tag{3.43}$$

Aggregating the workers' budget constraint and using the financial market equilibrium (aggregate accounting equality of the banking system[11]) as well as the previous equations, we can set the following market clearing condition in goods market :

$$C_t^w + C_t^g + C_t^p + q_t^k \left(I_t^p + I_t^g \right) + CapRegCost(t) + LiqRegCost(t) + Adj_t = Y_t \tag{3.44}$$

Where Adj_t includes all adjustment costs (in both good and banking sectors) when CapRegCost(t) and LiqRegCost(t) stand for the costs related to the capitalization and liquidity constraints.

3.3 Calibration

We fix several parameters to values in the range suggested by mainly the euro area data[12] from 1999 (creation of the euro zone) to the mid of 2007 (the beginning of the subprime

[11]Note that the aggregate level of interbank funds is equal to zero, $\int_0^1 IB^n dn = 0$.

[12]In the case when euro area data are not available when French data are, we make the choice to use the French data as a benchmark for calibration.

crisis) and if it is not available, we refer to the literature. Thus, relatively to the interest rates, we set the steady-state nominal interest rate value at 0.75% (in quarterly term) according to Euro Area data. That with an elasticity of deposit supply at -2.5 induce an annual deposit rate about 1.8% which corresponds to a households' discount factor of 0.9995. Relatively to bank lending rates, we calibrate the demand of elasticities at 2.5 and 4.2 for respectively small and large firms which corresponds to a a spread SME's loan rate - Corporate Loan rate about 100 bp.

With regard to volumes, we calibrate the LTV parameters θ^p and θ^g to 0.47 and 0.7 when we calibrate the resalable part of capital ι at 1/3. All of these parameters ensure a steady-state values of SMEs (resp. corporate firms) banks loans to GDP about 10% (resp. 30%).
Furthermore, we calibrate the parameters δ^X in a way to get Macaulay's maturities about 4, 5, 7, 10 and 15 years for respectively SMEs bank loans, large firms bank loans, large firms bonds, risk-less (sovereign) bond and households deposits.
Moreover, we calibrate the steady-state value of the corporate firms default rate about $6.5.10^{-2}$% in annual term which with the risk-less bond maturity and yield induce a corporate bond yield about 3.6% when the corporate bond to GDP ratio was set at 11%.

We set the steady state SME's part in the global production volume ν^y equal to 0.33 in line with official studies on the French economy[13] with SMEs referring particularly to independent SMEs.

Turning to the Basel constraints parameters, we first set the coefficient κ^K at 10 in line with the range of values estimated by Geralli et al.(2010). The calibration of parameter κ^L is more problematic since there is no benchmark model to use. We however choose to set κ^L in a way that, in a partial equilibrium model, a 10% increase in the liquidity constraint induces a similar impact on the bank lending rate to SMEs than a 10% increase in the capitalization ratio. This implies to set κ^L at a value about 1.10^{-3}.
Second, and in order to set the Basel III weighting coefficients, we assume that the banking sector holds Δ part of (at least) BBB rated corporate bonds, the remaining bonds are of worse quality. Note that we also exclude a very high quality of corporate bonds since the later usually correspond to public companies and are note significant in term of number.

Thus, some parameters entering in the regulatory constraints shown in section 3.2.4 depend on Δ. Indeed, according to Basel III requirements, we calibrate $\gamma_t^{L^G}$ and $\gamma_t^{T^G}$ at :

$$\gamma_t^{L^G} = \gamma_t^{T^G} = 1.0\Delta + 1.5(1 - \Delta)$$

and μ^{NT^g} and μ^{T^g} at :

$$\mu^{NT^g} = 0.5\Delta$$

[13]"Les chiffres-cl?s des TPE-PME", Minist?re de l'?conomie, de l'industrie et de l'emploi - DGCIS - October 2009.

$$\mu^{T^g} = \frac{(0.5(1-\Delta))}{3}$$

The rest of the parameters are calibrated as :

$$\gamma_t^{L^P} = 1.5 \qquad \mu^{IB} = \frac{1}{3}$$
$$\mu^D = 0.03 \qquad \mu^{L^P} = 0.5$$
$$\mu^{L^G} = 0.5 \qquad \mu^{JD} = \mu^D$$

We set Δ at 50% in order to match the ratio of outstanding amount of corporate bonds in the whole baking system assets.

The rest of parameters were calibrated at values which are common in the literature (especially the (Bayesian) estimated values found in Gerali et al. [34] and Darracq Pariès et al. [17] papers.). Table (**??** and **??**)in the appendix reports the values of the calibrated parameters.

3.4 The implementation of Basel III Constraints

3.4.1 Basel III Constraints

3.4.1.1 Liquidity Constraints vs Capitalization

In this sub-section, we model the scenario of a steadily increase in banking capitalization and liquidity constraints separately. To disentangle the effects of the liquidity constraint from the capitalization one, we shut down the capitalization constraints in the model when the liquidity is still active, and inversely for the capitalization shock.

With regard to the capitalization ratio, we take a scenario similar to the MAG Macroeconomic Assessment Group [54] by assuming a linear increase in the capitalization ratio of 1% through 16 quarters. Also, we assume that the agents have full information about the implementation process, we run in consequence a deterministic simulation keeping the non-linear property of agents behavior. For the liquidity constraints and since there is, as far as we know, no such modeling of the LCR as we do, we choose to implement a scenario of in increase in the LCR by +10% in 4 years, also with a linear implementation process.
The results are shown in Figure 3.1.

3.4.1.2 Liquidity Constraints

With respect to the liquidity constraint, an increase in the regulatory ratio has a direct impact on the bank lending rate as suggested by equations (3.37) to (3.40) in section 3.2.4. However, the impact of an increase in the regulatory liquidity ratio has two opposite effects

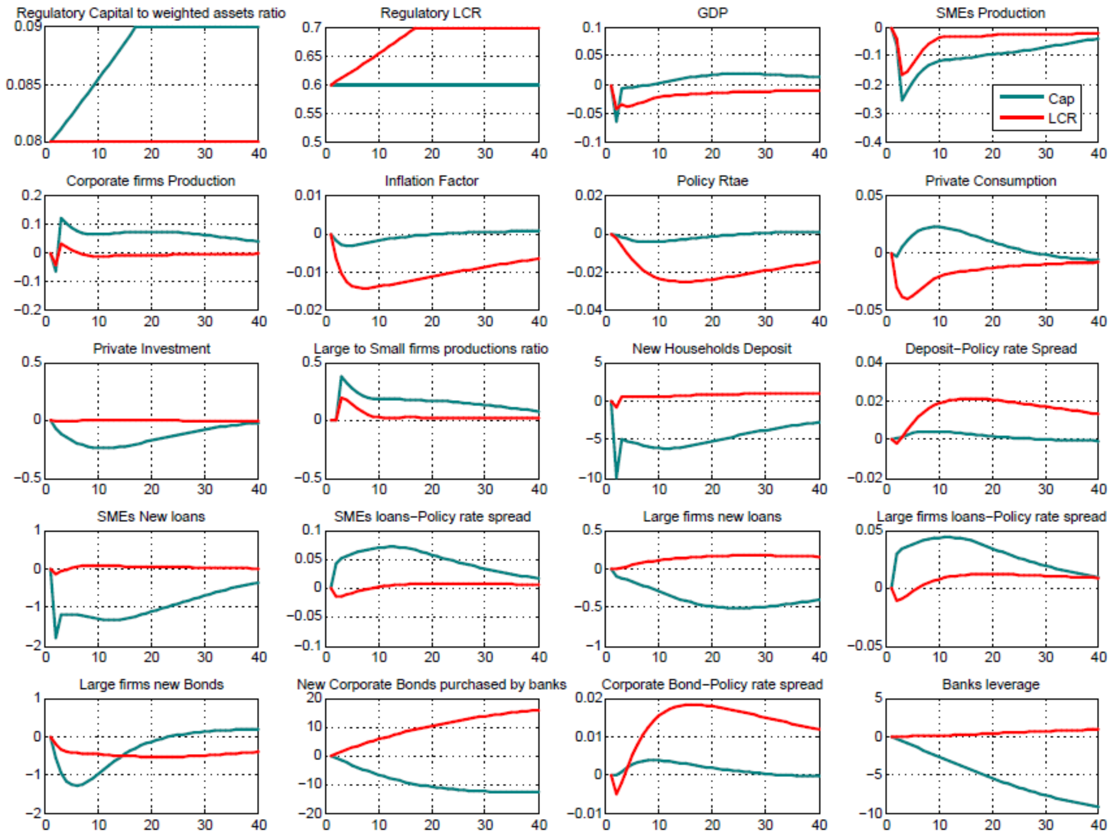


Figure 3.1: The impact of the Basel III new Capitalization (green curve) and Liquidity (red curve) thresholds

The regulatory ratios are in level. All rates are shown as absolute deviations from steady state, expressed in basis points. All other variables are percentage deviations from steady state.

on the bank lending rates. On the one hand, any increase in the interbank borrowing represent additional future cash outflows which reinforces the liquidity constraint burden while, on the other hand, any lending opportunity will loosen it, as it will create future cash inflows. Figure 3.1 shows that both the lending rates spreads (to SMEs and corporate firms) actually decrease reflecting a decline in bank lending rates. Note also that the decline is slightly more pronounced for SMEs than for large firms. Indeed and as it is shown by equation (3.37), the discount factor of future cash inflows is positively correlated to the maturity of the asset, thus by lending to SMEs, banks ensures themselves with future cash inflows with larger yields and in shorter time comparatively to a lending to large firms. The liquidity coverage ratio is then not necessarily harmful for the small firms, at least not directly.

Indeed, the increase in the LCR requirements has initially recessionary effects which are largely the consequence of the sharp decrease in private consumption. The latter is mainly due to a second order effect of the LCR , namely the increase in deposits. Indeed, on the one hand, deposits create more cash outflows, while more deposits is a way to increase future liquid assets, i. e. to purchase bonds in our model. Accordingly, in its scenario of development of the LCR, the Basel committee considers the scenario of partial retail deposit run-off which implies that the outstanding amount of households deposits should be (positively) listed in the LCR denominator definition. Moreover, this LCR denominator should also contains deposits repayments as they are considered as agreed future cash outflows. For these two reasons, we expect that banks would partially restrain deposits as well as their remuneration rate. Nevertheless, we note that according to our simulations exercise, both deposits volumes and interest rates spreads increase. This simultaneous increase indicates that this increase comes from the demand by the banking sector. This counter-intuitive effect finds also its origin in the definition of the LCR. Indeed, the LCR implementation accords particular importance to the High Liquid Assets (HLQ) - containing corporate bonds - that materializes with a high weighting factor in the LCR numerator (from 50% to 100%). Comparing to the weights of retail deposit volumes (between 3% for the most stable funds to 10% for the less stable ones), it can happen that the marginal benefit of holding liquid securities outpaces the marginal cost of holding deposits. Banks will then rather prefer to loosen their accounting constraint by increasing their liabilities (their demand for retail deposits) in order to purchase more liquid assets than limiting their leverage ratio. The LCR can, if it is implemented alone, not necessarily be at the origin of a deleveraging process. The increase in the deposit rate combined with the rise in corporate bonds spread puts upward pressure on the saving rates of households, which then cut in their consumption expenses. Figure 3.2 below shows the sensitivity of private consumption as well as the banking sector demand for liquid assets to the weights in the LCR definition.

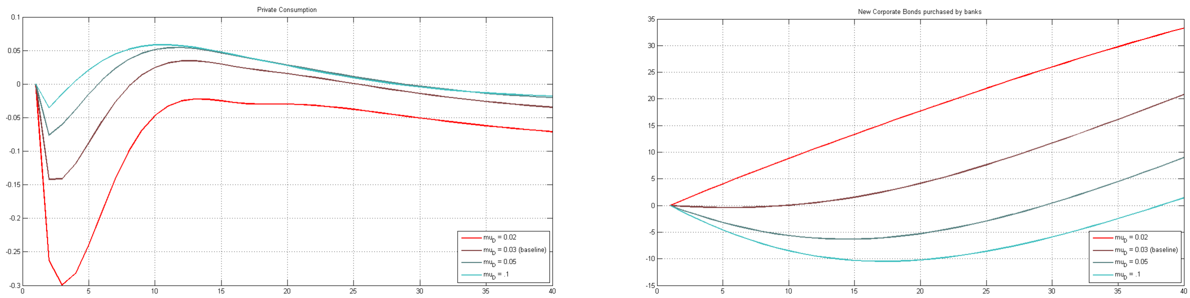


Figure 3.2: The sensitivity of the private consumption and of bank demand for corporate bonds to the LCR weighting coefficients for deposits

Concerning the other component of the aggregate demand, we note that the rise in the LCR regulatory constraint has no effect on private investment. This result corresponds actually to a slight increase in large firms investment which is compensated by the decline in SMEs investment. The presence of an alternative source of funding combined to the absence of a any restriction in the bank loans supply allow the large firms to handle the new Basel III constraint in a way which is relatively better than the SMEs as it can be shown by the ratio of large firms' production to small firms' production.

3.4.1.3 Capitalization Constraints

Turning to the other Basel III constraint, a first result to be addressed is the more pronounced recessive effect of the capitalization constraint comparing to the LCR effect. One key element behind this result is the absence of a strong reaction from the monetary authority. Indeed, while the LCR constraint triggers a decline in both marginal costs (bank lending rates) and aggregate demand resulting in disinflation, the capitalization constraint puts upward pressure on prices with a sharp increase in bank lending spreads. This reduces the disinflation effects which, in turn, limits the room for an accommodative monetary policy.

The capitalization ratio constraint aims among others to limit any surge in leverage from credit institutions. It is then not surprising to expect a deleveraging process from banking sector in the absence of any additional incentives to increase assets. Thus, in a scenario with no additional shocks, the rise in the regulatory capitalization threshold induces a deleveraging process from the banking sector as well as a concomitant rise in bank lending rates. An increase in the interest rates on the new bank loans would probably not be sufficient to match the regulatory constraint especially in case of long term maturities when the contribution of new interest rates in the apparent rate is negligeable. Banks resort to a cut in their bank loans as well as their bond purchase which induces a drop in their demand for retail deposits. This decline in demand for retail deposits is materialized trough a similar decline in deposit rates. Due to an intertemporal substitution effect, households increase slightly their consumption. These gains in consumption are however not able to compensate the sharp reduction in the demand for investment goods which has been magnified by the presence of financial frictions and more precisely the collateral constraint as emphasized in Gertler and Kiyotaki [36]. This collateral constraint plays also a key role in explaining differences in the impact of regulatory constraints between large and small companies. However we also wonder wether the perfect expectations are able to explain such large discrepancies between producers. Fig. 3.3 shows the results of an increase in Basel III capitalization ratio[14] when we substitute the perfect expectation assumption by rational expectations. Thus, in each period agents are surprised by the new enhancement in the regulatory capitalization threshold.

We note that with rational expectations, both small and large firms productions drop through all the implementation periods even if the drop in large firms companies is still relatively less important than the SMEs' one. This result suggests a non negligible impact of expectations in agents decision making. Indeed, one of our results is that Basel III constraints favor large firms assets at the expense of small firms'one, agents (bankers but also workers) will be much more incited to deal with large companies than small ones. Most of loanable funds as well as labor force will move towards large companies, which will in turn amplify the recessionary effect on small firms as it is shown in Fig. 3.1.

[14]Similar simulations has been done using Liquidity and both capitalization and liquidity shocks showing similar results.

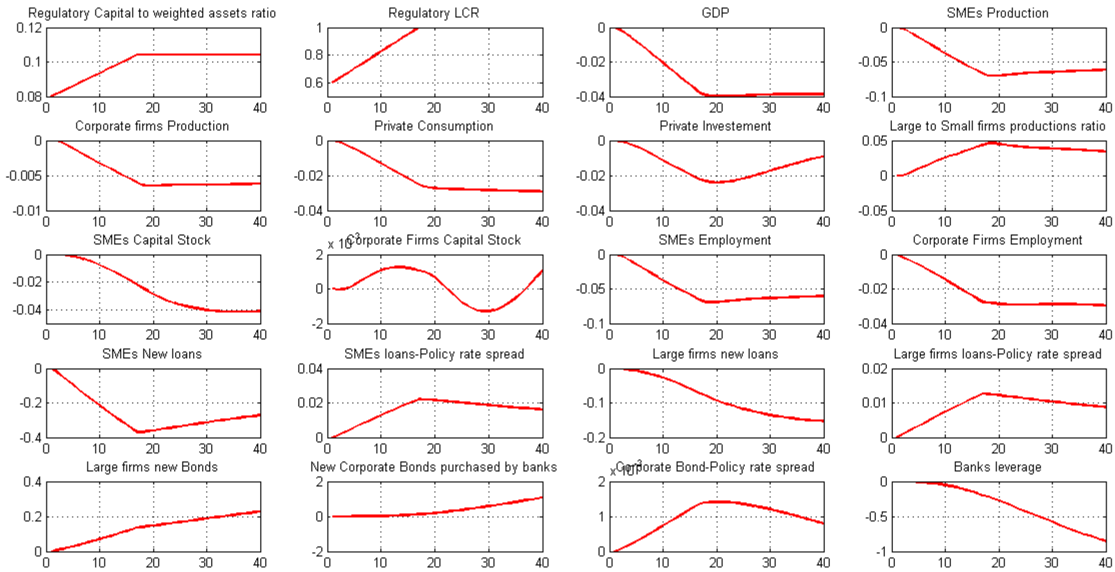


Figure 3.3: The impact of the Basel III new Capitalization and Liquidity thresholds with rational expectations The regulatory ratios are in level. All rates are shown as absolute deviations from steady state, expressed in basis points. All other variables are percentage deviations from steady state.

When in rational expectations framework, small firms production drops by about 1.5 the overall drop in the GDP, we see that this difference is much higher (about 4 times) in case of perfect expectations.

3.4.1.4 Simultaneous Shocks

In the following figure (3.4), we show the overall impact of the simultaneous implementation of both of the Basel III constraints. The main results that can be assessed is that, surprisingly, the global impact of both shocks is close to the sum of the impacts of each shock[15]. In other words, it seems there is no strong positive externalities between liquidity and capitalization constraints which makes them complementary.
Indeed, as a liquidity shock induces mainely a drop in bank lending rates spreads and no significant change in the bank leverage, no one of these effects contributes to the improvement in the capital-to-risk weighted assets ratio. As a consequence and in order to reach the new regulatory threshold, banks have to make a similar effort to what they would do in the absence of the LCR shock. As a result, the simultaneous regulatory shocks trigger a transitory dampening in the aggregate demand components.

[15]Note that the results related to the capitalization and the liquidity constraints differ for some variables from what has been shown in the previous section since in this exercise, we do not shut down the other constraint when we implement one.

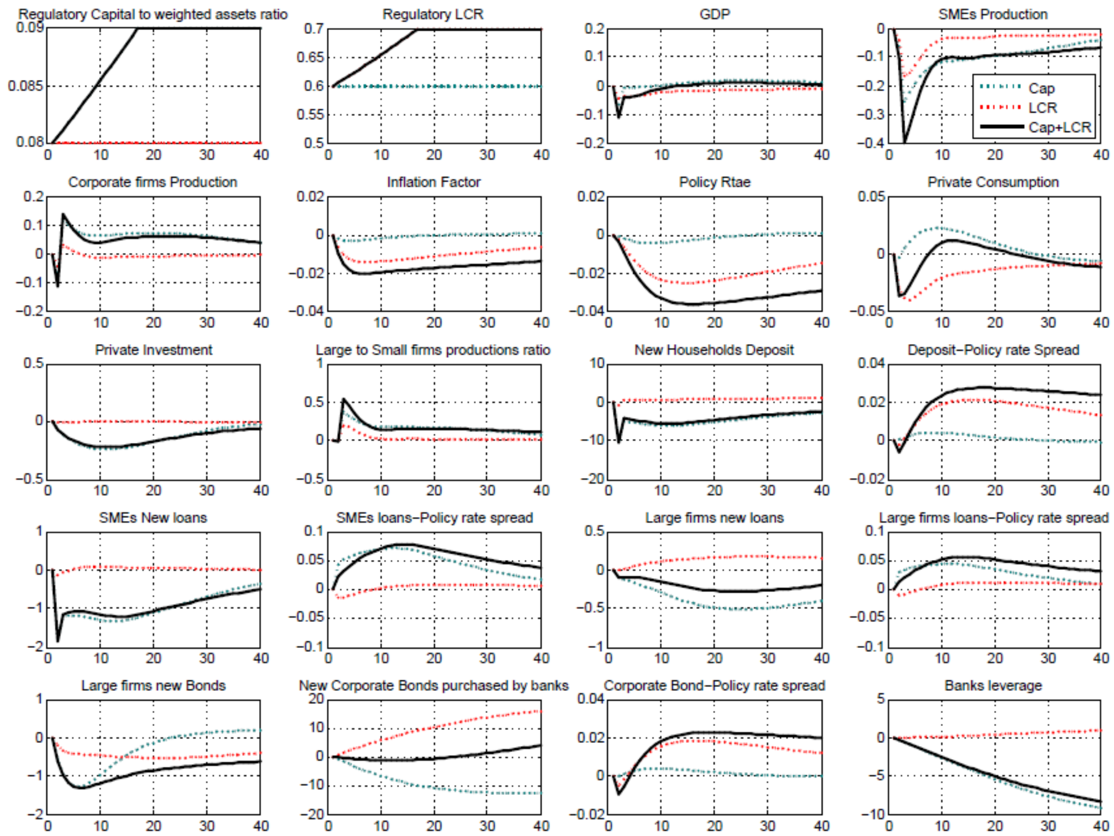


Figure 3.4: The overall impact of Basel III capitalization and liquidity constraints.

3.4.2 Basel III phase-in periods

In this section, we proceed to a similar exercise to the MAG Macroeconomic Assessment Group [54] reports which consists in examining the period of time during which banks would need to implement the new regulatory requirements. Indeed, banks, under the pressure of financial markets, would eventually have an incentive to implement the new requirements more rapidly than what has been set by the regulators. However,within a counter-factual scenario, regulators would extend the timeframe of the implementation in order to smooth the impact of the new regulation in time of crisis. For this purpose, we imagine three scenarios where the implementation process takes 2, 5 or 8 years. We also chose the use a linear implementation process in order to avoid additional hypothesis and notably those relative to the curvature that could influence the results.

Figure (3.5) shows the results for the three scenarios. As we would have expected, a short period implementation process triggers a sharp dampening in overall activity with a drop in production as well as the other key macro variables. We note also that, on the banking side, it is the impact on new loans that differ across the three scenarios while we only find slight differences in the lending rates spreads. This mainly results from the trade-off banks have to make between increasing their profit margins and lowering their leverage in order to meet the capitalization ratio. The origin of this effect depends on

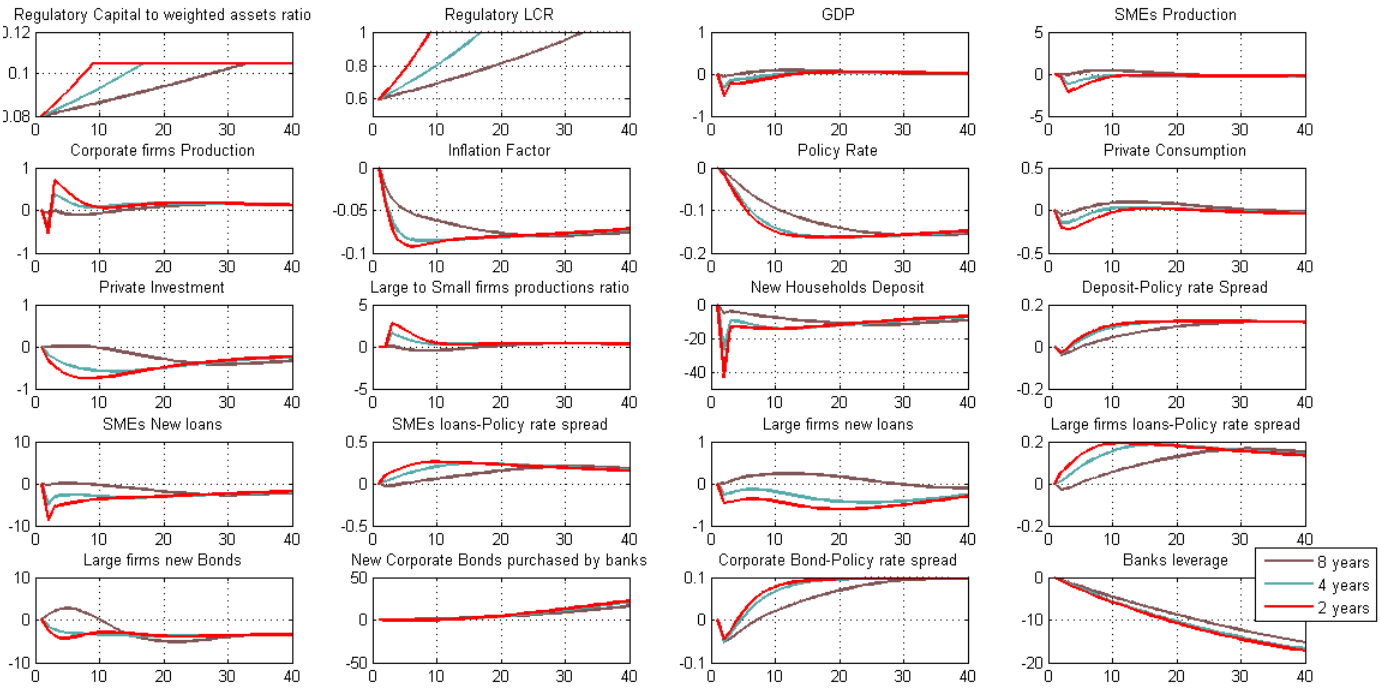


Figure 3.5: Simultaneous banks capitalization and Liquidity Shocks - The phase-in period. The Basel III regulatory variables are expressed in level. All rates are shown as absolute deviations from steady state, expressed in basis points. All other variables are percentage deviations from steady state.

what we can call the "degree of urgency" of meeting the constraint. Indeed, since our model takes into account differences in assets maturities. This feature plays a relevant role for banks' decisions in the sense that loan decisions have on average a longer lasting effect on banks' balance sheet as loans are assets with a maturity longer than one period. As a consequence, when a bank decides or has to meet quickly the regulatory constraint, it will probably make the choice of deleveraging rather than increasing profit margins. Thus, we simulate different scenarios with different values of κ^K that represent the more or less aggressive behavior from the regulator, we found that with high values of κ^K, the banks prefer to cut their loans and their corporate bond purchase in order to increase their capital-to-weighted assets ratio and thus meet the regulatory constraint, when with a low insistence from the regulator (low κ^K), banks make the choice to increase their margins whose effects takes relatively more time. The same results can be observed for banks under stress that are generally small or medium sized banks. Indeed, a low capitalized banks for example have to make greater efforts to meet the constraints. Consequently, they will probably have stronger incentives to cut their credit supply relatively to well capitalized banks. This would probably, at least in the short and medium term, enlarge the discrepancies between the two types of banks.

With a verylong implementation period (8 years here), banks are initially able to satisfy the (low) one-period regulatory requirements without deleveraging. It will maintain SMEs production level relatively high as compared to what we observed in the short-term implementation scenario. Thus, the discrepancy between SMEs and large firms production levels remains stable. The latter together with banks smooth increases in their profit margins limit the contractionnary impact of Basel III constraints and therefore induce a low variability in most of real sector aggregates.

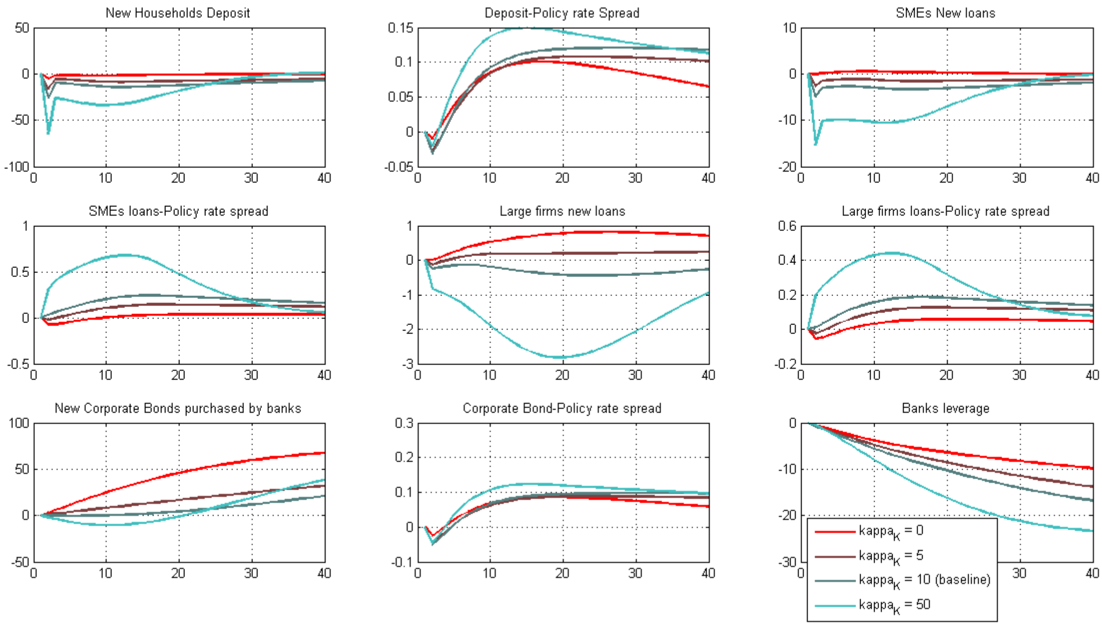


Figure 3.6: The impact of the wight of Basel III new Capitalization constraints.

All rates are shown as absolute deviations from steady state, expressed in basis points. All other variables are percentage deviations from steady state.

3.5 Conclusion

In this paper, we extend the results of the numerous studies on the Basel III new requirements implementation and notably those of the (MAG Macroeconomic Assessment Group [55] and MAG Macroeconomic Assessment Group [54]). Focusing on the impact of the new banking regulation in presence of firms'heterogeneity, we found that both capitalization and the liquidity coverage ratios widen the discrepancy between small and large companies in favor of the latter. This result is moreover amplified when we implement both constraints simultaneously. Indeed, we find that there is no potential positive spill-over effects between the implementation of the new capitalization ratio an the liquidity coverage ratio, which appear as more complementary than substitutable, as their effects are compounded when the two regulations are implemented jointly.

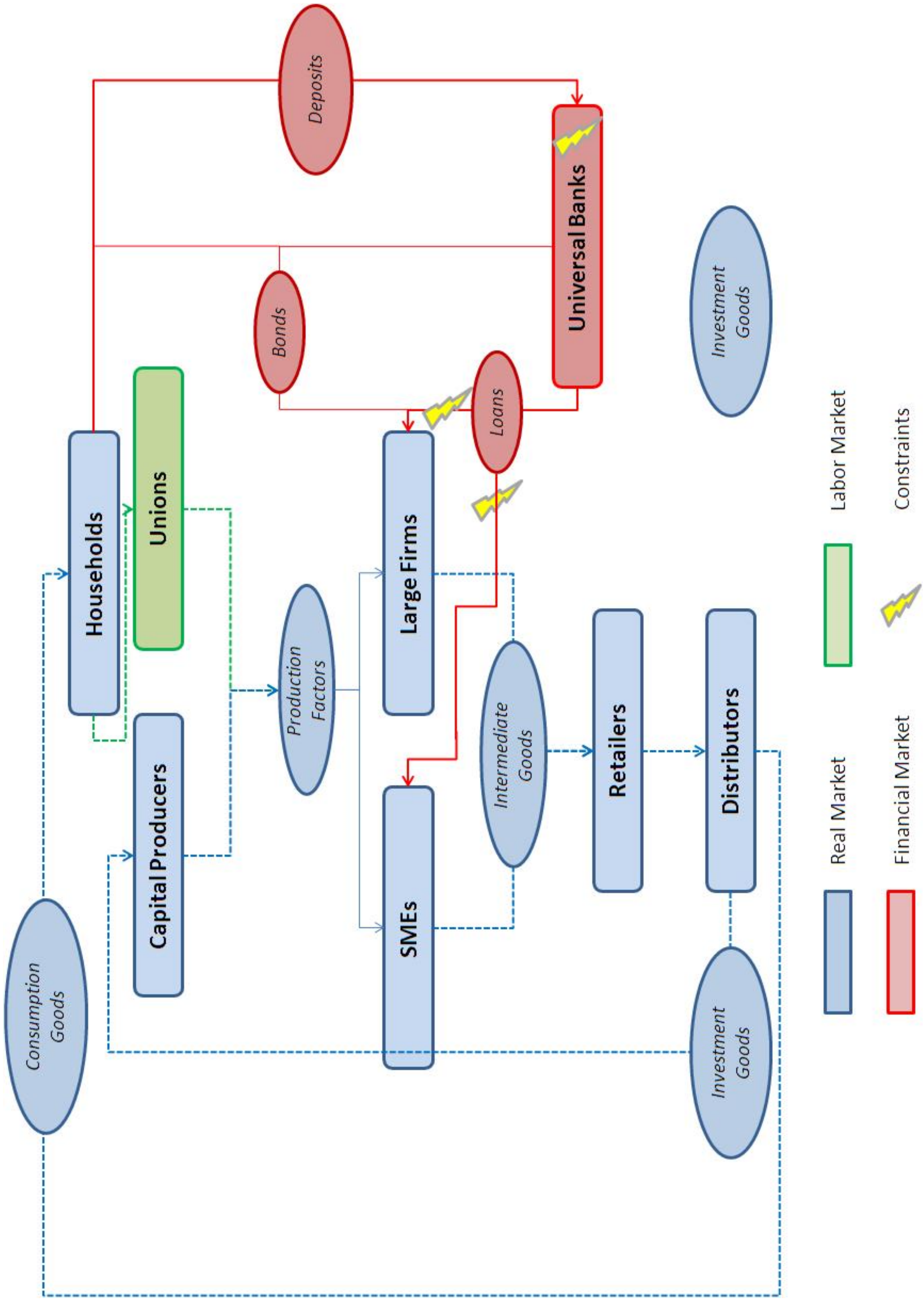
Appendices

A Tables & Graphs

Parameter	Description	Value
Households		
σ_c^w	Inter-temporal elasticity of substitution of workers'consumption	1
η^w	Habit in workers' consumption coefficient	0.6
σ_n	Inverse of the Frisch elasticity	1
ν_w	$\frac{\nu_w}{\nu_w-1}$ is the mark-up in the labor market	5
γ_w	Wage indexation	0.7
κ_w	Wage adjustment cost	500
Production		
σ_c^p	Inter-temporal elasticity of substitution of small entrepreneurs'consumption	1
η^p	Habit in small entrepreneurs' consumption coefficient	η^w
α	Capital share in the production function	0.25
δ	Capital depreciation rate	0.05
σ_c^g	Inter-temporal elasticity of substitution of large entrepreneurs'consumption	1
η^g	Habit in large entrepreneurs' consumption coefficient	η^w
ϕ	Capital producers' investment adjustment cost	1
ξ^y	Inverse of Elasticity of substitution between SMEs and large corporate	0.1
ν^y	SME's share in the production	0.33
ν^f	$\frac{\nu^f}{\nu^f-1}$ is the mark-up in the good market	3.86
γ_f	Price indexation	0.6
κ_f	Price adjustment cost	200
Banking Sector		
κ^{L^P}	SMEs'loans interest rate adjustment cost	4
κ^{L^G}	Large firms'loans interest rate adjustment cost	6
κ^D	Savers'deposits interest rate adjustment cost	10
ν^{L^P}	$\frac{\nu^{L^P}}{\nu^{L^P}-1}$ is the mark-up on rate on loans to SMEs	2.5
ν^{L^G}	$\frac{\nu^{L^G}}{\nu^{L^G}-1}$ is the mark-up on rate on loans to large corporate	4.2
ν^D	$\frac{\nu^D}{\nu^D-1}$ is the mark-down on rate on deposits	-2.5
κ^K	"Leverage" deviations cost	10
κ^L	"Liquidity" deviations cost	1.10^{-3}
δ^{L^P}	$(1-\delta^{L^p})$ The principal repayment part of the loans to SMEs residual outstanding amount	0.9446
δ^{L^G}	$(1-\delta^{L^g})$ The principal repayment part of the loans to large firms residual outstanding amount	0.9571
δ^{T^G}	$(1-\delta^{T^g})$ The principal repayment part of the large firms bonds residual outstanding amount	0.9715
δ^{T^S}	$(1-\delta^{T^g})$ The principal repayment part of the risk-less bonds residual outstanding amount	0.9823
δ^D	$(1-\delta^D)$ The principal repayment part of the households deposits	0.9907

Table A.1: Calibration

Parameter	Description	Value
Monetary Policy		
r_{π}	Taylor rule coefficient on inflation	2
$r_{\Delta\pi}$	Taylor rule coefficient on inflation growth	0
$r_{\Delta Y}$	Taylor rule coefficient on output growth	0
$\overline{R}$	Nominal policy rate in %(ssv)	0.75
$\overline{\pi}$	The long term Inflation rate in %(ssv)	0.49
Shocks		
ρ_z	The AR coefficient of the idiosyncratic shock	0.9
ρ_A	The AR coefficient of the global technology shock	0.95
ρ_r	The AR coefficient of the monetary policy shock	0
σ_A	The SD coefficient of the global technology shock	0.01
σ_r	The SD coefficient of the monetary policy shock	0.00125
σ_{ν^K}	The SD coefficient of the solvency ratio	0.0170
σ_{ν^L}	The SD coefficient of the LCR	0.0319


Deposits
Universal Banks
Bonds
Loans
Investment Goods
Households
Unions
Large Firms
Production Factors
Capital Producers
Intermediate Goods
Retailers
Distributors
SMEs
Consumption Goods
Investment Goods
Labor Market
Constraints
Real Market
Financial Market

Conclusion

L'ampleur de la dernière crise financière est telle qu'un consensus s'est dessiné pour affirmer que toutes les crises ne sont pas équivalentes et que la dernière pourrait, à ce titre, être considérée comme une crise anormale. Nous avons, dans notre première partie de thèse, donné un cadre formel à cette assertion en testant la pertinence de l'hypothèse de 'normalité', entendue dans le sens statistique des innovations qui prévaut dans la quasi-totalité des modèles économétriques actuels. En se basant sur un modèle VAR avec des variables relatives à la zone euro issues aussi bien du secteur réel que du secteur financier, nous confrontons les capacités prédictives de ce modèle VAR sous les deux hypothèses de normalité et de non normalité des innovations ; dans ce dernier cas, les innovations suivent une loi t de Student, qui est notamment caractérisée par des queues de distributions épaisses.
Ainsi, en incluant la dernière phase de récession dans notre période d'estimation, les résultats militent clairement en faveur de la distribution t de Student avec un nombre de degrés de liberté très faible, qui se situe aux alentours de 3 ou 4. Par ailleurs, en restreignant notre période d'estimation à la période pré-crise, les résultats deviennent beaucoup moins nets : le degré de liberté 'optimal' remonte alors à 6, sachant que les écarts de vraisemblances calculées avec chacune des deux spécifications sont très proches. La combinaison de ces deux résultats confirme non seulement la non-normalité de la dernière crise survenue en zone euro, mais permet également de l'identifier comme l'avènement de chocs rares.
En procédant à une analyse inférentielle du modèle, nous montrons là encore qu'une spécification standard (i.e. reposant sur des innovations normales) est susceptible de fournir des résultats économiquement contre-intuitifs, mais aussi fortement dépendants de la période d'estimation. En effet, nous nous sommes notamment intéressés à la transmission des chocs de risque de contrepartie sur le marché interbancaire, aux taux d'intérêts débiteurs des banques, ainsi qu'au volume des crédits bancaires octroyés. Nous montrons qu'avant la crise, un choc de risque de crédit engendrait une baisse des volumes de crédits bancaires, avec de surcroît un impact statistiquement non significatif sur les taux débiteurs, ce résultat prévalant quelle que soit la spécification retenue. Cependant, en prenant en compte la période de la dernière crise, une spécification 'normale' suggère un impact statistiquement positif sur les crédits (au moins la première période), tandis que l'impact sur les taux débiteurs demeure non significatif. En revanche, la prise en compte d'une distribution permettant la réalisation d'événements rares est davantage susceptible de fournir des résultats plus conformes à l'intuition économique : notre spécification utilisant une loi t de Student révèle qu'un choc de risque de crédit sur le marché interbancaire a un impact négatif statistiquement significatif sur les volumes de crédits, tandis que les taux débiteurs ont davantage tendance à augmenter.
Bien qu'il convienne naturellement, comme cela est toujours le cas dans ce type d'exercice, de tester la robustesse de tels résultats en variant aussi bien les méthodes d'identification des chocs structurels que les variables retenues, nous montrons l'inaptitude des modèles économétriques standard en période de crises, tant au niveau de leur capacité prédictive que de leur bien-fondé économique.

Par ailleurs, plusieurs études économétriques ont mis en exergue l'inefficacité ou encore les limites des politiques monétaires conventionnelles durant la dernière crise économique. Cependant, peu de travaux ont opté pour une approche structurelle pour asseoir un tel résultat, laissant un pan large à la détermination des causes réelles à l'origine d'un tel phénomène. Dans la même logique que ce qui a

été souligné précédemment, nous nous sommes intéressés à l'impact de la présence d'une forte volatilité dans le marché interbancaire sur la transmission de la politique monétaire.
Nous avons relevé que, durant les périodes de fortes incertitudes, les banques sont beaucoup moins enclines à tempérer les effets de la volatilité sur le marché interbancaire, comme elles l'auraient fait en période de haut de cycle. Nous relevons en outre un effet stagflationniste récurrent des chocs de volatilité, que l'on retrouve sur quasiment l'ensemble des marchés étudiés, dont le marché des crédits bancaires qui, en conséquence, affiche un niveau de *pass-through* supérieur à l'unité. Cet effet stagflationniste a déjà été souligné par Fernández-Villaverde et al. [27], qui l'expliquent par la présence de rigidités nominales, combinée à la courbure de la fonction du profit marginal aux alentours du prix optimal. Nous fournissons à notre tour une autre explication à ce phénomène, en complétant l'approche de Fernández-Villaverde et al. [27] et en mettant essentiellement l'accent sur le rôle de la spécification des rigidités nominales, reléguant au second plan le rôle de la forme de la courbe de profit marginal.
Nous montrons ainsi que des chocs d'incertitude sur le marché interbancaire peuvent altérer la transmission de la politique monétaire, notamment la politique monétaire accommodante, dans la mesure où les banques ont, sous l'effet "stagflationniste" évoqué ci-dessus, davantage tendance à maintenir leurs taux débiteurs à des niveaux relativement plus élevés qu'en période "normale". Il en résulte une augmentation (ou une moindre diminution, selon les situations) concomitante des bénéfices des banques commerciales, qui induit *in fine* à une amélioration de leur ratio de capitalisation.
Notons néanmoins que la réaction des banques centrales est en mesure de juguler les effets de l'incertitude sur les principales variables d'intérêt. Nous montrons en effet qu'une banque centrale menant une politique monétaire équilibrée entre lutte contre l'inflation et soutien à l'économie réelle est plus à même de réduire les effets des chocs d'incertitude pouvant survenir en temps de crise.

Autre réponse à la dernière crise financière, les réformes prudentielles de Bâle III constituent indéniablement l'élément le plus en vue de ces dernières années. Ces accords apportent des nouveautés en termes d'exigences réglementaires, dont notamment la mise en place d'un ratio de liquidité (*Liquidity Coverage Ratio*, ou LCR). Nous relevons dans notre troisième chapitre de thèse que la mise en place d'une contrainte de liquidité du type LCR ne contribue pas nécessairement à l'amélioration du ratio de capitalisation (et inversement). En effet, dans le cadre d'un modèle d'équilibre général avec des actifs de différentes maturités, nous relevons que la mise en oeuvre du LCR est susceptible de s'accompagner d'une baisse du spread de taux d'intérêts débiteurs par rapport au taux directeur, tandis que les volumes demeurent relativement stables. Ces dynamiques contrastent avec les effets d'un choc de capitalisation, caractérisés essentiellement par un relèvement des marges et un processus de *deleveraging* visant à diminuer la taille du bilan bancaire. Ces effets sont, par ailleurs, sensibles à la durée de la mise en oeuvre des nouvelles exigences réglementaires. Nous montrons ainsi qu'une mise en oeuvre des réformes lente et parfaitement anticipée par les agents permettrait d'éviter les effets récessifs transitoires de la nouvelle réglementation bancaire. Une mise en oeuvre graduelle s'étalant sur plusieurs années réduirait ainsi la probabilité d'un recours massif au *deleveraging*, et se traduirait par un relâchement de la contrainte de financement des PME.
Les PME sont par ailleurs davantage impactées par les nouvelles normes réglementaires qui accentuent de ce fait le différentiel de production et, *in fine*, de poids dans l'économie entre PME et GE. Ce différentiel s'explique naturellement par la possibilité des GE à recourir au financement obligataire en cas de rationnement de crédit.

Tous ces travaux mettent en évidence les potentialités de modèles macroéconomiques intégrant une description fine du secteur financier, et à ce titre plus détaillée que les modèles disponibles jusqu'à présent dans la littérature économique.
Ces travaux ouvrent la voie à des recherches complémentaires intégrant une meilleure description de la réglementation prudentielle et de ses effets macroéconomiques, s'agissant notamment du secteur bancaire parallèle ("*shadow banking*"). En effet, celui-ci, en tant que secteur "désintermédié", voire non régulé, n'a été abordé que de façon partielle, via les émissions obligataires. En outre, l'introduction d'agents hétérogènes (au-delà de notre distinction PME/GE) nous semble une piste de recherche fructueuse pour l'avenir.

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