Does Interbank Market Matter for Business Cycle Fluctuation? An Estimated DSGE Model with Financial Frictions for the Euro Area

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Abstract

The aim of this paper is to assess the impact of the interbank market on the business cycle. To do that, we build a DSGE model with heterogeneous households and banks.

The surplus bank can allocate its resources between interbank lending and risk free government bonds. This portfolio choice is affected by an exogenous counterpart risk shock on the interbank market. An increase of the counterpart risk diverts funds from the interbank markets toward the government bonds market. This mechanism allow us to capture the freeze of the interbank market and the fly to quality mechanism underlying the 2007 crisis.

Keywords: DSGE model, financial frictions, interbank market, Bayesian estimation.
JEL classification codes: E30, E44, E51.

1 Introduction

The interbank market is the primary source of fundings for banks that need to gather liquidity in order to create new loans. Shocks that interfere with its normal functioning can have significant repercussions both on the whole financial system and on the real side of the economy.

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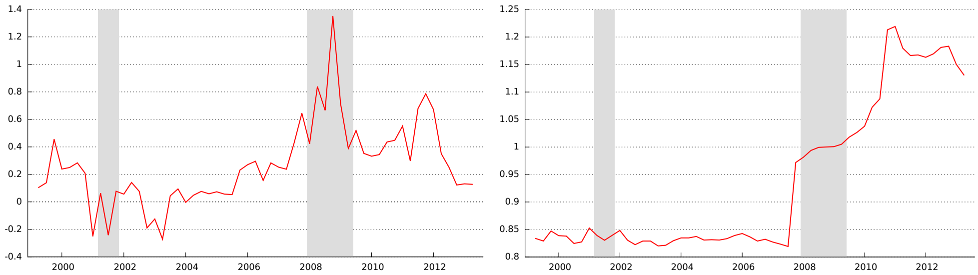
Figure 1a shows the spread between the three month Euribor and the overnight index swap on the EONIA interest rate. The so called OIS spread is considered one of the most important indicator to evaluate the proper functioning of the liquidity market. The higher the spread, the higher is the risk perceived by the financial intermediaries that operate on the interbank market.

(a) Euribor 3 Month - OIS spread (b) Gov Bonds detained by the MFI



Source: The OIS spread is taken from Datastream while the statistics of government bonds are from the ECB. OIS is expressed in percentage while government bond are in millions of euro. The gray bars represents recessions according to the NBER definition.

After the collapse of Lehman Brothers, banks do not trust each other anymore. The fear that in the balance sheet of a counterpart would be hidden an unquantifiable amount of toxic assets caused a sudden and extended drainage of liquidity from the interbank market. As a consequence the OIS spread at the end of 2008 rose of almost 100 basis point with respect to the beginning of the year. Banks looked for a "safe heaven" choosing low but safe returns like government bonds (See figure 1b).

In the last few years, several empirical papers tried to assess the determinants of the rise of the OIS spread during the financial crisis and they especially tried to disentangle the role of credit and liquidity risk. Socio (2011) found that the credit risk was the main factor determining the rise of the interest rates at the aftermath of the crisis while in a second phase the effect of the liquidity risk prevailed. Similar results were found by Filipović and Trolle (2013). Beirne (2012) contribution arrived to the opposite conclusion. In the pre crisis scenario, both liquidity and credit risk are irrelevant to explain the behavior of the OIS spread. Instead, during the most acute phase of the crisis, liquidity risk is the main driver of the OIS spread. After the massive liquidity injection by the ECB, credit risk became the most important factor to explain the OIS spread.

Other empirical contributions tried to investigate the relation between the interbank market freeze and the decreased of credit supply. For instance, Iyer et al. (2013), studying the relation between the European interbank market and the Portuguese firms, found a close connection between the 2007 interbank downturn and the firm credit contraction.

Despite the growing interest of the empirical literature on the role of interbank market during the last financial crisis, very few papers concentrate their attentions on the macroeconomic and general equilibrium effects of interbank default and/or liquidity shocks on the business cycle. The primary objective of this paper is try to fill this gap in order to better understand the role of the interbank market in the widespread of the financial crisis using a Dynamic Stochastic General Equilibrium framework.

In order to carry on our analysis, we decide to extend the model proposed by Gerali et al. (2010) including an interbank market like in Dib (2010) and deWalque et al. (2010) to analyze the effect of an unexpected increase of counterpart risk on interbank market similar in spirit to the framework proposed by Wickens (2011).

We find that *a*) an increase of the counterpart risk on the interbank market can generate a decrease of loans provided by the banks to the real economy and, as a consequence, a fall of the GDP, mainly driven by a drop of investments, *b*) this shock played a non negligible role in the 2008 rise of the interest rates in the money and credit market, *c*) moreover, this shock seems to crowd out the central bank intervention making the conduction of monetary policy through the adjustment of the short term interest rates less effective.

The paper is organized as follow. Section 2 presents the most recent contributions in the field of DSGE model with an explicit interbank sector. Section 3 explains in details the model and the relative equations. Sections 3 and 4 deal with the solution methods and the estimation techniques. Section 5 and 6 focus their attention on the dynamical properties of the model and the historical variance decomposition of the shocks. Finally, Section 7 summarizes the main findings and the possible extensions.

2 Literature review

From a theoretical point of view, Heider et al. (2009) proposed a model in which the counterpart risk plays a crucial role in the evolution of the interbank market after the 2007. In particular, the model is able to capture some stylized facts of the interbank crisis such us the accumulation of reserves by the banks, the increased of interest rates and the unsuccessful attempts of the central bank to restore the normal operations on the interbank market.

The paper proposed by Goodhart et al. (2009) is the first attempt to include an active interbank market into a standard macroeconomic model. They place in their model two kinds of banks. A surplus bank, which obtains funds from the household, and a deficit bank that receives loans from the surplus one to finance the corporate lending to the Yeoman farmer. The central bank is able to influence the interest rate only through the deficit bank. The main findings is that heterogeneity across financial intermediaries matters in order to identify the transmission mechanism of several structural shocks.

In a general equilibrium framework, deWalque et al. (2010) built up a RBC model upon the interbank market structure of Goodhart et al. (2009). The authors underlined how, a relatively simple model, captures some stylized facts of the interest rate structure and on defaults rate on interbank market. Moreover, the introduction of a capital requirement like the one proposed by the Basel I agreement reduces the long run growth but it improves the resistance of the system to shocks, while the Basel II accords enhances the business cycle fluctuation.

Dib (2010) constructed a model in which the saving bank, financed by households deposits, plays a crucial role in the allocation of the resources between interbank lending and the risk free government bond. The central bank can alter the composition of the saving bank balance sheet when it intervenes to stem the inflation growth or the output gap. The key result is that under a capital requirement regime the presence of a banking sector attenuates the effects of different shocks. Moreover, many stylized facts of the US business cycle are capture by the model making it particular suited to be used to analyze the impacts of the financial sector on the rest of the economy.

Gertler and Kiyotaki (2010) build a DSGE model with an interbank market in which all banks borrow from and lend to firms. In their model the interbank market arises because banks are subject to an idiosyncratic liquidity shock which has the effect of creating surplus and deficit intermediaries. Limited pleadgeability gives place to an endogenous leverage constraint where bankers need to use their own equity in order to attract external creditors both on the retail (deposits) and at the wholesale level (interbank borrowing/lending). Gertler and Kiyotaki (2010) use their model to investigate how several different credit policies could mitigate the negative effect of a financial crisis.

Carrera and Vega (2012) and Hilberg and Hollmayr (2011) build up a DSGE model with an interbank market in order to analyze alternative macroprudential policy rule. Carrera and Vega (2012) developed a hierarchical bank system in which the exchanges between the central bank and the retailers are managed by another subject called the narrow bank. The role of the narrow bank is to manage the liquidity provided by the central bank and to allocate these resources into the interbank market. The retail bank has the goal of obtaining savings and issuing loans to the real economy. The authors used the model in order to investigate the behavior of the macroprudential policy in presence of an interbank market finding out that a reserve requirement rule can be used jointly with the standard Taylor rule to avoid large swings of the interest rate.

Similar in spirit, Hilberg and Hollmayr (2011) developed a model in which an investment bank provides the liquidity to the retail banks. The retail bank is subject to a borrowing constraint (See Kiyotaki and Moore (1997) and Iacoviello (2005)) in the amount of funds it can obtain from the investment bank and it can collateralize only a fraction of its detained assets. In this case, the macroprudential policy rule is related to the haircut that the central bank could apply to the assets of the investment bank in order to provide liquidity. In normal time the central bank accepts only liquid assets like government bonds while during financial stress it can also buy illiquid asset back securities like loans. The authors find that relaxing the haircut is an effective tool to boost the interbank market lending and consequently economic growth.

The recent contribution by Boissay et al. (2013) explores a new frontier in macroeconomic modeling setting up a non linear DSGE model including a non trivial banking sector. Relying on global solution methods, the model is able to generate an interbank crisis endogenously, triggered by a small sequence of positive supply shock. The model is also able to capture several stylized facts of historical systemic banking crisis (see Schularick and Taylor (2012)).

3 The model

Our model is an extension of the one proposed by Gerali et al. (2010). The whole economy is made of several representative agents each of them maximizes his objective function under a budget constraint. Two kind of households, patient and impatient, live in the model. Patient households have a higher intertemporal discount factor than the impatients households. Therefore, patient households are net savers and they decide how much to consume, to work and the amount of deposits to allocate at the surplus bank. Impatient households are net borrowers and they choose how much to consume and to work. They finance part of their spending obtaining loans from the retail branch of the deficit bank. Both patient and impatient households sell their work to a union that sells a composite labor factor to the intermediate firm.

The rest of the real economy has a standard setting like in Smets and Wouters (2007) and Christiano et al. (2005). There are two kind of firms, the intermediate producers and the final goods producers. The intermediate firms operate under monopolistic competition and they are able to fix prices. They rent physical capital from the producers of capital goods and sell their intermediate goods to the producers of final goods. Final goods producers operate under perfect competition but with sticky prices. They buy the intermediate products, they pack them into an undifferentiated final good that they sell back to patient and impatient households. Intermediate firms could finance a fraction of their investment obtaining loans from the retail branch of the surplus bank.

The bank system of the model is an extension of Gerali et al. (2010) and Dib (2010). The deficit banks is modeled like in Gerali et al. (2010) and it is a net debtor on the interbank market. We have a retail branch that is directly connected with the firms and the households. The retail branches operate under monopolistic competition and they could set the interest rate on loans provided to the impatient households and the firms. A wholesale branch of the deficit banks has to manage the capital position of the holding choosing the optimal balance sheet of the bank group. Moreover, like in Dib (2010), deficit banks could choose the optimal amount of default over the interbank. this novelty allow us to introduce the counterpart risk in our framework. In order to keep the model as simple as possible, we introduce two simplification: a) there is no distinction in the model between credit and liquidity risk and we will describe the exogenous shock hitting the interbank market as a generic counterpart shock as described in Heider et al. (2009) and b) we consider only the unsecured interbank market like in deWalque et al. (2010) but differently from Hilberg and Hollmayr (2011).

The surplus banks collect loans from patient households and invest part of their deposits either in the interbank market or in government bond. Similar to deWalque et al. (2010), surplus banks are subjected to a disutility cost that is proportional to the interbank exposition. Monetary policy is conducted by the central bank following a Taylor rule. We close our model specifying a government sector that obeys to an intertemporal budget constraint and manages the tax rate according to a feedback rule like in Leeper (1991).

3.1 Patient households

Patient households choose $c(i)^P$, $h(i)^P$, and $d(i)^P$ (respectively, consumption, house services, and the amount of deposits) in order to maximize their utility function under the budget constraint. The utility function depends positively on consumption and houses services and negatively on the hours worked.

$$E_0 \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P)\epsilon_t^z log(c_t^P(i) - a^P c_{t-1}^P) + \epsilon_t^h log(h_t^P(i)) - \frac{l_t^P(i)^{(1+\phi)}}{1+\phi} \right] \quad (1)$$

where β_p is the intertemporal discount factor of patient households while a_p represents the external habit formation in consumption with respect to the whole Patient households consumption. The exogenous variables ϵ_t^z and ϵ_t^h are two stochastic disturbances affecting consumption preferences and the house services demand. The budget constraint for the patient households is described by the following equation

$$c_t^P(i) + q_t^h \Delta h_t^P(i) + d_t^P(i) = w_t^P(i) l_t^P(i) + \frac{(1+r_{t-1}^d)}{\pi_t} d_{t-1}^P(i) + Tr_t - T_t^P \quad (2)$$

The left hand side is the flow of expenses. It is composed by consumption, variation of the market value of housing services, where q^h is the real houses price, and the amount of deposit allocated at the surplus bank. The right hand side of equation 2 represents the resource owned by the patient households. w^P is the hourly wage , r^d is the net interest rate on deposits, π is the net inflation and T is a lump sum tax. All variables are expressed in real terms. Tr_t are the transfers from the economy to the patient households. We assume that final goods producer firms are completely owned by the Patient households and they transfer to them their profits J^r while the deficit banks redistribute only a fraction $(1-\Omega)$ of their profits to the households. T_t^P is a lump sum tax used to finance the government expenditures. Patients households are net savers and they decide to allocate a fraction of their income in bank deposits at the surplus bank.

3.2 Impatient Households

Impatient households choose $c(i)^I$, $h(i)^I$, and $b(i)^I$ in order to maximize their utility function under the budget constraint. They behave exactly like patient households, but instead of being net savers they are net borrowers due to their lower intertemporal discount factor. Consequently, they finance a fraction of their spending by obtaining loans $b(i)^I$ from the retail branch of the deficit bank.

$$E_0 \sum_{t=0}^{\infty} \beta_I^t \left[(1-a^I)\epsilon_t^z log(c_t^I(i) - a^p c_{t-1}^I) + \epsilon_t^h log(h_t^I(i)) - \frac{l_t^I(i)^{(1+\phi)}}{1+\phi} \right] \quad (3)$$

Their budget constraint is described by the following expression

$$c_t^I(i) + q_t^h \Delta h_t^I(i) + \frac{(1 + r_{t-1}^{bh})}{\pi_t} b_{t-1}^I(i) = w_t^I(i) l_t^I(i) + b_t^I(i) \tag{4}$$

As in Iacoviello (2005), the amount of funds the impatient households can receive from the deficit bank is limited by the following borrowing constraint:

$$(1 + r_t^{bh}) b_t^I(i) \leq m_t^I E_t[q_{t+1}^h h_t^I \pi_{t+1}] \tag{5}$$

The total exposure toward the deficit banks of the impatient households must be less or equal of the expected value of the collaterals (houses) owned by the households. m_t^I represents the stochastic loan-to-value-ratio.[1]

3.3 Entrepreneurs

The entrepreneurs are self employed intermediate goods producers. Entrepreneurs choose $c(i)^E$, $k(i)^E$, $l(i)^{E,P}$, $l(i)^{E,I}$, $b(i)^E$, $u(i)^E$, where each variable represents respectively consumption, capital used to produce intermediate goods, labor from patient and impatient household, the amount of loans obtained by the retail branch of the deficit bank and the degree of utilization of capital. Like impatient households, they are net debtor on the credit market. Differently from patient and impatient households, the utility function depends only on entrepreneur's consumption:

$$E_0 \sum_{t=0}^{\infty} \beta_E^t \left[(1 - a^E) log(c_t^E(i) - a^E c_{t-1}^E) \right] \tag{6}$$

The budget constraint of the entrepreneurs is described by the following expression:

$$\begin{aligned} & c_t^E(i) + w_t l_t^{E,P}(i) + w_t l_t^{E,I}(i) + \frac{(1 + r_{t-1}^{be})}{\pi_t} b_{t-1}^E(i) + q_t^k k_t^E + f(u_t(i)) k_t^E(i) \\ =& \frac{y_t^E}{x_t} + b_t^E(i) + q_t^k (1 - \delta) k_{t-1}^E(i) \end{aligned} \tag{7}$$

We specify the functional form of $f()$ like in Schmitt-Grohé and Uribe (2006):

$$f(u_t(i)) = \xi_1 (u_t(i) - 1) + \frac{\xi_2}{2} (u_t(i) - 1)^2 \tag{8}$$

The production function is a classical Cobb-Douglass where, A_t^E represents a stochastic total factor productivity shock.

$$y_t^E(i) = A_t^E \left[k_{t-1}^E(i) u_t(i) \right]^\alpha l_t^E(i)^{(1-\alpha)} \tag{9}$$

[1] Iacoviello (2005) demonstrates that in the neighborhood of the steady state the constraint always binds.We neglect the problem of the occasionally binding constraints. See for further references Guerrieri and Iacoviello (2015) and Brzoza-Brzezina et al. (2013).

Entrepreneurs use a combination of the labor supplied by the Patient and Impatient households following the expression

$$l_t^E(i) = l_t^{E,P}(i)^{\mu} l_t^{E,I}(i)^{(1-\mu)} \tag{10}$$

Like the impatient households, entrepreneurs are also subject to a borrowing constraint

$$(1 + r_t^{be}) b_t^E(i) \leq m_t^E E_t[q_{t+1}^k (1 - \delta) k_t^E(i) \pi_{t+1}] \tag{11}$$

While impatient households use their amount of houses as collateral, entrepreneurs use the expected value of their endowment of physical capital. Substituting equation 10 into equation 9 and then equation 9 and 8 into the budget constraint we maximize the utility function under equations 7 and 11 .

3.4 The real side of the economy

The rest of the real side of the economy is built on Christiano et al. (2005) and Smets and Wouters (2007). Capital producers operate under perfect competition. They buy the undepreciated capital from the intermediate producers and a fraction of final goods from the final goods producer. They combine these two imputs to produce new capital that they sell at the real price q_t^k to the intermediate firms. Final goods producers operate under perfect competition but sticky prices. They combine the intermediate goods into a final goods. We strictly follow Gerali et al. (2010) to model the labor market. Two agents operate in the labor market, unions and labor packers. Workers provide a differentiated labor factor to unions. Moreover, a continuum m of labor packers acquire labor from the unions and they sell, through a CES aggregator, an homogeneous labor factor to the intermediate firms.

3.5 Banking system

The banking system is built upon Gerali et al. (2010) and Dib (2010). Both the surplus and the deficit bank are made of a wholesale and a retailer branch. The aim of the wholesale branch is to defined the optimal balance sheet of the bank while the retailers have to set the interest rates on loans and deposits. The interbank market operate under perfect competition but the surplus bank have to face a limited enforcement problem: the deficit bank can decide (optimally) to not pay back a certain amount of interbank borrowing every periods. On the other side, the surplus bank can allocate its resources among risky interbank loans and government bonds. To keep the model simple, we introduce another simplification: we do not distinguish between secure and unsecured interbank market but we assume that all the interbank transactions are risky. The sequence of event in the interbank market strictly follow deWalque et al. (2010): at time t the deficit bank received an amount IB_t from the surplus bank. At time $t + 1$ the deficit bank decides the amount of defaults over the interbank market. Since defaults are costly, at time $t + 2$ the deficit bank have to pay a pecuniary default costs.

3.5.1 Deficit Banks

3.5.2 The wholesale branch

The problem the wholesale branch has to face is the maximization of the cash flow of the entire holding subject to the bank's balance sheet constraint:

$$\begin{aligned}\max E_0 \sum_{t=0}^{\infty} \beta_I^t \lambda_t^I \Big[&(1+R_t^b) B_t(j) - (1+r_t^{ib}) IB_t(j) \\ &+ (1+r_{t-1}^{ib})(1-\delta_t^d) IB_{t-1}(j) \\ &- K_t^b(j) - Adj_t^{kb}(j) - Adj_t^{\delta}(j) \Big]\end{aligned} \tag{12}$$

where $\beta_I^t \lambda_t^I$ represents the stochastic discount factor for the Wholesale branch[2], R_t^b , and r_t^{ib} are respectively the (net) interest rate on loans from the wholesale branch to each retailers and the (net) interest rate on the loans obtained on the interbank market. B_t is the total amount of assets, which includes both loans to impatient households and entrepreneurs. IB_t are the resources the deficit banks borrow on the interbank market from the surplus ones while K_t^b represents the bank capital. δ^d represents the share of interbank default that the Deficit bank could decide to not pay back. The term

$$Adj_t^{kb}(j) = \frac{k_{kb}}{2} \left(\frac{K_t^b(j)}{B_t(j)} - v_b \right)^2 K_t^b(j) \tag{13}$$

is the bank capital requirement. The lowest is the ratio between bank capital and the total asset the higher is the penalty cost of providing and additional unit of loans to the retail branch. v^b is fixed at the 8% in order to replicate the Basel II capital requirement constraint. The default option is costly for the banks. Similar to Dib (2010) and deWalque et al. (2010), the term Adj_t^{δ} represents a penalty cost that the deficit bank has to pay whenever it decides to default on interbank borrowing.

$$Adj_t^{\delta}(j) = \frac{\chi_{db}}{2} \left(IB_{t-2}(j) \delta_{t-1}^d(j) \right)^2 \tag{14}$$

Moreover, deficit bank has to obey in every period to the following balance sheet constraint

$$B_t = IB_t - \delta_t^d IB_{t-1} + K_t^b \tag{15}$$

Bank capital evolves according to the following law of motion

$$K_t^b(j) \pi_t = (1-\delta_b) \epsilon_t^{kb} K_{t-1}^b(j) + \Omega J_{t-1}^{db}(j) \tag{16}$$

δ_b and Ω are respectively the quarterly depreciation rate of bank capital and the share of profits used to accumulate new bank capital [3] Substituting the balance

[2]The stochastic discount factor is equal to the marginal utility of consumption of the Impatient households because we are assuming that they are the only owners of the bank

[3]Consequently, $(1-\Omega)$ is the dividend pay-off ratio that is the quantity of bank profit distributed to the Patient households. Assuming $\Omega = 1$ bank is following a zero dividends policy and all profits are used to increase the bank capital.

sheet constraint into the objective function and deriving with respect to B_t and δ_t^d we get the first order conditions for the wholesale branch problem

$$\begin{aligned} R_t^b =& r_t^{ib}(1-\beta^I \frac{\lambda_{t+1}^I}{\lambda_t^I}\delta_{t+1}^d) - k_{kb}\left(\frac{K_t^b}{B_t} - v^b\right)\left(\frac{K_t^b}{B_t}\right)^2 + \\ & \beta^{I^2}\chi^{db} E_t\left\{(\delta_{t+1}^d)^2 IB_t \frac{\lambda_{t+1}^I}{\lambda_t^I}\right\} \end{aligned} \tag{17}$$

Equation 17 links the interest rate on loans to interbank market condition and to the adjustment costs the bank have to face. In particular, the wholesale interest rate is affected by the capital requirement and by the expected value of defaults. If the bank is under capitalized, it has to pay a cost that is charge by the bank over the wholesale interest rate. Moreover, the share of expected interbank defaults impact positively on the wholesale interest rate: whenever the bank defaults, the subsequent costs are charged over the interest rate.

The deficit bank can also decide the optimal amount of interbank defaults.

$$\delta_t^d = \left(\frac{\lambda_t^I r_{t-1}^{ib}}{\beta^I \lambda_{t+1}^I \chi^{db} IB_{t-1}}\right)\epsilon_t^{\delta^d} \tag{18}$$

Equation 18 describes the evolution of the interbank default over time. Defaults increase when the interest rate over interbank borrowing is higher and they shrink when the total amount of interbank borrowing increase. ϵ_t^δ is a stochastic interbank counterpart risk shock. In the simulation section we will study the effect of an increase of such shock and how it will affect the business cycle.

3.5.3 The retail branch

The retail branch of the deficit bank has the task of providing loans to the households and the entrepreneurs. The retailer bankers operate under monopolistic competition and they have the power to set the interest rate on their loans. They have to maximize the following profits function

$$\max E_o \sum_{t=0}^{\infty} \beta_I^t \lambda_t^I \left[r_t^{bh}(j) b_t^I(i) + r_t^{be}(j) b_t^E(i) - R_t^b B_t(j) - Adj_t^{kn}\right] \tag{19}$$

subject to the loans demand of impatient households and entrepreneurs which are

$$b_t^n(i) = \left(\frac{r_t^{bn}(j)}{r_t^{bn}}\right)^{-\epsilon_t^{bn}} b_t^I \tag{20}$$

The adjustment costs are defined as

$$Adj_t^{kn} = \frac{k_{bn}}{2}\left(\frac{r_t^{bn}(j)}{r_{t-1}^{bn}(j)} - 1\right)^2 r_t^{bn} b_t^n \tag{21}$$

Every time the bank changes the interest rate it has to pay a cost in term of profit. This adjustment cost introduces stickiness in the setting of interest rates on loans.

We can look at the first order conditions for the retail branch as a New Keynesian Phillips Curve for loan interest rates (see Aslam and Santoro (2008)). Substituting the loans demand into the objective function and deriving with respect to r_t^{bh} and r_t^{be} we obtain

$$\begin{aligned} 1-\frac{\Lambda_t^{bn}}{\Lambda_t^{bn}-1}+\frac{R_t^b}{r_t^{bn}}\frac{\Lambda_t^{bn}}{\Lambda_t^{bn}-1}-k_{bn}\left(\frac{r_t^{bn}}{r_{t-1}^{bn}}-1\right)\frac{r_t^{bn}}{r_{t-1}^{bn}}+ \\ \beta_I E_t\left[\frac{\lambda_{t+1}^I}{\lambda_t^I}k_{bn}\left(\frac{r_{t+1}^{bn}}{r_t^{bn}}-1\right)\left(\frac{r_{t+1}^{bn}}{r_t^{bn}}\right)^2\frac{b_{t+1}^n}{b_t^n}\right]=0 \end{aligned} \tag{22}$$

where $n=h,e$. We express the elasticity of substitution between loans provided by different retails branches as a function of the mark up Λ [4]. Higher values of ϵ (or equivalently lower values of Λ_t) implies a lower market power and a lower margin of intermediation for the bank.

3.5.4 Aggregate activity

The profits of the entire holding are defined as the revenues coming from all the business lines of the bank minus the intra group activities and the adjustment costs. We can define the variable J_t^{db} as the total profits of the deficit group as

$$J_t^{db}=r_t^{bh}b_t^I+r_t^{be}b_t^E+r_t^gGB_t^{db}-r_t^{ib}IB_t(1-\delta_t^d)-\sum Adj_t^{db} \tag{24}$$

3.5.5 Surplus banks

The surplus bank collects deposit from the patient households and decide to invest these resources either in the interbank market or purchasing government bonds like in Dib (2010). The balance sheet of the bank is summarized by the following equation.

$$IB_t+GB_t^{sb}-\delta_t^dIB_{t-1}=D_t^P \tag{25}$$

Symmetrically to the deficit banks, the surplus bank is divided into a retails and a wholesale branch.

3.5.6 The retail branch

$$\max E_0\sum_{t=0}^{\infty}\beta_P^t\lambda_t^P\left[R_t^dd_t^b-r_t^dd_t^P(j)-\frac{k_d}{2}\left(\frac{r_t^d(j)}{r_{t-1}^d(j)}-1\right)^2r_t^dd_t^P\right] \tag{26}$$

subject to

$$d_t^P(j)=\left(\frac{r_t^d(j)}{r_t^d}\right)^{-\epsilon_t^d}d_t^P \tag{27}$$

[4]The elasticity of substitution could be express as a function of the mark up

$$\epsilon_t=\frac{\Lambda_t}{\Lambda_t-1} \tag{23}$$

that is the deposits demand of the patient households. The resulting first order condition is

$$
\begin{aligned}
&-1+\frac{\Lambda_t^d}{\Lambda_t^d-1}-\frac{r_t}{r_t^d}\frac{\Lambda_t^d}{\Lambda_t^d-1}-k_d\left(\frac{r_t^d}{r_{t-1}^d}-1\right)\frac{r_t^d}{r_{t-1}^d}+\\
&\beta_P E_t\left[\frac{\lambda_{t+1}^p}{\lambda_t^p}k_d\left(\frac{r_{t+1}^d}{r_t^d}-1\right)\left(\frac{r_{t+1}^d}{r_t^d}\right)^2\frac{d_{t+1}^p}{d_t^p}\right]=0
\end{aligned}
\tag{28}
$$

Equivalent to the expression found in Gerali et al. (2010). Equivalently to the case of the deficit bank the market power in setting the interest rate of deposits allows us to interpret the derivative of the objective function with respect to r_t^d as a New Keynesian Phillips curve for deposit interest rate.

3.5.7 The Wholesale branch

The wholesale branch maximizes the following objective function.

$$
\max E_0\sum_{t=0}^{\infty}\beta_P^t\lambda_t^P\left\{(J_t^{sb}(j))-\Gamma_t(j)\right\} \tag{29}
$$

The term J^{sb} is the profit of the holding and it could be defined as

$$
J_t^{sb}(j)=r_t^{ib}IB_t(j)-r_{t-1}^{ib}\delta_t^d(j)IB_{t-1}(j)+r_t^gGB_t^{sb}(j)-r_t^dd_t^P(j) \tag{30}
$$

where IB_t represents the interbank lending and GB_t the government bonds detained by the surplus bank. The term

$$
\Gamma_t=\frac{\Theta}{2}\left((\delta_t^d(j)IB_{t-1}(j)-\overline{\delta}^d\overline{IB})\right)^2 \tag{31}
$$

is a quadratic disutility related to the possibility of suffering a default on the interbank market. The disutility term could be interpreted as the cost the surplus bank has to sustain in case of an unexpected level of suffered defaults such as legal or repossession costs. Moreover, the banking activity is subject to the usual balance sheet constraint express by equation 25. Deriving and combining the optimality conditions with respect to IB_t and GB_t, we obtain the optimal balance sheet of the surplus bank determined by the following equation

$$
IB_t=E_t\left\{\frac{\overline{\delta^d}\overline{IB}}{\delta_{t+1}^d}+\frac{r_t^{ib}(1-\tilde{\beta}_t^p\delta_{t+1}^d)-r_t^g}{\Theta\tilde{\beta}_t^p(\delta_{t+1}^d)^2}\right\} \tag{32}
$$

where $\tilde{\beta}_t^p=\beta^p(\lambda_{t+1}^P/\lambda_{t+1}^P)$ is the patient households stochastic discount factor. Two main driving forces are in motion here: on one hand, the increase of defaults push up the interbank interest rate. Since the surplus bank is risk neutral, higher interest rate represent an incentive to increase the exposition on the interbank market. On the other side the increase of defaults affect negatively the amount of interbank lending through the disutility cost. At the same time monetary policy could divert resources from the interbank market steering the short term interest rate r_t^g.

3.6 Central Bank

The central bank manages the short term interest rates following a non linear Taylor rule:

$$(1+r_t) = (1+\overline{r})^{(1-\phi_R)}(1+r_{t-1})^{\phi_R}\left\{\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi}(\Delta y_t)^{\phi_Y}\right\}^{1-\phi_R}(1+\epsilon_r^R) \tag{33}$$

where $\overline{r}$ is the steady state value of the interest rate, while ϕ_R, ϕ_π and ϕ_Y are respectively the weights assigned by the central bank to the past short term interest rate, the inflation target and the GDP growth.

3.7 The Government

The government sector has to obey to an intertemporal budget constraint

$$G_t + GB_{t-1}\frac{(1+r^g_{t-1})}{\pi_t} = GB_t + T_t \tag{34}$$

where G_t is the exogenous public expenditure and T_t a lump sum tax. Following Leeper (1991), government fixes taxation according to the following non linear rule

$$T_t = \overline{T} + \rho_{fp}\left(\frac{GB^{sb}_{t-1}}{\pi_t} - \frac{\overline{GB^{sb}}}{\overline{\pi}}\right) \tag{35}$$

In order to close the model, we assume that the interest rate paid by the government bonds are equal to the interest rates set by the central bank $r_t = r^g_t$.

3.8 Market clearing conditions and autoregressive process

We close our model specifying fifteen exogenous shocks that evolve like AR(1) process in the form

$$\log(X_t) = (1-\rho)\log(\bar{X}) + \rho\log(X_{t-1}) + e_t \tag{36}$$

With respect to the original model we add two additional stochastic disturbances: the public expenditure G_t and the counterpart shock on the interbank market $(\epsilon_t^{\delta^d})$.

The resource constraint for the economy is described by the following equation

$$\begin{aligned} y_t =& c_t + q^k_t\left[k_t - (1-\delta)k_{t-1}\right] + k_{t-1}\left[\xi_1(u_t-1) + \frac{\xi_2}{2}(u_t-1)^2\right] + \\ & \frac{\delta_b K^b_{t-1}}{\pi_t} + G_t + \sum_{j=0}^{\infty} Adj^j_t \end{aligned} \tag{37}$$

where c_t is defined as

$$c_t = c^P_t + c^I_t + c^E_t \tag{38}$$

and

$$h = h_t^P + h_t^I \tag{39}$$

Without an explicit supply sector for housing, we close the model fixing a positive net supply $h = 1$ of the real estate sector. Moreover, the term $\sum_{j=0}^{\infty} Adj_t^j$ includes all the adjustment costs of the models.

4 Solution of the model

The log linearized version of the model can be written in the form proposed by Klein (2000)

$$AE_t \{H_{t+1}\} = BH_t + CZ_t \tag{40}$$

where H_t is a vector containing the endogenous variables of the model and Z_t the autoregressive process. The matrices A,B and C contain all the deep parameters of the model [5].

4.1 Dataset

We employ fourteen observable variables on the Euro area from 1998 : $Q1$ to 2014 : $Q2$ in order to carry on the estimation. We use, investment, consumption, house price, inflation, wage inflation, deposits, loans to households and entrepreneurs, deposits interest rate, central bank interest rate, interbank market interest rate, interest rate on households and firms loans. All variables, with the exception of the interest rates, are expressed in real terms. We made stationary all the time series applying the one side HP filter[6] and subtracting the sample mean from the interest rates. The vector of observable variables used to perform the estimation can be represented by

$$\underbrace{\Xi_t^{obs}}_{13*1} = \Xi_t - \overline{\Xi} \tag{41}$$

that is, as (log) deviations of the endogenous variables from the steady state values.

4.2 Bayesian estimation

Following Gerali et al. (2010) and DARRACQ PARIES et al. (2011), we use Bayesian techniques in order to estimate only a small subset of the parameters, focusing our attention only on those affecting the dynamic of the system. The steady state parameters are calibrated in line with the values of Gerali et al. (2010). The complete list of calibrated parameters can be found in table 1. We

[5] All the procedure is carried on using DYNARE. We used DYNARE 4.4.3 version Adjemian et al. (2011), a MATLAB and OCTAVE toolbox capable of solving and simulate DSGE model.

[6] Since we used quarterly data we assumed that the smoothness parameters of the HP filter is set equal to 1600. Following Stock and Watson (1999), the use of the one side HP filter allow the data to be fully compatible with the backward looking nature of the Kalman filter used to recover the likelihood function of our model. We adapt the MATLAB code provide by Meyer-Gohde (2010) to obtain the filtered series.

departed from the original numerical setting imposing a steady state ratio of the Basel II capital requirement equal to 8% , fixing the depreciation rate of bank capital close to 0.05, a slightly lower value then the one proposed in Gerali et al. (2010). We set the deficit bank default cost χ^{db} close to 0.99 in order to obtained a steady state value of the default δ^{d} equal to 0.0025 on quarterly base which implies a yearly rate of 1% of interbank defaults. We modify the original value of the elasticity of substitution to deposits and households and entrepreneurial loans in order to match the pre crisis mean of the interest rates. The complete list of steady state values implies by the model is reported in table 3 in the section C of the technical appendix.

Table 1: Calibrated parameters

Parameter	Definition	Value
β^{P}	Patient households discount factor	0.99430
β^{I}	Impatient households discount factor	0.97500
β^{E}	Entrepreneurs discount factor	0.97500
α	Capital share	0.25000
δ	Depreciation rate of physical capital	0.02500
ϕ	Inverse of Frisch elasticity	1.00000
μ	Share of Patient workers	0.80000
$\bar{m}^{I}$	Steady State value of LTV for impatient households	0.70000
$\bar{m}^{E}$	Steady State value of LTV for Entrepreneurs	0.35000
$\bar{\pi}$	Net Steady State inflation	1.00000
$\bar{\zeta}^{d}$	Elasticity of substitution of deposit	-2.2602
$\bar{\zeta}^{bh}$	Elasticity of substitution of households loans	3.39126
$\bar{\zeta}^{be}$	Elasticity of substitution of entrepreneurs loans	3.52017
ξ_1	Coefficient associated with the degree of utilization of physical capital	0.04590
ξ_2	Coefficient associated with the degree of utilization of physical capital	0.00459
v_b	Basel II capital requirement	0.08000
δ_b	Depreciation rate of bank capital	0.05016
Ω	Profits invested in new bank capital	1.00000
χ^{db}	Deficit bank default cost	0.98600

4.2.1 The choice of the Priors

Given the similarity between our model and Gerali et al. (2010) a very natural starting point for the selection of prior distributions is to choose those proposed in their original work. We choose to bring only slightly modifications with respect to the original setting. We choose an *Inverse Gamma* for the standard deviations of the structural shock. The prior mean and standard deviations are taken from Iacoviello (2014). This choice is motivated by the fact to be conservative about the relevance of the financial shocks. The related autoregressive components are set with a mean of 0.8 and the standard deviations equal to 0.1 using a *Beta* prior distribution. The parameter related to the disutily cost of the surplus bank (Θ) is the novelty of our estimation. Since we have few prior informations about this parameter we decide to be quite agnostic and setting a wide prior. We only assume a positive support choosing a *Gamma* prior with mean equal to 15 and a standard deviation equal to 10. We also include in the estimation the coefficient related to the fiscal policy rule ρ^{fp}. We set a *Gamma* distribution with mean 0.3, a value provide by Falagiarda and Saia (2013) in their calibration, and a standard deviation of 0.1. The detailed choice of the priors and their distributions could be find in Table 2.

4.2.2 Posterior distributions

We obtained the posterior distribution applying the classical procedure of Monte Carlo Markov Chain simulation (See for a detailed explanation Fernandez-Villaverde (2010)). We launched two Markov chains each of them composed by 1.000.000 draws. We choose the scale factor of the variance and covariance matrix of the random walk Metropolis-Hastings in order to obtained an acceptance rate slightly above the 26%. We also check the convergence of the chains through both the CUSUM statistic [7] and the Brooks and Gelman (1998) statistics.

The results are in line with Gerali et al. (2010). Some parameters deserve further discussion. The degree of persistence of habit formation in consumption is different among the different type of agents in the model. Patient Households presents a low value a^P of their persistence in consumption while the Impatient Households and the entrepreneurs presents higher values, 0.75 and 0.76 respectively. This result was previously found in Iacoviello and Neri (2010).

The disutility parameter Θ is quite high implying a strong negative effect of defaults on the surplus balance sheet. The counterpart shock displays a certain degree of persistence with an autoregressive coefficient ρ_{δ^d} close to 0.83. The complete list of estimated parameters can be found in the section C of the technical appendix.

[7] To obtain the COSUM statistics we exploit the DSGEBaseyianToolbox provid by Ambrogio Cesa Bianchi. It can be downloaded from https://sites.google.com/site/ambropo/DSGEBayesianToolbox.zip?attredirects=0 . The graph can be found in the section D of the technical appendix.

Table 2: RESULTS FROM BAYESIAN ESTIMATION

parameters	Prior shape	Post mode	Post mean	Confidence interval 5 %	Post Median	Confidence interval 95 %
k_p	$\Gamma[50, 20]$	53.78	64.90	53.78	62.85	98.93
k_{bh}	$\Gamma[6, 2.5]$	4.109	5.028	3.019	4.857	7.618
k_{be}	$\Gamma[3, 2.5]$	2.264	2.622	1.657	2.555	3.811
k_d	$\Gamma[10, 2.5]$	8.057	8.691	5.932	8.499	12.16
k_i	$\Gamma[2.5, 1]$	5.766	5.928	4.590	5.860	7.502
k_w	$\Gamma[50, 20]$	82.06	92.45	63.12	90.55	127.6
k_{kb}	$\Gamma[15, 5]$	20.59	22.57	15.53	22.05	31.48
Θ	$\Gamma[15, 10]$	34.23	31.88	17.64	31.49	47.28
a^P	$\mathcal{B}[0.6, 0.1]$	0.661	0.679	0.549	0.682	0.798
a^I	$\mathcal{B}[0.6, 0.1]$	0.758	0.750	0.604	0.759	0.865
a^E	$\mathcal{B}[0.6, 0.1]$	0.776	0.768	0.692	0.770	0.835
ι_w	$\mathcal{B}[0.5, 0.15]$	0.367	0.377	0.199	0.373	0.570
ι_p	$\mathcal{B}[0.5, 0.15]$	0.080	0.098	0.040	0.092	0.174
ϕ_R	$\mathcal{B}[0.75, 0.1]$	0.870	0.870	0.840	0.871	0.896
ϕ_π	Γ[2.2,0.15]	2.158	2.195	1.813	2.182	2.623
ϕ_y	$\mathcal{N}[0.1, 0.15]$	0.093	0.096	0.035	0.094	0.163
ρ_{fp}	Γ [0.3,0.1]	0.314	0.320	0.216	0.316	0.434

5 Quantitative experiment

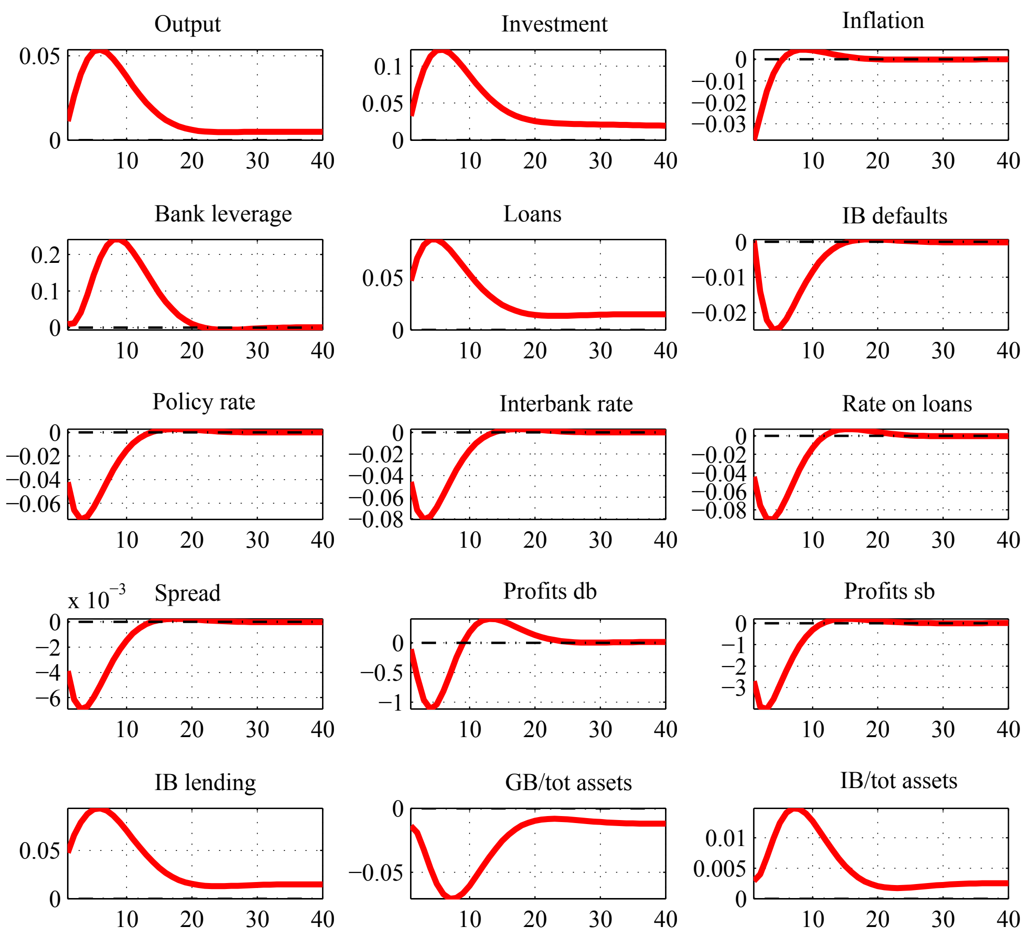
5.1 Technological shock

The impulse responses to a positive one standard deviation (on annual terms) technological shock (See Figure 2) present several of the standard features observed in the literature (see Smets and Wouters (2007) or Christiano et al. (2005)). Total output, driven by an increase of investments, reacts positively to an increase of technological efficiency, while the inflation rate decreases. Besides, the whole structure of the interest rates coherently decrease. The total amount of lending provided by the deficit bank to the economy increase for almost six quarters confirming the evidence found by Carrera and Vega (2012), pushed by the rise of interbank lending injected by the surplus bank. Similar to Dib (2010), the positive technological shock increase bank leverage and decreased the amount of interbank defaults. Contrary to Dib (2010), the interbank transactions increase, boosting the credit market, and enhancing economic activity. The lower interest rates on the credit market erode profits of both the types of banks ensuring more credit at lower rates to the real economy.

The surplus bank balance sheet is affected too by the TFP shock. The share of interbank lending over total assets increase [8]. In terms of a negative shock, we can

[8] The Share of interbank lending over total assets detained by the surplus bank is defined as $S_t^{ib} = \frac{IB_t}{GB_t+IB_t}$.

Figure 2: Technological shock



All the impulse response functions are calculated at the posterior median. The rates are absolute deviation from the steady state. All other variables are computed as percentage deviation from the steady state.

interpret it as a flight to quality scenario. A sudden deterioration of the economic conditions encourages the surplus bank to shrink risky interbank lending in favor of secure risk free government bonds .

5.2 Monetary policy shock

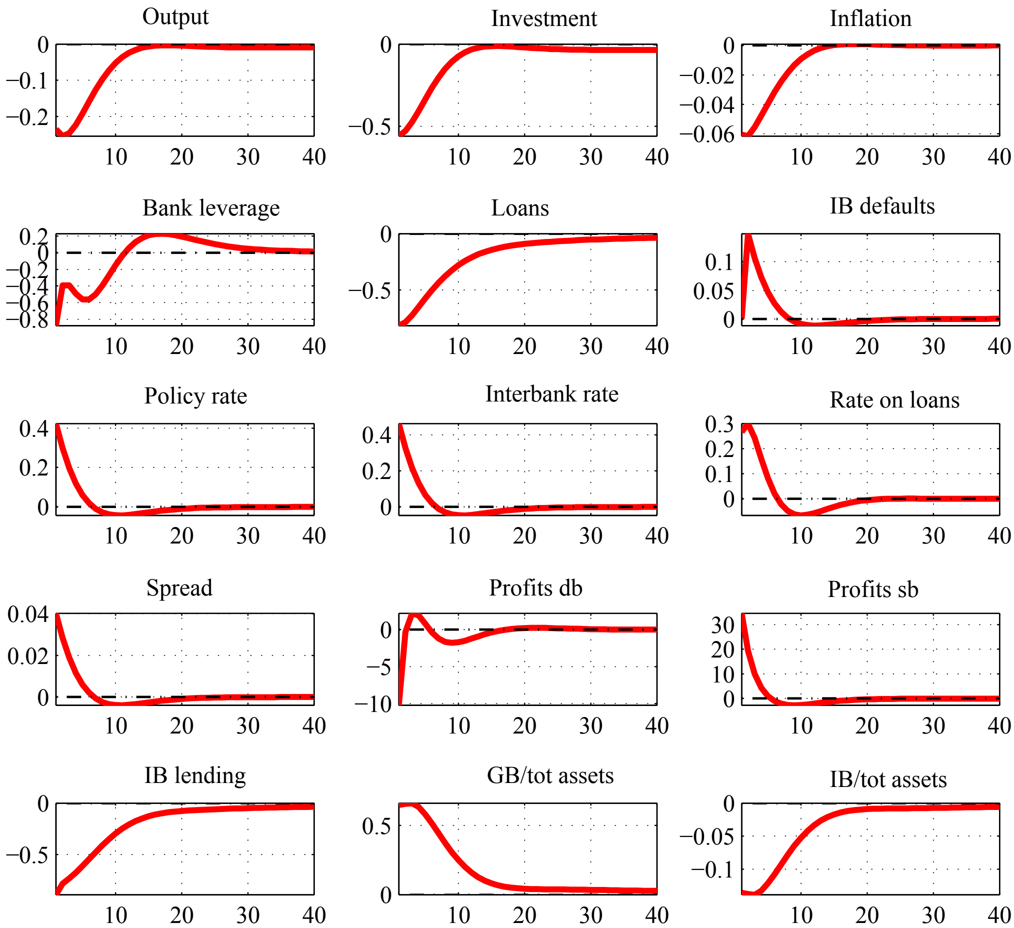
Figure 3 represents the response to an increase of 25 basis points of the central bank policy rate. The total output, even in this case driven by the drop of investments, and inflation fall. The entire structure of the interest rates rises sharply following the increase of the policy rate. It is worth to notice that credit tightness is not entirely transmitted to the credit market through the interbank market channel due to the presence of several credit market frictions. The fall of bank capital for the surplus bank is mainly due to the contraction of its own profits which are lowered by the higher cost of external financing implying a deleveraging process by the surplus bank. Instead, the profits of the surplus rise above the steady state level. The highest price paid over the liabilities is more than compensated by the higher earnings due to the rise of interest rate on interbank lending and risk free bonds. An increase of the policy rate seems to penalize more the net debtor on the market. The deficit bank suffers more the monetary restriction of the central bank, while the surplus bank could exploit the advantage of interbank lending at a higher price. The introduction of an interbank market seems to penalize more the weakest player on the market in favor of the surplus banks.

The increase of the policy rate also affects the composition of the balance sheet of the surplus bank diverting resources from the interbank market to the bonds market. The reason is that interbank lending is riskier, given a spike of interbank defaults, while at the same time the remuneration of detaining risk free bonds is higher.

5.3 Interbank counterpart shock

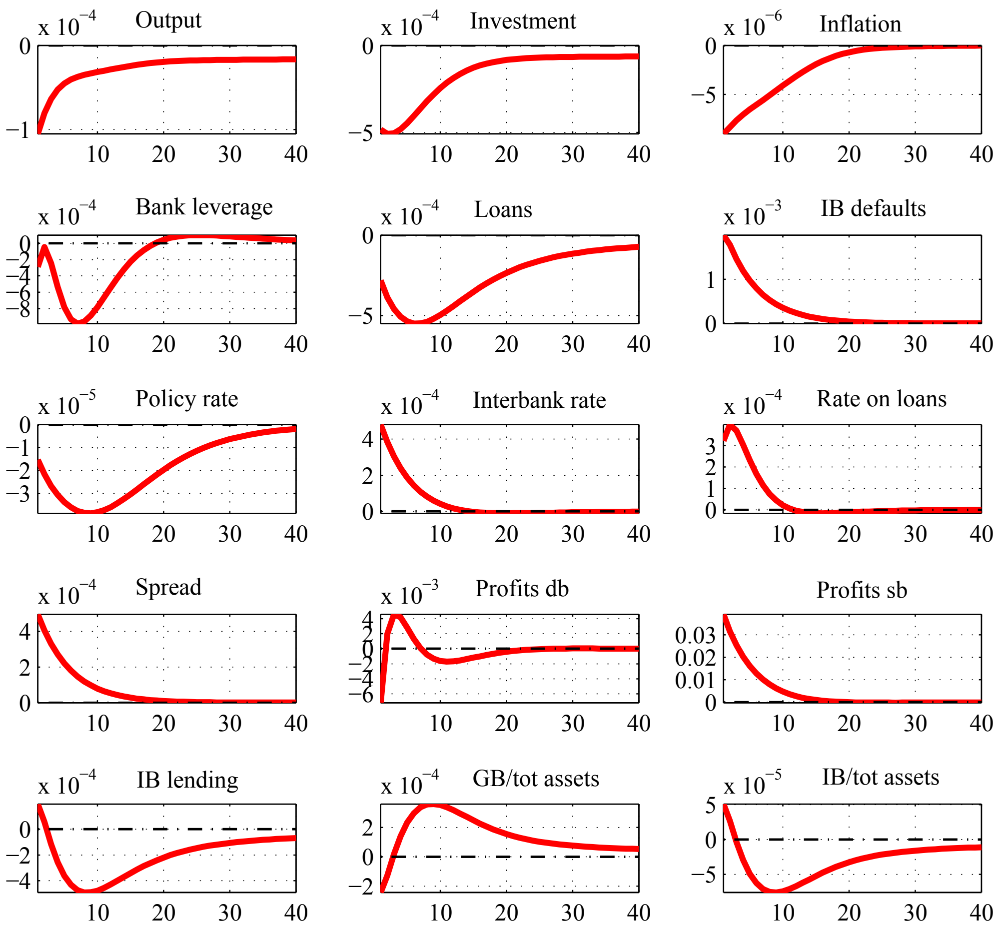
Figure 4 represents the impulse response functions of the model to a one standard deviation increase of the counterpart risk shock on the interbank market. We are not trying to match quantitatively the effect of an increase in riskiness on the interbank market but we are tying to understand qualitatively the story behind this mechanism. An increase of counterpart risk on the interbank market modifies the composition of the balance sheet of the surplus bank. The flight to quality mechanism pushes the surplus bank to reallocate resources on the risk free market instead of lending to the deficit bank. As a consequence, the interbank interest rate goes up causing an increase of the interest rate on the credit market. This increase is not fully transmitted to the retail market because of the presence of several adjustment shocks (k_{bh} and k_{be}) and the stickiness in the interest rate set by the retail branch of the deficit bank. The higher interest rates discourage credit demand, reducing the amount of loans used to purchase new intermediate

Figure 3: Monetary policy shock



All the impulse response functions are calculated at the posterior median. The rates are absolute deviation from the steady state. All other variables are computed as percentage deviation from the steady state.

Figure 4: Counterpart risk shock on the interbank market



All the impulse response functions are calculated at the posterior median. The rates are absolute deviation from the steady state. All other variables are computed as percentage deviation from the steady state.

capital and housing services, resulting in a credit crunch. At this point the recession spreads to the real economy through a contraction of the investments. As a consequence, the shrinkage of investments cause an erosion of the physical capital owned by the intermediate firms. The less the capital, the less is the value of the collateral the entrepreneurs could use to obtain credit from the bank, exacerbating the crisis on the credit market.

Coherently, facing the fall of the output, the central bank reacts cutting down the policy rate. In this framework the reduction of the interest rate is highly ineffective and it is not sufficient to restore the normal operation on the interbank market. The counterpart shock seems to have the same cross sectional effects of the monetary policy shock. The profits of the surplus bank increase while the profits of the deficit bank are eroded by the higher cost of interbank borrowing and they not compensated by the higher interest rate on credit.

6 Historical variance decomposition

In this section we focus our attention on the historical decomposition of the observable variables in order to understand the contribution of each shocks to the business cycle especially the role of the counterpart shock. In Figures 5 and 6 the historical decompositions of six main variables are reported.

As we expected, the interbank market shock seems to explain part of the rise of the interest rate on the credit market during and after the 2008 financial crisis confirming that the model is able to explained one of the transmission mechanism we described in the introduction. Even after the 2008 the tensions on the interbank market could be explained through the interbank riskiness shock at least until the end of the 2012. After the 2008, what really changed was the behavior of the ECB towards the prolonged recession. The ECB steered down the interest rate on the credit market drastically cutting the policy rate of over 300 basis points after the 2008 pumping a considerable amount of liquidity in the money market in part offsetting the detrimental effect of the counterpart shock.

The role of the interbank shock seems to affect in a different way the credit supply to the households with respect to the firms. The decrease of loans provided to households is explained for a significant portion by the adverse macroeconomic conditions and by a smaller, but non negligible, fraction by the interbank market shock. Instead, the drop of entrepreneurial loans seems to be completely explained by several financial factors such as a shrinkage of the loan to value ratio and the interbank market seems to play no role on the amount of credit available for the firms. The counterpart shock seems to work through two different channels. The interbank market shock raises interest rate and decrease the quantity of loans available to the households but on the other hand it seems to have no role in fixing the credit supply for the firms. The only active channel for the firms passes through the increase of interest rates that discourage investment and the acquisition of new capital.

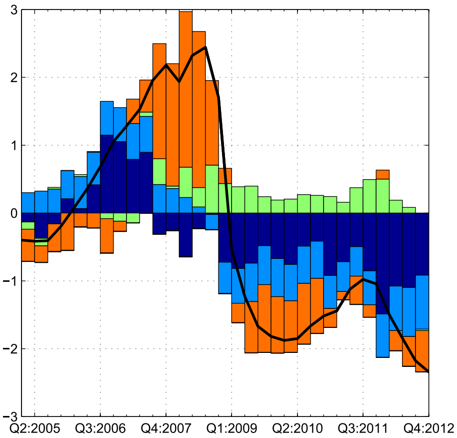
In general, like pointed out by Iacoviello (2014), after the 2007, a significant portion of the variations of the variables are driven by financial factors instead of real shocks .

7 Concluding remarks

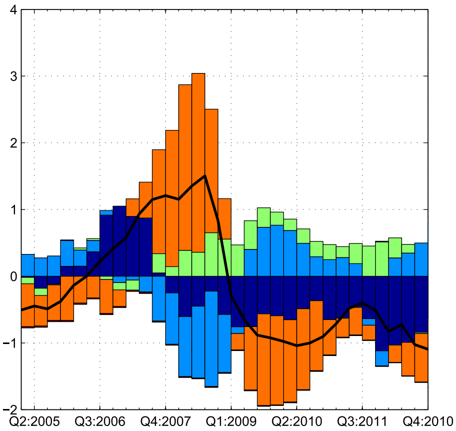
In this paper we highlighted the role of the interbank market as an important driver of the business cycle. We extended the model proposed by Gerali et al. (2010) including an interbank market like in Dib (2010) and we took it to the data of the Euro area using Bayesian estimation. The results suggest that our model could be able to replicate some features of the 2007 financial crisis, especially same interbank market stylized facts. A counterpart shock could divert resources from the risky interbank lending to a safer government bond holding, ending up with higher interest rate on entrepreneurial loans, less credit provided by the bank to the real economy, causing a recession driven by a fall of the investment. The historical decomposition we presented shows how part of the rise of interest rates during the

Figure 5: Historical variance decomposition

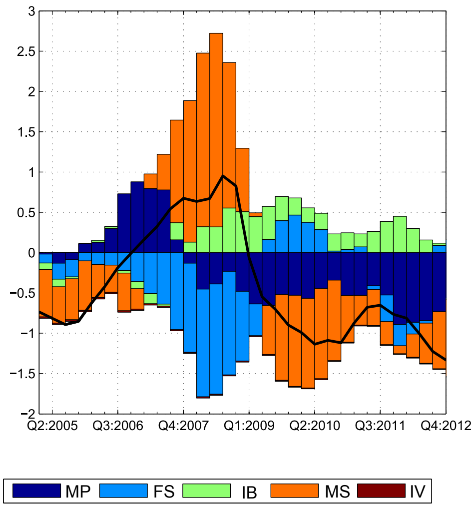
(a) Interbank interest rate



(b) Interest rate on entr loans



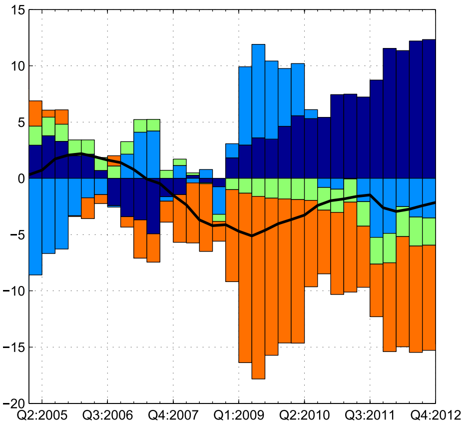
(c) interest rate on households loans



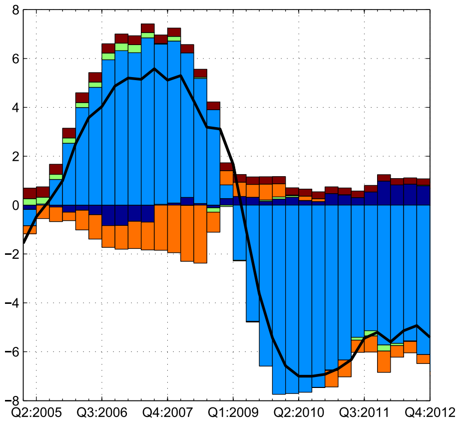
The dark blue bar represents the monetary policy shock, the light blue bar represents all the financial shocks, the green bar represents the counterpart shock, the orange bar group together all the real shocks. The historical decomposition are computed at the posterior median. The rates are absolute deviation from the steady state. All other variables are computed as percentage deviation from the steady state.

Figure 6: Historical variance decomposition

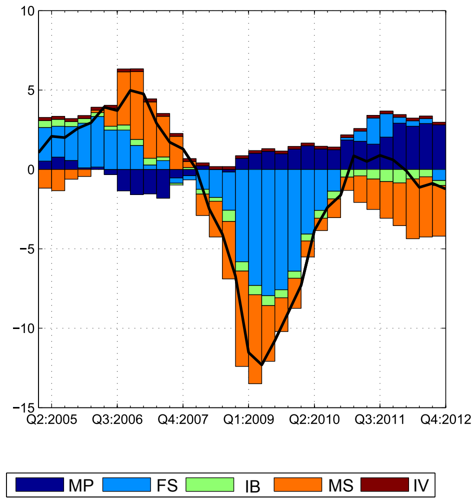
(a) Households loans



(b) Entrepreneurial loans



(c) Investments



The dark blue bar represents the monetary policy shock, the light blue bar represents all the financial shocks, the green bar represents the counterpart shock, the orange bar group together all the real shocks. The historical decomposition are computed at the posterior median. The rates are absolute deviation from the steady state. All other variables are computed as percentage deviation from the steady state.

financial crisis could be explained by the introduction of an interbank riskiness shock. We also investigate the role of monetary policy and we find out that in normal times the interbank market does not interfere with the transmission of the monetary policy. The rise of the interbank market interest rate counteracts the decrease of the policy rate reducing the effectiveness of the traditional tools of the monetary policy. Moreover, the historical decomposition highlights the different effects of the interbank market on households and firms. While the increase of interbank rates seems to affect both the households and the entrepreneurs interest rates, the effect of the interbank shock seems to shrink only the amount of credit available to the households.

Some critical questions remain unresolved. Our log-linearized framework is not the most suited to capture a proper portfolio choice. In order to do that we need to solve the model relying on higher order approximations making estimation a real challenge. Moreover, as reporting in Benes et al. (2014), financial shocks affecting the balance sheet of the banks are linked in a non linear way to the real economy. Even in this case, our set up it is not able to fully capture the role of the financial shocks and also of the interbank market.

Nevertheless, in term of storytelling, our model tells us a plausible and coherent tale about the interbank market turbulence during the 2007 financial crisis.

References

Stéphane Adjemian, Houtan Bastani, Fréderic Karamé, Michel Juillard, Junior Maih, Ferhat Mihoubi, George Perendia, Marco Ratto, and Sébastien Villemot. Dynare: Reference manual version 4. Dynare Working Papers 1, CEPREMAP, April 2011.

Aqib Aslam and Emiliano Santoro. Bank lending, housing and spreads. Discussion Papers 08-27, University of Copenhagen. Department of Economics, May 2008.

John Beirne. The EONIA spread before and during the crisis of 2007–2009: The role of liquidity and credit risk. *Journal of International Money and Finance*, 31(3):534–551, 2012.

Jaromir Benes, Michael Kumhof, and Douglas Laxton. Financial Crises in DSGE Models: A Prototype Model. IMF Working Papers 14/57, International Monetary Fund, April 2014.

Frederic Boissay, Fabrice Collard, and Frank Smets. Booms and systemic banking crises. Working Paper Series 1514, European Central Bank, February 2013.

Stephen P. Brooks and Andrew Gelman. General methods for monitoring convergence of iterative simulations. *Journal of Computational and Graphical Statistics*, 7(4):434–455, 1998.

Michał Brzoza-Brzezina, Marcin Kolasa, and Krzysztof Makarski. A penalty function approach to occasionally binding credit constraints. Technical report, 2013.

Cesar Carrera and Hugo Vega. Interbank market and macroprudential tools in a dsge model. Working Papers 2012-014, Banco Central de Reserva del Perú, June 2012.

Lawrence J. Christiano, Martin Eichenbaum, and Charles L. Evans. Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1):1–45, February 2005.

Matthieu DARRACQ PARIES, Christoffer Kok Sørensen, and Diego Rodriguez-Palenzuela. Macroeconomic propagation under different regulatory regimes: Evidence from an estimated dsge model for the euro area. *International Journal of Central Banking*, 7(4):49–113, 2011.

Gregory deWalque, Olivier Pierrard, and Abdelaziz Rouabah. Financial (in)stability, supervision and liquidity injections: A dynamic general equilibrium approach. *Economic Journal*, 120(549):1234–1261, December 2010.

Ali Dib. Banks, credit market frictions, and business cycles. Working Papers 10-24, Bank of Canada, 2010.

M. Falagiarda and A. Saia. Credit, Endogenous Collateral and Risky Assets: A DSGE Model. Working Papers wp916, Dipartimento Scienze Economiche, Universita' di Bologna, December 2013.

Jesus Fernandez-Villaverde. The econometrics of dsge models. *SERIEs*, 1(1):3–49, 2010.

Damir Filipović and Anders B. Trolle. The term structure of interbank risk. *Journal of Financial Economics*, 109(3):707–733, 2013.

Andrea Gerali, Stefano Neri, Luca Sessa, and Federico M. Signoretti. Credit and banking in a dsge model of the euro area. *Journal of Money, Credit and Banking*, 42(s1):107–141, 09 2010.

Mark Gertler and Nobuhiro Kiyotaki. Financial intermediation and credit policy in business cycle analysis. In Benjamin M. Friedman and Michael Woodford, editors, *Handbook of Monetary Economics*, volume 3 of *Handbook of Monetary Economics*, chapter 11, pages 547–599. Elsevier, 2010.

Charles A. E. Goodhart, Carolina Osorio, and Dimitrios P. Tsomocos. Analysis of monetary policy and financial stability: A new paradigm. CESifo Working Paper Series 2885, CESifo Group Munich, 2009.

Luca Guerrieri and Matteo Iacoviello. Occbin: A toolkit for solving dynamic models with occasionally binding constraints easily. *Journal of Monetary Economics*, 70(C):22–38, 2015.

Florian Heider, Marie Hoerova, and Cornelia Holthausen. Liquidity hoarding and interbank market spreads: the role of counterparty risk. Working Paper Series 1126, European Central Bank, December 2009.

Björn Hilberg and Josef Hollmayr. Asset prices, collateral and unconventional monetary policy in a dsge model. Working Paper Series 1373, European Central Bank, August 2011.

Matteo Iacoviello. House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review*, 95(3):739–764, June 2005.

Matteo Iacoviello. Financial Business Cycles. *Review of Economic Dynamics*, 2014.

Matteo Iacoviello and Stefano Neri. Housing Market Spillovers: Evidence from an Estimated DSGE Model. *American Economic Journal: Macroeconomics*, 2(2): 125–64, April 2010.

Rajkamal Iyer, Samuel Da-Rocha-Lopes, José-Luis Peydró, and Antoinette Schoar. Interbank liquidity crunch and the firm credit crunch: Evidence from the 2007-2009 crisis. Economics Working Papers 1365, Department of Economics and Business, Universitat Pompeu Fabra, April 2013.

Nobuhiro Kiyotaki and John Moore. Credit cycles. *Journal of Political Economy*, 105(2):211–48, April 1997.

Paul Klein. Using the generalized schur form to solve a multivariate linear rational expectations model. *Journal of Economic Dynamics and Control*, 24(10):1405–1423, September 2000.

Eric M. Leeper. Equilibria under 'active' and 'passive' monetary and fiscal policies. *Journal of Monetary Economics*, 27(1):129–147, February 1991.

Alexander Meyer-Gohde. Matlab code for one-sided HP-filters, 2010.

Stephanie Schmitt-Grohé and Martín Uribe. Optimal fiscal and monetary policy in a medium-scale macroeconomic model. Working Paper Series 612, European Central Bank, April 2006.

Moritz Schularick and Alan M. Taylor. Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises, 1870-2008. *American Economic Review*, 102(2):1029–61, April 2012.

Frank Smets and Rafael Wouters. Shocks and frictions in us business cycles: A bayesian dsge approach. *American Economic Review*, 97(3):586–606, June 2007.

Antonio De Socio. The interbank market after the financial turmoil: Squeezing liquidity in a "lemons market" or asking liquidity "on tap". Bank of Italy Working Papers 819, Bankof Italy, September 2011.

James H. Stock and Mark W. Watson. Forecasting inflation. *Journal of Monetary Economics*, 44(2):293–335, October 1999.

Michael R. Wickens. A DSGE model of banks and financial intermediation with default risk. CEPR Discussion Papers 8556, C.E.P.R. Discussion Papers, September 2011.