Interbank Markets and Unconventional Monetary Policies amid a Sovereign Debt Crisis

Aeimit Lakdawala*  Raoul Minetti*  María Pía Olivero†

Abstract

Interbank markets have been at the core of the international transmission of recent financial crises, including the euro area sovereign debt crisis. This paper studies the transmission of shocks in a two-country DSGE model where government bonds are used as collateral in interbank markets. We isolate an “interbank collateral channel” of transmission, which works through banks’ portfolio allocation between loans and government bonds, the resulting value of banks’ bond holdings and the tightness of collateral constraints in the interbank market. We find that, while in some scenarios this channel compounds a “bank net worth channel” in amplifying negative shocks, in other scenarios the “interbank collateral channel” acts as a macroeconomic stabilizer. Credit policies financed by government debt can erode this stabilizing effect.

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*Department of Economics, Michigan State University. Corresponding author: Raoul Minetti, minetti@msu.edu
†School of Economics, Drexel University.
1 Introduction

In the last 20 years or so, a key feature of the EU banking sectors has been the tendency of European banks to hold large amounts of sovereign bonds in their portfolios; of not only their domestic governments, but also of governments of other European countries. During the euro area sovereign debt crisis, banks’ exposure to sovereign debts put significant pressure on the financial position of the banking sector, resulting in a large cutback on the amount of credit granted to non-financial corporations. The complex links between sovereign debt dynamics and banks’ intermediation role are still relatively underexplored. Changes in the value of sovereign debt can affect banks’ net worth and capital constraints, thereby influencing the ability of the banking sector to extend credit to firms and households. This “banks’ net worth channel” of transmission has been increasingly investigated in recent years and has been shown to be quantitatively important in the transmission of sovereign debt crises (see Basu (2009), Bolton and Jeanne (2011), Bofondi and Sette (2012), Bedendo and Colla (2015) and Bocola et al. (2014), among others). However, changes in the value of sovereign debt can also affect banks’ access to liquidity, besides their net-worth position, because government bonds constitute the most important form of collateral pledged by banks in interbank markets. This “interbank collateral channel” of transmission can have a quantitative importance no smaller than the “banks’ net worth channel”, and yet we still have a limited understanding of its possible role during crises. Further, once we take this channel into account, relevant questions arise naturally about the impact of policy interventions. During the euro area crisis, various governments injected liquidity and equity in the banking sector to boost its financial stability. However, to the extent that these policies are financed through issuance of new government debt, they can dilute the safety and acceptability of government bonds as collateral in the interbank market. Put differently, the attempt to directly boost the liquidity of the banking sector can fire back via the effect of the debt-financed policy on banks’ access to interbank market liquidity.

In this paper, we aim to study the link between sovereign debt and credit market dynamics in a scenario where banks hold large amounts of sovereign bonds. Our emphasis is on the role that banks’ bond holdings can have in the interbank market and how they can influence the propagation of international shocks through the impact on banks’ access to interbank market liquidity.\(^1\) We posit a standard model of interbank borrowing (following Gertler and Kiyotaki (2011)) and extend it along two dimensions that are empirically motivated. First, an important reason for banks to hold sovereign bonds is for their use as collateral for wholesale funding in interbank markets.\(^2\) We then introduce a collateral constraint that explicitly captures this friction. Second, we build on the observation that a large share

\(^1\)The empirical analysis of section 2 shows that there is a strong link between sovereign bond holdings and activity in interbank markets.

\(^2\)See, for example, Bolton and Jeanne (2011) for a more detailed discussion.
of bonds issued by countries in the euro area periphery (Greece, Ireland, Portugal and Spain) were held
by banks in the core (France, Germany, UK, and Switzerland). This meant that aggregate shocks that
affected the value of periphery bonds had consequences not just for the periphery countries but also
for core countries through their effect on core banks’ balance sheets. Thus, we consider a two-country
setting where shocks in the periphery can spill over to the core and vice-versa.

Within this framework, a key result is that through the “interbank collateral channel” certain shocks
are amplified while others are mitigated relative to a frictionless model. An important type of shock
considered in the literature on financial frictions is a shock that induces exogenous variations in the value
of productive capital (see Gertler and Kiyotaki (2011) and Gertler and Karadi (2013), among others).
In our model economy, we find that the effect of this capital quality shock is mitigated relative to those
models. As is common in the literature, this shock tends to erode banks’ net worth, thus leading to a
contraction in bank lending. In our setting, however, while banks’ net worth does fall, bond prices and
holdings go up because banks’ appetite for government bonds (relative to participation in firms’ capital)
tends to increase when the negative capital quality shock hits. In turn, the increase in bond prices and
holdings has the effect of loosening the borrowing constraints faced by banks in the interbank market.
We label this mechanism a “portfolio switching effect”. Importantly, this effect highlights a potential
benefit of banks holding large amounts of sovereign bonds in their portfolios. During the sovereign debt
crisis in the euro area banks were often criticized for being responsible for a crowding out of loans to
firms. It was often argued that the switch of banks’ portfolios towards government bonds during the
crisis severely affected credit availability for firms. In our model it turns out that the portfolio switch
is instead a mechanism that attenuates the credit contraction, because it boosts collateral values in
interbank markets and, hence, banks’ access to liquidity, which in turn facilitates credit extension.

However, there is also a clear downside to these holdings. When a “bond quality” shock (a reduction
in the value of bonds) affects bank balance sheets in an adverse manner, the result is a tightening of
their collateral constraint which limits their ability to borrow in interbank markets. This leads to a drop
in funding for the productive sector and ultimately a reduction in output. The implication, consistent
with empirical evidence by Gennaioli, Martin, and Rossi (2014), is that the more severe are the frictions
in the interbank market (making banks hold more bonds), the worse the effect on output of a shock
hitting the value of sovereign debt. Note that this effect can arise in banks of a country that is different
from the source country of the sovereign debt shock, due to the international transmission.\textsuperscript{3}

As noted, during the euro area crisis, various governments conducted unconventional policies aimed
at supporting the banking sector. We study both the direct lending facilities recently instituted by
central banks and equity injections directly into the banking sector. An interesting policy-related

\textsuperscript{3} We also examine the effects of a supply-side shock to total factor productivity in the production sector of periphery
countries. The results suggest that the effects of supply-side shocks are attenuated by the frictions in interbank markets.
question that our model can help answer is whether credit policies used to mitigate a crisis in the periphery countries can also serve to avoid contagion to countries in the core. We show, however, that, since these policies are financed by increased government borrowing, they can potentially impair the safety of sovereign bonds and, hence, their acceptability as collateral in the interbank market. The implied lower pledgeability of collateral worsens the frictions faced by banks in the interbank market. As a result, these credit policies can end up having an adverse effect on banks' access to liquidity that counteracts the portfolio switching effect described above. Our results suggest that both direct lending and equity injections work very similarly as it relates to their effects on the domestic economy in the presence of all the shocks that we study. Interestingly, though, they have not only quantitatively but also qualitatively different implications for international spillovers.

To our knowledge, relatively few papers within the open economy macroeconomics literature look at issues similar to those we investigate: Guerrieri, Iacoviello, and Minetti (2012) (hereafter GIM), Bolton and Jeanne (2011) (hereafter BJ) and Kollmann, Enders, and Müller (2011) (hereafter KEM). In GIM banks hold both bonds and equity (in order to meet regulatory capital requirements). However, since GIM abstract from interbank markets, they cannot study issues related to how banks' ability to tap wholesale funding in interbank markets can transmit sovereign debt problems to the real sector. Introducing interbank markets and the presence of a lender of last resort into this environment allows us to study how, as a result of the increase in the riskiness of their portfolios, the banks of core European countries experienced a liquidity “freeze” in the interbank market. It also enables us to study the recent central bank policies aimed at avoiding the potential credit crunch in the core caused by sovereign debt problems in the periphery.

Our work is also motivated by the findings of previous empirical studies. Kalemli-Ozcan, Papaioannou, and Perri (2013) document that while the relationship between bilateral banking integration and business cycle synchronization has been historically negative, it has turned positive during the recent 2007-2009 financial crisis. In a nutshell, their point is that during or after a financial crisis, increased banking integration across countries is associated to business cycles being more positively correlated across countries, so that international integration in banking acts more as a destabilizer than as a hedging device across countries. Our story of an internationally integrated banking sector through the use of foreign bonds as collateral in wholesale funding introduces a channel of international contagion of sovereign risk and can therefore contribute to explaining these important facts uncovered by

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4Kalemli-Ozcan, Papaioannou, and Perri (2013) also study the role of banks in international shock transmission, but their banks are not subject to constraints (while borrowers are), and there are no interbank markets.

5BJ do look at interbank markets. They study the transmission of default shocks across financially integrated economies where contagion across countries happens through an integrated banking system that holds bonds and pledges them as collateral in interbank lending. They do so using a stylized 3-period, endowment economy model with exogenous returns to investment. Thus, their setting and the mechanisms they uncover are very different from those we study in our DSGE environment with endogenous investment, output and interest rate spreads.

Last, the paper is also related to a number of studies in the literature on the relationship between banking and sovereign default, but in the context of a closed economy without contagion: Basu (2009), Gennaioli, Martin, and Rossi (2014), Bocola et al. (2014),6 Bocola et al. (2014)7, Engler and Große Steffen (2014) and Padilla (2013).8

The rest of the paper is structured as follows. Section 2 provides empirical support for the links that we study in this paper. Section 3 presents the model. Section 4 presents the calibration strategy and the results. Section 5 concludes. Appendix A contains some details on the mathematical derivations. Supplementary results are relegated to Appendix B.

2 EMPIRICAL MOTIVATION

The mechanism that we put forward in this paper is motivated by two empirical observations. First, sovereign bonds constitute the most important form of collateral in interbank markets (see Tables 1, 2 and 3), so it is natural to ask how fluctuations in their values influence banks’ access to interbank market liquidity. Second, an increase in sovereign default risk of periphery countries coincided with an increase in turnover in the repo market using bond collaterals (see Figure 1). This evidence leads us to conjecture a significant link between interbank and sovereign bond markets.

Our model is also motivated in part by the goal of introducing a link between sovereign bond spreads and private sector interest rates. According to Bocola et al. (2014), this link is not yet satisfactorily studied in the previous literature. The correlation between sovereign bond spreads and credit conditions in the private sector is documented in Klein and Stellner (2014), Bedendo and Colla (2015), Bofondi and Sette (2012), Neri (2013) and Neri and Ropele (2013) for European markets; and Durbin and Ng (2000) and Cavallo and Valenzuela (2007) for emerging economies (see Figure 2). This link is also apparent

6In Basu (2009) banks hold government bonds to transfer resources across periods. As a result, when the government defaults it gains consumption (since some of the debt is held internationally) but it simultaneously lowers banks’ capital. Gennaioli, Martin, and Rossi (2014) present a model of endogenous sovereign default where banks hold bonds to store liquidity to finance future investments. In their framework better financial institutions allow banks to be more leveraged and therefore, more exposed to sovereign risk, such that default leads to a decline in private credit.

7Bocola et al. (2014) introduces households composed of bankers and workers. Limited enforcement of debt contracts between households and bankers means that the latter can walk away with the assets. This friction gives rise to a constraint on banks’ leverage and to a lower bound on net worth being the key determinant of banks’ borrowing capacity in retail deposit markets. Differently, we model an interbank market in each country which allows us to study both lending flows in this market and the correlation between sovereign and interbank rates. Second, instead of a leverage constraint in the market for retail deposits, our model introduces a collateral constraint on interbank borrowing.

8Padilla (2013) considers a sovereign default framework in which bankers lend to both the government and the corporate sector. When bankers are highly exposed to government debt, a default triggers a credit crunch and output collapse. In doing so he provides a mechanism competing with that in Mendoza and Yue (2012) to endogenize the costs of default. In his work banks’ holdings of sovereign debt are pinned down by supply and not by frictions in interbank markets. Therefore, his setup is silent about how default affects financial intermediation through interbank markets, which is the key mechanism in our paper.
from the data on credit to the private sector by deposit money banks and other financial institutions (as a share of GDP) for the following set of countries: United States, Japan, Euro Area, Germany, Spain, France, United Kingdom, Greece, Ireland, Iceland, Italy and Portugal. The correlation coefficient between these two series is negative for most of these countries, providing support to the argument that a higher sovereign default risk is associated with a reduction in the supply of bank credit (see Figure 3).9

Our model is also able to match the positive correlation in the data between sovereign bond yields and rates in interbank markets. In Table 1, we report the correlation coefficient between government bond yields and Euribor and EONIA rates.10 In most cases, an increase in sovereign default risk is associated with an increased cost of borrowing for banks in the interbank market.

Last, we want our model to match the result previously documented in the literature by Gennaioli, Martin, and Rossi (2014) that output contractions are larger around episodes of default in countries where banks hold more government bonds.

As we solve the model and obtain simulation results, we calculate the relevant moments of the simulated series and use them to assess whether our model can reproduce these features of the data.

3 The Model

The model is a stylized two-country model, where we will interpret one country as the core EU block and the other as the periphery block. In each country the economy consists of four sectors: households, non-financial firms, banks and a government. In this section, we present the optimization decisions faced by agents in the periphery. Analogous problems apply to agents in the core, and a ‘∗’ superscript is used to denote core variables.

We model interbank markets as in Gertler and Kiyotaki (2011). There is a continuum of non-financial firms of mass 1 located on a continuum of sectors. Capital is not mobile across sectors, but labor is perfectly mobile across sectors and firms. In each period investment opportunities arrive randomly to a fraction \( \pi^i \) of sectors. In a fraction \( \pi^n = (1 - \pi^i) \) of sectors there are no new investment opportunities. Only firms in sectors with investment opportunities can acquire new capital. To do so, they need to issue shares and sell them to banks. The arrival of investment opportunities is i.i.d. across time and across islands. As is standard in the literature on financial frictions, this introduces a link between developments in the financial sector and the real economy, and allows for frictions in financial

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9 The correlation equals -0.48 in the United States, 0.04 in Japan, -0.73 in the Euro Area, -0.63 in Germany, -0.65 in Spain, 0.07 in France, -0.73 in the UK, 0.4 in Greece, -0.63 in Ireland, -0.45 in Iceland, -0.62 in Italy, and -0.4 in Portugal.
10 The Euro OverNight Index Average is computed as a weighted average of all overnight unsecured lending transactions in the interbank market, undertaken in the European Union and European Free Trade Association (EFTA) countries by the panel banks.
intermediation to have real effects.

Banks intermediate funds between households (depositors) and non-financial firms. The interaction
with households and firms happens at two different times. The timing is as follows. In the first stage,
banks raise deposits from households and decide their government bond holdings. After the deposits
and bonds markets close, idiosyncratic uncertainty about the investing opportunities is revealed. Since
some banks will be associated with sectors that receive the investment opportunity, they will want to
borrow funds from banks that have surplus funds because they are associated with sectors that did
not receive this opportunity. A crucial assumption of our paper is that banks will be required to post
collateral in the form of government bonds to borrow in the interbank market. Note that if bonds
did not serve this role as collateral, the only reason why the first stage would matter would be that
it brings net funding for banks into the second stage. But since bonds provide this extra service as
collateral, banks will want to hold bonds to insure themselves against the investment uncertainty that
can potentially induce liquidity shortages.

The setup of the final goods producers is standard and similar to the one in Gertler and Kiyotaki
(2011). There are two types of non-financial firms: goods and capital producers. Goods producers
operate in a competitive market and choose the amount of labor and capital goods to buy from capital
producers.

Finally, the government of each country purchases goods and finances itself by levying lump-sum
taxes and issuing bonds which can be traded internationally.

3.1 Non-Financial Firms

3.1.1 Final Goods Producers  In every period $t$, final goods producers face an opportunity to
invest with probability $\pi^i_t$. Contingent on getting funding from intermediaries, these firms issue state-
contingent securities $X^i_t$ at a market price $Q^i_t$. They use these funds to buy new capital goods. Firms
in this sector operate a technology that is constant returns to scale in labor and capital and is given by

$$Y_t = A_t K_t^\alpha H_t^{1-\alpha}. \quad (3.1)$$

The factor demand curves are given by

$$w_t = (1 - \alpha) \frac{Y_t}{H_t} \quad (3.2)$$

$$Z_t = \alpha \frac{Y_t}{K_t} \quad (3.3)$$
where the wage rate is denoted by $w_t$ and the return to capital by $Z_t$. Finally, the log of total factor productivity (TFP, denoted by $A$) evolves exogenously according to an AR(1) process given by

$$
\log(A_{t+1}) = P \log(A_t) + \nu_{t+1}.
$$

Equation (3.4) shows the AR(1) in logarithms process followed by TFP, where $A_t \equiv (A_t, A_t^*)$ is part of the state vector of the model. $P$ is a matrix of coefficients and $\nu_t \equiv (\nu_t, \nu_t^*)$. The off-diagonal elements of $P$ define the spillovers from one country to the other. The elements of $\nu_t$ are serially independent, bivariate, normal random variables with contemporaneous covariance matrix $V$. TFP processes are potentially related across countries through the off-diagonal elements of both $P$ and $V$.

### 3.1.2 Capital Producers

The capital producing firms choose their investment levels to maximize the expected present discounted value of lifetime profits given by the value of new capital sold to firms in investing sectors minus the cost of investment inclusive of adjustment costs. Their optimization problem is:

$$
\max_{I_t} E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \left\{ Q^i_{t+i} I_{t+i} - \left[ 1 + f \left( \frac{I_{t+i}}{I_{t+i-1}} \right) \right] I_{t+i} \right\}.
$$

Therefore, in equilibrium the price of investment goods has to equal the marginal cost of producing capital goods according to

$$
Q^i_t = 1 + f \left( \frac{I_{t+i}}{I_{t+i-1}} \right) + \frac{I_{t+i}}{I_{t+i-1}} f' \left( \frac{I_{t+i}}{I_{t+i-1}} \right) - E_t \Lambda_{t,t+1} \left( \frac{I_{t+1}}{I_t} \right)^2 f' \left( \frac{I_{t+1}}{I_t} \right).
$$

Let $\delta$ be the rate of physical depreciation. Then, capital accumulated in sectors that receive investment opportunities is $I_t + \pi^i(1 - \delta)K_t$, while in sectors without them it is $\pi^n(1 - \delta)K_t$. Aggregating and denoting by $\psi_t$ a shock to the quality of physical capital available for production at time $t$, the law of motion for aggregate capital is

$$
K_{t+1} = \psi_{t+1} [I_t + (1 - \delta)K_t].
$$

The capital quality shock is meant to represent disruptions in the good producing sector that are unrelated to financial issues. One example is that certain goods become obsolete over time and this shock is a reduced form way of capturing the effect of that obsolescence on the capital stock. This provides a convenient way of capturing exogenous variation in the value of capital. Following Gertler and Kiyotaki (2011) we will assume that $\psi_t$ follows an autoregressive process.

$$
\psi_t = \rho^\psi \psi_{t-1} + \epsilon_t^\psi.
$$
3.2 Households  To keep the model tractable, we will follow the standard assumption of a representative household. Households are comprised of workers who earn wages and bankers who earn profits by managing financial intermediaries. However there is perfect consumption insurance within the household. We follow the setup in Gertler and Kiyotaki (2011) where bankers exit with a probability \((1 – \sigma)\) and transfer all their earnings to the household. This is done to ensure that banks cannot accumulate enough assets to end up in a situation where the collateral constraint never binds. To keep the relative number of workers and bankers constant, \((1 – \sigma)f\) workers randomly convert into bankers where \(f\) is the fraction of bankers.

Households earn the wage rate \(w_t\), a rate of return \(R_{D_t}^{D_t} \) on their deposits and profits from owning both intermediaries and non-financial firms, \(\Pi_t\). They use their funds for consumption \(C_t\), to pay lump-sum taxes \(T_t\), and hold deposits \(D_t\). Households smooth consumption through the use of banking sector deposits. They choose consumption, savings and labor supply to maximize lifetime utility according to

\[
\max_{C_t, D_t, H_t} E_0 \sum_{t=0}^{\infty} \beta^t H U(C_t, H_t) \tag{3.9}
\]

s.t.

\[
C_t + D_t + T_t = R_{D_t}^{D_{t-1}} D_{t-1} + w_t H_t + \Pi_t. \tag{3.10}
\]

Households’ optimization yields equations (3.11) and (3.12). Equation (3.11) is the standard labor supply condition stating that the intratemporal marginal rate of substitution between consumption and leisure has to equal the wage rate. Equation (3.12) is the Euler condition governing the intertemporal allocation of savings.

\[
- \frac{U_H'}{U_{C_t}'} = w_t \tag{3.11}
\]

\[
1 = \beta^H E_t \left[ \frac{U_{C_{t+1}}'}{U_{C_t}'} R_t^D \right] \tag{3.12}
\]

3.3 Banks  In period \(t\) the objective of each individual bank in sector \(h\) in the periphery is to choose deposits \((d_t)\), local and foreign bond holdings \((b_t^p\) and \(b_t^{p*}\), respectively), interbank position \((m_t^h)\) and holdings of shares in non-financial firms \((x_t^h)\), where the \(h \in \{i, n\}\) superscript represents whether an investing opportunity is available or not in that sector. Since deposits and bond holdings are chosen before uncertainty over types is realized, banks in sectors without investment opportunities find themselves with a surplus of funds, while banks in sectors with investment opportunities face a shortage.\(^{11}\) The former will then lend to the latter at an interest rate \(R_t^M\). The key assumption in our

\(^{11}\)Notice that \(d_t, b_t^p\) and \(b_t^{p*}\) are not indexed by \(h\).
model is that banks are required to pledge government bonds as collateral to borrow in the interbank market. This collateral requirement can cause the cost of credit for the production sector to increase over and above the risk-free rate. This is how the friction in interbank markets that we introduce works to inflict an actual cost on the real economy. The fact that banks are allowed to use both domestic and foreign bonds as collateral introduces a link between the domestic and foreign banking sectors. A shock to the value of foreign bonds changes the value of collateral that domestic banks can pledge. This change affects the cost of interbank borrowing and ultimately affects funding for firms in the domestic economy.

Interbank markets are domestic, so that lending banks in each country can borrow from non-lending banks only in their own country. While we could have well assumed international interbank markets, we chose to stay with markets that operate only at the domestic level because we want to focus on the international transmission channel that arises from the fact that both local and foreign bonds are used as collateral, and to disentangle this channel from that of flows of funds across countries in interbank markets.

Each bank of type $h$ maximizes the expected present discounted value of the stream of future dividends ($e$) discounted with the stochastic intertemporal discount factor $\Lambda$. In equilibrium, this is given by the households’ (bank owners) intertemporal marginal rate of substitution.\footnote{The effective discount factor between any periods $t$ and $t+i$ incorporates $\sigma^i$ to account for the conditional probability of still being in business up to period $t+i$.}

\[
\max_{d_t, b^p_t, b^p^*_{t-1}, m^h_t} V_t = E_t \sum_{i=0}^{\infty} \sigma^i \Lambda_{t,t+i} e^h_t = \Lambda_{t,t+i} \equiv \beta^i \frac{U^h_t}{U^h_{t+i}}
\]

\[
\text{s.t.} \\
\begin{align*}
  e^h_t &= \left[ Z_t + (1-\delta)Q^h_t \right] \psi_t x_{t-1} - R^{d}_{t-1} d_{t-1} - R^{M}_t m_{t-1} + b^p_{t-1} + b^{p*}_{t-1} - AC(b^p_{t-1}, b^{p*}_{t-1}) \\
  e^h_t &= \left( Q^h_t x^h_t + q_t b^p_t + q^*_t b^{p*}_t \right) - \left( m^h_t + d_t \right) \\
  m^h_t &\leq \frac{1}{\chi} \left( q_t b^p_t \omega_t + q^*_t b^{p*}_t \right)
\end{align*}
\]

Equation (3.14) introduces bank $h$’s profits in period $t$ where asset yields are given by the returns on firms’ shares and discounted bond payments minus the cost of deposits and interbank borrowing used to finance asset purchases. $Z_t$ is the dividend payment at $t$ on firms’ shares bought in $t-1$; $Q^h_t$ is the market price of a bank of type $h$’s claim of a unit of non-financial firms’ present capital\footnote{This market price is measured at the end of the period after types are realized and therefore, it is indexed by $h$ and it is a function of the volume of investment opportunities that the bank faces.}; $R^{d}_{t-1}$ and $R^{M}_t$ are the interest rates on deposits and interbank borrowing, respectively; and $\psi_t$ is an aggregate exogenous shock to the quality of capital. $AC(.)$ represents a convex adjustment cost for changing bond holdings.
Equation (3.15) is the balance sheet constraint according to which banks’ equity equals the difference between their assets and their liabilities.

Last, equation (3.16) imposes the collateral constraint according to which interbank borrowing cannot exceed \( \frac{1}{\chi} \) of the value of domestic and foreign bond holdings (priced at \( q_t \) and \( q_t^* \), respectively). As noted, we want to capture the fact that bonds issued by the sovereigns of periphery countries might become less desirable as collateral when these countries start using credit policies aggressively, to the extent that these policies are financed by issuance of new debt. We then let these bonds enter the collateral constraint with a factor of \( \omega_t \). When we discuss credit policies in subsection 3.4 below, we provide more details on the functional form we assume for \( \omega_t \) and its role in the model.

The banks’ FOCs with respect to \( d_t, x_t^h, b_t^p \) and \( b_t^{p*} \) are given by equations (3.17), (3.18), (3.19) and (3.20), respectively.

FOC w.r.t. \( d_t \):

\[
E_t \Lambda_{t,t+1} \Omega_{t+1} (R_t^D - R_t^M) = E_t \Lambda_{t,t+1} \chi \bar{\lambda}_t
\]  
(3.17)

where \( \bar{\lambda}_t = (\pi^i \lambda^i_t + \pi^n \lambda^n_t) \). Since in equilibrium the collateral constraint is never binding for banks in sector \( n \), \( \lambda^n_t = 0 \) and \( \bar{\lambda}_t = \pi^i \lambda^i_t \).

FOC w.r.t. \( x_t^h \):

\[
E_t \Lambda_{t,t+1} \Omega_{t+1} \left\{ \frac{[Z_{t+1} + (1 - \delta)Q_{t+1}^h]}{Q_t^h} \psi_{t+1} - R_t^M \right\} = E_t \Lambda_{t,t+1} \left\{ \lambda^p_t \chi \right\}.
\]  
(3.18)

FOC w.r.t. \( b_t^p \):

\[
E_t \Lambda_{t,t+1} \Omega_{t+1} \left[ \left( 1 - \frac{\partial AC(\cdot)}{\partial b_t^p} \right) q_t - R_t^M \right] = E_t \Lambda_{t,t+1} \left[ \bar{\lambda}_t (\chi - \omega) \right]
\]  
(3.19)

FOC w.r.t. \( b_t^{p*} \) is:

\[
E_t \Lambda_{t,t+1} \Omega_{t+1} \left[ \left( 1 - \frac{\partial AC(\cdot)}{\partial b_t^{p*}} \right) q_t^* - R_t^M \right] = E_t \Lambda_{t,t+1} \left[ \bar{\lambda}_t [\chi - 1] \right]
\]  
(3.20)

The intuition behind equation (3.17) is that in expected, discounted terms, the cost of deposits exceeds the cost of interbank borrowing for banks by a measure of the tightness of the collateral constraint given by two elements: (1) the parameter \( \chi \), which equals the reciprocal of the loan-to-value (LTV) ratio, and (2) the non-zero shadow value \( \bar{\lambda}_t \) of a binding constraint. This equation could also be interpreted as stating that the cost of both sources of funding have to be equal in expected terms, with \( E_t \Lambda_{t,t+1} \Omega_{t+1} R_t^D \) representing the cost of retail funds, and \( E_t \Lambda_{t,t+1} \left\{ \Omega_{t+1} R_t^M + \chi \bar{\lambda}_t \right\} \) the “effective” cost...
of interbank borrowing which consists of the interest rate on interbank loans plus the cost implied by a binding collateral constraint.

Equation (3.18) implies that the “effective” cost of interbank borrowing (which can be also thought of as the marginal cost of acquiring equity in the non-financial sector) has to optimally equal the marginal return of that equity given by the capital shock-adjusted sum of dividends plus capital gains/losses.

Similarly as in equation (3.18), the intuition behind equations (3.19) and (3.20) is that the “effective” cost of interbank borrowing (including the cost of collateral) has to equal the expected marginal return on domestic and foreign bonds net of adjustment costs,

\[ E_t \Lambda_{t,t+1} \Omega_{t+1} \left(1 - \frac{\partial AC(1)}{\partial p_t^*} \right) q_t \] and \[ E_t \Lambda_{t,t+1} \Omega_{t+1} \left(1 - \frac{\partial AC(1)}{\partial p_t^*} \right) q_{t+1} \], respectively.

Analogous optimization conditions apply to banks in the core where we use \( b_c \) to denote core banks’ total holdings of core bonds (priced at \( q^* \)), and \( b_c^* \) to denote core banks’ total holdings of periphery bonds (priced at \( q \)).

### 3.3.1 Evolution of Banks’ Net Worth

We use capital letters to denote aggregate quantities and \( N \) to denote aggregate net worth. Aggregate net worth for all banks of type \( h \) is:

\[ N^h_t = \pi^h \left\{ (\sigma + \xi) \left[ Z_t + (1 - \delta)Q_t^h \right] \psi_t X_{t-1} + (\sigma + \xi) \left( B_{t-1}^p + B_{t-1}^{p*} \right) - \sigma R_{t-1}^D D_t \right\} \] (3.21)

where \( \pi^h \) is the share of banks that are of type \( h \) and \( \sigma \) is the fraction of banks that survives until the current period. Included in the above expression is the net worth of new or entering entrepreneurs which is given by family transfers of \( \frac{\xi}{(1-\sigma)} \) of the value of assets of exiting entrepreneurs.

### 3.4 Fiscal and Credit Policy

The government finances government spending and credit policies through taxes and by issuing bonds. \( B_g^p \) is used to denote the total supply of bonds by governments in the periphery. Government spending and taxes are assumed to be determined by the following processes

\[ G_t = \rho^G G_{t-1} + (1 - \rho^G) m_G Y_t \] (3.22)

\[ T_t = \rho^T T_{t-1} + (1 - \rho^T) m_T Y_t \] (3.23)

In addition to the autoregressive component, we allow for government spending and taxes to be affected by the current level of output.

We consider two types of unconventional credit policy. In the first, the government lends directly to goods-producing firms. In the second, the government injects equity into banks. For both, the policy is represented as a simple rule where the government adds to firms’ financing or to the total net worth of banks, and finances these operations by issuing debt (\( B^g \)). The share of total financing or net worth
that is purchased by the government is modelled as an increasing function of the deviation with respect to steady state of the spread between returns on capital and the risk-free rate.

Direct lending \((X^g)\) and equity injections \((N^g)\) are governed by the following policy rules where time subscripts are omitted to simplify notation:

\[
X^{g,h} = \Phi X X^h \tag{3.24}
\]

\[
N^{g,h} = \Phi N N^h \tag{3.25}
\]

\[
\Phi X = \phi X \left[ (E_h R^k_h - R^d) - \left( \pi^i \tilde{R}^k_i + \pi^n \tilde{R}^k_n - \tilde{R}^d \right) \right] \tag{3.26}
\]

\[
\Phi N = \phi N \left[ (E_h R^k_h - R^d) - \left( \pi^i \tilde{R}^k_i + \pi^n \tilde{R}^k_n - \tilde{R}^d \right) \right] \tag{3.27}
\]

where \(X^{g,h}\) denotes direct lending to productive sector \(h \in \{i, n\}\), \(N^{g,h}\) denotes equity injections into banks of sector \(h \in \{i, n\}\), and \(E_h R^k_h\) is the expected return on capital shares across sectors conditional on being in sector \(h\) at time \(t\), i.e. \(E_h R^k_h \equiv \left\{ \pi^i \left[ \frac{Z_{t+(1-\delta)Q_{t+1}^i}}{Q_{t}^i} + \pi^n \frac{Z_{t+(1-\delta)Q_{t+1}^n}}{Q_{t}^n} \right] + \pi^i \tilde{R}^k_i + \pi^n \tilde{R}^k_n \right\} \).

Credit policy, in both forms, yields the obvious benefit of providing extra liquidity to entrepreneurs or to the banking sector. At the same time, in our framework we also allow the credit policy to present a trade-off: the pledgeability as collateral of bonds issued by countries in the periphery is decreasing in the share of issuance that is used to finance unconventional credit policies. In particular, we let the parameter \(\omega\) in banks’ collateral constraint be endogenous to the extent of credit policy intervention according to equation (3.28).

\[
\omega_t = \begin{cases} 
1 - \left( \pi^i Q_t^i X_{i,t}^g + \pi^n Q_t^n X_{n,t}^g \right) + \left( \pi^i N_{i,t}^g + \pi^n N_{n,t}^g \right) \\
B_t^g 
\end{cases} \tag{3.28}
\]

This modeling choice is based on the fact that during the euro area debt crisis in 2009 and 2010, government securities from countries under an assistance programme were no longer accepted in European repo markets (Engler and Große Steffen (2014)). The negative impact on default risk attached to sovereign bonds of financial rescue packages in 2000 in Europe has also been studied by Ejsing and Lemke (2011).14

3.5 Equilibrium In this section we use capital letters to denote aggregate quantities. In the market for bank securities, total securities issued on investing and non-investing sectors equals aggregate capital acquired by each type. Also, total securities includes both those “sold” to the private sector and the

\[
Gorton and Metrick (2012) \text{ provides evidence that increased risk on US-Treasury bonds led to a “run on repo” markets, contributing in part to the US financial crisis.}
\]
government:

\begin{align*}
X^i_t &= I_t + (1 - \delta)\pi^i K_t \quad (3.29) \\
X^n_t &= (1 - \delta)\pi^n K_t \quad (3.30)
\end{align*}

\[ X^p_{h,t} + X^n_{h,t} = X^h_t \quad h \in \{i, n\} \quad (3.31) \]

Markets clearing in the bonds market requires that bonds issued by governments in the periphery and the core, respectively are held by domestic and foreign banks.

\begin{align*}
B^g_t &= (B^p_t + B^c_t) \quad (3.32) \\
B^{g*}_t &= (B^{h*}_t + B^c_t) \quad (3.33)
\end{align*}

Market clearing in the market for interbank loans in each country requires

\begin{align*}
(M^i_t + M^{n*}_t) &= 0 \quad (3.34) \\
(M^{i*}_t + M^{n*}_t) &= 0 \quad (3.35)
\end{align*}

Finally, the balance sheet constraint of the entire banking sector is given by

\begin{align*}
\left( D_t + \sum_{h=i,n} N^h_t \right) &= \left( \sum_{h=i,n} Q^h_t X^h_t + q^p_t B^p_t + q^{p*}_t B^{p*}_t \right) \quad (3.36) \\
\left( D^{*}_t + \sum_{h=i,n} N^{h*}_t \right) &= \left( \sum_{h=i,n} Q^{h*}_t X^{h*}_t + q^{*}_t B^c_t + q^{*}_t B^{c*}_t \right) \quad (3.37)
\end{align*}

4 Calibration and Results

4.1 Calibration This section describes the parameter values used in the calibration for the periphery bloc, with the assumption that core parameters are the same. When these parameters are different across blocs, we provide an explanation.

For the households, we use GHHH preferences which results in the marginal utility of consumption
and the marginal disutility of labor effort to be of the following form:

\[ U'_{c_t} = \left( C_t - \gamma C_{t-1} - \frac{1}{\psi^H} H_t^{\psi^H} \right)^{-\sigma_c} - \beta^H \gamma \left( C_{t+1} - \gamma C_t - \frac{1}{\psi^H} H_{t+1}^{\psi^H} \right)^{-\sigma_c} \] (4.1)

\[ U'_{H_t} = (H_t^{\psi^H}-1) \] (4.2)

This assumption guarantees that there are no wealth effects on labor supply and that none of the results are driven by households’ labor effort rising in response to the negative effects of credit frictions on their wealth.

The household discount factor \( \beta^H \) is set to 0.97. This implies an annualized steady-state deposit rate of 3.09%. The other parameters of the utility function are assigned values that are fairly conventional in the literature. The intertemporal elasticity of substitution is set to 2, the price elasticity of labor supply parameter \( \psi^h \) is set to 2 following Mendoza and Yue (2012) and the degree of habit persistence in consumption \( \gamma \) is 0.45. The parameters that govern the frictions in interbank markets are chosen based on Gertler and Kiyotaki (2011). Thus, it is assumed that one fourth of the sectors face investment opportunities (\( \pi^i = 0.25 \)), that the survival rate of bankers is \( \sigma = 0.97 \), and that the transfer to entering bankers \( \varsigma \) is 0.003. In the production sector, the effective share and depreciation rate of capital are set to the standard values of \( \alpha =0.33 \) and \( \delta =0.025 \), respectively. The adjustment cost to capital function is specified as

\[ AC (K_{t+1}, K_t) = \frac{\phi^K}{2} \left( \frac{K_{t+1}}{K_t} - 1 \right)^2 \]

with \( \phi^K = 2 \).

The steady-state share of government spending \( m_G \) is set to 0.18 and that of tax revenue to \( m_T =0.20 \), which together yield a positive sustainable debt-to-GDP ratio in steady-state equal to \( \frac{(m_T-m_G)}{(1-q)} \).

The adjustment costs to bond holdings are introduced into the model to help pin down bond holdings. The adjustment cost parameters are set to match these holdings and spreads in the data for the European Union. \( \phi_{BP} \) is set to to match the spread between periphery and core yields \( \left( \frac{1}{q} - \frac{1}{q^*} \right) \) calculated in the data as the difference between yields on German bonds and average yields for French, Spanish and Italian bonds. \( \phi_{BP^*} \) is set to match the spread between German bond yields and interest rates on deposits in the German market obtained from the FRED database and averaged over the period 2003-2014. \( \phi_{BC^*} \) is set to match the data for the share of bonds issued by sovereigns in the periphery that are held within their own countries, i.e. the ratio \( \frac{B_p}{P_g} \) of 62%. \( \phi_{BC} \) is set to match the share of bonds issued by core countries that are held in the periphery from the European stress tests (see Tables
All parameter values are presented in Table 5. The relationship among all relevant interest rates in steady state for both the benchmark parametrization of the model (high \( \chi \)) and an alternative low \( \chi \) are presented in Table 6.

The intuition behind these results is the following. From equation (3.18) and since \( \lambda^a = 0 \), it follows immediately that in equilibrium \( R^k_n = \frac{Z}{Q_n} + (1 - \delta) = R^m \). Using the same logic, but understanding that the collateral constraint is assumed to be always binding for banks associated with production sectors that do receive investment opportunities, \( R^k_i > R^m \). From FOC (3.17) it becomes clear that the rate of return to shares in investing sectors also exceeds the interest rate on deposits such that \( R^k_i > R^d \).

Moreover, the cost of deposits for banks is higher than that of interbank borrowing since the former are not subject to collateral constraints. Last, from equations (3.19) and (3.20), the rate of return (net of adjustment costs) on sovereign bonds issued by the periphery exceeds the return on those issued by the core by a factor of \( (1 - \omega) \).

The key feature of our model is that banks are required to pledge bonds to borrow in the interbank market. The parameter \( \chi \) governs the tightness of this constraint, reflecting features that determine the willingness of lenders to make loans in the interbank market for a perceived quality of sovereign bonds. Notice that \( \chi > 1 \) is needed to generate positive spreads between the expected return on equity shares owned by the banking sector and its cost of funding. In the baseline calibration, we set the parameter in the collateral constraint \( \chi = 1.8 \). In an alternative scenario, we weaken the friction by setting \( \chi = 1.4 \). A lower value of \( \chi \) indicates that for a given level of bond holdings, banks can borrow more in the interbank market, that is, the collateral constraint is looser. We compare results for both cases in the discussion below. Since the constraint takes the form \( \chi M_i \leq \pi^i [q B^p \omega + q^* B^{p*}] \) and since \( \pi^i = 0.25 \), this calibration implies a steady-state ratio of interbank borrowing to bond holdings of approximately 15%.

4.2 Capital Quality Shocks

4.2.1 Effects on the Domestic Economy We start by studying the response of the economy to a negative capital quality shock in the periphery. The impulse response functions are presented in Figure 4. As a comparison, we plot the responses in a frictionless Real Business Cycle model as well as in a GK-type of model with interbank markets but without the collateral constraint and bond holdings. Note that relative to the frictionless model, output and capital fall more in our model. This is due to the adverse effect of the shock on the expected rate of return to capital, which leads firms in the

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production sector to lower their demand for investment, capital and employment, and their output. In the standard RBC model banks play no role other than being frictionless intermediaries between households and firms. When taking deposits from households they pay a rate of return equal to the rate that they charge when lending to firms, so that they play no role in the transmission of shocks.

By contrast, in our model with a collateral constraint imposed on banks’ borrowing in interbank markets, the effect of the shock on banks’ portfolios plays a crucial role in the transmission mechanism of shocks. In the benchmark calibration of the model, the net worth of banks falls by more than 10% in response to this shock that hurts the value of their most important asset: equity shares of ownership in the production sector. In the Gertler and Kiyotaki (2011) model with interbank markets and a “walk-away” constraint on banks, the drop in net worth would tighten that constraint and result in a further reduction of the supply of credit and an amplification of the shock. In our model with interbank markets and a collateral friction, an opposite mechanism is at work through which the effects of the shock are not amplified, but mitigated relative to the GK-type model.16 Notice that in Figure 4 the solid lines for the benchmark model lie in between the dashed ones (for the RBC) and the dotted ones (for the GK-type model). Even though the net worth of banks falls, as banks switch away from shares (now the lower quality and less attractive financial asset) towards bonds, here we get an increase in both the price and quantity of bonds.17 This has the effect of boosting the nominal value of banks’ bonds portfolio relative to that of bank shares, and actually loosening the collateral constraint in equation (3.16). Thus, we see a fall in the value of the spread between the expected return on capital on investing islands and the deposit rate. This is a feature that is unique to our model and is not present in other models with financial frictions like Gertler and Kiyotaki (2011). This extra feature arises because i) we introduced a richer asset structure for banks and, hence, allowed for a substitution channel to be at work between lending to firms and investment in government bonds; ii) the financial asset alternative to loans, that is, government bonds act as collateral in the interbank market. In response to a negative shock to one of the assets held by banks, capital in this case, banks are allowed to substitute away from capital and into sovereign bonds as an alternative asset. This effect allows for the collateral constraint to be alleviated, for banks’ access to liquidity to increase, and for their supply of credit to fall by less than in the GK-type of model.18 In what follows we call this the “portfolio switching” effect.

The “portfolio switching” effect, coupled with the fall in the demand for capital and for shares by firms in the investing sectors that is triggered by the shock, makes investment fall but by less than

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16 The GK-type of model is not exactly the same model as in GK since it does include interbank markets, but without the “walk-away” friction.
17 Another reason why the price of bonds $q$ increases is that the reduction in the effective (or quality-adjusted) quantity of capital raises its price $Q'$ and, by a standard arbitrage argument, the price of competing assets rises too.
18 This last result is evident from the drop in both the shadow value of the constraint ($\lambda$) and the spread between the expected return on capital and the risk-free rate.
otherwise. The drop in investment leads to a drop in capital and, as a result, also in the marginal product of labor, the demand for labor and employment. With both factors of production falling, output follows. With less output, domestic absorption follows, and both private consumption and government spending fall. This is how the link between frictions in credit markets and the real economy works. Thus, in our framework it turns out that the portfolio switch is a mechanism that attenuates the credit contraction, because it boosts collateral values in interbank markets and therefore, banks’ access to liquidity, which in turn facilitates credit extension. This is fundamentally different from a situation where the portfolio switch only means a crowding out of loans to the private sector. During the crisis in the euro area banks were often criticized for crowding out credit to firms because of an excess appetite for government bonds. Our results indicate that these criticisms might have been missing some nuisance.

In Figure 6 we present these results and compare them across two economies: a tight collateral constraint (high $\chi$) and a looser constraint (low $\chi$). Importantly, the tighter the collateral constraint, i.e. the higher the value of the parameter $\chi$, the more incentives banks face to switching since increasing bond holdings alleviates the constraint. Thus, the higher $\chi$, the stronger the “portfolio switching” effect.\(^{19}\)

4.2.2 International Transmission An appealing feature of our model is that it can shed some light on the international spillover of shocks. In figures 5 and 7 we plot the response of core variables to a reduction in $\psi$ in the periphery countries. Our model isolates a channel that works through bond holdings that adds to the direct effect on international trade in goods between the two countries. As a result, the effects on real variables in the periphery is mimicked in the core. It is important to note that this happens with no exogenous shock whatsoever in the core (the exogenous process assumed for $\psi$ does not allow for cross-country spillovers). The reason for the positive comovement across countries is the following: The increase in the price of bonds in the periphery ($q$) results, by a standard arbitrage argument, in an increase in bond prices in the core ($q^*$) as well. This drives down the demand for both domestic and foreign bonds by banks in the core ($B^c$ and $B^{c*}$, respectively); the effect on quantities dominates the effect on prices in bond markets; the nominal value of bond portfolios falls; the collateral

\(^{19}\)Worthy of note is that the price of bonds rises by more the tighter the constraint as bonds play a more important function in the model economy. As a result, the quantity demanded for bonds falls with a higher $\chi$. The net effect on the nominal value of bonds is a negative one. The negative shock also lowers the demand for bank shares in both investing and non-investing sectors and the demand for interbank borrowing by banks. This last effect is stronger for a tighter constraint. Then, the net effect is to relax the collateral constraint. Since the effect of the shock on prices is quantitatively similar in both the low and the high $\chi$ scenarios, but its effect on quantities ($B^p$ and $B^{p*}$), and since the reduction in the demand for shares by firms is stronger for a higher $\chi$, the relaxation of the constraint is weaker and the drop in its shadow value $\lambda$ is smaller for a tighter constraint. The pattern followed by $\lambda$ is also evident in the spread between the expected (across sectors) return to capital and the rate on deposits. Notice that both rates fall together with $\psi$, but the returns to capital do so more than proportionally, reflecting the relaxation of the collateral constraint. Keeping in mind that this relaxation of the constraint partially offsets the initial negative impact of the shock, and that this offsetting is weaker for a tighter constraint, the net negative effect on real variables of an exogenous fall in the quality of capital is stronger as $\chi$ rises and the constraint gets tighter.
constraint tightens; the amount of interbank borrowing \((M^i)\) that banks in the core are able to obtain drops; and their supply of credit to the production sector \((X^i)\) falls. With less financing available for investment, the demand for investment and capital drops in the foreign economy too; the marginal product of labor falls; the demand for labor falls; and both employment and output follow. Summarizing, even without any direct shock to the foreign economies, economic activity is negatively affected there because of the collateral friction in interbank markets.

An important caveat to our model is that the spillover effect arises because of how the increase in domestic bond prices translates to foreign bonds. In a richer environment (closer to actual economies) where bonds issued by sovereigns in the periphery and the core differ in risk, this link from \(q\) to \(q^*\) might be weakened relative to our model in which there are no risk considerations.

4.2.3 Unconventional Credit Policy Intervention

Direct lending from the central bank to the productive sector has three effects: First, it provides extra liquidity for firms so that the reduction in aggregate lending is less significant than that in private lending (i.e. from equations (3.24) and (3.36)

\[\hat{X} = \hat{X}^p - (1 - \Phi X)\]  
Since \(\hat{X}^p < 0\) and \((1 - \Phi X) < 0\), it turns out that \(\hat{X} > \hat{X}^p\) In absolute value, \(|\hat{X}| < |\hat{X}^p|\).  
Second, the share \(\omega\) of domestic bonds that can be pledged as collateral in interbank markets falls as a portion of government bonds issuance is devoted to financing the unconventional credit policy. Thus, all else equal, the introduction of the policy tightens the collateral constraint, partially eroding the portfolio switching effect described above. Third and last, since the policy intervention is financed with bond issuance, the supply of bonds increases in the periphery countries and the price of their bonds falls. The second and third effects lead the collateral constraint to become tighter and the spread to increase a few quarters after the shock initially hits the economy. Nevertheless, the liquidity effect described first seems to dominate so that the responses of all real variables, employment, investment, consumption and output, are all attenuated in the presence of credit policy.

Along the dotted lines in Figure 8 we have allowed for the policy to still work but in this case, the pledgeability of domestic bonds is not a function of the cost of implementing the policy (i.e. \(\omega\) in equation (3.16) is a constant). In this last case the second of the three effects described above is not present, so that the real effects are still attenuated but less noticeably than in the benchmark model. In other words, if pledgeability is not variable, then the policy is more effective at helping the economy out of the recession generated by the negative shock to capital.

The second type of credit policy intervention that we study is equity injections by the central bank directly into the banking sector. The effects of this policy resemble those of direct lending. Interestingly, even with public net worth \((N_g)\) increasing in both investing and non-investing sectors, total net worth in the banking sector falls by more when credit policy is implemented, underscoring the presence of a

\[^{20}\text{Since this is true for every sector, we have dropped the } h \text{ superscripts to simplify notation.}\]
crowding out effect on the private component of net worth (see Figure 10).

In terms of the transmission of their effects to countries in the core, these policies are qualitatively quite similar. With both policies and just two quarters after the shock, the increase in both the price and the quantity traded of bonds allows for bond value to increase, so that the shadow value of the constraint and the cost of credit fall, and all real variables rise in the core. Quantitatively, equity injections are more efficient, and our model uncovers a theoretical mechanism through which equity injections in the periphery benefit the core more, i.e. a mechanism that can justify why countries in the core would be more willing to finance the second type of credit policy (see figures 9 and 11).

In Table 7 we present the cumulative responses of output, employment, capital, investment and consumption for five economies: no policy intervention, direct lending and equity injections each with variable and constant pledgeability ($\omega$). The difference in cumulative responses (in percentage points) obtained by direct lending are 4, 2, 6, 11 and 6 for output, employment, capital, investment and consumption, respectively. The corresponding numbers for equity injections are 6, 3, 11, 9 and 8 percentage points.

4.3 Bond Returns Shocks

4.3.1 Effects on the Domestic and Foreign Economy In this section we study the economy’s response to a shock that exogenously lowers the rate of return of bonds issued by countries in the periphery. The impulse response functions are presented in figure 12 for alternative strengths of the collateral friction.\textsuperscript{21}

This shock makes periphery bonds less desirable, lowers the demand ($B^p$) and works to endogenously lower their market price ($q$). Since banks can also post foreign bonds (those issued by countries in the core) as collateral, the shock induces them to switch away from periphery bonds and towards core bonds, which in turn raises the demand for these bonds ($B^{p*}$) and their market price ($q^*$). The combined effect of the increase in the price and quantity of foreign bonds and the fall in the price and quantity of domestic bonds results in a reduction in the nominal value of the bond portfolio held by banks in the periphery, which tightens their collateral constraint and limits their ability to borrow in interbank markets.\textsuperscript{22} As a result, this forces banks to lower the amount of shares of ownership in the production sector ($X^i$ and $X^n$). With less investment financing available, firms in the periphery countries curtail their demand for capital and investment, which lowers the marginal product of labor and also induces them to lower their demand for labor. Employment and output follow.

\textsuperscript{21}For this type of shock we are not able to compare the predictions of our model with frictionless models since in those models banks do not hold sovereign debt.

\textsuperscript{22}This result is related to our calibration of bonds adjustment costs parameters which, consistent with home bias in asset markets, targets a ratio of domestic to total bonds in the data that is higher than 50%.
Next we compare the performance of the model in response to this shock for alternative strengths of the friction as governed by two values of the parameter in front of the collateral constraint, \( \chi \), so that a lower (higher) \( \chi \) represents a looser (tighter) collateral constraint. What we observe is that the initial effect of lowering the price and quantity demanded for bonds issued in the periphery is of approximately the same magnitude in both cases. However, a tighter constraint induces less switching. Therefore, the increase in the price of core bonds (\( q^* \)) is smaller and the increase in the quantity of them held by banks in the periphery (\( B^p* \)) is larger with a higher \( \chi \). The net result is a smaller reduction in the nominal value of bonds and a weaker tightening of the collateral constraint. As a result, the mechanism outlined in the previous paragraph is weakened for a larger \( \chi \) and the economy exhibits a smaller drop in the supply of credit, interbank borrowing, investment, employment and output. The key feature that drives the difference in results for these two models is that a looser constraint (i.e. a lower \( \chi \)) means that substitution from periphery to core bonds is easier, so that the substitution effect becomes stronger.\(^{23}\)

The results for the international transmission of the shock are presented in figure 13. The negative effects in the periphery are transmitted to countries in the core, so that employment, investment, output and consumption all fall there too.

4.3.2 Credit Policies

The results for credit policy interventions are presented in figures 14 and 16. We obtain that credit policies mitigate the impact of a bond return shock. Perhaps more interestingly, when we look at the international transmission of shocks, we find that equity injections in the periphery induce a reduction in the nominal value of bonds in the core that is even larger than in the benchmark model. Thus, in this case, policy intervention in the periphery hurts countries in the core. This is an interesting conclusion, in that it differs from those obtained for the case of capital quality shocks (see figures 15 and 17).

Summarizing, our model predicts that unconventional credit policy intervention in the periphery is indeed desirable for countries in the core when the source of the crisis is shocks to the quality of capital. However, when the source is shocks that directly impact the bond market, credit policy in the periphery can actually hurt countries in the core.

4.4 Simulation and International Spillovers

In this section we switch from an impulse response type of analysis to a simulation in which the economy is subject to a sequence of shocks. In this environment we study the features of the model that cause international spillovers and we look at the implied cross-country correlations for the main macroeconomic aggregates (consumption, employ-

\(^{23}\) Also at play is the fact that the drop in the demand for interbank loans (\( M^i \)) works to endogenously lower the interbank rate (\( R^{m^i} \)). This price effect partially offsets the negative impact of this shock on the supply of credit by the banking sector. Since with a tighter constraint (i.e. a higher \( \chi \)), the interbank rate falls by more than in the benchmark model, this plays a role to explain why the supply of shares \( X^i \) and \( X^{n^i} \) and therefore, all real variables fall by less with a tighter constraint.
ment, investment and output). Cross-country correlations for alternative models are presented in Table 8. Correlations for the standard two-country RBC model and the models with unconventional credit policies are also presented as a comparison. In this case we assume $\rho(A, A^*) = 0.05$ and $\rho(\psi, \psi^*) = 0.05$ to be able to generate non-zero correlations across countries even in the frictionless model.

When the economy is simulated in response to a series of capital quality, productivity and bond returns shocks, all of these aggregates exhibit positive correlations across countries in our model. This is because shocks in periphery countries affect the market value of both their own bonds and bonds issued by the core (through an arbitrage mechanism). Since these bonds are also held by banks in the core, their asset portfolios are also affected. In turn, this impacts the supply of credit by banks in the core, investment financing available in the core countries, the quantity of capital produced, employment, output, and consumption. This is the source of the international co-movement of all the macroeconomic aggregates in the benchmark version of the model.

As expected, once unconventional credit policies, in the form of either direct lending or equity injections, are implemented in the periphery countries, the international correlations of employment, investment and output all increase and that of consumption falls. Also, consistent with the results of the impulse response analysis, equity injections in the periphery result in stronger positive effects in the core than direct lending, so that cross-country correlations are higher when credit policy targets the banking sector rather than the production sector.

5 Conclusion

In this paper we are motivated by two empirical observations. First, sovereign bonds constitute the most important form of collateral in interbank markets. Second, interbank markets have been at the core of the transmission of recent financial crises, including the European sovereign debt crisis.

We build a DSGE model with governments issuing sovereign debt, interbank markets and international transmission links to study how sovereign bond holdings impact banks’ intermediation capacity and economic activity. In the recent literature, a large amount of attention has been paid to the European sovereign bond crisis and its detrimental effect on banks’ net worth and strength of balance sheets. While we acknowledge the importance of this channel, our results highlight an additional (and potentially overlooked) effect that banks’ holdings of sovereign bonds can have. Specifically, the effects of negative shocks that reduce the value of private loans given by banks can be mitigated if the value of sovereign bonds goes up. In fact, this rise in bond value works to loosen the collateral constraint faced by banks in interbank markets, which is an integral feature of our model. Overall, we find that our setting mitigates the response of the economy to certain shocks while amplifying the effects of other shocks.
We have also used our framework to revisit the effects of policies initiated to fight a credit crunch. Like in previous studies, credit policies like equity injections into banks help fight the negative consequences of a credit crunch by raising liquidity. However, to the extent that these policies are financed through the issuance of debt, they can potentially reduce the acceptability and pledgeability of government bonds as collateral in the interbank market. This can have an adverse effect on banks’ access to liquidity in the interbank markets that counteracts the stabilizing role of credit policies. Our model further predicts that unconventional credit policy in the periphery indeed makes countries in the core better off when the source of volatility is shocks to the quality of capital. However, when the source is shocks to bond returns, credit policy in the periphery can actually hurt countries in the core.

Since these general equilibrium effects of sovereign bond holdings have not been studied in this literature so far, we believe our findings can yield novel insights for policy-makers.
References


Table 1: Consolidated foreign claims and other potential exposures - ultimate risk basis

Amounts outstanding (millions of dollars) for domestically-owned banks against the public sector in the counterparty country

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<th>Share of claims against PIIGSS in overall claims</th>
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<td>UK</td>
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<td>US</td>
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*Source: BIS, Consolidated Banking Statistics, foreign exposure data.*
## Table 2: European Banks Exposure to Sovereign Debt

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</table>

The table shows exposure of banks of country in each column to sovereign of country in each row (as a % of banks’ risk-weighted total assets).

Source: European Stress Tests results for 2011 provided by the European Banking Authority.
Table 3: All US Banks’ Claims on the Public Sector of European Countries

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<td>4,050</td>
<td>6,863</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PIIGS</td>
<td>28,371</td>
<td>27,655</td>
<td>20,762</td>
<td>59,618</td>
<td>38,399</td>
<td>38,700</td>
<td>52,302</td>
<td>48,315</td>
<td>54,923</td>
</tr>
<tr>
<td>All countries (except US)</td>
<td>272,501</td>
<td>356,333</td>
<td>347,605</td>
<td>613,538</td>
<td>728,982</td>
<td>791,096</td>
<td>903,244</td>
<td>749,769</td>
<td>804,948</td>
</tr>
<tr>
<td>PIIGS/Total (%)</td>
<td>10.4</td>
<td>7.8</td>
<td>6.0</td>
<td>9.7</td>
<td>5.3</td>
<td>4.8</td>
<td>5.8</td>
<td>6.4</td>
<td>6.8</td>
</tr>
</tbody>
</table>

Source: Country Exposure Lending Survey of the Federal Reserve System.
Table 4: Interbank Rates and Bond Yields

<table>
<thead>
<tr>
<th>Core Countries</th>
<th>Periphery Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho(R_b \text{EA,Euribor}) )</td>
<td>0.85</td>
</tr>
<tr>
<td>( \rho(R_b \text{EA,EONIA}) )</td>
<td>0.72</td>
</tr>
<tr>
<td>( \rho(R_b \text{Germany,Euribor}) )</td>
<td>0.91</td>
</tr>
<tr>
<td>( \rho(R_b \text{Germany,EONIA}) )</td>
<td>0.86</td>
</tr>
<tr>
<td>( \rho(R_b \text{France,Euribor}) )</td>
<td>0.91</td>
</tr>
<tr>
<td>( \rho(R_b \text{France,EONIA}) )</td>
<td>0.85</td>
</tr>
<tr>
<td>( \rho(R_b \text{UK,Euribor}) )</td>
<td>0.88</td>
</tr>
<tr>
<td>( \rho(R_b \text{UK,EONIA}) )</td>
<td>0.82</td>
</tr>
<tr>
<td>( \rho(R_b \text{US,Euribor}) )</td>
<td>0.84</td>
</tr>
<tr>
<td>( \rho(R_b \text{US,EONIA}) )</td>
<td>0.77</td>
</tr>
<tr>
<td>( \rho(R_b \text{Japan,Euribor}) )</td>
<td>0.80</td>
</tr>
<tr>
<td>( \rho(R_b \text{Japan,EONIA}) )</td>
<td>0.63</td>
</tr>
<tr>
<td>( \rho(\text{average core } R_b,\text{Euribor}) )</td>
<td>0.87</td>
</tr>
<tr>
<td>( \rho(\text{average core } R_b,\text{EONIA}) )</td>
<td>0.78</td>
</tr>
</tbody>
</table>

In the model

No policy

| \( \rho(\frac{1}{q}R_m) \) | 0.6968 | \( \rho(\frac{1}{q^*}R^*_m) \) | 0.9758 |

Direct Lending

| \( \rho(\frac{1}{q}R_m) \) | 0.7914 | \( \rho(\frac{1}{q^*}R^*_m) \) | 0.9679 |

Direct Lending with constant \( \omega \)

| \( \rho(\frac{1}{q}R_m) \) | 0.8092 | \( \rho(\frac{1}{q^*}R^*_m) \) | 0.9657 |

Equity Injections

| \( \rho(\frac{1}{q}R_m) \) | 0.8799 | \( \rho(\frac{1}{q^*}R^*_m) \) | 0.888 |

Equity Injections with constant \( \omega \)

| \( \rho(\frac{1}{q}R_m) \) | 0.9311 | \( \rho(\frac{1}{q^*}R^*_m) \) | 0.9322 |


Note: \( R_b \) denotes bond yields. EA denotes Euro Area.
### Table 5: Baseline Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta^H$</td>
<td>0.97</td>
<td>Discount factor</td>
<td>Annualized interest rate of 3.1%</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.5</td>
<td>Habit parameter</td>
<td></td>
</tr>
<tr>
<td>$\sigma_c$</td>
<td>2</td>
<td>Risk aversion</td>
<td></td>
</tr>
<tr>
<td>$\psi^h$</td>
<td>2</td>
<td>Exponent on labor in preferences</td>
<td></td>
</tr>
<tr>
<td>$\psi^{h2}$</td>
<td>5</td>
<td>Parameter multiplying labor in preferences</td>
<td>$\frac{1}{3}$ of time at work</td>
</tr>
<tr>
<td><strong>Households</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Firms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.33</td>
<td>Capital share in production</td>
<td></td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.025</td>
<td>Capital depreciation rate</td>
<td></td>
</tr>
<tr>
<td>$\rho^A$</td>
<td>0.906</td>
<td>Persistence of technology shock</td>
<td>From Backus, Kehoe and Kydland (1992)</td>
</tr>
<tr>
<td>$\rho^\psi$</td>
<td>0.7</td>
<td>Persistence of capital quality shock</td>
<td></td>
</tr>
<tr>
<td>$\phi_K$</td>
<td>2</td>
<td>Investment adjustment cost parameter</td>
<td></td>
</tr>
<tr>
<td><strong>Banks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\xi$</td>
<td>0.003</td>
<td>Transfer to new bankers</td>
<td>From GK (2011)</td>
</tr>
<tr>
<td>$\sigma^i$</td>
<td>0.97</td>
<td>Banker survival rate</td>
<td>From GK (2011)</td>
</tr>
<tr>
<td>$\pi^t$</td>
<td>0.25</td>
<td>Probability of new investment opportunities</td>
<td>From GK (2011)</td>
</tr>
<tr>
<td>$\chi$</td>
<td>1.8</td>
<td>Interbank collateral constraint tightness</td>
<td></td>
</tr>
<tr>
<td>$\phi_{B_p}$</td>
<td>0.15</td>
<td>AC parameter for domestic bonds in periphery</td>
<td>$\left(\frac{1}{q} - \frac{1}{q^*}\right) = 0.01$</td>
</tr>
<tr>
<td>$\phi_{B_p^*}$</td>
<td>0.1</td>
<td>AC parameter for foreign bonds in periphery</td>
<td>$\left(\frac{1}{q} - R^{d*}\right) = 0.0047$</td>
</tr>
<tr>
<td>$\phi_{B_c}$</td>
<td>0.08</td>
<td>AC parameter for domestic bonds in core</td>
<td>$\frac{B_c}{B^*_c} = 0.07$</td>
</tr>
<tr>
<td>$\phi_{B_c^*}$</td>
<td>0.2</td>
<td>AC parameter for foreign bonds in core</td>
<td>$\frac{B_c}{B^*_c} = 0.62$</td>
</tr>
<tr>
<td><strong>Government</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m_G$</td>
<td>0.18</td>
<td>G/Y (steady-state)</td>
<td></td>
</tr>
<tr>
<td>$m_T$</td>
<td>0.20</td>
<td>T/Y (steady-state)</td>
<td>$\frac{2}{3}$ debt-to-GDP ratio</td>
</tr>
</tbody>
</table>

### Table 6: Interest Rates in Steady-State

<table>
<thead>
<tr>
<th>Benchmark ($\chi = 1.8$)</th>
<th>Low $\chi$ ($\chi = 1.4$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Periphery</strong></td>
<td><strong>Core</strong></td>
</tr>
<tr>
<td>$R^d$</td>
<td>1.0309</td>
</tr>
<tr>
<td>$R^{ds}$</td>
<td>1.0171</td>
</tr>
<tr>
<td>$Z$</td>
<td>0.0571</td>
</tr>
<tr>
<td>$R^k_i$</td>
<td>1.0704</td>
</tr>
<tr>
<td>$R^k_n$</td>
<td>1.0171</td>
</tr>
<tr>
<td>$q$</td>
<td>0.9379</td>
</tr>
<tr>
<td>$\frac{1}{q}$</td>
<td>1.0662</td>
</tr>
</tbody>
</table>
Table 7: Cumulative Responses of Real Variables  
(in % deviations with respect to the steady state)

<table>
<thead>
<tr>
<th>Capital Quality Shocks</th>
<th>Y</th>
<th>H</th>
<th>K</th>
<th>I</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>No policy</td>
<td>-45.56</td>
<td>-22.78</td>
<td>-92.81</td>
<td>-25.73</td>
<td>-50.25</td>
</tr>
<tr>
<td>Direct lending (ϕ=1)</td>
<td>-41.21</td>
<td>-20.61</td>
<td>-84.05</td>
<td>-14.27</td>
<td>-44.31</td>
</tr>
<tr>
<td>Direct lending - constant ω</td>
<td>-40.25</td>
<td>-20.13</td>
<td>-82.12</td>
<td>-11.98</td>
<td>-43.06</td>
</tr>
<tr>
<td>Equity injections ϕ_N=10</td>
<td>-39.84</td>
<td>-19.92</td>
<td>-81.43</td>
<td>-16.39</td>
<td>-42.54</td>
</tr>
<tr>
<td>Equity injections - constant ω</td>
<td>-38.25</td>
<td>-19.12</td>
<td>-78.23</td>
<td>-12.58</td>
<td>-40.46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TFP Shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
</tr>
<tr>
<td>No policy</td>
</tr>
<tr>
<td>Direct lending (ϕ=1)</td>
</tr>
<tr>
<td>Direct lending - constant ω</td>
</tr>
<tr>
<td>Equity injections (ϕ_N=10)</td>
</tr>
<tr>
<td>Equity injections - constant ω</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bond Returns Shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
</tr>
<tr>
<td>No policy</td>
</tr>
<tr>
<td>Direct lending (ϕ=1)</td>
</tr>
<tr>
<td>Direct lending - constant ω</td>
</tr>
<tr>
<td>Equity injections (ϕ_N=10)</td>
</tr>
<tr>
<td>Equity injections - constant ω</td>
</tr>
</tbody>
</table>

Table 8: International Transmission and Cross-Country Correlations

<table>
<thead>
<tr>
<th>RBC</th>
<th>GK</th>
<th>Benchmark</th>
<th>Direct Lending</th>
<th>Equity Injections</th>
</tr>
</thead>
<tbody>
<tr>
<td>ρ(C,C*)</td>
<td>-0.2736</td>
<td>-0.8792</td>
<td>0.4062</td>
<td>0.1493</td>
</tr>
<tr>
<td>ρ(I,I*)</td>
<td>0.1050</td>
<td>0.7640</td>
<td>0.6808</td>
<td>0.7704</td>
</tr>
<tr>
<td>ρ(H,H*)</td>
<td>-0.0134</td>
<td>0.3318</td>
<td>0.7285</td>
<td>0.7008</td>
</tr>
<tr>
<td>ρ(Y,Y*)</td>
<td>-0.0144</td>
<td>-0.6282</td>
<td>0.7285</td>
<td>0.7008</td>
</tr>
</tbody>
</table>
Figure 1: Interbank Repo Markets and Default Risk

Interbank Borrowing Euro money market (2003=100)

Total Turnover - Bilateral Repo Market
Figure 2: Loan Rates and government bond yields
Figure 3: Bank credit to the private sector and government bond yields
Figure 4: The figure shows the response of periphery variables to a capital quality shock in the periphery. The solid blue lines show the response from the benchmark model, while the dashed red show the response from the frictionless RBC model, and the green dotted do so for a model with interbank markets as in Gertler-Kiyotaki but without their “walk-away” friction.
Figure 5: The figure shows the response of core variables to a capital quality shock in the periphery.
Figure 6: The figure shows the response of periphery variables to a capital quality shock in the periphery for two alternative loan-to-collateral ratios in interbank markets.
Capital Quality Shock in Periphery: Effects in the Core

Figure 7: The figure shows the response of core variables to a capital quality shock in the periphery for two alternative loan-to-collateral ratios in interbank markets.
Figure 8: The figure shows the response of periphery variables to a capital quality shock in the periphery for the economy with and without direct lending as the credit policy.
Figure 9: The figure shows the response of core variables to a capital quality shock in the periphery.
Figure 10: The figure shows the response of periphery variables to a capital quality shock in the periphery for the economy with and without equity injections as the credit policy.
Figure 11: The figure shows the response of core variables to a capital quality shock in the periphery.
Figure 12: The figure shows the response of periphery variables to a shock to bond returns in the periphery for two alternative loan-to-collateral ratios in interbank markets.
Figure 13: The figure shows the response of core variables to a shock to bond returns in the periphery for two alternative loan-to-collateral ratios in interbank markets.
Figure 14: The figure shows the response of periphery variables to a shock to bond returns in the periphery with and without policy intervention.
Figure 15: The figure shows the response of core variables to a shock to bond returns in the periphery with and without policy intervention.
Figure 16: The figure shows the response of periphery variables to a shock to bond returns in the periphery with and without policy intervention.
Figure 17: The figure shows the response of core variables to a shock to bond returns in the periphery with and without policy intervention.
APPENDIX A: TECHNICAL APPENDIX

In this appendix we provide the entire derivation of the banks FOCs of section 3.3.

The Lagrangian for the system in equations (3.12)-(3.15) becomes:

\[
\ell = \sum_{h=1,n} \pi^h E_t \left\{ (1 - \sigma) e^h_t + \sigma e^{h+1}_t \right\} + \sum_{i=1}^{\infty} \sigma^i \Lambda_{t,i+1} \left\{ (1 - \sigma) e^{h,i} + \sigma e^{h,i+1} \right\} + \\
+ \sum_{h=1,n} \pi^h \sigma E_t \Lambda_{t,t+1} \lambda_t^h \left[ q_t b_t^p \omega_t + q_t^* b_t^{p*} - \chi m_t^h \right]
\]

\[s.t.\]

\[
e_t^h = f_t(x_{t-1}, m_{t-1}, d_{t-1}, b^p_{t-1}, b^{p*}_{t-1})
\]

\[
e_{t+1}^h = g_t(e^h_t)
\]

To get equation (3.17) of section 3.3, we proceed in the following steps:

FOC w.r.t. \(d_t\)

\[
\sum_{h=1,n} \pi^h \sigma E_t \Lambda_{t,t+1} \left[ (1 - \sigma) \frac{\partial f_{t+1}}{\partial d_t} + \sigma \frac{\partial g_{t+1}}{\partial e^h_{t+1}} \frac{\partial f_{t+1}}{\partial d_t} \right] = \\
= \sum_{h=1,n} \pi^h \sigma E_t \Lambda_{t,t+1} \lambda_t^h \chi \frac{\partial m^h_t}{\partial d_t},
\]

(0.3)

where we have used \(\lambda_t^h\) to denote the Lagrange multiplier associated to the collateral constraint.

Using \(\frac{\partial m^h_t}{\partial d_t} = -1\) (by the bank’s balance sheet constraint) and \(\frac{\partial f_{t+1}}{\partial d_t} = (R^M_t - R^D_t)\) and defining the shadow/marginal value of net worth at time \(t + 1\) as \(\Omega_{t+1} \equiv (1 - \sigma) + \sigma \left( \frac{\partial g_{t+1}}{\partial e^h_{t+1}} \right) = (1 - \sigma) + \\
\sigma \left( \left[ Z_{t+2} + (1-\delta)Q_{t+2}^h \right] \psi_{t+2} \right)^1\) equation (0.3) becomes:

\[E_t \Lambda_{t,t+1} \Omega_{t+1} \left( R^D_t - R^M_t \right) = E_t \Lambda_{t,t+1} \chi \lambda_t\]

(0.4)

where \(\lambda_t = \left( \pi^i \lambda_t^l + \pi^n \lambda_t^n \right)\). Since in equilibrium the collateral constraint is never binding for banks in

\[^1\]The marginal value of net worth is the weighted average of the marginal value of exit (with probability \((1 - \sigma)\)) and the marginal continuation value (with probability \(\sigma\)). In the case of bank exit the value is equal to 1. The continuation value is the return on assets that can be increased by acquiring an additional unit of equity.
sector $n$, $\lambda^n = 0$ and $\bar{\lambda}_t = \pi^i \lambda^i_t$.

To get equation (3.18) of section 3.3, we proceed in the following steps:

**FOC w.r.t. $x^h_t$**

$$\sigma E_t \Lambda_{t,t+1} \left[ (1 - \sigma) \frac{\partial f_{t+1}}{\partial x^h_t} + \sigma \frac{\partial g_{t+1}}{\partial e^h_{t+1}} \frac{\partial f_{t+1}}{\partial x^h_t} \right] = \sigma E_t \Lambda_{t,t+1} \lambda^h_t \chi \frac{\partial m^h_t}{\partial x^h_t}. \quad (0.5)$$

Using $\frac{\partial m^h_t}{\partial x^h_t} = Q^h_t$ (by the bank’s balance sheet constraint) and $\frac{\partial f_{t+1}}{\partial x^h_t} = \left[ Z_{t+1} + (1 - \delta) Q^h_{t+1} \right] \psi_{t+1} - R^M_{t+1} Q^h_t$, equation (0.5) becomes

$$E_t \Lambda_{t,t+1} \Omega_{t+1} \left\{ \left[ Z_{t+1} + (1 - \delta) Q^h_{t+1} \right] \psi_{t+1} - R^M_t \right\} = E_t \Lambda_{t,t+1} \left\{ \lambda^h_t \chi \right\}. \quad (0.6)$$

To get equation (3.19) of section 3.3, we proceed in the following steps:

**FOC w.r.t. $b^p_t$**

$$\sum_{h=i,n} \pi^h \sigma E_t \Lambda_{t,t+1} \left[ (1 - \sigma) \frac{\partial f_{t+1}}{\partial b^p_t} + \sigma \frac{\partial g_{t+1}}{\partial e^h_{t+1}} \frac{\partial f_{t+1}}{\partial b^p_t} \right] + \sum_{h=i,n} \pi^h \sigma E_t \Lambda_{t,t+1} \lambda^h_t \left[ \frac{q_t \omega_t - \chi}{\partial m^h_t} \right] \quad (0.7)$$

Using $\frac{\partial m^h_t}{\partial b^p_t} = q_t$ (by the bank’s balance sheet constraint) and $\frac{\partial f_{t+1}}{\partial b^p_t} = (1 - \frac{\partial AC(t)}{\partial q_t} - R^M_t q_t)$, equation (0.7) becomes:

$$E_t \Lambda_{t,t+1} \Omega_{t+1} \left( 1 - \frac{\partial AC(t)}{q_t} - R^M_t \right) = E_t \Lambda_{t,t+1} \left[ \bar{\lambda}_t (\chi - \omega) \right] \quad (0.8)$$

Similarly, the FOC w.r.t. $b^p^*_{t}$ is:

$$E_t \Lambda_{t,t+1} \Omega_{t+1} \left( 1 - \frac{\partial AC(t)}{q^*_t} - R^M_t \right) = E_t \Lambda_{t,t+1} \left\{ \bar{\lambda}_t [\chi - 1] \right\} \quad (0.9)$$
Appendix B: SUPPLEMENTARY RESULTS - Technology Shocks

Effects on the Domestic Economy

Next we study the response of the economy to a negative technology shock in the periphery. In Figure B.1 we plot the response of domestic variables. Here we see that the response of the real variables in our model is mitigated relative to the RBC and the GK-type models. The return to capital falls due to the standard channel through which a fall in TFP lowers the marginal product of factors of production. This lowers the demand for both factors of production, output falls and consumption follows. Also, standard is the increase in the deposit rate which reflects a higher price of current consumption in terms of future consumption since the shock is only temporary and lowers contemporaneous productivity relative to future productivity. With a fall in the returns to capital and an increase in the deposit rate, the spread between the two falls. All of these effects are also present in the frictionless RBC model.

In our model with idiosyncratic investment opportunities across production sectors, interbank markets and collateral frictions, this effect is moderated. The drop in productivity has two effects on the collateral constraint: First, it lowers the demand for banks shares and, hence, for interbank borrowing. Second, it drives bond prices down but raises the demand for them, raising the nominal value of bond portfolios. The combined effect works to relax the constraint and raise the supply of credit, so that the net (still negative) effect on the quantity of shares available to firms in goods markets ($X^i$ and $(X^i)^*$) is attenuated.

In conclusion, intuitively, capital, investment, employment, output and consumption all fall after a negative supply-side shock. However, the benefits of this shock for the real economy are indirectly mitigated by the frictions in credit and sovereign bond markets that we study in this paper.

In Figure B.3 we compare the results for alternative strenghts of the collateral friction. It is evident from these plots that the constraint is relaxed by more and its shadow value ($\lambda$) falls by more the lower $\chi$. Thus, the positive impact on real variables is attenuated by more and the net effect is smaller (in absolute value) the looser the constraint.

International Transmission

In figures B.2 and B.4 we look at the response of the core variables to this technology shock in the periphery. In the core, real variables actually increase. The same mechanism on the financial side is at play: the return to capital $R^k_i$ falls and, with an increase in the
deposit rate, the spread falls. However without the direct negative effect of worse technology (only happens in the periphery), this leads investment and capital to rise.

Thus, frictions in the financial sector lead to an improvement of the real economy (relative to a frictionless case). Notice that the law of motion assumed for TFP does not allow for exogenous cross-country spillovers of the shock. Therefore, as mentioned above, these results are isolating a very specific mechanism operating through the bond holdings of banks and interbank lending. This mechanism highlights a source of negative spillovers across countries, in this case, from the periphery to the core.

In Table B.1 we present the cumulative responses of output, employment, capital, investment and consumption for five economies: no policy intervention, direct lending and equity injections each with constant and variable pledgeability ($\bar{\omega}$ and $\omega_t$, respectively). The difference in cumulative responses (in percentage points) obtained by direct lending are 3, 2, 6, 10 and 4 for output, employment, capital, investment and consumption, respectively. The corresponding numbers for when the policy consists of equity injections are 4, 2, 5, 4 and 4 percentage points, respectively.

**Credit Policy** The conclusions regarding the effects of unconventional monetary policy described before for shocks to capital quality also apply to productivity shocks. In a nutshell, both policies help to attenuate the effects of worse technology, and more so when the marginal pledgeability of periphery bonds is not a function of credit policy (constant $\omega$). It is also the case here that equity injections work better than direct lending at helping the economy after the shock. See figures B.5 and B.7 for more details.
Table B.1: Cumulative Responses of Real Variables  
(in % deviations with respect to the steady state)

<table>
<thead>
<tr>
<th>TFP Shocks</th>
<th>Y</th>
<th>H</th>
<th>K</th>
<th>I</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>No policy</td>
<td>-20.39</td>
<td>-10.19</td>
<td>-9.67</td>
<td>-16.94</td>
<td>-19.4</td>
</tr>
<tr>
<td>Direct lending ($\phi=1$)</td>
<td>-17.46</td>
<td>-8.73</td>
<td>-3.71</td>
<td>-7.01</td>
<td>-15.03</td>
</tr>
<tr>
<td>Direct lending - constant $\omega$</td>
<td>-16.46</td>
<td>-8.23</td>
<td>-1.7</td>
<td>-4.63</td>
<td>-13.74</td>
</tr>
<tr>
<td>Equity injections ($\phi_N=10$)</td>
<td>-17.88</td>
<td>-8.94</td>
<td>-4.87</td>
<td>-20.49</td>
<td>-15.37</td>
</tr>
<tr>
<td>Equity injections - constant $\omega$</td>
<td>-16.22</td>
<td>-8.11</td>
<td>-1.52</td>
<td>-16.54</td>
<td>-13.23</td>
</tr>
</tbody>
</table>
Figure B.1: The figure shows the response of periphery variables to a technology shock in the periphery, for our model, the RBC model and a model with interbank markets as in Gertler-Kiyotaki (but without their “walk-away” friction).
Figure B.2: The figure shows the response of core variables to a technology shock in the periphery.
Figure B.3: The figure shows the response of periphery variables to a TFP shock in the periphery for two alternative loan-to-collateral ratios in interbank markets.
Figure B.4: The figure shows the response of core variables to a TFP shock in the periphery for two alternative loan-to-collateral ratios in interbank markets.
Figure B.5: The figure shows the response of periphery variables to a TFP shock in the periphery for the benchmark model and for the case of direct lending.
Figure B.6: The figure shows the response of core variables to a TFP shock in the periphery.
Figure B.7: The figure shows the response of periphery variables to a TFP shock in the periphery for the benchmark model and for the case of equity injections.
Figure B.8: The figure shows the response of core variables to a TFP shock in the periphery.