Sovereign Default Risk and Bank Balance Sheets*

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Abstract

This paper explores how banks' balance sheets and sovereign risk affect macroeconomic fluctuations jointly. The heightened sovereign risk and a potential default constrain the banks' ability to extend credit to firms. This happens through the capital requirement that limits the size of the bank loans to firms and government to a fraction of the banks' equity. An increase in non-performing loans to firms also hampers the bank balance sheets. With the joint interaction of sovereign risk and bank balance sheets in place, the paper, first, shows the bank balance sheet stresses and the government's need for funds to provide deposit insurance can trigger a sovereign default. The paper then examines how the introduction of specific risk weights for certain assets affect macroeconomic fluctuations and, more importantly, the joint determination of sovereign debt and banking crises.

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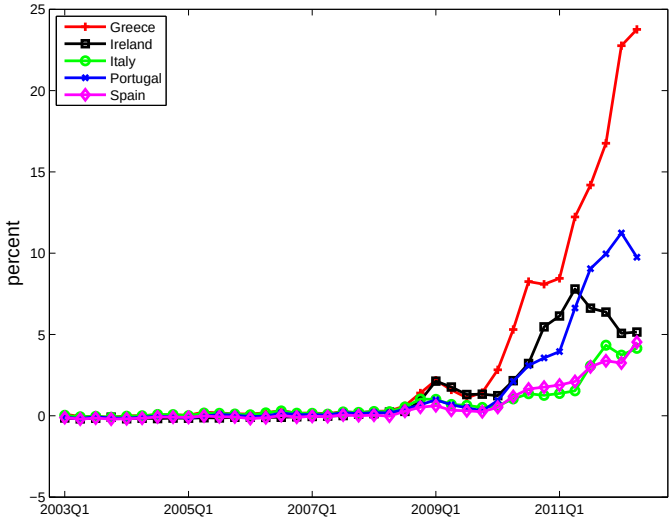
1 Introduction

As the financial crisis has been unfolding in Europe, sovereign debt default and its relationship with the banking sector climbed to the top of the global economic agenda. As the sovereign spreads in peripheral European countries (Greece, Ireland, Italy, Portugal, Spain, GIIPS, henceforth) started to rise rapidly as shown in Figure 1, banking sector in those countries has had difficulty in extending credit to nonfinancial corporations. As Figure 2 highlights loan rates started to rise rapidly (left panel) while net loans as a share of GDP started to decline rapidly (right panel). Despite the apparent 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 crisis remain unexplained.[1] 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.

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 banks. They supply labor to productive firms and make deposits to the financial sector. Firms have access to a risky technology that requires bank loans in order to be operated. The asset side of bank's balance sheet is determined by a mix between sovereign debt and the risky corporate loans. We assume deposit insurance which creates a moral hazard problem, leading the bank to engage in excessive lending to risky firms. This moral hazard problem also provides the rationale for capital requirements. We assume that 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

[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.

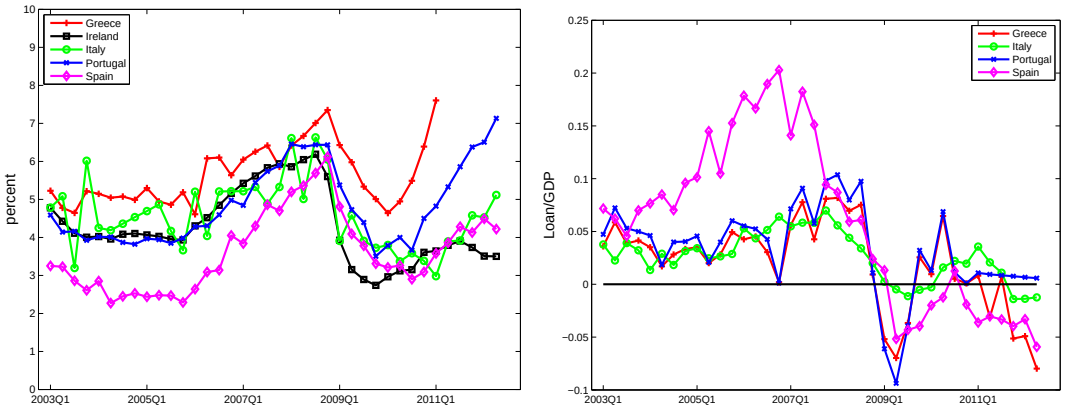
Figure 1: Spreads on 10-year Bonds in GIIPS



Notes: The graph shows the 10-year government bond spreads relative to German Bunds.

of foreign lenders.

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.

In our model, banks' balance sheets and sovereign risk affect macroeconomic fluctuations jointly. The heightened sovereign risk and a potential default constrain the banks' ability to extend credit to the firms. This happens through the capital requirement that limits the size of the loans from the banks to the firms and government to a fraction of their equity. The deterioration of the asset side of the balance sheet of banks can also arise from an increase in non-performing loans to the corporate sector. In this case, the banking crisis and the government's need for funds to provide the deposit insurance can trigger a sovereign default.

Armed with the unified framework of bank balance sheets and endogenous sovereign risk, we examine how the introduction of specific risk weights for certain assets affect macroeconomic fluctuations and, more importantly, the joint determination of sovereign debt and banking crisis. This experiment is motivated by the developments during the earlier stages of the European debt crisis. Many countries around the world including the euro area implemented Basel II, which relied heavily on the credit ratings of loans to their riskiness. For example, the capital requirement when a bank holds sovereign debt in its balance sheet was determined by the credit rating of the sovereign. This 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. As the sovereign debts of a few countries were being downgraded after the crisis was set in motion, the risk weights went up from zero to 100 percent, for Greek debt for example, as the sovereigns' rating was gradually downgraded by credit rating agencies. Using our framework, we will also be able to disentangle the effect of the inherent procyclicality of the Basel II capital requirement from other shocks and quantify its potential amplification during downturns.

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 requirements on macroeconomic fluctuations

is on 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 waive 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 connection with 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 difference from Sosa Padilla's work is that we introduce risky corporate loans and deposit insurance. These additional features allow us to study how bank risk-taking behavior and sovereign default 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 representative household, a continuum of firms, a finite number of banks and a government. Banks intermediate resources between the household sector, firms and the government. The government issues sovereign bonds and is not committed to repay.

2.1 Preferences and Endowments

Households preferences are

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

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

Households are endowed with a unit of labor that they can provide to the firms at wage rate w_t and y units of a non storable perishable good. They can place its endowment in domestic banks that pay a risk-free return r^d since we assume that there is deposit insurance. Households can also deposit its endowment with international financial intermediaries at risk free rate r_t. We denote deposits in domestic banks and international financial institutions by d^d and d^f, respectively, so $d^d+d^f=y$. The ownership of the banking and productive firms is assumed to be uniformly distributed across the population, and dividends (net of equity issuance) are shared equally in equilibrium. The government makes lump-sum transfers T_t to the households and collect taxes τ_t to pay for deposit insurance.

As we further will explain below, some firms in this economy can fail, so not all households that are employed receive wage payments. This implies that households' budget constraint is

$$c_t=\hat{w}_t h_t+(1+r^d)d^d+(1+r)d^f+\mathcal{D}_t^b+\mathcal{D}_t^f+T_t-\tau_t. \tag{2}$$

where $\hat{w}_t$ is the realized wage (that takes into account the fact that some workers are not repaid), $\mathcal{D}_t^b$ and $\mathcal{D}_t^f$ denote net dividend payments from the banking and the corporate sector respectively.

2.2 Firms Technology

The unit of production is a firm. They live for one period and have access to a production technology $f(z_{t+1}, n_t)$ that combines productivity z_{t+1}, and labor h_t. Firms make their labor decision in period t before productivity z_{t+1} is realized and are subject to an idiosyncratic shock that determines whether the project is successful or not. If the project is successful the technology returns $f(z_{t+1}, n_t)$ and if the project fails the return is zero. We assume that the production function has decreasing returns to scale. In particular, in the successful state $f(z_{t+1}, n_t)$ equals $z_{t+1}h_t^{\alpha}$ with $0 < \alpha < 1$.

The aggregate technology shock is denoted by $z_t \in Z$ and evolves as a Markov process $F(z', z) = \Pr(z_{t+1} = z' | z_t = z)$. We assume that the success probability depends on the aggregate productivity and is denoted by $p(z_{t+1})$. Moreover, we assume that there is less failure in good times. Specifically, $p(z_t)$ is assumed to be increasing in z_t, i.e., $p(z^1) > p(z^2)$ for any $z^1 > z^2$. While firms are ex-ante identical, they are ex-post heterogeneous, owing to the realizations of the shocks to the return on their project. In summary,

$$f(z_{t+1}, n_t) = \begin{cases} z_{t+1}h_t^{\alpha} & \text{with prob } p(z_{t+1}) \\ 0 & \text{with prob } 1 - p(z_{t+1}) \end{cases} . \tag{3}$$

Labor markets are competitive but they are not frictionless. Firms face a working capital constraint to hire workers. A fraction θ of the total wage bill needs to be paid in advance and require them to borrow, that is

$$\theta w_t h_t \leq \ell_t^d \tag{4}$$

where ℓ is the size of the loan the firm requests. This is a standard assumption in the literature and allows us to derive a simple loan demand function. Finally, we assume that there is limited liability.

Firms maximize their expected profit given by

$$E_t \left[\max \left\{ z_{t+1} h_t^{\alpha} - w_t h_t - \theta r_t^{\ell} \ell_t^{d}, 0 \right\} \right] \tag{5}$$

where r_t^{ℓ} is the interest paid out for a unit of working capital loan. The expectation is taken over the aggregate productivity shock and the idiosyncratic success/failure of the project.

2.3 Government

The government maximizes households' preferences. It borrows or saves using only one period non-contingent bonds denoted by B_{t+1}. Debt is issued in a competitive sovereign debt market at discounted price q_t. Domestic banks as well as foreign lenders participate in the market for sovereign debt. We denote borrowing by $B_t < 0$ and savings by $B_{t+1} > 0$. Proceeds from borrowing and lending in the sovereign debt market are transferred as a lump-sum to the household sector. We denote these transfers by T_t. The government also collect taxes τ_t from the household sector to pay for deposit insurance.

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 is not committed to repay its outstanding debt. At the beginning of the period, before 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 μ the government will recover its good standing in 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 $x_t = 1$ periods when is excluded from credit markets.

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

$$T_t = q_t B_{t+1} - B_t. \tag{6}$$

Conversely, after a default and during financial autarky $T_t = 0$.

2.4 Domestic Banking Sector

We assume that there is one large national bank that makes loans to firms $\ell_t^s \geq 0$, and receive deposits from the household sector $d_t \geq 0$. The bank can also accumulate government bonds b_{t+1}. Effectively one of the lenders of the government is the domestic banking sector. The present value of a bond that pays one unit of consumption in period $t+1$ is equal to q_t.

While the the bank is assumed to be the dominant player in the domestic loan market, 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 secondary markets. Since the bank is a dominant player, the bank internalizes the impact of its loan supply ℓ_t^s on the equilibrium loan interest rate r_t^ℓ. Moreover, since there is deposit insurance, it will be optimal to drive the interest rate paid on deposits to $r_t^d = r_t$.

Loans to the corporate sector and the government as well as any distributions to shareholders can be financed with either the internal funds generated by deposits, government bonds due or net new external funds, s_t ($s_t < 0$ implies equity issuance and $s_t > 0$ implies retained earnings). We assume that equity issuance entails additional costs so that the bank will never find it optimal to simultaneously pay dividends and to issue equity. In this dimension, we follow the tradition in macro corporate finance (see Hennessy and Whited (2005) for example) and assume a quadratic cost function. Formally, letting s_t denote the net payout to equity holders, we let total issuance costs be $\phi(s_t) = I_{[s_t<0]}[\phi_0(-s_t) + \phi_1 s_t^2]$.

If the government chooses not to default, the bank feasibility constraint at the beginning of the period is given by

$$\tilde{s}_t = d_t + b_t - \ell_t - q_t b_{t+1}. \tag{7}$$

where $\tilde{s}_t$ is the net payments. If the government defaults, the feasibility constraint

becomes

$$\tilde{s}_t = d_t - \ell_t. \tag{8}$$

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

$$e_t \equiv \ell_t + q_t b_{t+1} - d_t. \tag{9}$$

As in the current bank regulation, we assume that banks are subject to a capital requirement constraint. That is

$$e_t \geq \varphi \left(\ell_t + \omega(q_t) q_t b_{t+1} \right) \tag{10}$$

where $\varphi \in [0, 1]$ is the minimum fraction of risk-weighted assets that the value of equity can take and $\omega(q)$ is the weight on sovereign bonds–assumed to be a function of the bond price to reflect the fact that sovereign bonds might be "risk-free" or "risky" assets.

At the end of the period (e.g., after the realization of the aggregate and firms' idiosyncratic shocks), the value of net equity issuance by the bank is given by

$$s_{t+1} = \tilde{s}_t + p(z_{t+1})(1 + r_t^{\ell})\ell_t - (1 + r^d)d_t - \phi(\tilde{s}). \tag{11}$$

Then, the net payment to shareholders is

$$\mathcal{D}_{t+1} \quad = \quad s_{t+1} - \phi(s_{t+1}). \tag{12}$$

2.5 Foreign Lenders

A perfectly competitive foreign credit industry accepts deposits and makes loans to the sovereign country. Foreign creditors are risk-neutral and have unlimited access to funds at interest rate equal to $r \geq 0$.

The government borrows at price q_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. 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

$$\Omega_t = -q_t(-B_{t+1}) + \frac{(1-p_t)}{(1+r)}(-B_{t+1}), \tag{13}$$

where p_t denotes the expected probability of government default in period t. In equilibrium, foreign lender's profits will be zero.

2.6 Time Line

In this section, we describe the timing of the model. Each period is divided in to two sub-periods.

A period t starts and the state is $\{b_t, B_t, z_t, x_t\}$, 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 μ.
   - Banks collect deposits d_t from households, decide on the amount of loans ℓ_t and the value of net equity issuance $\tilde{s}_t$.
   - Firms choose the amount of loans ℓ_t^d and labor to demand h_t^d. Loan demand and supply determine the loan interest rate r^ℓ.
   - Households select the amount of labor to supply h_t^s. Labor demand and supply determined the equilibrium wage rate w.

2. Later in 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}. This determined the net payments to shareholders $\mathcal{D}(s_{t+1})$.
   - Government transfers are determined.
   - Households receive government transfers, wages, payments from the banking and corporate sector and consume.

3 Equilibrium

This section presents the problem of the household, the firm, the financial sector and the government in a competitive equilibrium. We then define formally what an equilibrium is. We use recursive notation.

3.1 Households' Problem

Recall that labor decisions are made before productivity and firm idiosyncratic shocks are realized. A fraction θ of workers will be paid in full (with a loan from the bank) and the rest will be paid only if the firm does not fail. This implies that $\hat{w}(z') = \theta w + (1-\theta)p(z')w$ In equilibrium, deposit insurance allows the bank to drive down the interest rate on deposits to r_t, so households are indifferent between placing their endowment in domestic or international banks.

At the beginning of the period, households determine its labor decision rule as the solution to the following problem

$$\max_{h} E\left[\frac{\left(c' - \chi\frac{h^{\eta}}{\eta}\right)^{1-\sigma}}{1-\sigma}\right] \tag{14}$$

s.t.

$$c' = h\hat{w}(z') + \mathcal{D}^b + \mathcal{D}^f + T + y(1+r). \tag{15}$$

The solution to this problem yields the following relationship between the labor supply and the wage rate

$$h^d = \left[\frac{w}{\chi}\left[\theta + E_t[p(z')](1-\theta)\right]\right]^{\frac{1}{\eta-1}}. \tag{16}$$

3.2 Firms' Problem and Labor Market

Firms maximize expected profits. In equilibrium, the working capital constraint (4) binds, and only for successful projects the limited liability constraint is not binding, so we can write the problem of any given firm as follows:

$$\max_h E\left[p(z')\left\{z'h^\alpha - wh(1+\theta r^\ell)\right\}\right] \tag{17}$$

The first order condition for the firms' optimization problem yields

$$\alpha h^{\alpha-1} E\left[p(z')z'\right] = E\left[p(z')\right] w\left(1+\theta r^\ell\right). \tag{18}$$

The first order condition equates the marginal product of labor to the wage bill, which equals wage rate plus the cost of holding working capital. Then, the labor demand is

$$h^s = w^{\frac{1}{\alpha-1}}\left[\frac{E\left[p(z')\right]\left(1+\theta r^\ell\right)}{\alpha E\left[p(z')z'\right]}\right]^{\frac{1}{\alpha-1}}. \tag{19}$$

In equilibrium, the labor market clears, so labor supply and demand are equalized. This implies that

$$h^{\alpha-1} = h^{\eta-1}\frac{\chi}{\left[\theta + E_t[p(z')](1-\theta)\right]}\left[\frac{E\left[p(z')\right]\left(1+\theta r^\ell\right)}{\alpha E\left[p(z')z'\right]}\right] \tag{20}$$

$$\Rightarrow h^*(r^\ell) = \left[\frac{\chi}{\left[\theta + E_t[p(z')](1-\theta)\right]}\right]^{\frac{1}{\alpha-\eta}}\left[\frac{E\left[p(z')\right]\left(1+\theta r^\ell\right)}{\alpha E\left[p(z')z'\right]}\right]^{\frac{1}{\alpha-\eta}} \tag{21}$$

where $h^*(r^\ell)$ denotes the equilibrium value of labor as a function of the loan interest rate r^ℓ.

Using the equilibrium in the labor market, we can derive the expression for the loan demand:

$$\ell^d(r^\ell) = \theta w h^* = \theta \left[\frac{\chi}{[\theta + E_t[p(z')](1-\theta)]}\right]^{\frac{\alpha}{\alpha-\eta}} \left[\frac{E\left[p(z')\right]\left(1+\theta r^\ell\right)}{\alpha E\left[p(z')z'\right]}\right]^{\frac{\eta}{\alpha-\eta}} \tag{22}$$

3.3 Bank's Problem

At the beginning of the period, the government decides whether to default on its outstanding debt or not. If the government decides not to default on its debt, the bank has access to the sovereign debt market. Independent of the default decision, the bank collects deposits from households and makes loans to the corporate sector. Bank decisions are affected by the actions of the government. The relevant state variables include its own bond holdings b, the level of productivity z but also the total amount of debt issued by the government B. It is also relevant to know whether the sovereign debt market is open or not. The bank takes as given the policy functions of the government B' and D.

Before the government has decided to default or not, the value of the bank with bond holdings b, when the total stock of government debt is B and the level of productivity is z is

$$W(b, B, z) = D(b, B, z)W^{d=1}(z) + (1 - D(b, B, z))W^{d=0}(b, B, z) \tag{23}$$

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

When the government does not default, bank optimization problem can be summarized as follows:

$$W^{d=0}(b, B, z) = \max_{\ell, d\in[0,y], b', \tilde{s}, s'} E\left[\mathcal{D}(s') + \tilde{R}^{-1}W(b', B', z')\right] \tag{24}$$

s.t.

$$\begin{aligned}
\tilde{s} &= d + b - \ell - q(b', B', z)b', && (25)\\
e &= \ell + q(b', B', z)b' - d, && (26)\\
e &\geq \varphi\left(\ell + \omega(q)q(b', B', z)b'\right), && (27)\\
s' &= \tilde{s} + p(z')(1 + r^{\ell})\ell - (1 + r^{d})d - \phi(\tilde{s}), && (28)\\
\mathcal{D}(s') &= s' - \phi(s'), && (29)\\
\ell &= \ell^{d}(r^{\ell}) && (30)
\end{aligned}$$

where $\tilde{R}^{-1}$ denotes the endogenous stochastic discount factor, equation (25) corresponds to resources available at the beginning of the period, equation (26) defines equity from the balance sheet identity, equation (27) is the capital requirement constraint, equation (28) denotes the available resources after the realization of the shocks, equation (29) is the net dividend payment and equation (30) is the loan market clearing condition.

Note that even though the bank acts competitively in the sovereign debt market, internalizes the fact that default decisions of the government are affected by its bond holdings, so the bond price changes with b'. The amount of loans that supplies to the corporate sector 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

$$W^{d=1}(z) = \max_{\ell, d \in [0,y], \tilde{s}, s'} E\left[\mathcal{D}(s') + \tilde{R}^{-1}\left(\mu W^{d=0}(0, 0, z') + (1 - \mu)W^{d=1}(z)\right)\right] \quad (31)$$

s.t.

$$\begin{aligned}
\tilde{s} &= d - \ell, && (32)\\
e &= \ell - d, && (33)\\
e &\geq \varphi\ell, && (34)\\
s' &= \tilde{s} + p(z')(1 + r^{\ell})\ell - (1 + r^{d})d - \phi(\tilde{s}), && (35)\\
\mathcal{D}(s') &= s' - \phi(s'), && (36)\\
\ell &= \ell^{d}(r^{\ell}) && (37)
\end{aligned}$$

When the government defaults, the only source of funds for the bank are the deposit and equity market. This has implications for the loan market equilibrium and is one of the endogenous costs of default.

The solution to this problem provides a bond decision rule $b'(b, B, z)$, net equity issuance in the no default and default state $\tilde{s}^{D=0}(b, B, z)$, $\tilde{s}^{D=1}(z)$,$s'^{D=0}(z', b, B, z)$, $s'^{D=1}(z', z)$ 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 $\ell^{D=1}(z)$.

3.4 Government

The government optimization problem can be expressed recursively as a function of $\{b, B, z\}$ as well as whether credit markets are open or not. The amount of bonds in hands of the banking sector b is relevant since consumers own the banks and the corporate sector and their consumption is affected by their flow of profits that in place are a function, among other variables, of b.

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

$$V(b, B, z) = \max_{D\{0,1\}} \left\{ V^{D=0}(b, B, z), V^{D=1}(z) \right\}, \quad (38)$$

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 default, it can issue new bonds and its maximization problem can be formulated as follows:

$$V^{D=0}(b, B, z) = \max_{B'} E\beta \left\{U(c', h^*) + V(b', B', z')\right\} \tag{39}$$

s.t.

$$\begin{aligned}
c' &= p(z')z'(h^*)^\alpha + B - q(b', B', z)B' - \phi(\tilde{s}) - \phi(s') && (40)\\
h^* &= h^*(r^{\ell, D=0}(b, B, z)) && (41)\\
b' &= b'^{D=0}(b, B, z) && (42)\\
\tilde{s} &= \tilde{s}^{D=0}(b, B, z) && (43)\\
s' &= s'^{D=0}(z', b, B, z) && (44)
\end{aligned}$$

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

$$V^{D=1}(z) = E\beta \left\{U(c', h^*) + \left[\mu V^{D=0}(0, 0, z') + (1-\mu)V^{D=1}(z')\right]\right\}. \tag{45}$$

s.t.

$$\begin{aligned}
c' &= p(z')z'(h^*)^\alpha - \phi(\tilde{s}) - \phi(s') && (46)\\
h^* &= h^*(r^{\ell, d=1}(z)) && (47)\\
\tilde{s} &= \tilde{s}^{D=1}(z) && (48)\\
s' &= s'^{D=0}(z', z) && (49)
\end{aligned}$$

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

The solution to this 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 of the productivity such that default is optimal given the level of debt in hands of the banks b and the total stock of debt issued by the government B,

$$\Gamma(b, B) = \{(z) \in \Upsilon : \quad D(b, B, z) = 1\}. \tag{50}$$

Using $\Gamma(b, B)$ we can compute the default probability of the government

$$p(b, B, z) = \int_{z' \in \Gamma(b,B)} F(dz', z). \tag{51}$$

3.5 Foreign Lenders and Equilibrium Bond Price

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:

$$q(b, B, z) = \frac{p(b, B, z)}{(1 + r)}. \tag{52}$$

3.6 Definition Recursive Competitive Equilibrium

To be done..

4 Quantitative Results

Table 1 summarizes the calibration parameters. We take the standard parameter values from the sovereign default literature. The new parameters unique for our analysis are calibrated to the Spanish data.[2] The risk aversion parameter σ is set to 2. The discount factor β is set to 0.953. Reentry probability

We now turn to the simulation results and the statistical properties of the model...

[2]Data details and sources are described in the Appendix.

Table 1: Calibration

Parameter	Notation	Value
Risk aversion	σ	2
Discount factor	β	0.953
Reentry probability	μ	0.282
Risk free interest rate	r_f	0.01
Interest rate on deposits	r_d	0.01
Autocorrelation of TFP	ρ	0.945
Standard deviation of TFP	σ_ϵ	0.025
Curvature parameter of labor supply	η	1.2
Scaling factor in GHH term	χ	0.85
Labor share in output	α	0.90
Capital requirement	φ	0.14
Working capital constraint	θ	0.50
Equity issuance cost parameter	ϕ_0	0.05
Equity issuance cost parameter	ϕ_1	0.00011

5 Conclusion

[To be completed]

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