Monetary and macroprudential policies in an estimated model with financial intermediation

Working Paper Research

by Paolo Gelain and Pelin Ilbas

May 2014 No 258

NationalBank OF BELGIUM
Eurosystem

Statement of purpose:

The purpose of these working papers is to promote the circulation of research results (Research Series) and analytical studies (Documents Series) made within the National Bank of Belgium or presented by external economists in seminars, conferences and conventions organised by the Bank. The aim is therefore to provide a platform for discussion. The opinions expressed are strictly those of the authors and do not necessarily reflect the views of the National Bank of Belgium.

Orders

For orders and information on subscriptions and reductions: National Bank of Belgium,
Documentation - Publications service, boulevard de Berlaimont 14, 1000 Brussels

Tel +32 2 221 20 33 - Fax +32 2 21 30 42

The Working Papers are available on the website of the Bank: http://www.nbb.be

ISSN: 1375-680X (print)
ISSN: 1784-2476 (online)

Abstract

We estimate the Smets and Wouters (2007) model augmented with the Gertler and Karadi (2011) financial intermediation sector on US data by using real and financial observables. Given the framework of the estimated model, we address the question whether and how standard monetary policy should interact with macroprudential policy in order to safeguard real and financial stability. For this purpose, monetary policy is described by a flexible inflation targeting regime using the interest rate as instrument, while the macroprudential regulator adopts a tax/subsidy on bank capital in a countercyclical manner in order to stabilize nominal credit growth and the output gap. We look at the gains from coordination between the central bank and the macroprudential regulator under alternative assumptions regarding the degree of importance assigned to output gap fluctuations in the macroprudential mandate. The results suggest that there can be considerable gains from coordination if the macroprudential regulator has been assigned a sufficiently high weight on output gap stabilization, i.e. the common objective with monetary policy. If, on the other hand, the main focus of the macroprudential mandate is on credit growth, the macroprudential policy maker can reach better outcomes, while the central bank does worse, in the absence of coordination. Therefore, whether and to which extent monetary policy gains from coordination with the macroprudential regulator depends on the relative weight assigned to output fluctuations in the macroprudential mandate. Our counterfactual analysis further confirms the effectiveness of the countercyclical macroprudential tax/subsidy in containing the amplification effects triggered by a financial shock, and suggests that having a macroprudential regulatory tool at work could have successfully avoided the massive drop in credit such as the one observed at the onset of the Great Recession.

JEL classification: E42, E44, E52, E58, E61

Keywords: Monetary policy, financial frictions, macroprudential policy, policy coordination, capital tax/subsidy.

Authors:

Paolo Gelain, Norges Bank, e-mail: paolo.gelain@norges-bank.no

Pelin Ilbas (corresponding author), Research Department, NBB, e-mail: pelin.ilbas@nbb.be.

We are grateful to Lars Svensson, Nobuhiro Kiyotaki, Peter Karadi, Glenn Rudebusch, Raf Wouters, Kjetil Olsen, Leif Brubakk, Junior Maih, Thea Kloster, Stefano Neri, Joe Pearlman, Jin Cao, Amund Holmsen, David de Antonio Liedo, Gisle Natvik, Alejandro Justiniano, Paul Levine, Diego Rodriguez-Palenzuela, Pau Rabanal, Hans Dewachter, Daria Finocchiaro, Matthias Paustian, Olivier Loisel, Arnoud Stevens, Hugues Famerée, Jan Smets, Francesco Furlanetto and seminar and conference participants at the National Bank of Belgium, the Norges Bank, the 2013 International Banking, Economics, and Finance Association conference in Seattle and the 9th Dynare conference in Shanghai for stimulating comments and discussions (remaining errors are our own).

TABLE OF CONTENTS

1 Introduction

The financial disruptions that started in the second half of 2007, which eventually led to the most severe global crisis since the Great Depression, have highlighted the importance of financial stability in maintaining overall macroeconomic stability, and paved the way for economists and policy makers around the globe to think about setting up new regulatory frameworks to better monitor financial developments and to act preemptively in order to avoid the build-up of financial imbalances, and hopefully decrease the likelihood of future crises.

This paper aims to contribute to these discussions by studying the implications of macroprudential policy in the context of an estimated medium-scale DSGE model for the US featuring a financial intermediation sector that is subject to frictions. In particular, we study the interaction between macroprudential policy, aimed at stabilizing nominal credit growth and the output gap, and monetary policy, which has been assigned a standard inflation targeting mandate. The gains from coordination are investigated under the assumption that both policy makers have the task to minimize their respective quadratic loss functions using separate instruments. We find that, to the extent that the macroprudential regulator assigns a sufficiently high weight to stabilizing the output gap, which is the objective it shares with the central bank, coordination between both policies implies a less volatile macroeconomic environment than the alternative case of no-coordination. When the financial stability objective of the regulator becomes more pronounced, however, lack of coordination yields better outcomes in terms of lower volatility of loss function objectives for the macroprudential regulator, but not for the central bank. This tradeoff in coordination gains is also present in a situation characterized by high real and financial volatility such as experienced during the recent financial crisis, and is robust to alternative definitions of financial stability. We perform a counterfactual analysis to demonstrate the effectiveness of a countercyclical macroprudential tax/subsidy on bank capital in reducing the amplification mechanism triggered by adverse credit market conditions. Based on these findings, we conclude that monetary policy alone could not have avoided the massive drop in credit supply, and that the presence of a separate macroprudential regulatory tool in addition to monetary policy would have been crucial to safeguarding a stable macroeconomic environment.

This paper is organized as follows. In the next section, we set out the motivation for this paper by outlining the main debate on how financial stability can, and should be, safeguarded, and which role monetary policy should play in the post-crisis policy landscape, followed by our contribution against the background of related literature in section 3. Section 4 outlines the modeling setup, which consists of the Smets and Wouters (2007) model augmented with the Gertler and Karadi (2011) financial intermediation sector. The estimation procedure is outlined and commented on in section 5, followed by a description of the monetary and macroprudential policy setup and the implied results from coordination experiments in section 6. Section 7 performs a robustness analysis to alternative objectives in the macroprudential loss function, while section 8 repeats the previously performed coordination exercises by accounting for post-crisis volatilities of the shocks. Section 9 performs an impulse response analysis, followed by a counterfactual exercise that assesses the role the macroprudential policy tool could have played had it been in place during pre-crisis period in section 10. Section 11 concludes.

2 Background and Motivation

The recent crisis has re-opened the debate on the role played by monetary policy in the build-up of financial imbalances. The mainstream view on the conduct of monetary policy prior to the crisis was largely determined by the standard inflation targeting framework with primary focus on price stability, to be maintained over the medium term, and typically combined with an objective on some measure of resource utilization, such as highest sustainable employment or output growth. It was commonly believed that, if the central bank is successful in maintaining low and stable inflation, this would also ensure real and financial stability. Supported by the view that financial markets were close to efficient in advanced countries, an explicit concern for financial stability was not assumed to be necessary for the central bank.[1] Since the outbreak of the 2007 - financial crisis, however, the consensus has shifted towards the view that price stability alone cannot safeguard financial stability and cannot prevent financial crises from occurring. There is common agreement that financial institutions should be supervised more and better than before, and their risk-taking behavior should be closely monitored. When there are signs of build-up of systemic risk, which makes the economy more prone to the crisis as the one recently experienced, intervention should be called for. The latter prescribes a macroprudential approach to monitoring the financial system and demands for an active intervention in the financial markets when necessary. There is however no consensus yet on whether monetary policy should play an active role in this respect and, if any, which implications it would have for the standard inflation targeting framework.[2] Below, we discuss two opposing views.

2.1 Integration of Macroprudential and Monetary Policy

Some argue that loose monetary policy in the period prior to the crisis played an important role in the build-up of financial imbalances since it encouraged excessive risk-taking behavior (search for yield). Changes in policy rates affect leverage, asset quality and the risk perception of banks, which in turn affect supply and cost of funds to bank-dependent borrowers. According to Borio and Zhu (2008), the "risk-taking channel" of monetary policy, which makes the explicit link between monetary policy and the risk perception of banks or their willingness to bear risk, may be significant enough to call for an active role for monetary policy in discouraging excessive risk-taking during an economic expansion (see also Adrian and Shin, 2010).

The proponents of an active role for monetary policy in the new framework for macroprudential policy therefore share the view that the central bank should fulfill a broader task than it did up to now, which has so far been a narrow focus on price stability. It should take into account the effects of its actions on risk-taking behavior and if necessary lean against a credit

[1] The two-pillar strategy adopted by the ECB provided room for monitoring various monetary and credit aggregates. However, also in the context of the two-pillar strategy, credit aggregates were solely considered to the extent that they posed a risk to price stability over the medium- to long-run.

[2] There is also no consensus on the appropriate tools and objectives for macroprudential policy. Although several proposals have been made, e.g. French et al. (2010) and Brunnermeier et al. (2009), to name a few.

boom, i.e. react to the build-up of financial imbalances, as macroprudential policy alone might not be sufficient to achieve this (e.g. De Grauwe, 2008, Borio, 2011). Moreover, given that financial imbalances tend to build up over a relatively long time frame, Bean (2003) suggests monetary policy to adopt a longer time horizon than it currently does with its medium-term inflation target. Woodford (2011) proposes a "natural extension of flexible inflation targeting", where the central bank should include a financial stability objective in addition to its standard objectives for price stability and output, and monitor the degrees of maturity transformation and leverage by financial institutions in order to assess systemic risk and react accordingly using interest rate policy.

2.2 Separation of Macroprudential and Monetary Policy

The opponents of incorporating financial stability concerns as an additional objective for monetary policy rely on the principle that specific macroprudential instruments (such as capital buffers, loan-to-value policies, minimum liquidity ratios, etc.) are much more effective at safeguarding financial stability than monetary policy. Svensson (2012) supports this view of separation of policies and instruments, and suggests that monetary and macroprudential policy should not be coordinated, and that monetary policy should only be concerned about financial stability to the extent that it affects its medium term forecasts of inflation and employment. This argument implies no change to the current inflation targeting framework.

Bernanke (2011) recognizes that the importance of financial stability has been neglected in the pre-crisis period and should be restored in the post-crisis period in a way that financial stability becomes as important as monetary policy and both can be complementary tasks of the central bank. He argues that this should not lead to major changes to the current (inflation targeting) framework for monetary policy, as the question on whether monetary policy can provide the right tools and whether better macroprudential tools are available to safeguard financial stability currently remains unanswered.

3 Contribution and Related Literature

Although there is a strong agreement on the need for an explicit role for macroprudential policy in order to address financial stability concerns, as discussed in the previous section, the appropriate operational framework for the latter and the desirable degree of interaction with monetary policy is still a topic under active discussion in policy institutions and academic circles.

This paper aims to contribute to the debate outlined in the previous section by quantifying the gains or losses from coordination between monetary and macroprudential policy within the framework of an estimated DSGE model for the US characterized by a financial intermediation sector. Our approach is most closely related to recent work by Angelini et al. (2012) in terms of methodology: we likewise describe both policies as separate agents that minimize their respective, quadratic loss functions having separate instruments at their disposal. Within this setup, we compute optimal simple rules and describe the full coordination regime as one where both policy makers behave like a single agent optimizing the joint loss function, while the no-coordination regime is set to be one in which the macroprudential regulator first sets policy, to which the central bank reacts. This paper, however, differs from Angelini et al. (2012) among four important dimensions. First, there are differences in terms of modeling framework and the economy considered. Angelini et al. (2012) analyze the gains from coordination within the estimated version of the Gerali et al. (2010) model for the euro area. Monetary policy is modeled to minimize a standard loss function using the interest rate instrument. They consider two macroprudential instruments: a capital requirement rule and the loan-to-value ratio, and three macroprudential objectives: the loans-to-output ratio, which is the financial stability objective, output and the variability of the instrument. We instead focus on a model estimated for the US economy featuring a bank capital channel arising from a moral hazard problem between bankers and depositors, which is addressed accordingly by a macroprudential tax/subsidy policy. Second, the focus of the policy experiments in this paper also differ from the ones in Angelini et al. (2012); they conduct their simulation experiments under alternative shock scenarios, such as demand vs. supply shocks in order to distinguish between normal times and crisis times, and conclude that when the economy is driven by supply shocks (i.e., "normal times") macroprudential policy has little to contribute to macroeconomic stability over the case of monetary policy only, but plays a more important role in the face of financial and housing market shocks. In this paper, we distinguish among scenarios essentially based on alternative definitions of the macroprudential mandate, in particular the importance assigned by the regulator to output gap stability in addition to nominal credit growth in the presence of all the structural shocks[3]. The third difference with Angelini et al. (2012) concerns the policy recommendations resulting from the coordination exercises. In their analysis, the choice of the weights in the macroprudential loss do not affect their policy recommendations, whereas we show that if a separate macrorpudential authority is to be set up and given its own mandate, full coordination with the monetary policy authority might not necessarily provide the best possible circumstances for the macroprudential policy maker to achieve its mandate. This is particularly the case if the mandate is focused relatively more on financial stability and less on output gap stabilization. Therefore, unlike Angelini et al. (2012), our analysis implies that if the macroprudential mandate is not designed to suit the full coordination framework appropriately (in other words, if its loss function weights are not chosen accordingly), this would come at the cost of increased output volatility, making the central bank worse off in the absence of full coordination, hence leading to coordination gains/losses that are not aligned among the policy makers. The fourth important difference with Angelini et al. (2012) is that the general focus in their paper leans more towards assessing the benefits of the existence of macroprudential policy over monetary policy, which depends on the degree of coordination between the two policy makers. Our analysis, on the other hand, takes the presence of macroprudential policy as given, after first having established its benefits in the standard version of the model, and conducts the optimal coordination experiments accordingly in order to detect potential pitfalls in the alternative coordination schemes considered. In addition, we justify the existence of a macroprudential regulator ex-post, i.e., by conducting a counterfactual experiment, to show

[3] Alternative financial stability definitions are considered in section 7 on robustness.

the effectiveness of macroprudential policy in containing the amplification effects triggered by a financial shock.

Bean et al. (2010) study the optimal interaction between monetary and macroprudential policy under discretion in the context of a slimmed down version of the model developed by Gertler and Karadi (2011). They consider the physical capital gap as the financial stability objective in the ad hoc macroprudential loss function, and use a lump sum levy/subsidy on bank capital as the macroprudential tool. Their results suggest that, to the extent that aggregate lending and riskiness in the banking sector are affected by bank leverage and bank capital, macroprudential policy is more effective than monetary policy alone leaning against the wind, hence concluding that each policy should be addressing their own separate objectives. Lima et al. (2012) consider, in a modeling context similar to Bean et al. (2010)[4], the implications of financial frictions on welfare optimal policy and the gains from commitment (compared to discretion) with and without the presence of a macroprudential instrument. In addition, they investigate the effects of financial frictions on optimized simple rules. They find that the gains from commitment when macroprudential regulation is in place increase when financial frictions are taken into account together with the zero lower bound considerations. The optimized simple rule in the latter case approaches a price level rule. The financial intermediation sector considered in this paper is, like in Bean et al. (2010) and Lima et al. (2012), based on Gertler and Karadi (2011). In this setup, financial intermediation plays a non-trivial role due to a moral hazard problem between depositors and banks, which gives rise to an exogenously triggered credit cycle and a role for macroprudential policy as an effective tool to prevent the amplification effects of financial shocks on the macroeconomy. We use a macroprudential tool that is similar to the one in the aforementioned papers, i.e. tax/subsidy on bank capital. The main difference between our approach and the approach taken by Bean et al. (2010) is the assumptions made about the policy setup: while Bean et al. (2010) focus on optimal discretionary solutions in assessing the gains from coordination, we assume commitment to optimal simple rules. The modeling of the macroeconomic framework followed in this paper is an additional source of difference with Bean et al. (2010) and Lima et al. (2012), who use models that are smaller in scale. Moreover, we conduct coordination exercises in the framework of an estimated model, while the former studies base their results within calibrated setups. In this paper, the Gertler-Karadi banking sector is embedded within an otherwise standard, medium-scale DSGE model, i.e. the Smets and Wouters (2007) model, which we estimate for the US using real and financial observables prior to performing policy exercises.

Darracq Pariès et al. (2010) derive optimal interest rate and capital requirement rules by minimizing an ad hoc loss function under full commitment in the context of an estimated DSGE model for the euro area with financially-constrained households and firms and an oligopolistic banking sector subject to capital constraints. Quint and Rabanal (2013) study the optimal mix of monetary and macroprudential policies in an estimated model of the euro area, where the policy makers maximize aggregate welfare in the euro area. They conclude that macro-prudential policy can always help improving the welfare of savers, but depending on the shocks

[4] In particular, they refer to Gertler Kiyotaki (2010).

hitting the economy, borrowers will not always gain such as in the case of a technology shock by enhancing the countercyclicality of lending spreads. De Paoli and Paustian (2013) study the gains from coordination in the context of a macroeconomic model featuring credit market frictions. They derive a welfare-based loss function and show that, in the face of cost-push shocks, coordination yields better outcomes, while assigning narrow mandates to monetary and macroprudential policies can mitigate coordination problems when both policies act independently under discretion.

4 Smets-Wouters Model augmented with the Gertler-Karadi Financial Sector

Before the financial crisis, the (New-Keynesian) structural models used both for policy analysis as well as academic research mainly focused on the expectations channel of monetary transmission, promoting focus on communication and central bank transparency, and assumed perfect financial markets with no explicit role for financial frictions that could possibly account for the effects of financial distress originating in the financial sector on the macroeconomy. Although exceptions like Bernanke, Gertler and Gilchrist (1999) and Iacoviello (2005) considered an explicit role for financial frictions in these models, those frictions would arise on the demand side of credit and, therefore, were silent on the effects of shocks that directly hit the financial intermediation sector. In order to address the role of macroprudential policy in achieving and safeguarding financial stability, one needs to explicitly model the banking sector that is subject to frictions in the supply of credit, originating from agency problems due to asymmetric information and costly financing constraints. Over the recent years, research in this area has provided a new generation of general equilibrium models, where interactions between demand and supply in credit markets have been given a more explicit role, as in Gertler and Karadi (2011), Gertler and Kiyotaki (2010), Gerali et al. (2010).[5] Given that financial intermediation plays a non-trivial role in the Gertler and Karadi (2011) framework due to a moral hazard problem between depositors and banks, we merge the banking sector proposed by the former authors into the otherwise standard setup of Smets and Wouters (2007) (see also Rannenberg, 2012). In this section, we present the linearized model[6]. Following Smets and Wouters (2007), the linearization is performed around the steady state balanced growth path. The steady state values are denoted by a star. Appendix I outlines the steady state implications of introducing the Gertler-Karadi financial sector to the original Smets-Wouters setup.

The household sector, which consumes, saves and supplies labour, is composed of workers and bankers (or financial intermediaries). The fraction of each type remains constant over time, but workers can over time switch to become bankers with probability θ.[7] Workers return their wages to the household they belong, bankers do the same regarding their retained earnings from banking activities. While households own the intermediaries they manage, they hold deposits

[5] Galati and Moessner (2010) provide a detailed literature review.

[6] We refer to a technical appendix, which is available on request, for detailed assumptions regarding the complete nonlinear relations.

[7] Note that this finite horizon for bankers is introduced in order to prevent them from becoming self-financed over time.

in banks that belong to other households. We first set out the equations resulting from non-banking activities, and turn to the financial intermediation sector afterwards. Workers supply differentiated labor, which is sold by an intermediate labor union to perfectly competitive labor packers, who in turn resell labor to intermediate goods producers. The goods markets consist of intermediate goods producers that operate under monopolistic competition and final goods producers that are perfectly competitive. The producers of intermediate goods sell these to the final goods firms who package them into one final good which is resold to the households.

The following consumption Euler equation is derived from the maximization of the households' non-separable utility function with two arguments, i.e., consumption and leisure:

$$c_t = c_1 c_{t-1} + (1-c_1)E_t c_{t+1} + c_2(l_t - E_t l_{t+1}) - c_3(r_t - E_t \pi_{t+1} + \varepsilon_t^b) \quad (1)$$

where

$$c_1 = \frac{\lambda/\gamma}{1+\lambda/\gamma}, c_2 = \frac{(\sigma_c - 1)(W_*^h L_*/C_*)}{\sigma_c(1+\lambda/\gamma)} \text{ and } c_3 = \frac{1-\lambda/\gamma}{\sigma_c(1+\lambda/\gamma)}$$

with γ the steady state growth rate and σ_c the intertemporal elasticity of substitution. Consumption c_t is expressed with respect to an external, time-varying, habit variable, leading to persistence in the consumption equation where λ is the nonzero habit parameter. Consumption is also affected by hours worked l_t, and, more precisely, is decreasing in the expected increase in hours worked $(l_t - E_t l_{t+1})$, and by the ex ante real interest rate $(r_t - E_t \pi_{t+1})$, where r_t is the period t nominal interest rate and π_t is the inflation rate. The disturbance term ε_t^b, which is an AR(1) process with i.i.d. normal error term $(\varepsilon_t^b = \rho_b \varepsilon_{t-1}^b + \eta_t^b)$, captures the difference between the interest rate and the required return on assets owned by households.[8]

Wage setting by the intermediate labor union implies a standard equation for the real wage w:

$$w_t = w_1 w_{t-1} + (1-w_1)(E_t w_{t+1} + E_t \pi_{t+1}) - w_2 \pi_t + w_3 \pi_{t-1} - w_4 \mu_t^w + \varepsilon_t^w \quad (2)$$

where

$$\begin{aligned} w_1 &= \frac{1}{1+\beta\gamma^{1-\sigma_c}}, w_2 = \frac{1+\beta\gamma^{1-\sigma_c}\iota_w}{1+\beta\gamma^{1-\sigma_c}}, w_3 = \frac{\iota_w}{1+\beta\gamma^{1-\sigma_c}} \\ \text{and } w_4 &= \frac{(1-\beta\gamma^{1-\sigma_c}\xi_w)(1-\xi_w)}{(1+\beta\gamma^{1-\sigma_c})\xi_w((\phi_w - 1)\varepsilon_w + 1)} \end{aligned}$$

with β the households' discount factor and ξ_w the Calvo-probability that nominal wages cannot be re-optimized in a particular period, i.e., the degree of wage stickiness. Wages that cannot be re-optimized in a particular period are partially indexed, with a degree of ι_w, to the past inflation rate, leading to the dependence of wages on previous period's inflation rate. The symbol ε_w is the curvature of the Kimball labor market aggregator and $(\phi_w - 1)$ the constant mark-up in the labor market. The wage mark-up, i.e., the difference between the real wage and the marginal rate of substitution between consumption and labor, is represented as follows:

$$\mu_t^w = w_t - mrs_t = w_t - (\sigma_l l_t + \frac{1}{1-\lambda}(c_t - \lambda c_{t-1})) \quad (3)$$

[8] Note that, although we introduce an additional financial shock that captures similar effects, we keep this shock in the analysis in order to preserve the comovement in consumption and investment.

with σ_l the elasticity of labor supply with respect to the real wage. the wage mark-up shock $\varepsilon_t^w = \rho_w \varepsilon_{t-1}^w + \eta_t^w - \mu_w \eta_{t-1}^w$ (with η_t^w an i.i.d. normal error).

The utilization rate of capital can be increased subject to capital utilization costs. Households rent capital services out to firms at a rental price. The investment Euler equation is represented as follows:

$$i_t = i_1 i_{t-1} + (1 - i_1) E_t i_{t+1} + i_2 q_t + \varepsilon_t^i \tag{4}$$

where

$$i_1 = \frac{1}{1 + \beta \gamma^{1-\sigma_c}}, i_2 = \frac{1}{(1 + \beta \gamma^{1-\sigma_c}) \gamma^2 \varphi}$$

with φ the elasticity of the capital adjustment cost function in the steady state, and $\varepsilon_t^i = \rho_i \varepsilon_{t-1}^i + \eta_t^i$ an AR(1) investment specific technology shock with i.i.d. error term. The real value of capital (q_t) is given by:[9]

$$q_t = q_1 E_t q_{t+1} + (1 - q_1) E_t r_{t+1}^k - (r_t - E_t \pi_{t+1} + \varepsilon_t^b) \tag{5}$$

where

$$q_1 = \beta \gamma^{-\sigma_c} (1 - \delta) = \frac{(1 - \delta)}{R_*^k + (1 - \delta)}$$

with δ the capital depreciation rate, and r_t^k the rental rate of capital with steady state value R_*^k. Capital services used in current production (k_t^s) depend on capital installed in the previous period since newly installed capital becomes effective with a lag of one period:

$$k_t^s = k_{t-1} + z_t \tag{6}$$

with z_t the capital utilization rate, which depends positively on r_t^k:

$$z_t = z_1 r_t^k \tag{7}$$

where

$$z_1 = \frac{1 - \psi}{\psi}$$

with ψ normalized between zero and one, a positive function of the elasticity of the capital utilization adjustment cost function. The capital accumulation equation is written as follows:

$$k_t = k_1 k_{t-1} + (1 - k_1) i_t + k_2 \varepsilon_t^i \tag{8}$$

where

$$k_1 = \frac{(1 - \delta)}{\gamma} \text{ and } k_2 = (1 - (1 - \delta)/\gamma)(1 + \beta \gamma^{1-\sigma_c}) \gamma^2 \varphi$$

[9] In order to define the gross return to capital ret_t^k according to the more familiar real business formulation, it is possible to show that equation 5 can be replaced by the following fully equivalent two equations

$$ret_t^k = (1 - q_1) r_t^k + q_1 q_t - q_{t-1} - \varepsilon_{t-1}^b$$

$$E_t ret_{t+1}^k = r_t - E_t \pi_{t+1}$$

In the model with financial frictions the relation between $E_t ret_{t+1}^k$ and $r_t - E_t \pi_{t+1}$ stated in the second equation is different due to the wedge (spread) created by imperfect capital markets. It also follows that in the model without financial frictions the steady state of the return on capital $\overline{ret}_*^k$ is equal to $R_*^k + (1 - \delta)$. In Appendix III we show how that steady state changes when financial frictions are on.

The monopolistically competitive intermediate goods producers set their prices in line with Calvo (1983), which leads to the following New-Keynesian Phillips curve:

$$\pi_t = \pi_1 \pi_{t-1} + (1-\pi_1) E_t \pi_{t+1} - \pi_2 \mu_t^p + \varepsilon_t^p \tag{9}$$

where

$$\pi_1 = \frac{\beta\gamma^{1-\sigma_c}\iota_p}{1+\beta\gamma^{1-\sigma_c}\iota_p} \text{ and } \pi_2 = \frac{(1-\beta\gamma^{1-\sigma_c}\xi_p)(1-\xi_p)}{(1+\beta\gamma^{1-\sigma_c}\iota_p)\xi_p((\phi_p-1)\varepsilon_p+1)}$$

and ι_p is the indexation parameter, ξ_p the degree of price stickiness in the goods market, ε_p the curvature of the Kimball aggregator and $(\phi_p - 1)$ the constant mark-up in the goods market. μ_t^p is the price mark-up, i.e., the difference between the marginal product of labor and the real wage:

$$\mu_t^p = mpl_t - w_t = \alpha(k_t^s - l_t) + \varepsilon_t^a - w_t \tag{10}$$

The price mark-up shock follows an ARMA(1,1) process: $\varepsilon_t^p = \rho_p \varepsilon_{t-1}^p + \eta_t^p - \mu_p \eta_{t-1}^p$ where η_t^p is an i.i.d. normal error term. $\varepsilon_t^a = \rho_a \varepsilon_{t-1}^a + \eta_t^a$ is the total factor productivity with an i.i.d. normal error term. The firms' cost minimization condition results into the following relation between the rental rate of capital, the capital-labor ratio and the real wage:

$$r_t^k = -(k_t^s - l_t) + w_t \tag{11}$$

Equilibrium in the goods market is represented as follows:

$$\begin{aligned} y_t &= c_y c_t + i_y i_t + z_y z_t + g_y \varepsilon_t^g \\ &= \phi_p(\alpha k_t^s + (1-\alpha) l_t + \varepsilon_t^a) \end{aligned} \tag{12}$$

where y_t represents aggregate output, $z_y = R_*^k k_y$, $c_y = 1 - g_y - i_y$ the steady state share of consumption in output, $i_y = (\gamma - 1 + \delta) k_y$ the steady state share of investment in output, k_y the steady state share of capital in output and g_y the ratio of exogenous spending over output. Exogenous spending is assumed to follow an AR(1) process, including an i.i.d. total factor productivity shock: $\varepsilon_t^g = \rho_g \varepsilon_{t-1}^g + \eta_t^g + \rho_{ga} \eta_t^a$. ϕ_p equals one plus the share of fixed costs in production and α is the capital share in production.

For estimation purposes, we will represent monetary policy by the following interest rate rule

$$r_t = \rho_r r_{t-1} + (1-\rho_r)\left\{r_\pi \pi_t + r_y\left(y_t - y_t^p\right)\right\} + r_{\Delta y}\left[\left(y_t - y_t^p\right) - \left(y_{t-1} - y_{t-1}^p\right)\right] + \varepsilon_t^r \tag{13}$$

where the monetary policy shock ε_t^r follows a first-order autoregressive process with an IID-Normal error term: $\varepsilon_t^r = \rho_R \varepsilon_{t-1}^r + \eta_t^r$.

Financial intermediaries lend funds obtained from households to non-financial firms. Their balance sheet is composed as follows

$$q_t + s_t = n_S n_t + b_S b_t$$

where s_t is the the quantity of financial (long-term) claims on non-financial firms that the intermediary holds, n_t is the amount of net worth that intermediaries have at the end of period t, b_t the short-term deposits the intermediary obtains from households, and

$$n_S = \frac{N_*}{S_*}, \text{ and } b_S = \frac{B_*}{S_*}$$

Given that $q_t + k_t$ is the value of capital acquired by firms and $q_t + s_t$ is the value of claims against this capital, arbitrage implies that $q_t + k_t = q_t + s_t$.

Deposits held by households with the intermediary at time t, pay the non-contingent real gross return rr_{t+1} at $t+1$, where $rr_t \equiv r_t - E_t\pi_{t+1}$. Intermediary assets earn the stochastic return ret^k_{t+1} over this period. The bankers' objective is to maximize expected terminal wealth, and their equity capital evolves as the difference between earnings on assets and interest payments on liabilities. As long as the expected discounted difference between ret^k_{t+1} and rr_{t+1} is positive, the intermediary has incentives to expand its assets by borrowing indefinitely from households. To limit its ability to do so, following moral hazard/costly enforcement problem is introduced by Gerlter and Karadi (2011): at the start of each period, the banker can divert a fraction Γ_t of available funds and transfer it back to the household he or she belongs to, for example in the form of large dividends or bonuses. Depositors can in this case force the intermediary into bankruptcy in order to recover the remaining fraction $1 - \Gamma_t$ of assets. However, depositors can not recover the remaining fraction Γ_t of funds diverted by the intermediary due to the high associated costs. Differently from Gertler and Karadi (2011), who treat Γ_t as a constant, we follow Dedola et al. (2013) and Bean et al. (2010), by assuming that Γ_t is time varying. In particular, we model Γ_t as an AR(1) process $\Gamma_t = (1-\rho_\Gamma)\Gamma_* + \rho_\Gamma\Gamma_{t-1} + \eta^\Gamma_t$. We will interpret this as a financial shock, reflecting a change in the perceptions of the depositors regarding the extent to which they will be able to recover their deposits. Therefore, a positive shock to Γ_t captures an increase in the risk associated to holding deposits at the financial intermediary, and will make the moral hazard problem more severe, leading to disruptions in the financial intermediation process since less funds will be available to lend to non-financial firms.[10]

The agency problem between depositors and intermediaries restricts the leverage ratio of the latter to the point where the incentive to divert funds is exactly offset by the costs of doing so. Hence, the amount of assets that the banker can acquire will depend positively on the equity capital as follows

$$q_t + k^s_t = lev_t + n_t \tag{14}$$

where lev_t is intermediaries' leverage, defined as

$$lev_t = \eta_t - l_1\Gamma_t - l_2 \upsilon_t \tag{15}$$

and

$$l_1 = \frac{\Gamma_*}{\Gamma_* - \upsilon_*}, \text{ and } l_2 = \frac{\upsilon_*}{\Gamma_* - \upsilon_*}$$

The variable υ_t can be interpreted as expected discounted marginal gain to the banker of expanding assets by a unit, holding net worth constant, while η_t is the expected discounted value of having another unit of net worth, holding assets constant, which can be expressed as

$$\eta_t = \eta_1 \left(E_t\Lambda_{t+1} + rr_t\right) + \eta_2 E_t\left\{\Lambda_{t+1} + z^{GK}_{t,t+1} + \eta_{t+1}\right\} \tag{16}$$

$$\upsilon_t = \upsilon_1\left[\left(\overline{ret}^k_* E_t ret^k_{t+1} - \overline{RR}_* rr_t\right) + \left(\overline{ret}^k_* - \overline{RR}_*\right) E_t\Lambda_{t+1}\right] + \upsilon_2 E_t\left\{\Lambda_{t+1} + x_{t,t+1} + \upsilon_{t+1}\right\} \tag{17}$$

[10] Dedola et al. (2012) interprete a positive shock to Γ_t as a confidence loss.

where

$$\eta_1 = \frac{\beta}{\gamma^{\sigma_c}} \frac{(1-\theta)\overline{RR}_*}{\eta_*},\ \eta_2 = \frac{\beta}{\gamma^{\sigma_c}}\theta Z_*^{GK},\ \upsilon_1 = \frac{\beta}{\gamma^{\sigma_c}}\frac{(1-\theta)}{\upsilon_*},\ \text{and } \upsilon_2 = \frac{\beta}{\gamma^{\sigma_c}}\theta X_*$$

and $x_{t,t+i}$ is the gross growth rate in assets between t and $t+i$, and $z_{t,t+i}^{GK}$ is the gross growth rate of net worth, expressed as follows

$$z_{t-1,t}^{GK} = z_1\left(\overline{ret}_*^k ret_t^k - \overline{RR}_* rr_{t-1}\right) + z_2 lev_{t-1} + z_3 rr_{t-1} \tag{18}$$

$$x_{t-1,t} = lev_t - lev_{t-1} + z_{t-1,t}^{GK}$$

where

$$z_1 = \frac{\overline{lev}_*}{Z_*^{GK}},\ z_2 = \frac{\overline{lev}_*\left(\overline{ret}_*^k - \overline{RR}_*\right)}{Z_*^{GK}},\ \text{and } z_3 = \frac{\overline{RR}_*}{Z_*^{GK}}$$

Finally, the stochastic discount factor Λ_t and the marginal utility of consumption $U_{c,t}^{'}$ are defined as follows

$$\Lambda_t = U_{c,t}^{'} - U_{c,t-1}^{'} \tag{19}$$

$$U_{c,t}^{'} = u_1 l_t - u_2 c_t + u_3 c_{t-1} \tag{20}$$

where

$$u_1 = (\sigma_c - 1)\, L_*^{(1+\sigma_l)},\ u_2 = \frac{\sigma_c}{1-\lambda},\ \text{and } u_3 = \frac{\sigma_c \lambda}{\gamma(1-\lambda)}$$

The law of motion for n_t, i.e. the sum of net worth of existing intermediaries (n_{et}) and the net worth of entering, or "new" intermediaries (n_{nt}), is given by

$$n_t = n_1 n_{et} + n_2 n_{nt} \tag{21}$$

where $n_1 = \overline{NE}_*/N_*$ and $n_2 = \overline{NN}_*/N_*$. Since the fraction θ of bankers at $t-1$ survive until the next period t, n_{et} is given by

$$n_{et} = z_{t-1,t}^{GK} + n_{t-1} \tag{22}$$

Each new banker receives a start-up fund from the household he or she belongs to. This fund is proportional to the funds managed by the exiting bankers, namely $(1-\theta)\, Q_t S_{t-1}$. Hence, the household transfers every period a fraction $\omega/(1-\theta)$ of this value to its newly entering bankers, leading in aggregate to

$$n_{nt} = q_t + k_t^s$$

Finally, the premium the banker earns on its assets is expressed as follows

$$Prem_t = E_t ret_{t+1}^k - rr_t \tag{23}$$

We do not rely on the presence of a macroprudential rule in the estimation process, as we do not regard this to be crucial for obtaining realistic estimates for the sample period considered in the next section. We therefore leave the discussion of plausible macroprudential policies to Section 6, which introduces the policy coordination setup.

5 Estimation

In this section, we elaborate on the choice of our estimation sample and the data set we composed to perform the estimations, followed by a brief discussion of the estimated parameters and the empirical fit.

5.1 Data and Methodology

We use a quarterly dataset on the US containing following ten observables: log difference of the real GDP, log difference of real consumption, log difference of real investment, log difference of real wage, log of hours worked, log difference of the GDP deflator, the federal funds rate, the Gilchrist-Zakrajsek (2012) spread (GZ-spread, henceforth), log difference of the real net worth, and the return to capital constructed by Gomme et al. (2011). The first seven observables correspond to the dataset used in the estimation of Smets and Wouters (2007). We consider the GZ-spread as a reasonable proxy for the premium given that the authors show that the spread is closely related to measures of financial intermediary health, which makes the spread a good predictor of distress in the financial intermediation sector[11]. The return to capital series constructed by Gomme et al. (2011) is chosen due to its consistency with the model definition[12].

Appendix II contains the details regarding the dataset. The estimation sample ranges over the period 1990:1-2007:4. The reason for not starting the estimation sample is due to the availability of qualitative financial data, in particular the net worth series. We consider a training sample of 20 quarters (i.e., 5 years) to initialize the estimations. The estimation period is limited until 2007:4 due to the distortionary effects of the binding zero lower bound and the crisis period on the estimates of some of the structural parameters, such as the wage rigidities[13]. However, we use the post-crisis sample in order to account for the volatilties of structural shocks in section 8.

The structural equations are accompanied by eight structural shocks (ε_t^b, ε_t^w,ε_t^i, ε_t^p, ε_t^a, ε_t^g, ε_t^r,Γ_t) and two autoregressive measurement errors of order one accompanying the measurement equations of the GZ-spread and the return to capital[14].

The system is estimated with Bayesian methods. The observed quarterly growth rates in the real GDP, real consumption, real investment, and real wages are split into a common trend growth, $\bar{\gamma} = (\gamma - 1)100$, and a cycle growth. The quarterly growth rate of the real net worth is split into a separate, constant growth, $\bar{\gamma}^n$ and a cycle growth. Hours worked in the steady state is normalized to zero. The quarterly steady state inflation rate $\bar{\pi} = (\Pi_* - 1)100$ serves the role

[11] For the computation of the GZ-spread, Gilchrist and Zakrajsek (2012) consider each loan obtained by each set of firms taken from the COMPUSTAT database. They compare for every single case the interest rate actually paid by the firm with what the US government would have paid on a loan with a similar maturity. In terms of default risk, their sample spans the entire spectrum of credit quality, from "single D" to "triple A". The aggregate spread is accordingly an arithmetic average of the credit spreads on each single corporate bond.

[12] In particular, given that the GZ-spread is used as an observable for the premium, there is a gap between the model's definition for the premium, (23), which is based on the return to capital $E_t ret_{t+1}^k$, and the definition used to construct the data, which is not consistent with $E_t ret_{t+1}^k$. Therefore, the observable for $E_t ret_{t+1}^k$ is added in order to address this inconsistency.

[13] see Galí (2011) and Galí, Smets and Wouters (2012) for more details.

[14] These measurement errors turn out to explain about one third of the variance in the spread and the return to capital, respectively.

of the inflation target, implying that monetary policy's objective is to stabilize inflation around its sample mean, as in Ilbas (2010 and 2012). In addition, we estimate $\overline{r} = (\frac{\gamma^{\sigma_c}\Pi_*}{\beta} - 1)100$ (the steady state nominal interest rate), the net worth growth in the steady state $\overline{cn} = \left(Z_*^{GK} - 1\right)100$ and the steady state of the net premium $\overline{PREM}_*$ according to $\overline{cs} = \overline{PREM}_*100$. Finally, the steady state return on capital is estimated according to $\overline{crk} = \left(\overline{ret}_*^k - 1\right)100$. The estimation of these steady state values has implications for the number of parameters that can be freely estimated. We show in Appendix I that, given the estimated steady state values, parameter σ_c can be uniquely pinned down by steady state restrictions and therefore is not estimated.

We initially maximize the posterior distribution around the mode, and use the Metropolis-Hastings algorithm to draw from the posterior distribution in order to approximate the moments of the distribution and calculate the modified harmonic mean[15]. We refer to Appendix III for assumptions regarding the prior distributions of the parameters.

5.2 Parameter Estimates

Table 1 presents the estimation results. We focus mainly on the discussion of the parameter estimates relating to the financial block, since the remaining structural parameters are broadly in line with those reported by Smets and Wouters (2007)[16],[17].

[**Insert Table 1**]

The estimation results lead to the following values implied by the steady state restrictions (see Appendix I) on the intertemporal elasticity of substitution, $\sigma_c = 0.7082$, the steady state net premium, $\overline{PREM}_* = 0.0049$, the steady state leverage ratio, $\overline{LEV}_* = 3.7484$, the fraction of divertible bank capital, $\Gamma_* = 0.6782$, the survival rate of bankers, $\theta = 0.9704$, and the gross growth rate of bankers' net worth $Z_*^{GK} = 1.0227$.

Comparing the financial sector parameters to previously estimated values is a challenging task given that a number of studies adopting the Gertler-Karadi banking sector framework either calibrate the parameters concerning the financial sector (Lima et al., 2012 and Villa and Yang, 2011), or perform estimations in the absence of financial observables (Villa, 2013). To our knowledge, the only exception is Gortz and Tsoukalsa (2012). The latter authors use two sector-specific spreads and a measure of bank equity in the set of observables but do not consider the information content provided by these variables on the steady state values of the endogenous variables and the restrictions imposed by the Gertler-Karadi framework on the steady state as described in Appendix I. Nevertheless, the implied share of divertible funds, $\Gamma_* = 0.6782$, turns out to be considerably higher than the value of 0.381 calibrated by Gertler and Karadi (2011), and similar values set by Dedola et al. (2013) and Gortz and Tsoukalsa (2012) for the US. The steady state premium is estimated to be 0.0049, which implies 50 basis points on quarterly basis, which differs from the Gertler-Karadi calibration of 0.002475 and is at the source of the

[15] For estimation purposes we rely on *dynare*, which can be downloaded from the website *www.dynare.org.*

[16] The exceptions are the estimated values of the habit persistence and the investment adjustment cost parameters, which are somehwat lower than the values estimated by Smets and Wouters (2007).

[17] The associated posterior distribution and convergence graphs are availabe on request.

high value implied for Γ_*. The remaining implied parameters are broadly in line with the values calibrated by Gertler and Karadi (2011).

In order to assess the relevance of the financial shock for real economic activity within our estimated framework, we report in the first line of Table 2 the variance decomposition of output at the infinite horizon. The investment specific shock explains together with the technology shock more than 50 percent of the volatility of output. The financial shock is the third most important shock and explains about 13 percent of the output volatility. This is in line with recent empirical studies in estimated models featuring financial frictions, which suggest an important role for financial shocks[18]. For example, Jermann and Quadrini (2012) show in the context of an estimated model similar to Smets and Wouters (2007), featuring financial frictions and financial shocks, that credit shocks contribute to at least one-third of the variance of US output and labour. Christiano et al. (2013) find that two financial shocks (risk shock and equity shock) account for 16 percent of US output fluctuations, while Liu et al. (2010) show that between 5 and 12 percent of US output variability is explained by their collateral shock depending on the considered horizon. Inflation volatility is mainly driven by price and wage markup shocks. These two shocks explain around 80 percent of the volatility of inflation, which is in line with Smets and Wouters (2007). Table 2 also gives the variance decomposition of the policy rate, which suggests that the largest share of the interest rate volatility can be explained by the demand shocks such as the risk premium and investment specific shocks, followed by the financial shock. The latter explains about 7 percent of the volatility in the interest rate.

[**Insert Table 2**]

5.3 Model Fit

We assess the empirical fit of the estimated model by comparing the standard errors, auto- and cross-correlations of the observables to their counterparts implied by the posterior distribution. Table 3 shows the standard errors of the data against the 90 percent posterior intervals implied by the model. The model succeeds well in matching the volatilities of investment, hours worked, wages and inflation. While the model implied standard errors of output, consumption and the policy rate do not capture the actual volatilities, the latter lie fairly close to the interval bounds so that the fit can still be considered as rather satisfactory. Regarding net worth, return to capital and the premium, however, the model tends to overestimate their volatilities. Figure 1, which plots the autocorrelations up to the fifth order, shows that the model with the exception of the return to capital and net worth does a good job at matching the persistence of all variables fairly well.

[**Insert Table 3**]
[**Insert Figure 1**]

Finally, Table 4 reports the cross-correlation statistics for the observables. Regarding the observables we have in common with Smets and Wouters (2007), i.e., output, consumption,

[18] See Quadrini (2011) for a survey.

investment, real wage, hours worked, inflation and the policy rate, the model does a good job at capturing the cross-correlations observed in the data. The same conclusion holds for the financial observables, in particular for the premium and net worth. It is worth noting that the model manages to capture the counter-cyclicality of the premium. Moreover, the co-movement between output, inflation and net worth is correctly captured by the model.

[**Insert Table 4**]

5.4 Transmission of Shocks in the Estimated Model

Before introducing the coordination setup between monetary and macroprudential policy, we assess in this subsection the potential role macroprudential regulation could play in addressing financial frictions within our current modeling framework. Hence, we look at the impulse responses of inflation, output gap and credit growth, which are the three assumed objective variables considered by policy makers in the next section, in the estimated model, i.e. when no macroprudential regulator is present, and then introduce the following instrument rule for macroprudential policy in order to assess to which extent this affects the transmission process of the shocks:

$$\tau_t = (y_t - y_{t-1}) + 0.1(credit_t - credit_{t-1}) \tag{24}$$

The instrument adopts a lump-sum levy/subsidy on bank capital that is set in function of credit and business cycle indicators in a counteryclical manner[19]. As in Bean et al. (2010), we assume that the levy/subsidy will capture the main policy effects of countercyclical bank capital buffers and limits to bank leverage, since leverage in the current modeling framework of the Gertler-Karadi financial intermediation sector is not a free choice variable. Given that our framework does not explicitly model the distortions that macroprudential policy should address, such as default, systemic risk or reducing the probabilities of tail events, we take for granted the presence of the macroprudential regulator. Instead, we focus in this paper on how the transmission of shocks and volatilities of main macroeconomic variables are affected in the presence of macroprudential policy and its interaction with monetary policy. Therefore, although the approach taken in this paper is more of a pragmatic nature, this strategy allows us to remain in the framework of an (estimated) DSGE model that is representative to workhorse models used in the majority of policy institutions for forecasting and policy analysis, with the main advantage of being data driven. Although important progress has been made in the literature to explain the role for macroprudential policy, such as the theory relying on the pecuniary externality approach (see Benigno et al., forthcoming, and references therein), it currently remains a challenge to incorporate these features in a more elaborated and realistic model setting that can be used for policy exercises[20]. Despite the fact that credit cycles do not appear endogenously due to the presence of systemic risk in our setup, the amplification

[19] Higher weights on the credit growth variable tend to magnify the benefits of the macroprudential rule. We have therefore chosen to discuss the case where the weight is relatively low, which still allows us to make our point.

[20] An important contribution in this direction is Dewachter and Wouters (2012), who implement endogenous financial risk in a standard DSGE model and calibrate the model.

mechanism caused by the moral hazard problem in the banking sector gives rise to an exogenous credit cycle triggered by financial shocks, which can eventually lead to large drops in output. For this reason, the macroprudential policy potentially plays a beneficial role in our setup, since it can address these consequences of the amplification mechanism in the face of financial shocks directly through the use of specific macroprudential tools which can be more effective than interest rate policy. Hence, although admittedly ad hoc, equation (24) allows us to realistically capture the tax implications of the Dodd-Frank act and Basel III on bank capital, and to take into account the macroprudential measures exogenously imposed by the regulators on banks in order to affect their behavior.[21]

[**Insert Figure 2**]

The solid lines in Figure 2 show the responses of the three variables to a technology, investment specific, financial, and a monetary policy shock, respectively, in the estimated model. In addition, the broken lines represent the responses in the presence of the macroprudential regulator. The first panel of the figure corresponds to the responses under a technology shock, which leads to a smaller increase in credit growth in presence of macroprudential regulation, while the latter does not affect the response of inflation much. However, although the macroprudential instrument does not affect the impact response of the output gap, it clearly helps to stabilize it faster than in the standard estimated model. Similar conclusions can be drawn for the case of the investment specific shock, albeit in the opposite direction, i.e. the macroprudential instrument contains the decrease in credit growth, has a small effect on impact and dynamic response of inflation and stabilizes output around potential quicker than would have been the case with monetary policy only. Looking at the responses to a financial shock in the third panel, again the presence of the bank capital intervention has a strong and stabilizing effect on the output gap, while having a modest effect on inflation and credit growth. Finally, the last panel shows that, although the presence of the macroprudential instrument does not affect the transmission of th monetary policy shock as in the case of the other shocks, it does soften the impact on all the variables considered compared to the standard monetary policy only case.

Based on the impulse response analysis, we can conclude that introducing a countercyclical bank capital tax/subsidy instrument to the standard estimated model helps to stabilize the standard objective variables that concern monetary policy, in particular the output gap, and improves the tradeoffs with the credit variable in the face of technology and investment specific shocks.

6 The Monetary and Macroprudential Policy Setup

In this section, we discuss the main assumptions regarding monetary and macroprudential policy and the way in which the coordination experiments are set up, followed by a discussion of the results arising from the coordination exercises.

[21] Unlike the monetary policy rule, we do not assume smoothing of the macroprudential instrument. The reason is that when we allow for smoothing, the optimal coeffcient for the smoothing parameter that we compute in the next section always turns out to be very close or equal to zero.

6.1 Monetary Policy

The central bank is assumed to adopt a flexible inflation targeting regime, represented by the following standard and ad hoc one-period loss function:

$$Loss_t^{CB} = \pi_t^2 + \lambda_y^{CB}(y_t - y_t^p)^2 + \lambda_r^{CB} r_t^2 \quad (25)$$

The main objective of the central bank is to stabilize inflation around the (steady state) target, and to keep output as close as possible to its potential level[22]. In addition, we assume that, to some extent, the central bank also would like to keep some stability in the short term interest rates. The weight on the inflation target is normalized to one, hence the weights on output gap and interest rate volatility are relative weights. In the simulation exercises, we fix the weight on the output gap $\lambda_y^{CB} = 0.5$, while the weight on interest rate volatility $\lambda_r^{CB} = 0.1$. These values are considered to be in line with flexible inflation targeting, and approach the monetary policy preferences reasonably well[23]. The above loss function is minimized using the estimated model to compute the optimal coefficients of the following Taylor type of rule with interest rate smoothing[24]:

$$r_t = \rho r_{t-1} + \alpha_\pi \pi_t + \alpha_y (y_t - y_t^p) \quad (26)$$

6.2 Macroprudential Policy

We assume that the macroprudential regulator has been assigned its own loss function. It is a challenging task to propose a set of objectives that can be considered as standard, since there is no established practice of representing macroprudential policy in the form of an ad hoc loss function. As noted by Galati and Moessner (2010), there is no common definition of financial stability objectives that should be pursued by macroprudential policy. We therefore closely follow recent work by Quint and Rabanal (2013) and Angelini et al. (2012) in considering an alternative set of financial stability objectives for the design of macroprudential policy. In the baseline case, we adopt the following loss function for the macroprudential regulator:

$$Loss_t^{mp} = \lambda_y^{mp}(y_t - y_t^p)^2 + \lambda_{\Delta c}^{mp}(credit_t - credit_{t-1})^2 \quad (27)$$

We assume that the macroprudential regulator receives a double mandate, i.e. stabilizing the real economy by assigning weight to deviations of output from potential, and the financial cycle which is expressed in terms of nominal credit growth. In the simulation experiments we will replace the latter objective by alternative measures of financial stability, such as the ratio of credit to GDP and the premium. The presence of the output gap in the macroprudential loss function reflects the concern to stabilize the indirect effects originating from disruptions to financial variables that are not included in the loss function, but could affect the real economy even in the presence of price stability. Moreover, the Basel III regulation refers to "reducing

[22] Potential output corresponds to the level of output prevailing in the absence of nominal rigidities and constant markups.

[23] We refer to the literature on the estimation of policy preferences, see, e.g. Ilbas (2012) and the references therein.

[24] Note that this rule is slightly different from, although more simplified than, the estimated Taylor rule (13). The qualitative results remain, however, unchanged when we consider the rule (13) instead.

the risk of spillover from the financial sector to the real economy" as one of the main objectives of the regulatory reforms.[25] In the baseline case (27), it is assumed that both objectives receive equal weights, i.e., $\lambda_y^{mp} = \lambda_{\Delta c}^{mp} = 0.5$; the macroprudential regulator assigns equal importance to financial stability and output stabilization. We will consider below the cases in which the financial objective becomes relatively more and less important than output stability, respectively, by considering alternative values for λ_y^{mp}.

As a macroprudential instrument, we adopt the lump-sum levy/subsidy on bank capital introduced in the previous section[26],[27]:

$$\tau_t = \beta_y(y_t - y_{t-1}) + \beta_c(credit_t - credit_{t-1}) \tag{28}$$

In analogy with the central bank´s optimization problem, the macroprudential regulator seeks to minimize the loss function (27) to compute the optimal values of β_y and β_c. The bank capital equation is accordingly modified by the addition of τ_t:

$$n_t = n_1 n_{et} + n_2 n_{nt} - \tau_t \tag{29}$$

In the following, we set out the alternative coordination schemes between the central bank and the macroprudential regulator that will be considered in the simulation exercises.

6.3 The Case of Coordination

The coordination case is assumed to be one of full cooperation between the two policy makers. This results into a situation where the two respective optimization problems are merged into one, joint optimization problem:

$$Loss_t^{CB+mp} = \pi_t^2 + (\lambda_y^{CB} + \lambda_y^{mp})(y_t - y_t^p)^2 + \lambda_r^{CB} r_t^2 + \lambda_{\Delta c}^{mp}(credit_t - credit_{t-1})^2 \tag{30}$$

We treat the above problem as one of a single policymaker that has been assigned the task to minimize the joint loss function, having two instruments, i.e. the interest rate rule (26) and the bank levy/subsidy (28), at disposal.[28]

6.4 The Case of No-Coordination

In the no-coordination case, we adopt a dynamic setting where the macroprudential policy maker moves first[29] and sets the macroprudential rule that minimizes (27) by taking the monetary

[25] Angelini et al. (2011) base their choice of output fluctuations in the macroprudenaital loss function on the Committee on the Global Financial System (2010), which states that macroprudential policy should aim to address financial disruption in order to avoid negative real economy effects.

[26] In the baseline exercises, we opt for growth rates in both output and credit variables as arguments in the macroprudential instrument in order to contain the responsiveness of the tax/subsidy policy. Replacing the output growth term by the level (or the first difference) of the more volatile output gap does neither affect the qualitative results, nor the policy implications obtained in the rest of the paper.

[27] Unlike the monetary policy rule, we do not assume smoothing of the macroprudential instrument. The reason is that when we allow for smoothing, the optimal coeffcient for the smoothing parameter always turns out to be very close or equal to zero.

[28] We leave aside the institutional setup and practical implementation of the full coordination case, since this is beyond the scope of this paper. One interpretation of the joint loss function is to charge the central bank with macroprudential objectives, implying an adjustment to its mandate of flexible inflation targeting.

[29] In practice it does not make a difference to the obtained results whichever policy maker moves first, as the procedure convergences to the same numerical results.

policy rule (26) as given, to which monetary policy reacts (i.e. follows) in setting the interest rate by minimizing (25) and taking the macroprudential rule (28) as given.[30] In the next stage, the optimal reaction of monetary policy is taken into account by macroprudential policy, etc. This process continues until the coefficients in both rules (26) and (28) have reached convergence.[31,32].

6.5 Results from Coordination Experiments

We compare the results under coordination and no-coordination by varying the relative importance of the output gap component in the macroprudential loss function (27). In the next section, we consider alternative financial stability objectives to the baseline objective of credit growth in order to assess the robustness of the results. As previously noted, we keep the preference parameters in the monetary policy loss function (25) fixed throughout the simulation exercises. Given that there is more uncertainty around the appropriate objective that macroprudential policy should address on the one hand, and the relative importance that should be assigned to additional non-financial objectives such as output, on the other hand, we find it more appropriate to focus on alternative loss function specifications and preferences for (27).[33]

[Insert Table 5]

Table 5 reports the optimal coefficients obtained for the monetary policy and the macroprudential rules, the implied volatilities of the objectives and the losses under the two alternative degrees of coordination. The first result that stands out is that, in all the cases, the optimal interest rate rule appears to be a difference rule. This is not surprising, given that in the context of forward looking expectations the interest rate typically shows a highly inertial behavior.[34] The first panel in the table assigns equal weight to the output gap and credit growth in the macroprudential loss function (27). The optimal response of the interest rate instrument to the output gap considerably declines in the absence of coordination. This is due to the fact that, under coordination, the single policy maker incorporates the preference for output stabilization of both the central bank and the macroprudential regulator, which leads to a higher optimal response of the interest rate to the output gap. For the same reason, the optimal response of

[30] This setup in spirit corresponds to the "partial coordination" case considered by Cecchetti and Kohler (2012).

[31] This approach is also adopted by Angelini et al. (2012) in a similar context of macroprudential and monetary policy coordination. See also Dixit and Lambertini (2003), where the interaction is applied to the case of monetary and fiscal policy.

[32] For simulation pruposes, we use the routines developed by Junior Maih for implementing optimal simple rules, which allows for a high number of coefficients to be maximized simultaneously. These routines are robust to initial conditions and more likely to yield global optima.

[33] The case of a standard inflation targeting regime has been extensively studied and we therefore refer to the literature for comparison with alternative objectives and preference parameters.

[34] The forward-looking nature of the expectations allows for future responses of the interest rate to the shocks to be anticipated by the private sector. This causes an immediate adjustment of expectations, affecting the current behaviour of private agents, and implying part of the stabilization effects that is needed by policy that has not responded yet. This in turn leads to a more moderate policy response, thereby causing the inertial behaviour in the interest rate, than would be the case in models with purely backward-looking expectations. See e.g. Rotemberg and Woodford (1998), who show that most efficient rules show superinertial behaviour, with a coefficient on the lagged interest rate larger than one. See also Ilbas (2006) and references therein.

macroprudential policy to output is lower under coordination than under no-coordination. In the latter case, the levy/subsidy needs to be more responsive to output in order to reach the separate objectives of the macroprudential regulator. Given that macroprudential policy has only two objectives of its own, the optimal response to credit growth is much higher when there is no coordination. Turning to the volatilities, the degree of coordination has little effect on the standard errors of inflation and the interest rate. Although the output gap appears in the loss function of both policy makers, lack of coordination seems to increase the volatility of this variable considerably. The reason is that, under full coordination, stabilizing the output gap is as important as the inflation target to the single policy maker. Under no-coordination, however, inflation becomes the main target for the central bank, who will now tolerate a relatively more volatile output gap in order to keep the inflation close to target. The credit growth variable gains from the lack of coordination, since the macroprudential regulator allows for a higher optimal response to it in the macroprudential rule. In terms of total unconditional loss, both policies gain from coordination. The central bank can decrease its loss by around 30 percent if it coordinates with the macroprudential regulator, while the latter can improve its loss by 22 percent because the gains in terms of lower output volatility outweigh the costs of higher credit volatility under coordination.

In the second panel of the table, the results are reported under the assumption of a higher preference for output gap stabilization in the macroprudential loss function. The weight λ_y^{mp} in this case is set equal to 1, implying the output gap variable to become more important for the macroprudential regulator than the financial objective. Coordination has qualitatively similar implications to the optimal coefficients of both rules as in the previous panel, where $\lambda_y^{mp} = 0.5$. The same observation can be made regarding the volatilities of the target variables. Hence, when the macroprudential regulator assigns a higher weight to the output gap component in the macroprudential loss function, lack of coordination continues to be more costly in terms of a higher volatility in the output gap, while credit growth still benefits from the absence of coordination since the macroprudential tool is more responsive to credit changes. The gain in terms of lower volatility in credit growth, however, is smaller than before since the increase in the optimal response to this variable in the macroprudential rule is also smaller due to the lower relative importance of nominal credit growth in the macroprudential loss function with respect to the output gap objective. The gains from coordination therefore are higher for macroprudential policy in this case, given that the costs in terms of higher output volatility increase: a decrease in loss of around 43 percent can be achieved for macroprudential policy if there would be a move from no-coordination to a regime of full coordination. The central bank in turn would achieve a gain of around 25 percent by moving to the full coordination framework.

The third panel of the table considers the case of a low weight on the output gap in the macroprudential loss function, i.e., $\lambda_y^{mp} = 0.1$, such that credit growth becomes relatively more important for macroprudential policy. Like in the previous two cases of higher λ_y^{mp}, the optimal coefficient on the output gap in the interest rate rule decreases, while the optimal macroprudential rule shows a higher response to the output gap and the growth of credit when we move from coordination to no-coordination. The increase in the optimal response to credit growth, now being an even more important objective than the output gap for macroprudential policy, is however much stronger than before. This also explains the stronger decline in the volatility of credit growth when we move towards a regime of coordination. As before, we observe an increase in output gap volatility due to the lower weight assigned to the latter objective in the macroprudential loss function. Regarding the monetary policy objectives, we observe a slight increase in the volatility of the interest rate in moving towards the no-coordination regime. In terms of loss, we now observe that while the macroprudential regulator would lose from coordination with the central bank, the latter would be better off under the coordination regime. In particular, the macroprudential regulator woul have to incur an increase in loss of about 70 percent if it would start coordinating with the central bank, while the latter would achieve a gain of 56 percent in terms of loss. Clearly, there is a high cost related to coordination for the macroprudential regulator when its main concern is focused on credit because the tax/subsidy policy is a more effective tool to address credit growth deviations and, therefore, allowing the macroprudential tool to focus mainly on credit will be more beneficial despite the implied increase in output gap volatility. Coordination, on the other hand, helps the central bank to stabilize its own objectives.

In the debate on whether monetary policy should play a prominent role in maintaining financial stability, our results based on Table 5 suggest that the answer to this question would be yes if monetary policy and macroprudential policy have common objectives that receive a sufficiently high weight in their respective mandates. If the objectives are separated, the macroprudential regulator would instead gain from the absence of coordination since this allows her to focus more effectively on achieving her financial stability objective, while the central bank continues to gain from coordination, giving rise to a tradeoff between the gains for both policy makers. When the output gap starts to play a more prominent role in the mandate of the macroprudential regulator, measured in terms of an increasing value for λ_y^{mp}, better outcomes can be achieved when the two policy makers fully coordinate and act as a single policy maker with two instruments at disposal. This can be done by assigning the macroprudential policy task to the central bank, for example, by augmenting its standard objectives of price and output stability by financial stability objectives as in the case of the joint loss function (30). This approach is in line with Woodford´s (2011) proposal of a "natural extension of flexible inflation targeting". If the output gap becomes a sufficiently less important objective in the macroprudential loss function, in that it becomes inferior to the financial stability objective as measured by credit growth, not both policy makers will gain from coordination. In particular, the macroprudential regulator would be much better off in the absence of coordination such that it can focus more effectively on its own financial stability objective. This, however, comes at the cost of increased output volatility, which makes the central bank worse off in the absence of coordination. Although the central bank always gains from coordination, the gains from coordination for the macroprudential regulator in this setup depend on how the macroprudential framework is set and whether the macroprudential regulator should aim mainly financial objectives, or in addition, also be concerned about effects on business cycle fluctuations. In the case where the financial stability mandate is clearly separated from the inflation targeting mandate with no common objectives, the regulator can achieve better outcomes in the absence of coordination. In the latter case, the Tinbergen principle[35] applies to the regulator, implying that specific macroprudential instruments are much more effective at safeguarding financial stability than monetary policy. Using monetary policy to achieve financial stability would be suboptimal and lead to poorer outcomes for financial stability. This view is also supportive of Svensson´s (2012) argument on the separation of policies and instruments, where different authorities should be responsible for monetary policy and financial stability, in a way that also different authorities are responsible for monetary policy and fiscal policy.

The conclusions drawn from this section differ from the one obtained by Angelini et al. (2012), who show for the euro area that during "normal times" (economy driven by supply shocks), coordination between both policies is more beneficial than no-coordination, although the coordination gains achieved by introducing a macroprudential policy maker are limited compared to "crisis times" (dominated by financial and housing market shocks). In contrast to the results obtained in this section, the conclusions drawn by Angelini et al. (2012) are not affected by (changes) in the respective loss function specifications and/or the weights assigned to the objectives.

7 Robustness to Alternative Financial Stability Objectives

In the previous section, we considered nominal credit growth as the objective in the macroprudential loss function. In this section, we look at the following two alternative objectives: the credit-to-GDP ratio as a proxy for bank leverage (in deviation from steady state values), as suggested by Angelini et al. (2012) and Quint and Rabanal (2013), and the spread measure following the (micro-founded) loss function derived by Cecchetti and Kohler (2012)[36]. Table 6 reports the optimal coefficients and the volatilities of the objectives under coordination and no-coordination, respectively, when both the output gap and the financial objectives receive equal weight, i.e., $\lambda_y^{mp} = \lambda_X^{mp} = 0.5$, in the macroprudential loss function:

$$Loss_t^{mp} = \lambda_y^{mp}(y_t - y_t^p)^2 + \lambda_X^{mp} X_t^2 \tag{31}$$

where X_t is either the credit-to-GDP ratio or the spread.[37]

[**Insert Table 6**]

Most conclusions based on the comparison between the coordination and the no-coordination cases in Table 5 remain to hold when the nominal credit growth is replaced by either the credit-to-GDP ratio or the spread in the macroprudential loss function (27). As before, the optimal

[35] The Tinbergen (1956) principle states that when separate instruments are used to reach separate targets, policy will be more effective.

[36] We also investigated robustness under the credit gap case, but results remain similar to the alternatives discussed in this section. We therefore decided to leave this case out from the discussion.

[37] We have done the exercises for varying degrees of λ_y^{mp} as in the previous section, and the results remain to hold qualitatively, i.e., for increasing values of λ_y^{mp}, better outcomes can be achieved when the two policy makers fully coordinate, while for lower values of λ_y^{mp}, only the macroprudential regulator gains in the absence of coordination. Due to spatial limitations, we do not report these results here, but they are available from the authors on request.

response to the output gap in the monetary policy rule is higher in the coordination case, compared to the no-coordination case due to the coordination gains that a single policy maker can achieve in the presence of a common objective of output gap stabilization that is considered to be sufficiently important to monetary and macroprudential policy. When the macroprudential policy loss function includes the credit-to-GDP ratio as an objective, the optimal response to output growth in the macroprudential rule is zero, contrary to the alternative cases. The lack of response to output however is compensated by a stronger reaction to credit growth. Also the increasing response to the credit growth variable in moving from coordination to a regime without coordination is much more pronounced than when the credit growth or the spread objectives enter the loss function of the macroprudential regulator. In line with the previous results, a lack of coordination increases the volatility of the output gap in both cases considered in Table 6. Given that $\lambda_y^{mp} = \lambda_X^{mp} = 0.5$, under full coordination output gap stabilization becomes as important as the inflation target to the single policy maker, which does not apply when a regime of no-coordination is at place. The volatility reduction in the financial objective in moving towards a no-coordination regime is however more limited when the spread is included in the loss function, or even absent as in the case of the credit-to-GDP ratio where we observe even a slight increase. Overall, the main conclusions based on the previous results regarding the gains from coordination hold also in the case of the alternative financial stability objectives. In particular, given the relative importance of the output gap in both policies´ loss functions, macroprudential policy has the potential to achieve a loss reduction of about 12 percent with the credit-to-GDP ratio and 33 percent with the spread objectives, respectively, if there would be a move from no-coordination to a regime of full coordination. Although there would be a considerably small gain for the central bank (less than 3 percent) with the credit-to-GDP ratio objective, the gain in the case of the spread objective would be about 23 percent.

8 Matching post-crisis Volatilities of the Shocks

The results in Tables 5 and 6 are based on the parameter values estimated over the sample period 1990:1-2007:4, which for reasons explained previously is limited to the pre-crisis period that spans the great moderation period characterized mainly by low macroeconomic volatility. Although the aim of the exercise is to analyze the effects of alternative frameworks for macroprudential policy that holds during normal times by varying the degree of importance attached to output in the macroprudential loss function, it is important to investigate how the previous results are affected when we take into account the increase in the volatility of macroeconomic and financial variables as experienced in the post-2008 period. Policy reactions that are optimal within the context of a more stable macroeconomic environment do not necessarily remain to be optimal when there is an increase in uncertainty and volatility in the shocks that hit the economy in times of crisis. In this section, we look at the extent to which the policy recommendations based on the previous sections might need to be modified when the economy is hit by a crisis. For this purpose, we evaluate the estimated model using all available data, i.e. the sample up to 2010:3, in order to obtain the smoothed series of the shocks for the post-crisis period 2008:1-2010:3, and their corresponding volatilities[38]. Assuming no change in the deep parameters[39], we repeat the previous exercise by replacing the estimated values of the standard errors of all the shocks in the model by their values corresponding to the period 2008:1-2010:3. Table 7 reports the results, from which we can mainly deduce similarities with previous results with respect to the optimal coefficients of the monetary and macroprudential rules. Like before, the optimal response of the interest rate to the output gap decreases when there is a move from coordination towards no-coordination for each alternative value for λ_y^{mp}, while the optimal responses to both output and credit growth in the macroprudential rule increase, reflecting the ability of the macroprudential regulator to focus more on reaching its own objectives in the absence of coordination. This is, in analogy with the previous results, particularly the case for the optimal reaction on credit growth when the latter becomes the most important objective for macroprudential policy: the third panel of Table 7 reports a strong increase in the response coefficient from 3.16 to 20.57. The gains from coordination for both policies when post-crisis shocks are in place are comparable in magnitude to those based on standard errors estimated with pre-crisis data, for the cases of $\lambda_y^{mp} = 0.5$ and $\lambda_y^{mp} = 1$, i.e., when the output gap objective receives a sufficiently high weight in the macroprudential loss function. When the financial stability objective dominates in the macroprudential mandate (third panel), the macroprudential regulator is just like before better off in the absence of coordination given that the value of its loss would increase by about 111 percent if it would coordinate with monetary policy, while monetary policy does not gain from the absence of coordination and could achieve a loss reduction of around 53 percent if it would coordinate with macroprudential policy. This finding is consistent with the previous results based on the pre-crisis shock volatilities where the gains from coordination between the two policies are only aligned for higher values of λ_y^{mp}. Moreover, the focus on the financial stability mandate by the macroprudential regulator in a context of high financial and real instability is too costly, because the volatility gain achieved by the central bank with coordination could be accompanied by less volatile inflation and interest rates as well since demand shocks, in particular the role played by the financial shock, play a relatively more important role during the post-2007 period.

We can therefore conclude that, setting λ_y^{mp} to high values, irrespective of whether the economy is in a state of financial and real instability, would be more effective and lead to better outcomes than if the macroprudential regulator would mainly focus on its financial stability objective and ignore to a large extent the real economy. The reason is that, if the macroprudential mandate imposes a sufficiently high weight on the output gap, there will be no conflict between monetary and macroprudential policy.

[**Insert Table 7**]

[38] All shocks (except for the investment specific shock which increases by magnitude of three, and the wage markup shock which remains nearly unaffected), increase in volatility with respect to the post-2008 sample up to an order of magnitude of two.

[39] We admit the strength of this assumption. It would be interesting to take into account possible breaks in the structural parameters as well during the estimation process. In addition, we discard the zero lower bound problem. Although not implying that these concerns are not sufficiently relevant, they are beyond the scope of the current paper but we wish to take them into account in future work.

9 Impulse Response Analysis

In this section, we compare the responses of selected variables to a technology and a financial shock, respectively, under coordination and no-coordination cases against the responses implied by the estimated version of the model. The responses for the coordination and no-coordination cases are obtained under the standard loss function assumption for monetary policy (25) and equal preferences for the output gap and the credit growth objectives in the macroprudential mandate, i.e., the macroprudential loss function (27) with $\lambda_y^{mp} = \lambda_{\Delta c}^{mp} = 0.5$.

Following a positive technology shock, the interest rate responds more strongly to the fall in inflation in the no-coordination case, since the central bank is more able to act according to its own mandate, than under coordination. Although the effect on total output remains very similar under the alternative coordination regimes, the response of credit is much more limited in the absence of coordination due to the higher increase in the cost of finance (i.e. the premium). The effect on bank leverage, however, is higher in the latter case because the response of net worth (not shown) is more restricted since the macroprudential regulator reacts more to increasing credit and output in the form of higher taxes on bank capital when there is no coordination with the central bank. As a consequence, while the premium and bank leverage are countercyclical in the benchmark estimated model[40], both variables become procyclical in the presence of a macroprudential tax policy that operates in a countercyclical manner.

[**Insert Figure 3**]

Figure 4 shows that the interest rate, like in the case of the technology shock, responds more strongly to a financial shock in the absence of coordination. Since the macroprudential regulator is able to quickly react to the negative effect of the financial shock, credit is affected by much less under both coordination regimes compared to the benchmark estimated model. Given that the regulator has more free play in the absence of coordination, the counteracting effect on credit is even more pronounced, and the premium increases by less in the absence of coordination. This finding confirms our earlier conclusion that lack of coordination between authorities implies more stable credit since the macroprudential tool directly affects net worth and credit supply, making it a more effective policy tool to address credit concerns. We further notice again the procyclical nature of leverage in the presence of a macroprudential regulator applying a bank capital subsidy in response to contracting output and credit after a confidence loss.

[**Insert Figure 4**]

10 Counterfactual: Monetary Policy Only vs. Optimal Monetary and Macroprudential Coordination Policy

In this section, we perform a counterfactual experiment to compare the historical values and the volatilities of inflation, output gap and credit growth implied by the estimated model to the

[40] The feature of countercyclical leverage is also present in Gertler and Karadi (2011).

values and volatilities in two alternative cases, i.e. the case of a single (monetary) policymaker minimizing the standard loss function (25), on the one hand, and the case of optimal coordination between the latter and a macroprudential regulator minimizing (27) with $\lambda_y^{mp} = \lambda_{\Delta c}^{mp} = 0.5$, on the other hand. The purpose of this exercise is to assess the extent to which the presence of a macroprudential regulator could have contributed to macroeconomic and financial stability over the estimation period (the pre-crisis) and beyond (the post-2007 period). For this exercise, we regard the case where macroprudential policy assigns equal weight to output and credit as the most likely policy setup that would have been in place during the pre-crisis period, given that a macroprudential policy maker focusing on financial objectives only would have been the most likely scenario only in the period after the financial crisis. Moreover, equal weights on output and credit in (27) allows us to focus on the coordination case, which implies more benefits than under no-coordination. It is important to notice that, the case of optimal coordination could also be regarded as one where a single policy maker, for example monetary policy, is assigned additional financial stability objectives. The difference with the standard case of a single policy maker, however, is that the policy maker now has two separate instruments at disposal.

Figure 5 shows the historical output gap, inflation and credit growth and their respective standard errors implied by the estimated model and the counterfactual optimal monetary policy. It is clear from the figure that the output gap would have gained a significant reduction in volatility, and that, as a consequence, the post-2007 drop in output could have largely been avoided if monetary policy would have been optimal. The almost complete stabilization in output, however, comes at the cost of more volatile inflation. Figure 5 finally shows that optimal monetary policy would have had almost no effect on the volatility of credit and could not have prevented the large drop in credit.

[**Insert Figure 5**]

Figure 6 plots the case of optimal coordination between monetary and macroprudential policies or, put differently, a single policy maker paying attention to credit growth stabilization with two instruments at disposal. Although optimal coordination policy slightly increases the volatility of output gap (increase in standard deviation from 0.15 to 0.21) and inflation (increase in standard deviation from 0.61 to 0.79) when compared to the single optimal policy case, the presence of a separate macroprudential policy tool leads to a significant drop in the volatility of credit (from 1.63 to 0.73). This finding is consistent with the impulse response analysis discussed in the previous section, and suggests that an operational macroprudential policy tool that directly affects bank capital in a countercyclical manner is a far more effective tool in stabilizing credit growth. Indeed, Figure 6 suggests that, had there been a macroprudential policy maker coordinating with monetary policy in the period prior to the crisis, credit growth would have been much more contained, hence the massive drop in credit leading to the recent financial crisis could have been largely avoided. This result confirms the necessity of a macroprudential regulatory tool paying particular attention to the credit cycle, and that attention to monetary policy objectives alone is not sufficient to address credit market frictions.

[**Insert Figure 6**]

11 Conclusion

This paper studies the optimal gains from coordination between monetary and macroprudential policies in the framework of an estimated DSGE model for the US featuring financial frictions on the supply side of credit. We find that the gains from coordination can be high in cases where the macroprudential regulator, in addition to its financial stability concern, sufficiently cares about output gap stabilization, i.e. an objective it shares with monetary policy. These gains disappear when the main objective of macroprudential policy is assumed to be financial stability. In the latter case, macroprudential policy can reach better outcomes in terms of lower unconditional loss in the absence of coordination, while the monetary policy maker continues to gain from coordination. Therefore, in order to avoid a tradeoff in the gains from coordination, a relatively important weight should be assigned to the common objective of output fluctuations in the macroprudential mandate. These conclusions are robust to alternative definitions of the financial stability objective in the loss function of the macroprudential regulator and continue to hold when we take into account the post-crisis volatilities in the structural shocks. A counterfactual analysis further confirms the effectiveness of a countercyclical macroprudential tax/subsidy in preventing the amplification effects triggered by a financial shock. In particular, our analysis suggests that the presence of the macroprudential regulatory tool could have successfully avoided the massive drop in credit leading to the recent financial crisis, and that attention to monetary policy objectives alone has not been sufficient in that matter.

Although our results are broadly in line with previous research, we would like to stress that the policy implications are conditional on the modeling framework and the empirical estimates and, therefore, need not necessarily hold in the context of other economies or more realistic settings in which nonlinearities and endogenous build-up of systemic risk are taken explicitly into account. Neither are the conditions imposed by the zero lower bound on the interest rates considered explicitly. These are important concerns which we intend to address in future work.

References

Adrian, T. and Shin, H.S. 2010. The Changing Nature of Financial Intermediation and the Financial Crisis of 2007-2009. Annual Review of Economics 2. pp. 603-18.

Angelini, P., Neri, S. and Panetta, F. 2012. Monetary and Macroprudential Policies. ECB working paper (MARS network) no. 1449.

Basel Committee on Banking Supervision. 2011. Basel III: a global regulatory framework for more resilient banks and banking systems. BIS.

Bean, C. 2003. Asset Prices, financial imbalances and monetary policy: are inflation targets enough? in Richards and Robinson (eds.) Asses prices and Monetary policy, 48-76. Reserve bank of Australia.

Bean, C., Paustian, M., Penalver, A. and Taylor, T. 2010. Monetary Policy after the Fall. Bank of England working paper.

Benigno, G., Chen, H., Otrok, C., Rebucci, Young, E.R. forthcoming. Financial Crises and Macro-Prudential Policies. Journal of International Economics.

Bernanke B, Gertler M, Gilchrist S. 1999. The Financial Accelerator in a Quantitative Business Cycle Framework. In *Handbook of Macroeconomics*, Taylor J, Woodford M (eds). Amsterdam: North Holland.

Bernanke B and Gertler. 2001. Should Central Banks Respond to Movements in Asset Prices? American Economic Review, Vol. 91. pp. 253-257.

Bernanke, B. 2011. The effects of the Great Recession on Central Bank Doctrine and Practice. speech at 56th Economic conference, Federal Reserve Bank of Boston.

Borio, C. and Zhu, H. 2008. Capital regulation, risk-taking and monetary policy: a missing link in the transmission mechanism. BIS working paper no. 268.

Borio, C. 2011. Central banking post-crisis: what compass for uncharted waters? BIS working paper no. 353.

Brunnermeier, M., Crockett, A., Goodhart, C., A. and Shin, H. 2009. The Fundamental Principles of Financial Regulation. CEPR report.

Checchetti, S., Genberg, H., Lipsky, J. and Wadhwani, S. 2000. Asset Prices and Central Bank Policy. London: International center for Monetary and Banking studies.

Checchetti, S. and Kohler, M. 2012. When capital adequacy and interest rate policy are substitutes (and when they are not). BIS working paper no. 379.

Christiano, L., Motto, R. and Rostagno, M. 2013. Risk Shocks. NBER Working Paper 18682.

Committee on the Global Financial System. 2010. Macroprudential instruments and frameworks: a stocktaking of issues and experiences. CGFS papers no. 38.

Darracq Pariès, M., Kok Sørensen, C. and Rodriguez Palenzuela, D. 2011. Macroeconomic propagation under different regulatory regimes: evidence from an estimated DSGE model for the euro area. *International Journal of Central Banking*, vol. 7(4). pp. 49-113.

Dedola, L., Karadi, P., and Lombardo, G. 2013. Global Implications of National Unconventional Policies. *Journal of Monetary Economics*, vol. 60 (1): pp. 66-85.

De Grauwe, P. 2008. The Risks of being Chairman in the Age of Turbulence. International Finance 11:1. pp 109-115.

De Paoli, B. and Paustian, M. 2013. Co-ordinating monetary and macroprudential policies. mimeo.

Dewachter, H. and Wouters, R. 2012. Endogenous risk in a DSGE model with capital-constrained financial intermediaries. National Bank of Belgium working paper no. 235.

Dixit, A. and Lambertini, L. 2003. Interactions of Commitment and Discretion in Monetary and Fiscal Policies. *American Economic Review* vol. 93 (5): 1522-1542.

French, K., Baily, M., Campbell, J. et al. 2010. The Squam Lake Report: fixing the financial system. Princeton University Press.

Galí, J., Smets, F., and Wouters, R. 2011. Unemployment in an Estimated New Keynesian Model. *NBER Working Paper 17084.*

Galati, G. and Moessner, R. 2010. Macroprudential policy - a literature review. BIS working paper.

Gerali, A., Neri, S., Sessa, L. and Signoretti, F.M. 2010. Credit and Banking in a DSGE Model of the Euro Area. *Journal of Money, Credit and Banking* 42. pp. 107–141.

Gertler, M. and Karadi, P. 2011. A Model of Unconventional Monetary Policy. *Journal of Monetary Economics* 58(1). pp. 17-34.

Gertler, M. and Kiyotaki, N. 2010. Financial Intermediation and Credit Policy in Business Cycle Analysis.

Gilchrist, S. and Zakrajšek, E. 2012. Credit Spreads and Business Cycle Fluctuations. *American Economic Review* 102 (4): 1692-1720.

Gomme, P., Ravikumar, B., and Rupert, P. 2011. The Return to Capital and the Business Cycle. *Review of Economic Dynamics* vol. 14 (2): 262-278.

Gortz, C. and Tsoukalas, J. 2012. News and financial intermediation in aggregate and sectoral fluctuations. mimeo.

Iacoviello, M. 2005. House Prices, Borrowing Constraints and Monetary Policy in the Business Cycle. *American Economic Review*, Vol. 95. pp. 739-764.

Ilbas, P. 2006. Optimal Monetary Policy rules for the Euro area in a DSGE framework. Center for Economic Studies Discussion papers ces 0613, Katholieke Universiteit Leuven.

Ilbas P. 2010. Estimation of Monetary Policy Preferences in a Forward-Looking Model: a Bayesian Approach. *International Journal of Central Banking* **6:3** : 169-209.

Ilbas, P. 2012. Revealing the Preferences of the US Federal Reserve. *Journal of Applied Econometrics* **27** : 440–473.

Jermann, U. and Quadrini, V. 2012. Macroeconomic Effects of Financial Shocks. *American Economic Review* 102(1) : 238-71.

Justiniano A., Primiceri G.E., and Tambalotti A. 2011. Is There a Trade-Off Between Inflation and Output Stabilization? *mimeo.*

Lima, D., Levine, P., Pearlman, J., Yang, B. 2012. Optimal Macro-Prudential and Monetary Policy. University of Surrey working paper.

Liu, Z., Wang, P., and Zha, T. 2010. Do Credit Constraints Amplify Macroeconomic Fluctuations? Federal Reserve bank of Atlanta Working Paper 2010-1.

Quadrini, V. 2011. Financial Frictions in Macroeconomic Fluctuations. *Economic Quarterly* Volume 97 (3): 209–254.

Quint, D. and Rabanal, P. 2013. Monetary and Macroprudential Policy in an estimated DSGE Model of the Euro Area. IMF working paper wp/13/209.

Rannenberg, A. 2012. Symmetric Information in credit markets, bank leverage cycles and macroeconomic dynamics. National Bank og Belgium wp 224 and ECB working paper (MARS network) no. 1487.

Reinhart, C. and Rogoff, K. 2009. This Time is Different: Eight-Centuries of Financial Folly. Princeton University Press.

Rotemberg, J.J. and Woodford, M. 1998. Interest-Rate Rules in an Estimated Sticky Price Model. NBER Working Papers 6618.

Smets F, Wouters R. 2003. An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association* **1 (5)** : 1123-1175.

Smets F, Wouters R. 2007. Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. *American Economic Review* **97** : 586-606.

Svensson, L. 2012. Comment on Michael Woodford, "Inlfation Targeting and Financial Stability". *Penning-och valutapolitik* 2012:1.

Taylor, J.B. 2012. Monetary Policy Rules Work and Discretion Doesn't: A Tale of Two Eras. forthcoming, *Journal of Money Credit and Banking.*

Tinbergen, J. 1956. Economic Policy: Principles and Design, Amsterdam: North-Holland.

Villa, S. and Yang, J. 2011. Financial Intermediaries in an Estimated DSGE Model for the UK. In Interest Rates, Prices and Liquidity. Lessons from the Financial Crisis, eds. J. Chadha and S. Holly, Cambridge University Press.

Villa, S. 2013. Financial frictions in the Euro Area: a Bayesian assessment. ECB Working Paper 1521.

Woodford, M. 2011. Inlfation Targeting and Financial Stability. mimeo.

Appendix I : Steady State

This appendix outlines the implications of introducing financial frictions for the steady state of the original Smets-Wouters model. Although most of the Smets and Wouters (2007) steady state derivations are unaffected, some exceptions are important to point since they also affect the estimation process. In the following, we abstract from reporting those relationships that remain unaffected, and refer to the technical appendix accompanying Smets and Wouters (2007) instead. Therefore, we only repeat the steady state relations that need to be adjusted, together with the set of steady state assumptions that we have added, the latter relating to the Gertler-Karadi block.

The estimation of the three constants $\overline{cn}$, $\overline{cs}$, $\overline{crk}$ yields the steady state values of the corresponding variables, namely the gross net worth growth rate, the net premium, and the gross return on capital, as follows

$$Z_*^{GK} = 1 + \frac{\overline{cn}}{100}$$
$$\overline{PREM}_* = \frac{\overline{cs}}{100}$$
$$\overline{ret}_*^k = 1 + \frac{\overline{crk}}{100}$$

According to equation (23), the presence of the premium implies the following relationship between the return to capital and the real interest rate

$$\overline{RR}_* = \frac{\overline{ret}_*^k}{1 + \overline{PREM}_*}$$

For the consumption Euler equation to be satisfied, parameter σ_c has to respect the following steady state restriction

$$\sigma_c = \frac{log\left(\overline{RR}_*\right) + log\left(\beta\right)}{log\left(\gamma\right)}$$

where, as in Smets-Wouters, $\gamma = 1 + \overline{\gamma}/100$ and $\beta = 1/(1 + constebeta/100)$. The remaining steady state variable from the original Smets-Wouters framework affected by the presence of financial frictions is the rental rate of capital. In particular, we need the following to hold

$$\overline{ret}_*^k = \left(1 + \overline{PREM}_*\right)\overline{RR}_*$$

$$\overline{ret}_*^k = R_*^k + (1 - \delta)$$

As a result,

$$R_*^k = \left(1 + \overline{PREM}_*\right)\overline{RR}_* - 1 + \delta$$

where $\overline{RR}_*$ is also equal to $\beta^{-1}\gamma^{\sigma_c}$.

Using the Smets-Wouters steady state values for W_*, c_y, k_y, and l_k (i.e. the labour to capital ratio), we proceed with the Gertler-Karadi block. We compute the consumption to capital ratio c_k

$$c_k = \frac{c_y}{k_y}$$

and use this in order to compute the steady state level of capital K_*

$$K_* = -\frac{(1-\sigma_c)\, W_*}{c_k \left(1-\frac{\lambda}{\gamma}\right)(\sigma_c - 1)\,(l_k)^{\sigma_l}}$$

The implied steady state of hours worked is

$$L_* = l_k K_*$$

Regarding the Gertler-Karadi block, the steady state of leverage is

$$\overline{LEV}_* = \frac{(Z_*^{GK} - \overline{RR}_*)}{\overline{PREM}_*}$$

which implies the following value for θ

$$\theta = \frac{1 - \omega \overline{LEV}_*}{\overline{PREM}_* \overline{LEV}_* + \overline{RR}_*}$$

Using the fact that, by definition, $X_* = Z_*^{GK}$, we compute the remaining steady state values

$$\upsilon_* = \frac{\beta}{\gamma^{\sigma_c}} \frac{(1-\theta)\, \overline{PREM}_*}{1 - \frac{\beta}{\gamma^{\sigma_c}} \theta X_*}$$

$$\eta_* = \frac{\beta}{\gamma^{\sigma_c}} \frac{(1-\theta)\, \overline{RR}_*}{1 - \frac{\beta}{\gamma^{\sigma_c}} \theta Z_*^{GK}}$$

$$\Gamma_* = \frac{\eta_*}{\overline{LEV}_*} + \upsilon_*$$

$$N_* = K_* \overline{LEV}_*$$

$$\overline{NE}_* = \theta Z_*^{GK} N_*$$

$$NN_* = \omega K_*$$

Appendix II : Data Appendix

Following series are used as observables: real GDP, consumption, investment, hours worked, real wages, GDP deflator, the Gilchrist-Zakrajsek (2012) spread (GZ-spread, henceforth), net worth, return to capital and the federal funds rate. The source of the series on GDP, nominal personal consumption and fixed private investments is the Bureau of Economic Analysis database of the US Department of Commerce. The GZ-spread is taken from the dataset accompanying the publication on the AER website (http://www.aeaweb.org/content/articles/articles_detail.php?doi=10.1257/aer.102.4.1692). Return to capital is based on the series provided in Gomme et al. (2011). The net worth growth rate is computed using data on all commercial banks' real net worth. To obtain the latter, we started from all commercial banks' nominal credit (Board of Governors of the Federal reserve system database, Assets and Liabilities of Commercial Banks in the United States, table H8/H8/B1001NCBAM) and from all commercial banks' nominal deposit (Board of Governors of the Federal reserve system database, Assets and Liabilities of Commercial Banks in the United States, table H8/H8/B1058NCBAM).[41] The two nominal series are divided by the GDP deflator. The difference between real credit and real deposit is the real net worth. Real GDP is expressed in terms of 1996 chained dollars. Consumption, investment and net worth are deflated with the GDP deflator. The log difference of the Implicit price deflator is used to compute inflation. Hours worked and hourly compensation for the non farming business sector for all persons are obtained from the Bureau of Labor Statistics. Real wage is computed by dividing the latter series by the GDP price deflator. The average hours index is multiplied with Civilian Employment figures of 16 years and over in order to correct for the limited coverage of the non farming business sector with respect to the GDP. The federal funds rate is downloaded from the FRED database of the Federal Reserve Bank of St-Louis. Inflation, interest rate, return to capital and the GZ-spread are expressed in quarterly frequency. Remaining variables are expressed in 100 times log. In order to express the real variables in per capita terms, we divide them by the population over 16. All series are seasonally adjusted.

[41] Both series can also be donwloaded from the FRED database with codes TOTBKCR and DPSACBW027SBOG, respectively.

Appendix III : Prior Assumptions

Following Smets and Wouters (2007), we fix the annual depreciation rate on capital at 10 percent, i.e., $\delta = 0.025$, the ratio of exogenous spending to GDP, g_y, at 0.18, the mark-up in the labor market in the steady state (λ_w) at 1.5 and the curvature of the Kimball aggregator in both goods and labor markets (ε_p and ε_w) at 10. The proportional transfer to entering bankers, ω, is set at 0.002. The prior assumptions for the remaining parameters are reported in Table 8.

[**Insert Table 8**]

The prior assumptions regarding the structural parameters corresponding to the Smets and Wouters (2007) are kept unchanged. The standard errors of all the error terms, including the measurement errors, are assumed to have an inverted gamma distribution with 2 degrees of freedom and a mean of 0.10. The persistence parameters of all shock processes and the MA coefficients are assumed to have a beta distribution with a prior mean of 0.5 and a prior standard error of 0.2. The steady state inflation rate is assumed to be gamma-distributed with a quarterly mean of 0.62% and standard error of 0.1, as in Smets and Wouters (2007). The priors assumptions for the remaining steady state parameters, i.e. return to capital, premium and net worth growth, are chosen according to the properties of the corresponding series in the sample.

Table 1: **Estimation results**

Marginal Likelihood (MHM)	-635.44		
	mode	mean	lower - upper
structural parameters			
φ investment adjustment cost	2.97	3.31	$1.85 - 4.69$
λ habit persistence	0.27	0.28	$0.20 - 0.35$
ξ_w Calvo wage stickiness	0.76	0.73	$0.59 - 0.85$
σ_l elast. of labor wrt real wage	2.06	2.10	$1.26 - 2.95$
ξ_p Calvo price stickiness	0.75	0.74	$0.65 - 0.82$
ι_w wage indexation	0.48	0.49	$0.25 - 0.74$
ι_p price indexation	0.34	0.38	$0.17 - 0.58$
ψ capital utiliz. cost	0.82	0.81	$0.70 - 0.92$
ϕ_p (1+fixed costs in production)	1.43	1.43	$1.27 - 1.59$
$(\beta^{-1}$ $1)100$ const. discount	0.09	0.10	$0.04 - 0.16$
L_* constant labor supply	-0.13	-0.08	$-1.36 - 1.18$
$\bar{\gamma}$ constant growth rate	0.48	0.47	$0.43 - 0.52$
α share of capital in production	0.22	0.22	$0.18 - 0.26$
$\overline{crk}$ const. return to capital	0.93	0.93	$0.82 - 1.05$
$\overline{cs}$ const. premium	0.48	0.48	$0.38 - 0.57$
$\overline{cn}$ const. net worth growth	2.27	2.26	$1.98 - 2.54$
$\bar{\pi}$ const. inflation	0.55	0.55	$0.46 - 0.65$
ρ_r interest rate smoothing	0.85	0.85	$0.81 - 0.88$
r_π inflation coeff. Taylor rule	1.95	1.98	$1.65 - 2.29$
r_y output gap coeff. Taylor rule	0.08	0.08	$0.03 - 0.13$
$r_{\Delta y}$ output gap diff. Taylor rule	0.19	0.19	$0.16 - 0.23$
shock processes			
σ_a technology	0.37	0.38	$0.32 - 0.44$
σ_b risk premium	0.10	0.11	$0.08 - 0.13$
σ_g exogenous spending	0.36	0.37	$0.32 - 0.43$
σ_l investment specific	0.24	0.24	$0.18 - 0.31$
σ_p price mark-up	0.10	0.10	$0.08 - 0.13$
σ_w wage mark-up	0.33	0.33	$0.26 - 0.40$
σ_R mon. policy shock	0.09	0.10	$0.08 - 0.12$
σ_Γ financial shock	1.88	1.95	$1.39 - 2.49$
σ_{prem} meas. err. premium	0.14	0.15	$0.12 - 0.17$
σ_{retk} meas. err. return to cap.	0.97	0.99	$0.83 - 1.14$
ρ_a AR(1) technology	0.90	0.91	$0.84 - 0.98$
ρ_b AR(1) risk premium	0.85	0.85	$0.81 - 0.89$
ρ_g AR(1) exogenous spending	0.96	0.96	$0.95 - 0.98$
ρ_l AR(1) investment specific	0.97	0.95	$0.92 - 0.99$
ρ_p AR(1) price mark-up	0.79	0.73	$0.55 - 0.91$
ρ_w AR(1) wage mark-up	0.69	0.65	$0.41 - 0.89$
ρ_{ga} effect of technology on exports	0.52	0.52	$0.35 - 0.70$
μ_p MA(1) price mark-up	0.66	0.54	$0.28 - 0.79$
μ_w MA(1) wage mark-up	0.60	0.50	$0.24 - 0.77$
ρ_R AR(1) monetary policy	0.15	0.18	$0.07 - 0.29$
ρ_Γ AR(1) financial shock	0.99	0.98	$0.98 - 0.99$
ρ_{prem} AR(1) meas. err. premium	0.93	0.92	$0.88 - 0.97$
ρ_{retk} AR(1) meas. err. ret. to cap.	0.54	0.54	$0.39 - 0.70$

Note: The table reports the marginal likelihood (modified harmonic mean) and the posterior estimation results (the posterior mode, the posterior mean and the 90% confidence bounds) for the estimated parameters. The posterior estimation results are obtained with the Metropolis-Hastings sampling algorithm based on $400,000$ draws, from which the first 20% draws are discarded. The posterior mode is obtained from the numerical optimization of the posterior kernel.

Table 2: **Variance decomposition of output, inflation and the interest rate**

	techn. shock	risk premium	exog. spending	inv. specific shock	mon. pol. shock	price mark-up	wage mark-up	financial shock
Output	20.92	11.84	3.17	35.63	5.33	6.32	4.33	12.45
Inflation	2.51	7.85	0.36	2.98	5.03	55.77	24.45	1.05
Interest rate	4.29	64.29	1.23	13.33	3.07	2.18	5.01	6.60

Note: The Table reports the variance decompositions at the infinite horizon, based on the mode of the posterior distribution reported in Table 1.

Table 3: **Volatlity Comparison Observables (Actual vs. Model)**

Observable	Standard Error	
	Data	Model (5th-95th percentiles)
Output growth*	0.56	0.64 – 0.96
Consumption growth*	0.48	0.51 – 0.76
Investment growth**	1.73	1.95 – 3.43
Hours worked**	2.03	1.06 – 2.63
Wage growth**	0.71	0.60 – 0.91
Inflation**	0.23	0.21 – 0.40
Interest rate*	0.46	0.18 – 0.43
Net Worth growth	3.73	5.17 – 7.89
Return to Capital	0.52	1.73 – 2.46
Premium	0.20	0.37 – 0.81

Note: The table compares the standard errors of the observables based on the data to the corresponding 90 percent posterior interval implied by the estimated model. The observables for which actual standard errors are matched by the model are denoted by a double star. The obervables denoted by one star refer to the cases where the interval does not include the actual standard errors, but the vlaue of the latter is close to the bounds of the interval.

Table 4: **Cross-Correlations Observables (Actual vs. Model)**

	output	consumption	investment	hours worked	wages	inflation	interest rate	net worth	return to capital	premium
output	1.00									
consumption	0.63∗	1.00								
	(0.14 − 0.62)									
investment	0.63 ∗ ∗	0.50	1.00							
	(0.56 − 0.82)	(−0.31 − 0.26)								
hours worked	0.17 ∗ ∗	0.30 ∗ ∗	0.16 ∗ ∗	1.00						
	(0.03 − 0.34)	(−0.24 − 0.30)	(0.02 − 0.45)							
wages	−0.05∗	0.18 ∗ ∗	−0.01 ∗ ∗	0.27 ∗ ∗	1.00					
	(−0.04 − 0.40)	(−0.20 − 0.24)	(−0.06 − 0.40)	(−0.01 − 0.41)						
inflation	−0.42 ∗ ∗	−0.50 ∗ ∗	−0.31 ∗ ∗	−0.34	−0.25 ∗ ∗	1.00				
	(−0.48 − 0.06)	(−0.50 − −0.01)	(−0.43 − 0.25)	(−0.29 − 0.51)	(−0.32 − 0.17)					
interest rate	−0.14 ∗ ∗	−0.07 ∗ ∗	−0.26 ∗ ∗	0.6 ∗ ∗	0.18 ∗ ∗	0.16 ∗ ∗	1.00			
	(−0.32 − 0.23)	(−0.30 − 0.21)	(−0.30 − 0.32)	(−0.07 − 0.83)	(−0.23 − 0.23)	(0.13 − 0.72)				
net worth	0.18 ∗ ∗	0.20	0.31 ∗ ∗	0.04 ∗ ∗	−0.11	−0.14 ∗ ∗	−0.07 ∗ ∗	1.00		
	(0.26 − 0.62)	(0.29 − 0.65)	(0.00 − 0.43)	(−0.22 − 0.12)	(−0.06 − 0.34)	(−0.27 − 0.11)	(−0.25 − 0.10)			
return to capital	−0.03	−0.26	0.06 ∗ ∗	−0.18 ∗ ∗	−0.18	0.16∗	−0.21 ∗ ∗	0.06	1.00	
	(0.17 − 0.57)	(0.21 − 0.60)	(−0.06 − 0.42)	(−0.25 − 0.23)	(−0.08 − 0.33)	(−0.31 − 0.15)	(−0.25 − 0.23)	(0.71 − 0.90)		
premium	−0.24 ∗ ∗	−0.17 ∗ ∗	−0.31 ∗ ∗	−0.06 ∗ ∗	0.08 ∗ ∗	−0.13 ∗ ∗	−0.39 ∗ ∗	−0.16 ∗ ∗	0.07 ∗ ∗	1.00
	(−0.48 − −0.02)	(−0.27 − 0.25)	(−0.61 − −0.07)	(−0.85 − −0.02)	(−0.34 − 0.11)	(−0.52 − 0.27)	(−0.76 − 0.14)	(−0.22 − 0.11)	(−0.31 − 0.16)	

Note: The table compares the cross-correlation coefficients of the observables based on the data to the corresponding 90 percent posterior interval, reported below the actual values in brackets, implied by the estimated model. The observables for which the cross-correlation coefficients are matched by the model are denoted by a double star. The obervables denoted by one star refer to the cases where the interval does not include the actual the cross-correlation coefficient, but the value of the latter is close to the bounds of the interval.

Table 5: **Coordination vs. No-Coordination in the baseline case**

				Coordination	No-Coordination
I	$\lambda_y^{mp} = \lambda_{\Delta c}^{mp} = 0.5$		Optimal Monetary Policy Rule		
			ρ	1	1
			α_π	0.24	0.27
			α_y	1.01	0.26
			Optimal Macroprudential Policy Rule		
			β_y	1.01	2.91
			β_c	2.51	7.24
			Volatilities (standard errors)		
			π_t	0.55	0.54
			$(y_t - y_t^p)$	0.18	0.62
			r_t	0.62	0.58
			$(credit_t - credit_{t-1})$	0.62	0.33
			$Loss_t^{CB}$	0.36	0.52
			$Loss_t^{mp}$	0.21	0.27
II	$\lambda_y^{mp} = 1$	$\lambda_{\Delta c}^{mp} = 0.5$	Optimal Monetary Policy Rule		
			ρ	1	1
			α_π	0.24	0.25
			α_y	1.76	0.28
			Optimal Macroprudential Policy Rule		
			β_y	0.86	2.46
			β_c	2.37	4.92
			Volatilities (standard errors)		
			π_t	0.56	0.52
			$(y_t - y_t^p)$	0.12	0.53
			r_t	0.64	0.56
			$(credit_t - credit_{t-1})$	0.63	0.42
			$Loss_t^{CB}$	0.36	0.45
			$Loss_t^{mp}$	0.21	0.37
III	$\lambda_y^{mp} = 0.1$	$\lambda_{\Delta c}^{mp} = 0.5$	Optimal Monetary Policy Rule		
			ρ	1	1
			α_π	0.25	0.35
			α_y	0.47	0.22
			Optimal Macroprudential Policy Rule		
			β_y	1.39	3.21
			β_c	2.99	21.04
			Volatilities (standard errors)		
			π_t	0.52	0.57
			$(y_t - y_t^p)$	0.34	0.96
			r_t	0.57	0.62
			$(credit_t - credit_{t-1})$	0.56	0.13
			$Loss_t^{CB}$	0.36	0.82
			$Loss_t^{mp}$	0.17	0.10

Note: The table compares the results under coordination and no-coordination, where the macroprudential objectives are expressed in terms of the output gap and the (nominal) credit growth, i.e., $Loss_t^{mp} = \lambda_y^{mp}(y_t - y_t^p)^2 + \lambda_{\Delta c}^{mp}(credit_t - credit_{t-1})^2$, for varying weights on the output gap λ_y^{mp} and $\lambda_{\Delta c}^{mp} = 0.5$. The loss function of monetary policy, i.e., $Loss_t^{CB} = \pi_t^2 + \lambda_y^{CB}(y_t - y_t^p)^2 + \lambda_r^{CB} r_t^2$, remains unchanged throughout the exercise with values $\lambda_y^{CB} = 0.5$ and $\lambda_r^{CB} = 0.1$.

Table 6: **Coordination vs. No-Coordination with alternative macroprudential objectives**

	$X_t = \frac{Credit_t}{GDP_t}$		$X_t = spread$	
	Coordination	No-Coordination	Coordination	No-Coordination
Optimal Monetary Policy Rule				
ρ	1	1	1	1
α_π	2.03	0.37	0.02	0.06
α_y	2.56	0.26	1.81	0.78
Optimal Macroprudential Policy Rule				
β_y	0	0	0.14	0.20
β_c	18.1	36.46	0.39	1.05
Volatilities (standard errors)				
π_t	0.73	0.58	0.42	0.43
$(y_t - y_t^p)$	0.57	0.86	0.10	0.33
r_t	0.89	0.64	0.44	0.43
X_t	1.95	1.98	0.40	0.37
$Loss_t^{CB}$	0.77	0.75	0.20	0.26
$Loss_t^{mp}$	2.06	2.33	0.08	0.12

Note: The table compares the results under coordination and no-coordination for alternative macroprudential objectives, where the macroprudential objectives are expressed in terms of the output gap and the financial variable X_t equal to credit-to-GDP ratio and the spread, respectively, in $Loss_t^{mp} = \lambda_y^{mp}(y_t - y_t^p)^2 + \lambda_{\Delta c}^{mp} X_t^2$, where $\lambda_y^{mp} = \lambda_X^{mp} = 0.5$. The loss function of monetary policy, i.e., $Loss_t^{CB} = \pi_t^2 + \lambda_y^{CB}(y_t - y_t^p)^2 + \lambda_r^{CB} r_t^2$, remains unchanged like before throughout the exercise with values $\lambda_y^{CB} = 0.5$ and $\lambda_r^{CB} = 0.1$.

Table 7: **Coordination vs. No-Coordination with more volatile shocks**

			Coordination	No-Coordination
I	$\lambda_y^{mp} = \lambda_{\Delta c}^{mp} = 0.5$	Optimal Monetary Policy Rule		
		ρ	1	1
		α_π	0.34	0.32
		α_y	1.10	0.20
		Optimal Macroprudential Policy Rule		
		β_y	0.62	3.15
		β_c	2.59	6.15
		Volatilities (standard errors)		
		π_t	1.22	1.63
		$(y_t - y_t^p)$	0.42	1.56
		r_t	1.42	1.73
		$(credit_t - credit_{t-1})$	1.58	0.92
		$Loss_t^{CB}$	1.78	4.15
		$Loss_t^{mp}$	1.34	1.64
II	$\lambda_y^{mp} = 1$ $\lambda_{\Delta c}^{mp} = 0.5$	Optimal Monetary Policy Rule		
		ρ	1	1
		α_π	0.34	0.30
		α_y	1.97	0.18
		Optimal Macroprudential Policy Rule		
		β_y	0.47	2.93
		β_c	2.43	3.59
		Volatilities (standard errors)		
		π_t	1.32	1.18
		$(y_t - y_t^p)$	0.09	1.60
		r_t	1.63	1.82
		$(credit_t - credit_{t-1})$	1.57	1.31
		$Loss_t^{CB}$	2.02	2.60
		$Loss_t^{mp}$	1.24	3.41
III	$\lambda_y^{mp} = 0.1$ $\lambda_{\Delta c}^{mp} = 0.5$	Optimal Monetary Policy Rule		
		ρ	1	1
		α_π	0.35	0.41
		α_y	0.51	0.24
		Optimal Macroprudential Policy Rule		
		β_y	1.06	3.70
		β_c	3.16	20.57
		Volatilities (standard errors)		
		π_t	1.11	1.23
		$(y_t - y_t^p)$	0.97	2.13
		r_t	1.26	1.38
		$(credit_t - credit_{t-1})$	1.43	0.40
		$Loss_t^{CB}$	1.86	3.97
		$Loss_t^{mp}$	1.12	0.53

Note: The table compares the results under coordination and no-coordination by applying post-crisis values for the magnitudes of the volatilities of the shock processes, where the macroprudential objectives are expressed in terms of the output gap and the (nominal) credit growth, i.e., $Loss_t^{mp} = \lambda_y^{mp}(y_t - y_t^p)^2 + \lambda_{\Delta c}^{mp}(credit_t - credit_{t-1})^2$, for varying weights on the output gap λ_y^{mp} and $\lambda_{\Delta c}^{mp} = 0.5$. The loss function of monetary policy, i.e., $Loss_t^{CB} = \pi_t^2 + \lambda_y^{CB}(y_t - y_t^p)^2 + \lambda_r^{CB} r_t^2$, remains unchanged throughout the exercise with values $\lambda_y^{CB} = 0.5$ and $\lambda_r^{CB} = 0.1$.

Table 8: **Prior assumptions**

structural parameters	distrib.	mean	stand. dev.	**shock processes**	distrib.	mean	stand. dev.
φ investment adjustment cost	Normal	4	1.5	σ_a technology	InvGamma	0.1	2
λ habit persistence	Beta	0.7	0.1	σ_b risk premium	InvGamma	0.1	2
ξ_w Calvo wage stickiness	Beta	0.5	0.1	σ_g exogenous spending	InvGamma	0.1	2
σ_l elast. of labor wrt real wage	Normal	2	0.75	σ_l investment specific	InvGamma	0.1	2
ξ_p Calvo price stickiness	Beta	0.5	0.1	σ_p price mark-up	InvGamma	0.1	2
ι_w wage indexation	Beta	0.5	0.15	σ_w wage mark-up	InvGamma	0.1	2
ι_p price indexation	Beta	0.5	0.15	σ_R mon. policy shock	InvGamma	0.1	2
ψ capital utiliz. cost	Beta	0.5	0.15	σ_Γ financial shock	InvGamma	0.1	2
ϕ_p (1+fixed costs in production)	Normal	1.25	0.12	σ_{prem} meas. err. premium	InvGamma	0.1	2
$(\beta^{-1}-1)100$ const. discount	Gamma	0.25	0.1	σ_{retk} meas. err. ret. to cap.	InvGamma	0.1	2
L_* constant labor supply	Normal	0	2	ρ_a AR(1) technology	Beta	0.5	0.2
$\bar{\gamma}$ constant growth rate	Normal	0.4	0.1	ρ_b AR(1) risk premium	Beta	0.5	0.2
α share of capital in production	Normal	0.3	0.05	ρ_g AR(1) exogenous spending	Beta	0.5	0.2
$\overline{crk}$ const. return to capital	InvGamma	1.14	0.60	ρ_l AR(1) investment specific	Beta	0.5	0.2
$\overline{cs}$ const. Premium	InvGamma	0.43	0.25	ρ_p AR(1) price mark-up	Beta	0.5	0.2
$\overline{cn}$ const. net worth growth	Normal	1.78	3.73	ρ_w AR(1) wage mark-up	Beta	0.5	0.2
$\bar{\pi}$ const. inflation rate	Gamma	0.62	0.1	ρ_R AR(1) monetary policy	Beta	0.5	0.2
ρ_r interest rate smoothing	Beta	0.75	0.1	ρ_{ga} effect of techn. on exports	Beta	0.5	0.2
r_π inflation coeff. Taylor rule	Normal	1.5	0.25	μ_p MA(1) price mark-up	Beta	0.5	0.2
r_y output gap coeff. Taylor rule	Normal	0.12	0.05	μ_w MA(1) wage mark-up	Beta	0.5	0.2
$r_{\Delta y}$ output gap diff. Taylor rule	Normal	0.12	0.05	ρ_Γ AR(1) financial shock	Beta	0.5	0.2
				ρ_{prem} AR(1) meas. err. premium	Beta	0.5	0.2
				ρ_{retk} AR(1) meas. err. ret. to cap.	Beta	0.5	0.2

Note: The table shows the prior distribution, prior means and the prior standard errors for the structural parameters, the shock processes (where the standard errors of the shocks are denoted by σ and the AR (1) coefficients of the persistent shocks by ρ) and the monetary policy parameters.

Figures

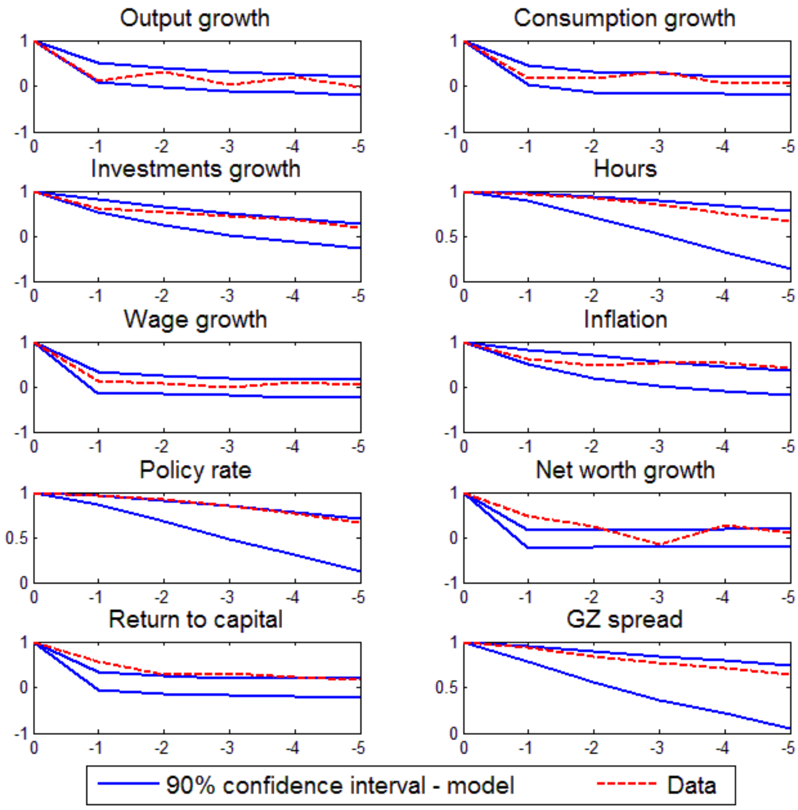

Figure 1. Autocorrelations Observables (Actual vs. Model)

Note: The figure plots the autocorrelations of the observables up to the fifth order, where the dashed line refers to the data and the solid lines represent the 90 percent confidence bounds.

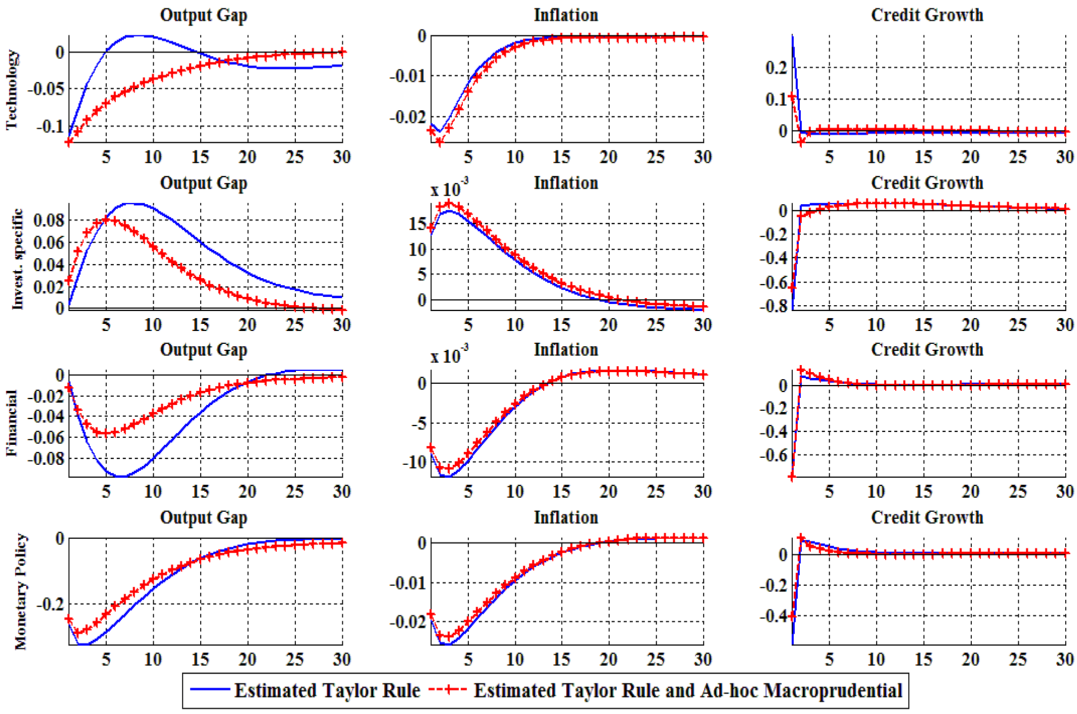

Figure 2. Impulse Responses Estimated Model

Note: The figure plots the impulse responses of output gap, inflation and credit growth in the estimated version of the model where monetary policy is represented by a Taylor rule and macroprudential is absent (solid line), and where the ad-hoc macroprudential policy rule in the form of a bank capital tax/subsidy $\tau_t = (y_t - y_{t-1}) + 0.1(credit_t - credit_{t-1})$ is added (starred line).

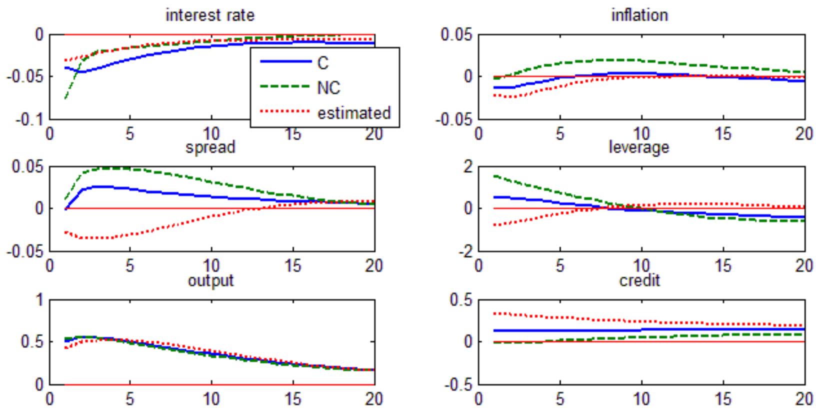

Figure 3. Impulse Responses: Technology Shock

Note: The figure plots the impulse responses to a positive technology shock under coordination (full line) and no-coordination (dashed line) against the responses implied by the estimated version of the model (dotted line). The responses for the coordination and no-coordination cases are obtained under the standard loss function assumption for monetary policy (25) and equal preferences for the output gap and the credit growth objectives in the macroprudential mandate, i.e., the macroprudential loss function (27) with $\lambda_y^{mp} = \lambda_{\Delta c}^{mp} = 0.5$.

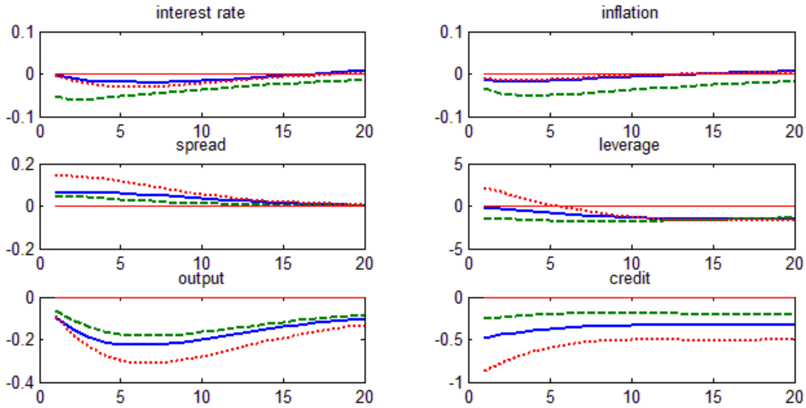

Figure 4. Impulse Responses: Financial Shock

Note: The figure plots the impulse responses to a positive financial shock under coordination (full line) and no-coordination (dashed line) against the responses implied by the estimated version of the model (dotted line). The responses for the coordination and no-coordination cases are obtained under the standard loss function assumption for monetary policy (25) and equal preferences for the output gap and the credit growth objectives in the macroprudential mandate, i.e., the macroprudential loss function (27) with $\lambda_y^{mp} = \lambda_{\Delta c}^{mp} = 0.5$.

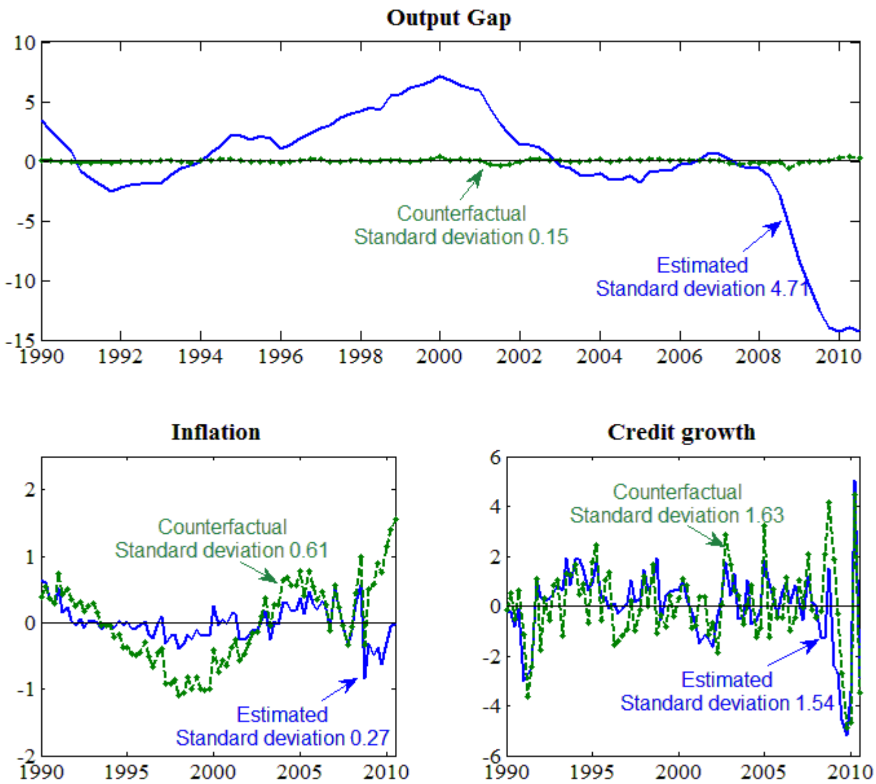

Figure 5. Counterfactual Analysis: Monetary Policy Only

Note: The figure shows the historical ouptut gap, inflation and credit growth and their respective standard errors implied by the estimated model (full line) and the counterfactual optimal monetary policy (dotted line), where the latter minimizes the standard loss function (25) and macroprudential policy is absent.

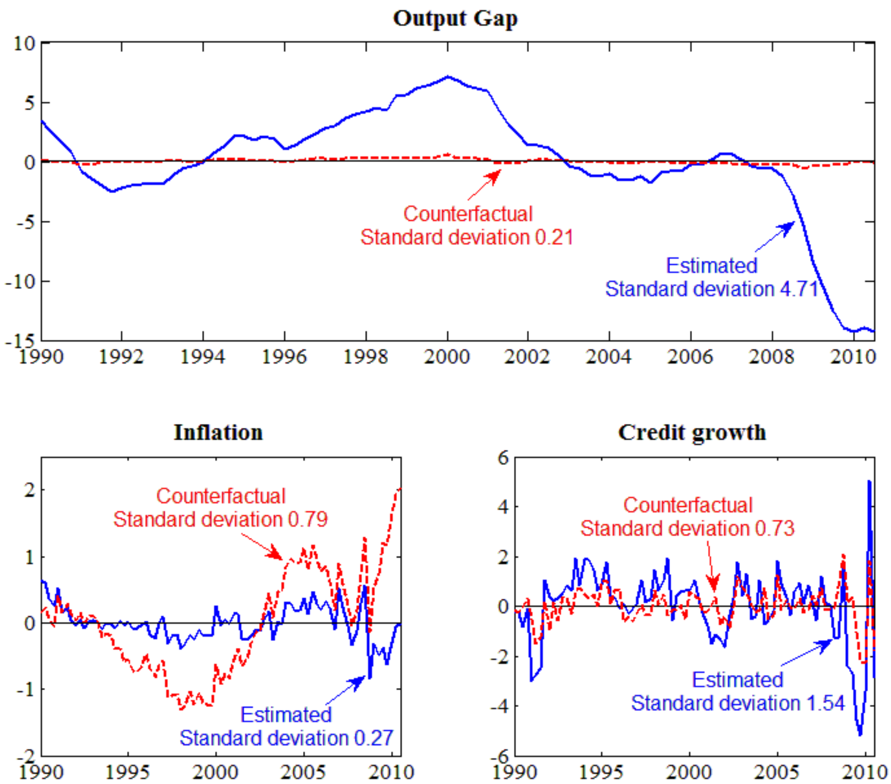

Figure 6. Counterfactual Analysis: Optimal Monetary and Macroprudential Coordination

Note: The figure shows the historical ouptut gap, inflation and credit growth and their respective standard errors implied by the estimated model (full line) and the counterfactual optimal coordination between monetary and macroprudential policies (dashed line) where the former minimizes the standard loss function (25) and the latter minimizes (27) with $\lambda_y^{mp} = \lambda_{\Delta c}^{mp} = 0.5$

NATIONAL BANK OF BELGIUM - WORKING PAPERS SERIES

The Working Papers are available on the website of the Bank: http://www.nbb.be.

209. “Wage and employment effects of a wage norm: The Polish transition experience” by A. de Crombrugghe and G. de Walque, *Research series*, February 2011.
210. “Estimating monetary policy reaction functions: A discrete choice approach” by J. Boeckx, *Research series*, February 2011.
211. “Firm entry, inflation and the monetary transmission mechanism” by V. Lewis and C. Poilly, *Research series*, February 2011.
212. “The link between mobile telephony arrears and credit arrears” by H. De Doncker, *Document series*, March 2011.
213. “Development of a financial health indicator based on companies' annual accounts”, by D. Vivet, *Document series*, April 2011.
214. “Wage structure effects of international trade: Evidence from a small open economy”, by Ph. Du Caju, F. Rycx and I. Tojerow, *Research series*, April 2011.
215. “Economic importance of the Belgian ports: Flemish maritime ports, Liège port complex and the port of Brussels - Report 2009”, by C. Mathys, *Document series,* June 2011.
216. “Verti-zontal differentiation in monopolistic competition”, by F. Di Comite, J.-F. Thisse and H. Vandenbussche, *Research series*, October 2011.
217. “The evolution of Alexandre Lamfalussy's thought on the international and European monetary system (1961-1993)” by I. Maes, *Research series*, November 2011.
218. “Economic importance of air transport and airport activities in Belgium – Report 2009”, by X. Deville and S. Vennix, *Document series*, December 2011.
219. “Comparative advantage, multi-product firms and trade liberalisation: An empirical test”, by C. Fuss and L. Zhu, *Research series*, January 2012.
220. “Institutions and export dynamics”, by L. Araujo, G. Mion and E. Ornelas, *Research series*, February 2012.
221. “Implementation of EU legislation on rail liberalisation in Belgium, France, Germany and the Netherlands”, by X. Deville and F. Verduyn, *Document series*, March 2012.
222. “Tommaso Padoa-Schioppa and the origins of the euro”, by I. Maes, *Document series*, March 2012.
223. “(Not so) easy come, (still) easy go? Footloose multinationals revisited”, by P. Blanchard, E. Dhyne, C. Fuss and C. Mathieu, *Research series*, March 2012.
224. “Asymmetric information in credit markets, bank leverage cycles and macroeconomic dynamics”, by A. Rannenberg, *Research series*, April 2012.
225. “Economic importance of the Belgian ports: Flemish maritime ports, Liège port complex and the port of Brussels - Report 2010”, by C. Mathys, Document series, July 2012.
226. “Dissecting the dynamics of the US trade balance in an estimated equilibrium model”, by P. Jacob and G. Peersman, *Research series*, August 2012.
227. “Regime switches in volatility and correlation of financial institutions”, by K. Boudt, J. Daníelsson, S.J. Koopman and A. Lucas, *Research series*, October 2012.
228. “Measuring and testing for the systemically important financial institutions”, by C. Castro and S. Ferrari, *Research series*, October 2012.
229. “Risk, uncertainty and monetary policy”, by G. Bekaert, M. Hoerova and M. Lo Duca*, Research series*, October 2012.
230. “Flights to safety”, by L. Baele, G. Bekaert, K. Inghelbrecht and M. Wei, *Research series*, October 2012.
231. “Macroprudential policy, countercyclical bank capital buffers and credit supply: Evidence from the Spanish dynamic provisioning experiments”, by G. Jiménez, S. Ongena, J.-L. Peydró and J. Saurina, *Research series*, October 2012.
232. “Bank/sovereign risk spillovers in the European debt crisis”, by V. De Bruyckere, M. Gerhardt, G. Schepens and R. Vander Vennet, *Research series*, October 2012.
233. “A macroeconomic framework for quantifying systemic risk”, by Z. He and A. Krishnamurthy, *Research series*, October 2012.
234. “Fiscal policy, banks and the financial crisis”, by R. Kollmann, M. Ratto, W. Roeger and J. in't Veld, *Research series*, October 2012.
235. “Endogenous risk in a DSGE model with capital-constrained financial intermediaries”, by H. Dewachter and R. Wouters, *Research series*, October 2012.
236. “A macroeconomic model with a financial sector”, by M.K. Brunnermeier and Y. Sannikov, *Research series*, October 2012.
237. “Services versus goods trade: Are they the same?”, by A. Ariu, *Research series*, December 2012.

238. "Importers, exporters, and exchange rate disconnect", by M. Amiti, O. Itskhoki and J. Konings, *Research series*, December 2012.
239. "Concording EU trade and production data over time", by I. Van Beveren, A.B. Bernard and H. Vandenbussche, *Research series*, December 2012.
240. "On the origins of the Triffin dilemma: Empirical business cycle analysis and imperfect competition theory", by I. Maes, *Research series*, December 2012.
241. "The Influence of the Taylor rule on US monetary policy", by P. Ilbas, Ø. Røisland and T. Sveen, *Research series*, January 2013.
242. "Economic importance of the Belgian ports: Flemish maritime ports, Liège port complex and the port of Brussels - Report 2011", by C. Mathys, *Document series,* July 2013.
243. "The fragility of two monetary regimes: The European Monetary System and the Eurozone", by P. De Grauwe and Y. Ji, *Research series*, October 2013.
244. "Funding liquidity, market liquidity and TED spread: A two-regime model", by K. Boudt, E. C.S. Paulus and D. W.R. Rosenthal, *Research series*, November 2013.
245. "Robustifying optimal monetary policy using simple rules as cross-checks", by P. Ilbas, Ø. Røisland and T. Sveen, *Research series*, November 2013.
246. "Household and firm leverage, capital flows and monetary policy in a small open economy", by M. Pirovano, *Research series*, November 2013.
247. "The BIS and the Latin American debt crisis of the 1980s", by P. Clement and I. Maes, *Research series*, December 2013.
248. "The importance of the right amount of business resources for firms' exporting behavior", by I. Paeleman, C. Fuss and T. Vanacker, *Research series*, December 2013.
249. "The role of financial frictions during the crisis: An estimated DSGE model", by R. Merola, *Research series*, December 2013.
250. "Bank reactions after capital shortfalls", by C. Kok and G. Schepens, *Research series*, December 2013.
251. "Why firms avoid cutting wages: Survey evidence from European firms", by P. Du Caju, T. Kosma, M. Lawless, J. Messina and T. Rõõm, *Research series*, December 2013.
252. "The distribution of debt across euro area countries: The role of individual characteristics, institutions and credit conditions", by O. Bover, J. M. Casado, S. Costa, Ph. Du Caju, Y. McCarthy, E. Sierminska, P. Tzamourani, E. Villanueva and T. Zavadil, *Research series*, December 2013.
253. "Micro-based evidence of EU competitiveness: The CompNet database", by CompNet Task Force, *Research series*, March 2014.
254. "Information in the yield curve: A macro-finance approach", by H. Dewachter, L. Iania and M. Lyrio, *Research series*, March 2014.
255. "The Single supervisory mechanism or 'SSM', part one of the Banking Union", by E. Wymeersch, *Research series*, April 2014.
256. "Nowcasting Belgium", by D. de Antonio Liedo, *Research series*, April 2014.
257. "Human capital, firm capabilities and productivity growth", by I. Van Beveren and S. Vanormelingen, *Research series*, May 2014.
258. "Monetary and macroprudential policies in an estimated model with financial intermediation", by P. Gelain and P. Ilbas, *Research series*, May 2014.

National Bank of Belgium
Limited liability company
RLP Brussels – Company's number: 0203.201.340
Registered office: boulevard de Berlaimont 14 – BE-1000 Brussels
www.nbb.be

Editor

Jan Smets

Member of the Board of directors of the National Bank of Belgium

Layout: Analysis and Research Group
Cover: NBB AG – Prepress & Image

Published in May 2014