Sovereign Risk and Bank Balance Sheets: The Role of Macroprudential Policies

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Abstract

This paper explores the role of bank balance sheets, sovereign default risk, and capital adequacy requirements in amplifying aggregate fluctuations. The paper, first, proposes a unified model of defaultable sovereign debt and bank balance sheets to capture regularities on bank credit to firms, banks’ holdings of sovereign bonds, and the behavior of sovereign debt and default. The model captures the procyclical bank credit and countercyclical bank holdings of sovereign bonds. Since the sovereign defaults indiscriminately, bank losses due to a default hampers its lending to firms, thereby, generating an endogenous cost of default. The paper then conducts counterfactual policy experiments in line with Basel III. Our preliminary findings suggest that the introduction of leverage ratios is superior to increasing the capital requirement on risk weighted assets where sovereign bonds are assigned a zero weight.

**JEL Classification:** F41, E44, D82

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1 Introduction

In light of the recent financial crisis in Europe, sovereign debt default and its relationship with the banking sector climbed to the top of the global economic agenda. The rise of sovereign spreads in peripheral European countries (Figure 1) coincided with a decline in loans extended to nonfinancial corporations and an increase in the interest rates associated with these loans. As Figure 2 highlights, corporate sector loan interest rates started to rise gradually in 2006, peaking in early 2009 (left panel) while net loans as a share of GDP declined rapidly in early 2009 (right panel) coinciding with the peak of the interest rates. These negative trends reversed in late 2009 perhaps due to various policy interventions but this reversal appears to have been temporary considering the more recent increases in the interest rate coupled with the decline in credit.

Despite the evident link between sovereign risk and banking sector stresses highlighted in earlier research and resurfaced in the European crisis, the macroeconomic implications of a sovereign debt default coupled with a banking sector stress or a banking crisis remain unexplained. This paper aims to fill this gap by providing a framework to understand the linkages between sovereign risk and bank balance sheets and quantify how regulatory changes in the banking sector (such as capital requirements) affect macroeconomic fluctuations, the risk of sovereign default and the probability of a banking crisis.

To do so, we build a quantitative model that incorporates households, firms, domestic banks, foreign lenders, and a sovereign. The sovereign’s problem is in the spirit of Eaton and Gersovitz (1981) in that it maximizes the households’ welfare and strategically chooses to default or not on its debt. Households own both firms and the bank. They supply labor to productive firms and make deposits to the financial sector. Firms have access to a risky technology that requires bank loans to be operated. The asset side of bank’s balance sheet is determined by a mix between sovereign debt and corporate loans both of which are risky. We assume deposit insurance which creates a moral hazard problem, potentially leading the bank to engage in excessive lending to risky firms. The existence of such moral hazard problem provides a rationale for the use of capital requirements, which limits the bank lending not to exceed a certain fraction of risk weighted assets. Domestic banks are dominant players in the domestic corporate credit market but that they act as competitive players in the sovereign debt market. The price of the sovereign bond is determined by the no arbitrage condition of foreign lenders.

In our model, banks’ balance sheets and sovereign risk affect macroeconomic fluctuations.

\[1\] Reinhart and Rogoff (2010) document the strong link between banking crises and sovereign default across many advanced and emerging countries. They show that banking crises most often either precede or coincide with sovereign debt crises.
jointly. The heightened risk of a potential sovereign default constrains the banks’ ability to extend credit to the firms. This happens through the capital requirement—as mentioned earlier, the capital requirement limits the size of the bank loans to a multiple of its equity. In our baseline scenario, the capital requirement follows closely that in Basel II Accords where the sovereign bond receives a zero-weight in the computation of the risk weighted assets. A reduction in the loan supply hampers production of the firms that require bank loan to operate their projects. Hence, output falls, which, in turn, increases sovereign default risk further.

Using our model, we examine several modifications to the capital requirements. Specifically, we examine how these modifications affect macroeconomic fluctuations and, more importantly, the joint determination of sovereign debt and banking crisis. These experiments are motivated by the discussions during the design of Basel III after the onset of the European debt crisis.²

Many countries around the world including the euro area implemented Basel II during the crisis, which relied heavily on the credit ratings of sovereign bonds to assess their riskiness. The reliance on credit ratings was formalized in Basel II using a risk weighting scheme for bank assets in which sovereign debt holdings have zero weight if the sovereign is rated above a certain rating. In addition, within the Eurozone, all sovereign bonds received preferential treatment in that the risk weights on these Eurozone sovereigns’ bonds received a zero weight regardless of the sovereign’s credit rating. Comparing scenarios with a higher capital requirement on risk weighted assets where the sovereign bond continues to receive a zero weight with ones where a leverage requirement is imposed with a 100 percent weight on sovereign bonds, we find that the former policy does not improve lending to the firms even though it does force the bank to increase its capital.

This paper connects various strands of literature. The first is the sovereign debt literature that focuses mostly on building models with endogenous sovereign default with the aim of accounting for emerging markets business cycle characteristics, e.g., Aguiar and Gopinath (2006), Arellano (2008), and Mendoza and Yue (2008), among others. The difference with this literature is that we incorporate a domestic banking sector and we study how it interacts with the government borrowing and default decisions. The analysis of bank capital

²For example, ECB Executive Board member Benoit Coeure stated: “There is no reason a priori any particular kind of asset should be treated as risk-free by banks. That’s a general principle that deserves to be supported.” (See http://www.reuters.com/article/email/idUSBRE9AP0GX20131126) Similarly, Bundesbank President Jens Weidmann wrote: “…the current regulatory treatment is incompatible with the principle of individual responsibility; the market interest rate no longer reflects the riskiness of the investment. I am aware that banks as well as governments are afraid of rising funding costs as a result of ending the regulatory privileges afforded to sovereigns.” (See http://www.ft.com/cms/s/0/81a505a4-278c-11e3-8feb-00144feab7de.html)
requirements on macroeconomic fluctuations is in the spirit of Van den Heuvel (2002) and Van den Heuvel (2008). Both of these studies assume a regulatory bank capital requirement and analyze its macroeconomic implications as well as its welfare costs.

Our work is also related to a more recent line of papers on sovereign debt and financial sector. Bolton and Jeanne (2010) study sovereign risk in connection with the recent waiver of sovereign debt crises in Europe. They emphasize cross border spillovers of sovereign risk in an environment with financial integration. Our paper is related to theirs in that they also explore the importance of banks in sovereign default risk. Gennaioli, Martin and Rossi (2010) study the interaction between sovereign default and domestic banks’ lending in a theoretical model. They consider a sovereign that borrows to finance a public project and domestic banks hold sovereign debt in order to reduce the sovereign’s incentives to default because the sovereign internalizes the worsening of domestic banks’ balance sheets. Differently from these papers, we build a quantitative framework in which capital requirements are at the center of the analysis. Finally, Sosa Padilla (2012) studies the relationship between sovereign default and bank credit. The main differences from Sosa Padilla’s work are that we introduce risky corporate loans, deposit insurance, and capital requirements. These additional features allow us to study how bank risk-taking behavior and sovereign default risk interact. Moreover, we are able to analyze the effect of important regulatory changes proposed in the Basel accords and how they affect the incentives of financial intermediaries and the government.

2 Environment

The economy is populated by a continuum of households, a continuum of firms, a bank and a government. The bank intermediates resources between the households, the firms and the government. The government issues sovereign bonds and cannot commit to repay.

2.1 Households

Household preferences are

\[ E_0 \left[ \sum_{t=0}^{\infty} \beta^t \frac{\left( c_t - \frac{h_t^2}{\eta} \right)^{1-\sigma}}{1-\sigma} \right] \]

where \( E_0 \) denotes the expectation operator, \( \beta \in (0, 1) \) denotes the discount factor, \( c_t \) denotes the stochastic stream of consumption, \( h_t \) denotes the level of labor supply, and \( \sigma \) denotes the coefficient of relative risk aversion.

Households are endowed with a unit of labor and \( \bar{d} \) units of a nonstorable perishable
good. They can supply labor to the firms at wage rate \( w_t \). And they can deposit a part of their endowment to domestic banks that pay a risk-free return \( r^b \). Households can also deposit a part of their endowment to international financial intermediaries at risk-free rate \( r \). We denote deposits in domestic banks and international financial institutions by \( d^b \) and \( d^i \), respectively, so that \( d^b + d^i = \bar{d} \). The ownership of the bank and the productive firms is assumed to be uniformly distributed across the population, and dividends (net of equity issuance) are shared equally in equilibrium. The government collects lump-sum taxes \( T_t \) from the households to balance its budget.

As we further explain below, some firms in this economy can fail. Thus some households that are employed receive no wage payments. With these assumptions, the households’ aggregate budget constraint is

\[
c_t = \hat{w}_t H^s_t + (1 + r^b) d^b + (1 + r) d^i + \Pi^b_t + \Pi^f_t - T_t,
\]

where \( \hat{w}_t \) is the realized wage, which takes into account the fact that some workers are not repaid so \( \hat{w}_t = p(z_{t+1}) w_t \) where \( p(z_{t+1}) \) is the fraction of the firms that succeed and make the wage payment. \( \Pi^b_t \) and \( \Pi^f_t \) denote net dividend payments from the bank and the firm, respectively. In equilibrium, deposit insurance allows the bank to drive down the interest rate on deposits \( r^b \) to \( r \), so households are indifferent between placing their endowment in domestic or international banks.

The solution to the above problem yields the following relationship between aggregate labor supply and the wage rate\(^4\):

\[
H^s_t = \left[ w_t \ E_t[p(z_{t+1})]\right]^{\frac{1}{\eta - 1}}.
\]

### 2.2 Firms’ Problem

Firms in the corporate sector live for one period and have access to an investment project with technology given by \( f(z_{t+1}, a_t, h_t) = z_{t+1} a_t h_t^\alpha \) that combines aggregate productivity \( z_{t+1} \), idiosyncratic productivity shock \( a_t \), and labor \( h_t \). In addition, operating the project requires a firm to borrow one unit of loan from the bank. The production function has decreasing returns in the variable input \( h_t \) so that \( 0 < \alpha < 1 \). Firms make their labor hiring decisions in period \( t \) after observing idiosyncratic productivity but before the realization of \( z_{t+1} \). Labor markets are competitive and the wage rate is denoted by \( w_t \). The idiosyncratic

\(^3\)The return on deposits is risk-free since we assume that there is deposit insurance.

\(^4\)Our notation is such that upper case letters stand for the aggregated correspondent of the variables denotes with lower case letters.
productivity shock, $a_t$, determines whether the project is successful or not. If the project is successful, the return is $f(z_{t+1}, a_t, h_t)$, and if the project fails, the return is zero. We assume that there is limited liability, in that failing firms do not repay the borrowed loans from the bank.

The aggregate technology shock is denoted by $z_t \in Z$ and evolves as a Markov process $F(z', z) = \Pr(z_{t+1} = z'|z_t = z)$. Idiosyncratic productivity is drawn from a continuous distribution $A$ with support in $A = \{a, \bar{a}\}$. The success probability of the project depends on aggregate productivity and is denoted by $p(z_{t+1}) \in [0,1]$. We assume that $p(z_t)$ is increasing in $z_t$, (i.e., $p(z^1) > p(z^2)$ for any $z^1 > z^2$), that is, fewer firms fail in good times. While firms are ex-ante identical, they are ex-post heterogeneous, owing to the realizations of the shocks to the return on their project and the idiosyncratic productivity. In summary,

$$f(z_{t+1}, a_t, 1, h_t) = \begin{cases} z_{t+1}a_t h_t^\alpha & \text{with prob } p(z_{t+1}) \\ 0 & \text{with prob } 1 - p(z_{t+1}) \end{cases}.$$  \hspace{1cm} (4)

At the beginning of the period, after the realization of $a_t$, firms maximize their expected profits given by

$$\max_{h_t \geq 0} \{E_t [\max \{z_{t+1}a_t h_t^\alpha - w_t h_t - r_t^\ell, 0\}] \}$$  \hspace{1cm} (5)

where $r_t^\ell$ is the interest paid out for a unit of loan from the bank. The expectation is taken over the aggregate productivity shock and the idiosyncratic success/failure of the project. This formulation implies that in equilibrium, there is a threshold idiosyncratic productivity above which a firm decides to operate the project by borrowing from the bank. We denote this threshold by $a^*(z_t, w_t, r_t^\ell)$. Since only for successful projects the limited liability constraint is not binding, we can define operating profits for an individual firm as follows:

$$\pi^f(z_t, a^*(z_t, w_t, r_t^\ell), w_t, r_t^\ell) = \max_{h_t} E_t \left[ p(z_{t+1}) \{ z_{t+1}a_t h_t^\alpha - w_t h_t - r_t^\ell \} \right].$$  \hspace{1cm} (6)

Then, $a^*(z_t, w_t, r_t^\ell)$ is the solution to the following equation

$$\pi^f(z_t, a^*(z_t, w_t, r_t^\ell), w_t, r_t^\ell) = 0.$$  \hspace{1cm} (7)

The threshold $a^*(z_t, w_t, r_t^\ell)$ determines firms’ demand for loans

$$\ell^d(r_t^\ell) = \int_{a^*(z_t, w_t, r_t^\ell)} dA(a).$$  \hspace{1cm} (8)

Firms that choose to operate the technology determine the demand for labor. For a firm
with a given idiosyncratic productivity $a_t$, the first order condition obtained from the above optimization problem yields the following relationship, which equates the expected marginal product of labor to the expected wage.

$$E_t [p(z_{t+1})z_{t+1}] a_t \alpha h_t^{\alpha - 1} = E_t [p(z_{t+1})] w_t. \tag{9}$$

By rearranging, we can derive the labor demand of a firm as follows:

$$h(z_t, a_t) = w_t^{\frac{1}{\alpha - 1}} \left[ \frac{E_t [p(z_{t+1})]}{\alpha E_t [p(z_{t+1}) z_{t+1}]} \right]^{\frac{1}{\alpha - 1}} \left( \frac{1}{a_t} \right)^{\frac{1}{\alpha - 1}}. \tag{10}$$

Integrating over the projects that are operated, we obtain aggregate labor demand:

$$H_t^d = w_t^{\frac{1}{\alpha - 1}} \left[ \frac{E_t [p(z_{t+1})]}{\alpha E_t [p(z_{t+1}) z_{t+1}]} \right]^{\frac{1}{\alpha - 1}} \int_{\alpha(z_t)}^{\alpha} \left( \frac{1}{a_t} \right)^{\frac{1}{\alpha - 1}} dA(a). \tag{11}$$

Replacing Equation (10) into Equation (6) we obtain:

$$\pi^f(z_t, a_t, w_t, r_t^f) = E_t \left[ p(z_{t+1})z_{t+1} a_t w_t^{\frac{1}{\alpha - 1}} \left[ \frac{E_t [p(z_{t+1})]}{\alpha E_t [p(z_{t+1}) z_{t+1}]} \right]^{\frac{1}{\alpha - 1}} \left( \frac{1}{a_t} \right)^{\frac{1}{\alpha - 1}} \right. \left. - p(z_{t+1}) w_t \left[ w_t^{\frac{1}{\alpha - 1}} \left[ \frac{E_t [p(z_{t+1})]}{\alpha E_t [p(z_{t+1}) z_{t+1}]} \right]^{\frac{1}{\alpha - 1}} \left( \frac{1}{a_t} \right)^{\frac{1}{\alpha - 1}} \right] - p(z_{t+1}) r_t^f \right]$$

$$= (E_t[p(z_{t+1})z_{t+1}])^{\frac{1}{\alpha - 1}} a_t^{\frac{1}{\alpha - 1}} w_t^{\frac{1}{\alpha - 1}} [E_t[p(z_{t+1})]]^{\frac{1}{\alpha - 1}} \alpha^{1 - \alpha}$$

$$- (E_t[p(z_{t+1})z_{t+1}])^{\frac{1}{\alpha - 1}} a_t^{\frac{1}{\alpha - 1}} w_t^{\frac{1}{\alpha - 1}} [E_t[p(z_{t+1})]]^{\frac{1}{\alpha - 1}} \alpha^{1 - \alpha} - E[p(z_{t+1})]r_t^f$$

$$= (E_t[p(z_{t+1})z_{t+1}])^{\frac{1}{\alpha - 1}} a_t^{\frac{1}{\alpha - 1}} w_t^{\frac{1}{\alpha - 1}} [E_t[p(z_{t+1})]]^{\frac{1}{\alpha - 1}} \alpha^{1 - \alpha} - E_t[p(z_{t+1})]r_t^f$$

Then, using Equation (7), we can solve for the threshold productivity:

$$a^*(z_t, w_t, r_t^f) = \left[ \frac{r_t^f}{\alpha^{1 - \alpha} - \alpha^{1 - \alpha}} \right]^{\alpha - 1} E_t[p(z_{t+1})] w_t^{\alpha} \tag{12}$$

Assuming a Uniform distribution for the idiosyncratic productivity shocks, $A = U[a, \bar{a}]$, aggregate labor demand can be written as

$$H_t^d = w_t^{\frac{1}{\alpha - 1}} \left[ \frac{E_t [p(z_{t+1})]}{\alpha E_t [p(z_{t+1}) z_{t+1}]} \right]^{\frac{1}{\alpha - 1}} \left[ \frac{2 - \alpha}{\bar{a}^{2 - \alpha}} - a^*(z_t, w_t, r_t^f)^{\frac{2 - \alpha}{\alpha - \alpha}} \right] \frac{1}{\bar{a} - \frac{1}{2 - \alpha}}. \tag{13}$$
Market clearing requires \( H^d = H^s \) and hence
\[
[w_t E_t[p(z_{t+1})]]^{\frac{1}{\eta}} = w_t^{\frac{1}{\eta-1}} \left[ \frac{E_t [p(z_{t+1})]}{\alpha E_t [p(z_{t+1})]} \right]^{\frac{1}{\alpha-1}} \left[ \frac{z_t^{\frac{2-\alpha}{\alpha}} - a^*(z_t, w_t, r_t^f)^{\frac{2-\alpha}{\alpha}}}{\alpha - \frac{\alpha}{2} - \alpha} \right] \frac{1}{\alpha - \frac{\alpha}{2} - \alpha}. \quad (14)
\]

The condition above can be used to solve for \( w \) as a function of \( z_t \) and \( r_t^f \). This gives us aggregate labor and the loan demand as a function of \( \{z_t, r_t^f\} \). The bank chooses \( r_t^f \) which determines aggregate loans and the equilibrium interest rate.

Note that in this setting, aggregate output is
\[
y(z_{t+1}) = p(z_{t+1}) z_{t+1} \int_{a^*}^{\bar{a}} a_t h(a_t)^\alpha \frac{1}{\bar{a} - a} da. \quad (15)
\]

### 2.3 Domestic Banking Sector

We assume that there is one large national bank that extends loans to firms \( \ell_t \geq 0 \), and receives deposits from the households \( d_{t+1} \geq 0 \). The bank can also purchase government bonds \( b_{t+1} \) at price \( q_t \). The bank is the dominant player in the domestic loan market, but it acts competitively in the sovereign debt market. This assumption is motivated by the high degree of concentration of the banking sector in European countries and the fact that sovereign debt is traded in the secondary markets. Since the bank is a dominant player, it internalizes the impact of its loan supply \( \ell_t \) on the equilibrium loan interest rate \( r_t^f \). Moreover, since there is deposit insurance, it will be optimal to set the interest rate paid on deposits to the risk free rate, \( r_t^b = r \).

Lending to the firms and the government as well as any distributions to shareholders can be financed with the internal funds generated by deposits and government bonds due, or with new external funds, \( s_t \) (\( s_t < 0 \) implies equity issuance and \( s_t > 0 \) implies retained earnings). We assume that equity issuance entails costs so that the bank will never find it optimal to simultaneously pay out dividends and to issue equity. In doing so, we follow the tradition in the corporate finance literature (e.g., Hennessy and Whited (2005)) and assume a quadratic cost function. Formally, assuming \( s_t \) denotes the net payout to equity holders, total issuance costs equal \( \phi(s_t) = I_{|s_t|<0} [\phi_0(-s_t) + \phi_1 s_t^2] \).

Since the government in our setting can be in default, the bank’s optimization problem will be different depending on whether the sovereign bond market is open or not. If the bond market is open, the bank feasibility constraint at the beginning of the period is given by
\[
\tilde{s}_t = d_t^b + b_t - \ell_t - q_t b_{t+1}, \quad (16)
\]
where \( \tilde{s}_t \) is the net payments. If the bond market is closed, the feasibility constraint becomes

\[
\tilde{s}_t = d^b_t - \ell_t.
\]  

(17)

Using the bank’s balance sheet identity, equity after loans have been extended can be defined as

\[
e_t \equiv \ell_t + q_t b_{t+1} - d^b_t.
\]  

(18)

Consistent with the Basel Accords, we assume that banks are subject to a capital requirement constraint. That is

\[
e_t \geq \varphi (\ell_t + \omega q_t b_{t+1}),
\]  

where \( \varphi \in [0, 1] \) is the minimum fraction of total assets that the value of equity can take. \( \omega \) denotes the weight on sovereign bonds—assumed to be zero in our baseline scenario in line with the preferential treatment of euro area sovereigns in Basel II.

At the end of the period—i.e., after the realization of the aggregate and firms’ idiosyncratic shocks—the value of net equity issuance by the bank is given by

\[
s_{t+1} = \tilde{s}_t + p(z_{t+1})(1 + r^b_t)\ell_t - (1 + r^b_d) d^b_t - \phi(\tilde{s}_t).
\]  

(20)

Then, the net payment to shareholders is

\[
\Pi^b_{t+1} = s_{t+1} - \phi(s_{t+1}).
\]  

(21)

Below we lay out the recursive formulation of the bank’s problem. The relevant state variables are banks’ own bond holdings \( b \), the level of aggregate productivity \( z \), the total amount of debt issued by the government \( B \), and whether the sovereign debt market is open or not. The bank takes as given the policy functions of the government.

Before the government decides to default or not, the value of the bank for a given level of bank bond holdings \( b \), the total stock of government debt \( B \), and the level of productivity \( z \) is

\[
W(b, B, z) = D(b, B, z)W^{D=1}(z) + (1 - D(b, B, z))W^{D=0}(b, B, z),
\]  

(22)

where \( D(b, B, z) \) is the default decision of the government. \( W^{d=1}(z) \) denotes the value of the bank if the government defaults and \( W^{d=0}(b, B, z) \) denotes the value of the bank if the government does not default.

When the government does not default, the bank optimization problem can be summa-
ized as follows:

\[
W^{D=0}(b, B, z) = \max_{\ell, d^b \in [0, d], b', s, s'} E \left[ \tilde{R}^{-1} (\Pi^b(s') + W(b', B', z')) \right]
\]  

(23)

s.t.

\[
\tilde{s} = d^b + b - \ell - q(b', B', z)b',
\]

(24)

\[
e = \ell + q(b', B', z)b' - d^b,
\]

(25)

\[
e \geq \varphi (\ell + \omega q(b', B', z)b'),
\]

(26)

\[
s' = \tilde{s} + p(z')(1 + r^\ell)\ell - (1 + r^b)d^b - \phi(\tilde{s}),
\]

(27)

\[
\Pi^b(s') = s' - \phi(s'),
\]

(28)

\[
\ell = \ell^d(r^\ell)
\]

(29)

where \(\tilde{R}^{-1}\) denotes the endogenous stochastic discount factor, equation (24) corresponds to resources available at the beginning of the period, equation (25) defines equity from the balance sheet identity, equation (26) is the capital requirement constraint, equation (27) denotes the available resources after the realization of the shocks, equation (28) is the net dividend payment and equation (29) is the loan market clearing condition.

Note that even though the bank acts competitively in the sovereign debt market, it internalizes the fact that the default decisions of the government are affected by the banks’ bond holdings, so the bond price changes with \(b'\). The amount of loans extended to firms determines the equilibrium loan interest rate.

When the government defaults on its debt or if the period starts with the government in financial autarky, the problem of the bank is

\[
W^{D=1}(z) = \max_{\ell, d^b \in [0, d], \tilde{s}, s'} E \left[ \tilde{R}^{-1} (\Pi^b(s') + \mu W^{D=0}(0, 0, z') + (1 - \mu)W^{D=1}(z)) \right]
\]  

(30)

s.t.

\[
\tilde{s} = d^b - \ell,
\]

(31)

\[
e = \ell - d^b,
\]

(32)

\[
e \geq \varphi \ell,
\]

(33)

\[
s' = \tilde{s} + p(z')(1 + r^\ell)\ell - (1 + r^b)d^b - \phi(\tilde{s}),
\]

(34)

\[
\Pi^b(s') = s' - \phi(s'),
\]

(35)

\[
\ell = \ell^d(r^\ell)
\]

(36)
When the government defaults, the only sources of funds for the bank are the deposit and equity issuance. The lack of funds through the government bond market has implications for the loan market equilibrium and also features as one of the endogenous costs of default.

The solution to the bank’s optimization problems provides a bond decision rule \( b' (b, B, z) \), net equity issuance functions in the no default and default states \( s^{D=0} (b, B, z) \), \( s'^{D=0} (z', b, B, z) \), \( s^{D=1} (z) \), respectively and the equilibrium corporate loan interest rate in each case \( r^{\ell,D=0} (b, B, z) \) and \( r^{\ell,D=1} (z) \) that are derived from the loan supply decision rules \( \ell^{D=0} (b, B, z) \) and \( \ell^{D=1} (z) \).

2.4 Government

The government is benevolent in that it maximizes households’ objective function. It borrows or saves using one period non-contingent bonds denoted by \( B_{t+1} \). Debt is issued in a competitive sovereign debt market at a discounted price, \( q_t \). Domestic banks as well as foreign lenders participate in the market for sovereign debt. We denote sovereign’s borrowing by \( B_t < 0 \) and savings by \( B_{t+1} > 0 \). Any losses (or proceeds) from borrowing and lending in the sovereign debt market are funded through lump-sum taxation of the households. We denote these taxes by \( T_t \).

If the government borrows, it receives \( q_t B_{t+1} \) units of current period goods and promises to deliver \( B_{t+1} \) units of the following period good. The government cannot commit to repay its outstanding debt. At the beginning of the period, before the credit markets open, it can choose to default, \( D_t = 1 \), or not, \( D_t = 0 \). In case of default, the government is excluded from borrowing and lending for a stochastic number of periods. More specifically, after a default, with probability \( \mu \) the government will regain access to the credit markets and with probability \( 1 - \mu \), it will stay in financial autarky. Let \( x_t = 0 \) denote periods when the government is in good credit standing (i.e., it has access to borrowing or saving) and let \( x_t = 1 \) denote periods when it is excluded from the credit markets.

If the government chooses not to default, its budget constraint is

\[
T_t = q_t B_{t+1} - B_t. \tag{37}
\]

During financial autarky, the government’s budget constraint becomes \( T_t = 0 \).

To formulate the government optimization problem, we first derive the level of consumption in default and nondefault states that enter into the government budget constraint. We first define consumption in the default state. Given the realized aggregate profits in the
corporate sector:

$$\Pi_t^f = \int_{\tilde{a}^*}^{\tilde{a}} \pi^f(z_t, a_t, w_t, r_t^f) = p(z_{t+1})z_{t+1} \int_{\tilde{a}^*}^{\tilde{a}} a_t h_t^a \frac{1}{\alpha - a} da - w_t H_t^s - \ell_t r_t^f$$

$$= y(z_{t+1}) - p(z_{t+1})w_t H_t^s - p(z_{t+1})\ell_t r_t^f,$$

and, the realized aggregate profits in the Banking Sector,

$$\Pi_t^b = p(z_{t+1})(1 + r_t^b)\ell_t - (1 + r_t^b)d_t^b - \ell_t + d_t^b - \phi(\bar{s}) - \phi(s')$$

$$= p(z_{t+1})r_t^b \ell - (1 - p(z_{t+1}))\ell_t - r_t^b d_t^b - \phi(\bar{s}) - \phi(s'),$$

the aggregate consumption in default state is

$$c_{t+1} = p(z_{t+1})w_t H_t^s + \bar{d}(1 + r_t^b) + \Pi_t^f + \Pi_t^b$$

$$= p(z_{t+1})w_t H_t^s + \bar{d}(1 + r_t^b) + y(z_{t+1}) - p(z_{t+1})w_t H_t^d - p(z_{t+1})\ell_t r_t^f +$$

$$p(z_{t+1})r_t^b \ell_t - (1 - p(z_{t+1}))\ell_t - r_t^b d_t^b - \phi(\bar{s}) - \phi(s')$$

$$= y(z_{t+1}) - (1 - p(z_{t+1}))\ell_t + \bar{d} + (\bar{d} - d_t^b)r_t^b - \phi(\bar{s}) - \phi(s').$$

Similarly, in the non-default state, given the realized aggregate profits in the banking sector

$$\Pi_t^b = p(z_{t+1})r_t^b \ell_t - (1 - p(z_{t+1}))\ell_t - r_t^b d_t^b - \phi(\bar{s}) - \phi(s') + b_t - q_t b_{t+1},$$

and given the definitions of government taxes and profits of the firms provided above, aggregate consumption is

$$c_{t+1} = p(z_{t+1})w_t H_t^s + \bar{d}(1 + r_t^b) + \Pi_t^f + \Pi_t^b - T_t$$

$$= y(z_{t+1}) - (1 - p(z_{t+1}))\ell_t + \bar{d} + (\bar{d} - d_t^b)r_t^b - \phi(\bar{s}) - \phi(s') + (B_t + b_t) - q_t(B_{t+1} + b_{t+1}).$$

Using these consumption equations, we can now formulate the government optimization problem recursively as a function of state variables, \(\{b, B, z\}\), and the availability of access to the credit markets. The amount of bonds held by the bank, \(b\), needs to be carried through as a state variable since households own the bank and the firms and household consumption is affected by flow of bank and firm profits, which, in turn, is a function of \(b\), among other variables.

At the beginning of the period, if the government is in good credit condition, the government decides whether to default or not \((D = 1\) or \(D = 0\)). The value at state \(\{b, B, z\}\) is
given by

\[ V(b, B, z) = \max_{D(0,1)} \{ V^D=0(b, B, z), V^D=1(z) \} , \]  

(38)

where \( V^D=0(b, B, z) \) is the value if the government chooses to pay back and remain in the credit market and \( V^D=0(z) \) is the continuation value if the government defaults.

If the government chooses not to default, it can issue new bonds and its maximization problem can be formulated as follows:

\[ V^D=0(b, B, z) = \max_B E\beta \{ U(c', h^*) + V(b', B', z') \} \]  

(39)

s.t.

\[ c' = p(z')z'(h^*)^\alpha + (B + b) - q(b', B', z')(B' + b') - \phi(\bar{s}) - \phi(s') \]  

(40)

\[ h^* = h^*(r^{f,D=0}(b, B, z)) \]  

(41)

\[ b' = b'^{D=0}(b, B, z) \]  

(42)

\[ \bar{s} = \bar{s}^{D=0}(b, B, z) \]  

(43)

\[ s' = s'^{D=0}(z', b, B, z) \]  

(44)

The value function when the government chooses to default is given by:

\[ V^D=1(z) = E\beta \{ U(c', h^*) + \left[ \mu V^D=0(0, 0, z') + (1 - \mu)V^D=1(z') \right] \} . \]  

(45)

s.t.

\[ c' = p(z')z'(h^*)^\alpha - \phi(\bar{s}) - \phi(s') \]  

(46)

\[ h^* = h^*(r^{f,d=1}(z)) \]  

(47)

\[ \bar{s} = \bar{s}^{D=1}(z) \]  

(48)

\[ s' = s'^{D=0}(z', z) \]  

(49)

While in autarky, the country may regain access to external markets with an exogenous probability \( \mu \). When the economy returns to financial markets, it does so with no debt, \( B = 0 \) and \( b = 0 \), and with a continuation value of \( V^D=0(0, 0, z) \).

The solution to the government optimization problem provides a debt policy function \( B'(b, B, z) \) and the optimal default decision rule \( D(b, B, z) \). The default policies determine a default set \( \Gamma(b, B) \) defined as the set of values for the productivity such that default is optimal given the level of debt held by banks \( b \) and the total stock of debt issued by the
government $B$,  
\[
\Gamma(b, B) = \{(z) \in \mathcal{Y} : D(b, B, z) = 1\}.
\]  
(50)

Using $\Gamma(b, B)$ we can compute the default probability of the government  
\[
\lambda(b, B, z) = \int_{z' \in \Gamma(b, B)} F(dz', z).
\]  
(51)

### 2.5 Foreign Lenders and Equilibrium Bond Price

Foreign lenders are risk-neutral and have unlimited access to funds at interest rate equal to $r \geq 0$. Foreign lenders act competitively and invest in sovereign bonds. They also receive deposits, $d^i$, from the households.

The government borrows at price $q_t$. If the government borrows, it receives $q_tB_{t+1}$ units in the current period and promises to deliver $B_{t+1}$ units in the following period. Since the government is not committed to repay its debt, the equilibrium price function will depend on the default probability $p_t$.

Expected profits on a loan of size $B_{t+1}$ at price $q_t$ are equal to  
\[
\Omega_t = -q_t(-B_{t+1}) + \frac{(1 - p_t)}{(1 + r)}(-B_{t+1}),
\]  
(52)

where $p_t$ denotes the expected probability of government default in period $t$. In equilibrium, foreign lenders’ profits will be zero.

Foreign lenders make zero expected profit on each of the contracts offered to the government. This implies that the equilibrium bond price is given by:  
\[
q(b, B, z) = \frac{\lambda(b, B, z)}{(1 + r)}.
\]  
(53)

### 2.6 Time Line

In this section, we describe the timing of the model. Each period is divided into two sub-periods. In period $t$, the state vector is defined as $\{b_t, B_t, z_t, x_t\}$, where $b$ denotes bond holdings of the bank, $B$ is the total stock of sovereign debt, $z$ is the productivity shock and $x \in \{0, 1\}$ denotes whether the government is in good credit standing ($x = 0$) or in financial autarky ($x = 1$).

1. Beginning of period decisions:

- If $x_t = 0$, the government chooses to default or not ($D_t = \{0, 1\}$).
If $d_t = 0$, the government chooses $B_{t+1}$, banks choose $b_{t+1}$ taking as given the schedule of bond prices $q_t$. $x_{t+1} = 0$ in this case.

If $d_t = 1$ the sovereign debt market is closed and $x_{t+1} = 1$.

- If $x_t = 1$, the government is in financial autarky so no bonds are issued. $x_{t+1} = 0$ with probability $\mu$.
- Banks collect deposits $d_t$ from households, decide on the amount of loans $\ell_t$ and the value of net equity issuance $\tilde{s}_t$.
- Firms choose the amount of loans $\ell^d_t$ and labor to demand $h^d_t$. Loan demand and supply determine the loan interest rate $r^d$.
- Households select the amount of labor to supply $h^s_t$. Labor demand and supply determine the equilibrium wage rate $w$.

2. At the end of the period, $z_{t+1}$ and firm idiosyncratic shocks are realized

- The fraction of projects that fail is determined. Total output is determined.
- Banks profits are realized and banks decide on the amount of equity to issue $s_{t+1}$, which in turn determines the net payments to shareholders $\Pi(s_{t+1})$.
- Government transfers are determined.
- Households receive government transfers, wages, payments from the banks and firms and consume.

### 2.7 Definition Recursive Competitive Equilibrium

To be done.

### 3 Quantitative Analysis

#### 3.1 Calibration

Table 1 summarizes the parameter values we use in the quantitative experiments. We set the parameter values using a combination of calibration and estimation methods. For the calibration, we rely on existing studies and reduced form estimations using Spanish data.

Following existing studies in the literature, the risk aversion parameter $\sigma$ is set to 2. The discount factor $\beta$ is set to 0.96. The reentry probability $\mu$ is set to 0.25. The curvature parameter of the labor supply, $\eta$, is set to 1.30. The labor share in output, $\alpha$ is set to 0.66. The risk-free interest rate, $r$ is set to 2 percent, calculated using average real government
bond yields of Germany in 1999–2012. The interest rate paid on deposits, $r^b$, is also set to 2 percent for simplicity. The capital requirement coefficient, $\varphi$, is 4 percent, which is the Tier 1 capital requirement under Basel II.

The remaining parameters are set to match the moment conditions we discuss shortly and also summarized in Table 2. The autocorrelation of TFP, $\rho$, is set to 0.51 based on an AR(1) estimation of Spanish multi-factor productivity data from OECD in 1984–2011 period. We do not set $\sigma_\varepsilon$ to the value estimated using this procedure because since we do not model capital accumulation and investment, doing so yields an output variability in the model that is significantly less than that in the data. Hence, we set $\sigma_\varepsilon$ in order to match the model-implied output variability to that in the data which is 2.58 percent using HP-detrended IFS data on real output in 1980–2012. This exercise implies $\sigma_\varepsilon = 2.26$ percent. Finally, we calibrate the maximum and minimum values of probability of firm success, $p(z^{\max})$ and $p(z^{\min})$. To do so, we use impaired loans to total loans ratio from Bankscope for the largest five banks in Spain based on total assets. The minimum value of the probability of success is set to $1 - 0.04$, as the average of the impaired loans ratio for 2008-2012 is 0.04, while the maximum value is $1 - 0.008$, based on the average value of 0.008 for the same ratio in 2004–2007.

The remaining parameters that need to be estimated are total deposits ($\bar{d}$), equity issuance cost parameters ($\varphi_0$ and $\varphi_d$), and the lower and upper bounds of the idiosyncratic firm shocks ($\underline{a}$ and $\bar{a}$). Our estimation procedure is simulated method of moments with the target moments listed in Table 2. We mainly choose first moments as targets with the goal of matching the relative size of the various bank balance sheet items, the share of bank’s bond holdings in the sovereign bond market to their corresponding values in the data. In addition, we ensure that while the sovereign debt market is closed, the capital adequacy requirement for the bank binds in all possible realizations of the exogenous shocks. With this approach, we link the relative size of the main model ingredients to the data while primarily examining the second moments to judge the performance of the model. The estimation procedure implies values of $\{0.28, 0.20, 0.45, 0.10, 0.15\}$ for the parameters $\{\bar{d}, \underline{a}, \bar{a}, \varphi_0, \varphi_d\}$. Note that with these values, the cost of issuing new equity while the sovereign is in default is 50 percent more expensive than during normal times.

The selection of time period over which to compute mean bond spreads is not a straightforward task. Government bond yields in Spain follow a U-shaped trajectory if we compute these yields starting in 1979—the beginning year of the most comprehensive sample in IFS. During post-1999 period, however, the spreads of Spanish bonds over German bond (deflated by respective country inflation rates) appear minuscule until 2009. Hence the post-1999 period essentially implies 11 years of almost zero spreads and three years of larger spreads;
with an average of less than 50 bps. Thus, focusing only on the post-1999 period might be misleading. To get a more accurate, longer-term view, we calculate the average spreads for the entire data starting in 1979, which yields 149 bps. This estimate also lies between the highest and lowest spreads observed in the post-1999 period.

We compute the remaining target moments as follows. We compute the equity to assets ratio based on data for the largest 5 Spanish banks—with respect to total assets—that did not receive any capital injection by the government in the Bankscope data set. We restrict our analysis to only these banks to avoid biasing the equity ratios by, otherwise, including those banks that were subject to capital injections or have merged with other banks; we do not model any of these aspects in our framework. We find an average equity to total assets ratio of 6.37 percent for the 2004-2012 period, the entire available period in the Bankscope.

Similarly, the share of bank’s bond holdings to its total assets are also from Bankscope, for the same banks. Bankscope reports the total for the government securities as opposed to the banks’ holdings of its own sovereign bonds, so we multiply the total government security holdings by the share of Spanish banks’ holdings of Spanish government bonds to their total government securities reported by the 2010 euro area stress test (0.77) conducted by the European Banking Authority. After this adjustment, we estimate the share of bank’s bond holdings to total assets to be 5.32 percent for the 2004–2012 period.

3.2 Quantitative Results

We now turn to the simulation results and the statistical properties of the model. We first highlight the performance of the model in accounting for some important stylized facts on the behavior of government bonds and the banks’ portfolio. Table 3 lists the key moments in the first column, and lists the corresponding moments implied by the model in the second column. The first five lines in the table report the target moments in the estimation as explained in detail previously. As highlighted in the table, our model does a fairly good job in accounting for those stylized facts.

The next two lines compare the behavior of the mean total government debt to output, $E[B/y]$, and the mean unconditional default probability, $E[\lambda]$ in the model relative to that in the data. In examining the behavior of government debt, we focus on data for the gross general government debt from IFS, which include both domestic and foreign debt. Unlike most existing studies in the recent literature, we do not restrict ourselves to only external debt since, in our framework, debt is held both by domestic and foreign agents. However, similar to those studies, our model supports a fairly small amount of government debt in equilibrium compared to the data, 57 percent in the data and 3 1/4 percent in the model.
Our model implies an unconditional default probability of 1.05 percent. For Spain, Reinhart, Rogoff and Savastano (2003) report 13 default episodes since 1500 which implies an annual default probability of 2.53 percent. However, all of the reported defaults for Spain took place in pre-1900 period, with no default reported in the 20th century and the fact that it is part of the European Monetary Union (EMU) should be taken into account when assessing the default probability for Spain in the most recent decade. A reasonable range most likely is in between zero and 2.53 percent. The former estimate (zero) is in line with the number of default episodes since Spain’s EMU entry in 1999, assuming the EMU entry marks the beginning of a more “relevant” history. And the latter estimate (2.53 percent) is in line with the longest time series data available, ignoring all other factor. The model-implied probability of 1.05 percent is close to the mid-point of this range, hence, we think that our model performs well in this regard.

Next, we examine three second moments that are widely analyzed in the emerging market business cycles literature, the standard deviation of output, $\sigma(y)$, standard deviation of consumption relative to output, $\sigma(c)/\sigma(y)$, and the correlation of the trade balance with output, $\rho(tb/y, y)$. Even though Spain is an advanced economy, the observed business cycle fluctuations in the data resemble those of emerging markets where consumption is more variable than output and the trade balance is counter-cyclical. Our model performs reasonably well in matching these moments. More specifically, the model-implied consumption variability is about the same as that of output and the trade balance is weakly countercyclical.

The next two moments are the correlations of total sovereign debt to output ratio and bank’s bond holdings to output ratio with output. These two correlations suggest that both in the data, and in the model, the sovereign issues more debt in bad times, consistent with the recent surge of debt during the crisis. At the same time, the bank holds more of the government bonds in bad times.

In our framework, the bank finds it optimal to reallocate its asset portfolio which consists of loans to firms and government bond holdings, such that it gives more weight to government bonds in bad times. This is because firms’ demand for loans goes down, leaving the bank with smaller monopoly profits and also the return on the sovereign bond goes up. Such portfolio

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5This estimate is also close to the widely-cited default probability of 3 percent for Argentina.
6The national accounts data are from IFS covering 1980-2012. Nominal private consumption is deflated with CPI, deseasonalized using X-12 and HP-filtered.
7Sovereign debt to output ratio is total gross general government debt as explained in the calibration section. For bank’s bond holdings, we take depository corporations’ net claims on general government based on nation-wide residency from IFS. The advantage of IFS data over Bankscope is that it goes back to 1999 at quarterly frequency while Bankscope usually is available starting in 2004 or later depending on the specific bank.
8Broner, Erce, Martin and Ventura (2013) also document an increase in home bias in sovereign bond markets during turbulent times.

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reallocation is evident in the negative correlation between bank’s bond holding and output \((\rho(b/y, y) = -0.09)\) and a positive correlation between loans and output \((\rho(\ell, y) = 0.29)\).

The interest rates on loans to firms, \(r^\ell\) is highly, positively correlated with output both in the data and in the model. In the data, we take the interest rate on loans to nonfinancial corporations up to 1-yr from IFS (available starting in 2003:q1) and deflate it with the CPI inflation. Absent any policy intervention, in a downturn, one may expect a decline in credit to be accompanied by an increase in the interest rate, implying a negative correlation between output and the interest rate. The data, however, suggests the opposite relationship between these two series, which might, partly, be due to policy interventions. The interest rate rises and peaks in 2008:q4, which is the peak of the economic boom and then falls until 2010:q3. The interest rate picks up again afterwards during the most turbulent times for Spain. This pattern suggests that the policy can achieve procyclical interest rates generally with the exception of during more severe crises episodes such as the recent one. Hence, the data suggest overall a procyclical interest rate. Our model also has the same prediction but for, potentially, different reasons than those that drive the observed patterns in the data as we do not model interest rate policy. In our model, the monopoly profit maximization of the bank delivers the result that when the demand for loans is high, the bank chooses to extend more loans at a higher price. So, not only do they extract more profits through larger loans but also they charge a higher price. Given a highly concentrated banking system in Spain, such a mechanism may be in place in real world also. However, policy interventions discussed above is likely to be playing a role as well.

Loans and interest rates are negatively correlated. This is evident in Equation 12, which suggests that the threshold productivity increases with the interest rates on the loans to firms. Loans are simply determined by the threshold productivity with a higher threshold productivity implying fewer firms deciding to operate their projects and the aggregate demand for labor being smaller.

When the market for sovereign bonds is open, for given productivity, the larger bank bond holdings \((b)\) are associated with smaller loans. A closer look at Equations 24–26 reveal why this is the case. For a given source of funds, the banks starts the period with, i.e., \(b + d\) an expansion of these funds to finance a larger asset portfolio, i.e. \(\ell + q^\ell b\) requires new equity issuance. Since the equity issuance is costly and it is the total assets that is constrained by costly equity issuance, when the bank finds it profitable to extend large loans to the firms, it also finds it optimal to cut back on the purchases of sovereign bonds. Note that if issuing

\[9\text{The data correspondent for } \ell \text{ is the net claims on other sectors (i.e., non-government) of nation-wide residency depository corporations from IFS. We take the first difference and look at the correlation between the flow of loans and output.}\]
new equity were costless, such a trade-off would not be present.

Combining the bank’s balance sheet identity in Equation 25 with the capital requirement in Equation 26 and the fact that $\omega = 0$ in our baseline case helps further understand the link between firm loans and bank’s sovereign bond holdings:

\[(1 - \varphi)\ell + qb' \geq d.\]

The above equation suggests that since equity is defined as the difference between assets and liabilities in the balance sheet, it is not just the loans to firms that matter but also the holdings of sovereign bonds are important. One key difference between the two is that an extra term $(1 - \varphi)$ appears in front of loans. This is because each unit of extra loan increases the equity requirement by $\varphi$ but there is no such mechanism for bond holdings in the baseline scenario. During default, the above expression becomes:

\[(1 - \varphi)\ell \geq d.\]

Given our calibration that ensures that the capital requirement binds for sure during exclusion, loans are simply $\ell = d * (1 - \varphi)$.

On the sovereign’s side, ceteris paribus, the sovereign has weaker incentives to default when the stock of sovereign bonds is smaller and when the bank holds more bonds. The former result is standard in sovereign default models due to the benefit from defaulting being smaller if the amount of debt that is defaulted on is smaller. The latter result is novel in our framework that arises because the sovereign internalizes the fact that when the domestic bank holds more of these bonds, its balance sheet deteriorate more, having a larger negative effect on its lending to the firms and output. Such internalization is evident in Figure 3, which shows that the price of sovereign bonds is higher when the bank holds more of them.

Having understood the model dynamics for given productivity, we can analyze the response of the economy to fluctuations in productivity. First, remember that lower aggregate productivity shocks coincide with a smaller fraction of the firms that succeed. Hence, fewer firms operate their project and demand for loans is smaller. As a result, the bank extends fewer loans while demanding more sovereign bonds. This implies a trade-off for the sovereign when it makes its default decision. On the one hand, lower productivity and output strengthens its incentives to default to avoid low levels of consumption, on the other hand, larger bond holdings by the bank weakens its default incentives as explained above. In equilibrium, we find that the former effect is stronger and the sovereign is more likely to default during low productivity periods.
3.3 Policy Alternatives

We now analyze counterfactual scenarios to examine the implications of the changes in the capital requirement. Table 4 summarizes our findings. The first column shows the baseline results. In the second column, the capital requirement coefficient, \( \varphi \), is set to 0.06, which is also the value in Basel III. The third column keeps the capital requirement at the baseline value of 0.04 but the right hand side of the constraint is modified to include bank’s sovereign bond holdings in risk-weighted-assets with a corresponding weight (\( \omega \)) of 100 percent. This case with \( \omega \) of 100 percent corresponds to a so-called “leverage ratio,” which captures total assets without any risk weighting. In the last column, the capital requirement coefficient is set to 0.03, and the weight on sovereign bonds is 100 percent. This very last column captures the leverage requirement in Basel III.

A higher capital requirement in the second column with \( \varphi = 0.06 \) leads the bank to issue twice as much new equity (see the line for \( E[\tilde{s}] \)) as that in the baseline. In addition, the equity to total assets ratio is twice as much as that in the baseline, which is consistent with more new equity issuance when \( \varphi \) is higher. During default, capital requirement is binding for all states as in the baseline so the equity to assets ratio simply equals 0.06. This “more prudent” behavior of the bank does not lead to improved lending in the form of higher mean or weaker procyclicality for loans. This is because the bank finds it optimal to buy more sovereign bonds instead of extending more loans to the firms with the additional funds available through new equity issuances. Loans to firms are subject to a larger capital requirement with a higher \( \varphi \) making them more costly compared to purchasing sovereign bonds. Consistently, we observe a higher mean bank bond holdings with \( \varphi = 0.06 \) than under the baseline.

In general, higher bank bond holdings are associated with higher debt levels that the sovereign can sustain in equilibrium which also holds in the case of \( \varphi = 0.06 \). This is intuitive considering that the sovereign internalizes the effects of its default decision on bank lending. Hence, higher bank holdings imply that the sovereign can issue more bonds without having to face excessively low bond prices.

The case with \( \omega = 1 \) reported in column three leads the bank to hold somewhat less government bonds compared to the baseline, without affecting the mean loans to the firms. When government bonds are treated similar to other risky assets against which capital needs to be held, the bank finds holding government bonds less attractive. Overall, in this case, loans are less variable, less pro-cyclical, and the default is less frequent; hence, consumption and output are less variable. Eliminating the preferential treatment of sovereign bonds contains macroeconomic fluctuations without having the bank to hold additional equity, but the stock of government bond that is supported in equilibrium becomes smaller.
Finally, in the last column, we parameterize the capital requirement such that it corresponds to the newly-introduced leverage requirement in Basel III which is very similar to our parameterization in column three with a $\phi$ of 0.03 instead of 0.04. In this case, the new equity issuance as well as the default risk are the lowest among all scenarios. Consistently, consumption variability is fairly low. Compared to the other alternatives we look at, the column four appears to lower default risk and increase the mean government debt without reducing mean loans. However, it does somewhat increase procyclicality of loans and their standard deviation as reflected in the output variability.

4 Conclusion

With the recent financial crisis in Europe, sovereign debt default and its relationship with the banking sector climbed to the top of the global economic agenda. This paper proposes a model to examine the link between sovereign risk and banking sector stresses. The model captures the procyclical bank credit and countercyclical bank holdings of sovereign bonds. Since the sovereign defaults indiscriminately, bank losses due to a default hampers its lending to firms, thereby, generating an endogenous cost of default.

Using the model, we quantify how regulatory changes in the banking sector (such as capital requirements) affect macroeconomic fluctuations, the risk of sovereign default and the probability of a banking crisis. Our preliminary findings suggest that the introduction of leverage ratios is superior to increasing the capital requirement on risk weighted assets where sovereign bonds are assigned a zero weight.
References


Table 1: Parameter Values

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<thead>
<tr>
<th>Parameter</th>
<th>Notation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calibrated Parameters</strong></td>
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<tr>
<td>Risk aversion</td>
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<td>Discount factor</td>
<td>$\beta$</td>
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<td>Reentry probability</td>
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<td>Risk free interest rate</td>
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<td>Interest rate on deposits</td>
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<td>Curvature parameter of labor supply</td>
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<tr>
<td>Labor share in output</td>
<td>$\alpha$</td>
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</tr>
<tr>
<td>Capital requirement</td>
<td>$\varphi$</td>
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</tr>
<tr>
<td>Lower bound for probability distribution for projects</td>
<td>$p_{z_{min}}$</td>
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</tr>
<tr>
<td>Upper bound for probability distribution for projects</td>
<td>$p_{z_{max}}$</td>
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</tr>
<tr>
<td><strong>Estimated Parameters</strong></td>
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</tr>
<tr>
<td>Autocorrelation of TFP</td>
<td>$\rho$</td>
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<td>Standard deviation of TFP (percent)</td>
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<td>Total deposits</td>
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<td>Equity issuance cost parameter</td>
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<td>Equity issuance cost parameter in default state</td>
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<tr>
<td>Upper bound of the idiosyncratic firm shocks</td>
<td>$\overline{a}$</td>
<td>0.45</td>
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</table>

Notes: This table summarizes the parameter values. A set of parameters are calibrated and the remaining set of parameters are estimated using a simulated method of moments approach. The target moments for the estimation are summarized in the main text.
Table 2: Target Moments

<table>
<thead>
<tr>
<th>Moment</th>
<th>Source</th>
<th>Value</th>
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<td>$E[\text{spread}]$</td>
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</tr>
<tr>
<td>$E[b/B]$</td>
<td>EBA Stress Test in 2010</td>
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<tr>
<td>$E^{D=1}[e/(l+qb')]$</td>
<td>n.a.</td>
<td>4.00</td>
</tr>
<tr>
<td>$E^{D=0}[e/(l+qb')]$</td>
<td>Bankscope</td>
<td>6.37</td>
</tr>
<tr>
<td>$E[qb'/(l+qb')]$</td>
<td>Bankscope</td>
<td>5.32</td>
</tr>
</tbody>
</table>

Notes: This table lists the target moments for the simulated method of moments exercise.

Table 3: Long-run Moments

<table>
<thead>
<tr>
<th>Moment</th>
<th>Data</th>
<th>Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E^{D=1}[e/(l+qb')]$</td>
<td>n.a.</td>
<td>4.00</td>
</tr>
<tr>
<td>$E^{D=0}[e/(l+qb')]$</td>
<td>6.37</td>
<td>5.48</td>
</tr>
<tr>
<td>$E^{D=0}[qb'/(l+qb')]$</td>
<td>5.32</td>
<td>4.36</td>
</tr>
<tr>
<td>$E[\text{spread}]$</td>
<td>1.49</td>
<td>1.54</td>
</tr>
<tr>
<td>$E[b/B]$</td>
<td>77.41</td>
<td>70.06</td>
</tr>
<tr>
<td>$E[B/y]$</td>
<td>56.95</td>
<td>3.26</td>
</tr>
<tr>
<td>$E[\lambda]$</td>
<td>n.a.</td>
<td>1.05</td>
</tr>
<tr>
<td>$\sigma(y)$</td>
<td>2.58</td>
<td>2.69</td>
</tr>
<tr>
<td>$\sigma(c)/\sigma(y)$</td>
<td>1.11</td>
<td>0.99</td>
</tr>
<tr>
<td>$\rho(tb/y, y)$</td>
<td>-0.29</td>
<td>-0.09</td>
</tr>
<tr>
<td>$\rho(b/y, y)$</td>
<td>-0.20</td>
<td>-0.09</td>
</tr>
<tr>
<td>$\rho(B/y, y)$</td>
<td>0.29</td>
<td>0.08</td>
</tr>
<tr>
<td>$\rho(\ell, y)$</td>
<td>0.36</td>
<td>0.29</td>
</tr>
<tr>
<td>$\rho(r^t, y)$</td>
<td>0.68</td>
<td>0.64</td>
</tr>
</tbody>
</table>

Notes: This table summarizes the long-run moments in the data and in our simulations. All the mean values, denoted as $E[\cdot]$, and the standard deviation of output, $\sigma(y)$, are reported in percent.
Table 4: Counterfactual Experiments: Changes in the Capital Requirement

<table>
<thead>
<tr>
<th>Moment</th>
<th>Baseline</th>
<th>$\varphi = 0.06$</th>
<th>$\varphi = 0.04$</th>
<th>$\varphi = 0.03$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E^{D=0}[e/(\ell + qb')]$</td>
<td>5.480</td>
<td>11.612</td>
<td>4.987</td>
<td>5.947</td>
</tr>
<tr>
<td>$E[B/y]$</td>
<td>3.258</td>
<td>5.060</td>
<td>2.768</td>
<td>3.257</td>
</tr>
<tr>
<td>$E[b/y]$</td>
<td>2.282</td>
<td>5.060</td>
<td>2.166</td>
<td>3.257</td>
</tr>
<tr>
<td>$E[d^p]$</td>
<td>0.278</td>
<td>0.272</td>
<td>0.279</td>
<td>0.278</td>
</tr>
<tr>
<td>$E[\ell]$</td>
<td>0.282</td>
<td>0.281</td>
<td>0.282</td>
<td>0.280</td>
</tr>
<tr>
<td>$E[\hat{s}]$</td>
<td>-0.004</td>
<td>-0.009</td>
<td>-0.003</td>
<td>-0.002</td>
</tr>
<tr>
<td>$E^{D=0}[\text{spread}]$</td>
<td>1.540</td>
<td>3.737</td>
<td>1.633</td>
<td>1.000</td>
</tr>
<tr>
<td>$E[\lambda]$</td>
<td>1.046</td>
<td>1.858</td>
<td>0.859</td>
<td>0.745</td>
</tr>
<tr>
<td>$\sigma(y)$</td>
<td>2.693</td>
<td>2.987</td>
<td>2.568</td>
<td>2.963</td>
</tr>
<tr>
<td>$\sigma(c)$</td>
<td>2.679</td>
<td>3.109</td>
<td>2.783</td>
<td>2.774</td>
</tr>
<tr>
<td>$\rho(\ell, y)$</td>
<td>0.291</td>
<td>0.525</td>
<td>0.026</td>
<td>0.590</td>
</tr>
</tbody>
</table>

Notes: This table summarizes some key moments in the baseline, the first column, and with alternative parameterizations of the capital requirement in the subsequent columns. All the mean values, denoted as $E[\cdot]$, with the exception of $E[d^b]$, $E[\ell]$, $E[\hat{s}]$ are reported in percent. The standard deviation of output, $\sigma(y)$, and the standard deviation of consumption, $\sigma(c)$ are also reported in percent.

Figure 1: Spreads on 10-year Bonds in Peripheral Europe

Notes: The graph shows the 10-year government bond spreads relative to German Bunds.
Figure 2: Loan Rates and Net Loans to Nonfinancial Corporations

Notes: The graph on the left shows the loan rates for newly-issued bank loans to the nonfinancial corporations. The graph on the right shows the volume of net loans to nonfinancial corporations as a share of respective GDPs.

Figure 3: Bond Price Schedule with Various Bank Holdings of Government Bonds

Notes: This figure shows the price schedule for three different levels of bank’s holdings of government bonds conditional on a neutral TFP shock state.