Domestic Debt, Financial Intermediaries, and the Dynamics of Investment

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Abstract

Sovereign defaults that end up in a credit crunch are distinguished by a deep drop in output and protracted recovery — relative to defaults not affecting credit markets. In these events, most of the public debt is issued through domestic markets and a significant share of domestic banks' assets are government bonds. This paper studies how the exposure of the banking system to government debt accounts for the dynamics of investment and output during a default followed by a contraction in domestic credit. I develop a quantitative model that features capital accumulation, financial intermediation and endogenous sovereign default. Banks invest in capital and buy bonds issued by a benevolent government. They are financially constrained to issue deposits by the value of their net worth. In a sovereign default banks' investment in capital drops as their net worth decreases. I calibrate the model to match the fraction of banks' assets held as government bonds, the mean investment to GDP, and investment volatility for economies that experienced distress in domestic credit after a default. The model is able to reproduce the untargeted observed dynamics of output, investment, consumption, deposits, and bank's assets around default events. I use the model to illustrate the trade-off that government debt held in the banking sector provides between the ex-ante incentives to default and ex-post cost of default. An increase of 50 % in the share of bonds to bank's assets decreases the probability of default, but increases the volatility of investment to GDP by 23% and reduces the level of investment to GDP by 18%. With a lower capital stock, the ability to insure the economy against productivity shocks lessens, and the volatility of consumption relative to GDP increases by 13 %.

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1 Introduction

Recent empirical studies have documented particular regularities in default events that precede an episode of domestic credit distress.[1] First, they are distinguished by a severe and protracted decline in GDP compared to defaults that do not lead to a credit crunch. Second, they lead to a simultaneous drop in investments, deposits, and banks' assets. Third, economies that experienced such a default issued 85 % of their public debt in domestic markets. Fourth, following these events, the share of a government's bonds to assets that are held by domestic banks increases substantially in the run-up to default.

In this paper, I quantitatively study the effect that a default on domestically-held debt has on physical capital accumulation through assessing the impact on banks' balance sheets. I develop a closed economy model that incorporates both endogenous sovereign default and domestic banks that simultaneously invest in bonds and physical capital. In the model, investment is directly affected by the contraction in credit following a default. The model is calibrated to simulate the effects on a set of economies that face a contraction in domestic credit after a default. The model can replicate the untargeted boom, bust, and recovery dynamics around default events. During the boom, the government increases its issuance of debt, which is acquired by banks. In turn, this increase in debt raises the exposure of banks' balance sheets in the event of default. A sovereign default triggers a decrease in banks' assets and new deposits. Accordingly, during the bust, distressed banks reduce their investment in physical capital, and their consumption and output fall.

I also provide a framework that builds on a closed economy business cycle model with financial intermediation and endogenous sovereign default. The model features banks that use their own net worth, along with external funds from households' deposits, to buy short-term government bonds and to provide funding for firms. Bank loans are the only source of funding for firms to buy capital goods. Banks are financially constrained to issue deposits due to an agency problem between households and banks. Banks' ability to issue deposits depends on the level of their net worth, which can be used as collateral. Government bonds and loans to firms make up the asset side of banks' balance sheets.

[1] See Asonuma and Trebesch (2016), Balteanu and Erce (2018), and Asonuma et al. (2020).

In this setup, government debt issuance and repayment decisions affect banks' lending for capital goods via two channels. First, a banks' net worth evolves as the returns of assets invested in the previous period. A sovereign default depletes the returns to bondholdings and, consequently, banks' net worth. Provided that banks are constrained to issue deposits given the value of their net worth, the number of external deposits is reduced. Hence, banks' loans, which are used for capital goods, contract after the default. Second, as the government issues more debt, it crowds-out potential loans for firms. In particular, during episodes where the government issues an important amount of debt, it can negatively affect physical capital accumulation.

In this economy, the government finances a constant level of expenditure by labor income tax and issuing short-term debt. During each period, the government can either default or repay. The government is benevolent and maximizes a household's lifetime utility by considering the effects of its bond issuance on capital accumulation and deposit holdings. However, it must consider the cost of disrupting credit intermediation.

I use this model to study the disruption of capital accumulation in sovereign defaults that are followed by domestic credit distress. I calibrated the model to reproduce the moments related to capital accumulation, credit intermediation, and sovereign default. The model precisely reproduces targeted moments such as the observed investment–output ratio, output and investment volatility, banks' bondholdings as share of assets, the deposits–output ratio, and the default rate. At the same time, the model correctly predicts a set of untargeted moments such as debt to GDP (0.17 in the data vs 0.10 in the model) and correlations between consumption and output (0.60 vs 0.98), investment and output (0.50 vs 0.38), and deposits and output (-0.01 vs 0.04).

The model is able to capture the dynamics surrounding the boom and contractions in default events that preceded distress in domestic credit. In the boom, output, consumption, investment, and deposits grow at 2.7%, 2%, 7%, and 5%, respectively. The model is able to capture 99%, 84%, 87%, and 134% of the increase in output, consumption, investment, and deposits, from three years to one year before the default. During the bust, the output, consumption, investment, and deposits fall by 4%, 3%, 12%, and 11%, respectively. The model accounts for 110%, 120%, 107%, and 87%, of the contraction in output, consumption, investment, and deposits, respectively. In addition, the dynamics of the model resemble the recovery observed in the data of around three years.

I show that the empirical evidence is consistent with the model's prediction that investment drops heavily in defaults when a high share of domestic banks' assets are government bonds. I build a panel of countries with information of investment, banks' bondholdings to assets, and default events. I estimate a pooled regression of investment on default events, banks' bondholdings to assets, country-fixed effects, and time-varying effects. I found that, during a default, large drops in investment are associated with a high level of bondholdings held by banks previous to this event. Therefore, this exercise provides evidence that a default affects the credit-investment channel through the exposure of banks' balance sheets to government debt.

In this economy, capital is an important asset for consumption smoothing. By accumulating capital, the government increases its insurance against the total-factor productivity (TFP) shocks. Hence, by issuing sovereign debt, the government disrupts the accumulation of an asset that is useful to smooth consumption. I use the model to quantify how the ratio of the volatilities of consumption and GDP changes due to the crowding-out of investment in capital. I recalibrated the model to match an increase of 50% in the share of bonds to assets. In this case, the mean investment to capital decreased by 18 %, and the ratio of the volatilities of investment and GDP increased by 23 %. As the economy maintains a lower and volatile accumulation of capital, the consumption smoothing that the capital can provide decreases. In fact, the ratio of the volatilities of consumption and GDP increased by 13 %. At the same time, by introducing a higher ex-post cost of default, the probability of default decreased from 2.7 % to 1.01 %. Therefore, increasing the share of bonds in the economy can reduce the risk of default at the cost of diminishing the ability to smooth consumption across TFP shocks.

Based on the sample of countries used to calibrate the model, I document that countries with a high level of deposits to GDP maintain high levels of investment, a low ratio of volatilities of investment and GDP, and a low ratio of volatilities of consumption and GDP. I use the model to explain this fact because it can reproduce this pattern. In the model, I varied the parameter of the financial friction, which represented the share of net worth used as collateral for new deposits. By varying this parameter, I targeted the high and low levels of deposits to GDP. The model shows that high levels of deposits allow for higher investment as there are more resources to lessen the crowding-out effect of a bank's bondholdings. Also, with high levels of deposits, the ratio of volatilities of investment and GDP was lower in comparison to the cases with low levels of deposits. Therefore, an economy with high levels of deposits accumulates higher levels of capital, which is an asset that provides insurance against TFP shocks.

Finally, I use the model to show that the government benefits from a default by not increasing the labor income tax rate at the level that would do in case of repayment. I simulated the labor income tax in equilibrium around the default window. I quantify that after a default, the labor income tax rate increases from 25 % to 30 %. Then, I simulated a counterfactual of the labor income tax rate, which would be levied if the government repaid and kept issuing debt. In this case, after a default, the tax rate increased from 25 % to 36 %. The reduced labor income tax rate benefits the government as the labor income tax is distortionary.

Related Literature. This paper is related to a strand of literature that introduces sovereign default decisions into real business cycle models. Gordon and Guerron-Quintana (2017) studied the quantitative properties of sovereign default models with capital accumulation in small open economies. In their model, the government borrowed from international markets to invest in capital as it offered insurance against TFP shocks. They showed that their model could reproduce the cyclical properties of GDP and investment along with the business cycle properties of small, open economies. Park (2017) the role of capital accumulation in sovereign defaults that take place in good times. The author showed that, in good times, the government could borrow to overinvest in capital and then default. These decisions held as long as it had enough capital to lessen the costs of default. In contrast with these models, I focus on a closed economy where the resources for investment in capital comes from intermediary banks. In my model, banks use households' deposits and their accumulated net worth for investment in capital goods. Additionally, in my model, the government crowds-out capital instead of being a source for investment.

This paper builds on literature that has studied the effects of sovereign default on banks that are important holders of governments' debt. Sosa-Padilla (2018) examined the effect that Argentina's default on domestic banks had on output and credit. In this model, banks buy bonds from the government and issue loans to finance working capital for labor. In a default, a bank's assets decrease, and, as a consequence, the credit for working capital drops. In a similar setup, Pei (2016) allowed banks to provide loans for capital goods. This author assumed that default only affected loans for working capital to hire labor. My work contrasts with theirs in two ways. First, I focus on the effect that default has on capital accumulation through the credit channel. Second, I focus on default events where deposits drop simultaneously with credit. In my model, banks can issue deposits but are financially constrained by a share of their net worth. In a default, as the net worth decreases, deposits drop and, as a consequence, credit drops.

My paper contributes to growing literature that evaluates the importance of domestic financial frictions in the transmission of sovereign risk to the economy and, consequently, in the government's debt issuance decisions. Bocola (2016) introduced a model where financially constrained banks accumulated domestic government debt and lent to firms. With a persistent increase in exogenous sovereign risk, banks perceive that their funding conditions can be expected to become more constrained today and in the future; hence, they introduce a premium in firms' lending rates. In turn, the increase in the cost of credit leads to a decrease in investment decisions. Gonzalez-Aguado (2019) studied the sovereign debt composition of external and domestic debt with a government that could discriminate and default selectively across domestic and foreign holders. In this study, the domestic holders are financially constrained banks that intermediate resources from households to firms. The aforementioned author showed that economies with higher financial developments tilted their portfolio compositions of debt to domestic banks. I contribute to this literature by showing that a quantitative model with financial frictions and a default in domestic debt is able to reproduce the joint dynamics of macroeconomic and banking variables around default events that are followed by a contraction in credit.

Layout This paper is organized as follows. In section 2, I present the model and the equilibrium of the economy. In section 3, I discuss the parametrization of the model and numerical solution that enable the reproduction of several features of the data. In section 4, I present the quantitative results of the model, and in section 5, I discuss concluding remarks.

2 Model

This section outlines a closed economy populated by households, firms, and a benevolent government. I introduce a financial sector which is modeled as in Gertler and Kiyotaki (2010). I follow Bocola (2016) and include a government bond which is bought by financial intermediaries. In every state, the government can decide whether to repay or default. Therefore, this asset can provide a return unless the government decides to default.

In this economy, each household has two agents workers and bankers. Workers supply labor to a final good producer. Bankers issue deposits to households and invest in capital and bonds. Firms transform loans into capital and repay the returns. The government has a constant expenditure which is financed with labor income tax and by issuing sovereign debt.

The aggregate state of the economy at the beginning of the period incorporates endogenous and exogenous state variables. The endogenous states are the domestic bondholdings b, the capital in the economy k, and deposits d. The exogenous state variable incorporates the productivity shock z.

In the remainder of this section, I describe the sequential problem for each agent and the recursive competitive equilibrium. In the appendix, I discuss the numerical strategy for the solution of the model.

2.1 Households

There is a continuum of identical households. Each household has a fraction of workers f and a fraction of bankers, $1-f$ with consumption insurance among both types. A household values consumption c and dislikes labor l according to utility $u(c, l)$ and discounts the future at the rate β. Also, the household is able to save through deposits issued by banks. Labor is supplied to a final good firm in exchange of wage rate w. Savings d earn a risk-free return r and are managed by bankers from other households. I denote by π the net dividends that the household receives from its shares on financial intermediaries, by π and by τ the labor the income tax. I let the households to be the owners of the firms, each period they have to face a cost in order to endow the firm with capital provided by banks, this cost is defined by $\Phi(k_{t+1}, k_t)$. Households make plans for consumption, labor supply, and deposits in order to maximize its lifetime utility. Therefore, they solve the following problem

$$\max_{c_t, l_t, d_{t+1}} \sum_{t=0}^{\infty} \beta^t u(c, l)$$

$$\text{s.t.}$$

$$c_t + \frac{d_{t+1}}{r_t} = d_t + (1 - \tau_t) w_t l_t + \pi_t + \Phi(k_{t+1}, k_t).$$

I denote the household's stochastic discount factor as $\Lambda_{t,t+1} = \beta^{t+1} \frac{u_c(c_{t+1}, l_{t+1})}{u_c(c_t, l_t)}$.

2.2 Financial intermediaries: bankers

Each period the composition of bankers varies as follows. Once the returns of the previous period are realized, bankers use those returns and pay back households' deposits. Next, each banker observes with probability $1 - \psi$ a random variable indicating that he exits as a financial intermediary. A banker is replaced by a worker and receives initial net worth $\bar{n}$ to start to operate. At the same time, a banker that exits becomes a worker.[2]

Bankers work as financial intermediaries and lend funds to final good firms. Every period, bankers buy government bonds b_{t+1} at price q_{t+1} and issue loans to firm k_{t+1} which involve a return R_{t+1} in the next period. They fund these assets with deposits d_t, their own net worth n_t and pay dividends π_t^b to households. Bankers net profits $\pi = \psi \pi_t^b - (1 - \psi) \bar{n}$ are the sum of its dividends and the starting net worth received by a new banker. The banker balance sheet is represented as follows:

$$q_t b_{t+1} + k_{t+1} = \frac{d_{t+1}}{r_t} + n_t - \pi_t^b$$

In this setup, I assume that bankers cannot issue deposits beyond a share of their own capital, that is:

$$d_{t+1} = \lambda n_t$$

[2]These assumptions prevents the banker to over accumulate wealth and do not need external funding.

where λ is the share of net worth that can be used as collateral to issue new deposits. The net worth of bankers that do not exit evolves as:

$$n_{t+1} = b_{t+1} + R_{t+1}k_{t+1} - d_{t+1}.$$

At time t the banker problem involves choosing bonds, loans to firms, deposits, and dividends such that it maximizes the expected discounted flow of wealth that will arise if it remains as banker considering the evolution of its net worth, the constraint to issue deposits, and the balance sheet of each period. The problem can be characterized as follows:

$$\begin{aligned} \underset{b_{i+1},k_{i+1},d_{i+1}}{max} \; & \mathbb{E}\sum_{i=t}^{\infty} \Lambda_{t,i+1}\psi^{i-t}\{(1-\psi)n_{i+1} + \psi\pi^b_{i+1}\} \\ \text{s.t.} \; & \\ & q_{i+1}b_{i+1} + k_{i+1} = \frac{d_{i+1}}{r_i} + n_i - \pi^b_i \\ & d_{i+1} = \lambda n_i \\ & n_{i+1} = b_{i+1} + R_{i+1}k_{i+1} - d_{i+1} \end{aligned}$$

where I denote the discount factor as $\Lambda_{t,i+1} = \beta^{i+1}\frac{u_c(c_{i+1},l_{i+1})}{u_c(c_t,l_t)}$.

2.3 Firms

Firms face a technology shock z_t which follows the process

$$z_{t+1} = (1-\rho) + \rho z_t + \varepsilon_{t+1} \quad \varepsilon_{t+1} \sim \mathcal{N}(0,1).$$

Firms produce final goods by hiring capital k_t and labor services l_t from technology $y_t = z_tF(k_t, l_t)$. Labor services are hired each period when production takes place. Firms possess a one-to-one technology to convert loans into capital goods that can be used in the production of next period. Capital depreciates at rate $\delta \in (0,1)$ after is used for production. The firm repay for loans that are used Therefore, the problem of the firms becomes

$$max_{k_t,l_t} z_t F(k_t, l_t) + (1-\delta)k_t - R_t k_t - w_t l_t$$

2.4 Government

Each period, a government face a constraint

$$g + b_t = q_t b_{t+1} + \tau_t w_t l_t$$

where it has to finance an amount of debt g and the current stock of debt b_t with the income from taxing labor supply $\tau_t w_t l_t$ and new issuance of debt $q_t b_{t+1}$. In case of repayment the government has access to issue debt domestically b_{t+1} at price q_t. Also government's have to repay one-period government debt issued at previous period b_t. In case of default, the government repudiates the total stock of debt b_t but is not able to issue new debt b_{t+1}. At the end of the period the government can recover the access to domestic financial markets with probability $(1-\theta)$ with a zero debt to repay.

In this economy the aggregate resource constraint that emerges from consolidating the household budget constraint, banks' balance sheets and accumulated net worth, and government budget constraint is

$$c_t + g + i_t = F(k_t, l_t)$$

where I define the investment as $i_t = k_{t+1} - (1-\delta)k_t + \Phi(k_{t+1}, k_t)$.

2.5 Competitive equilibrium

A competitive equilibrium given government policies $\{g, \tau, b\}_{t=0}^{\infty}$ is a set of allocations $\{c, l, k, d, \pi\}_{t=0}^{\infty}$ and prices $\{q, R, r, w\}_{t=0}^{\infty}$ such that:

Allocations $\{c, l, , d\}_{t=0}^{\infty}$ solves household's problem.

Allocations $\{b, k, d\}_{t=0}^{\infty}$ solves banker's problem.

Allocations $\{k, l\}_{t=0}^{\infty}$ solves firm's problem.

Government's policies $\{g, \tau, b\}_{t=0}^{\infty}$ satisty the government's budget constraint.

The aggregate resource constraint holds.

Market clearing for bonds, deposits, capital, labor.

2.6 Recursive problem

In the recursive problem the state variables are b, k, d, z which represent bonds, capital, deposits, and the exogenous TFP process, respectively. Before proceeding to show the government's recursive problem, I define several results from the bankers' problem that allows me to characterize the price of the government debt.

Proposition 1. *In the recursive banks' problem:*

i) Bankers' value function is linear in net worth.

ii) The price of the domestic bond can be represented as:

$$q = \frac{\mathbb{E}[\hat{\Lambda}(b', k', d', z')\,[1 - D(b', k', d', z')]}{\mathbb{E}[\hat{\Lambda}(b', k', d', z')R(b', k', d', z')]}$$

where the adjusted discounted factor of the banks' problem is represented with $\hat{\Lambda}(b', k', d', z') = \mathbb{E}\Lambda(b', k', d', z')[\psi + (1-\psi)\alpha(b', k', d', z')]$ *and* $\alpha(b, k, d, z)$ *is the banks' marginal value of their wealth.*

Proof see appendix C.

From proposition 1 we can observe several results that allow us to characterize bankers' problem solution. First, the linearity of the vale function we can obtain that bankers' dividends π^b are zero. Second, the price of the government's bond is the discounted expected return to capital for the next period adjusted for the probability of repayment. The discount factor is $\hat{\Lambda}(b', k', d', z')$ considers that a banker can remain as financial intermediary with probability $(1 - \psi)$. Therefore, with probability $1 - \psi$ the discount factor incorporates the marginal value of remaining as a banker.

In the government's recursive problem, it chooses policies for debt issuance b' and default decision D considering the optimality conditions in the competitive equilibrium of the economy given the current state of the economy (b, k, d, z). The problem can be described as follows:

$$V(b,k,d,z) = \max_{D\in\{0,1\}} \left\{V^R(b,k,d,z), V^{NR}(k,d,z)\right\}$$

and the value for repayment solves

$$V^R(b,k,d,z) = \max_{c,k',b',d',l} \{u(c,l) + \beta \mathbb{E}[V(b',k',d',z')]\}$$

$$\text{s.t.} \begin{array}{ll} \text{Resource constraint} & : \begin{array}{l} zF(k,l) = c + i + g \\ k' = (1-\delta)k + i - \Phi(k',k) \end{array} \\ \text{Government budget constraint} & : \; g + b = (1-\tau)wl + qb' \\ \text{Competitive equilibrium} & : \begin{cases} r = \beta \frac{\mathbb{E}u'_c(c',l')}{u'_c(c,l)} \\ q = \frac{\mathbb{E}[\hat{\Lambda}(b',k',d',z')[1-D(b',k',d',z')]]}{\mathbb{E}[\hat{\Lambda}(b',k',d',z')R(b',k',d',z')]} \\ R = zF_K(k,l) + (1-\delta) \\ w = zF_l(k,l) \\ \frac{d'}{r} = \lambda N \\ k' + qb' = d + N \\ N = \psi(Rk + b - d) - (1-\psi)\bar{n}. \end{cases} \end{array}$$

and the value for default solves

$$V^{NR}(k,d,z) = \max_{c,k',d',l} \left\{ u(c,l) + \beta E[\theta V^{NR}(k',d',z') + (1-\theta)V(b',k',d',z')] \right\}$$

$$\text{s.t.} \quad \begin{array}{ll} \text{Resource constraint} & : \begin{array}{l} zF(k,l) = c + i + g \\ k' = (1-\delta)k + i - \Phi(k',k) \end{array} \\ \text{Government budget constraint} & : \; g = (1-\tau)wl \\ \text{Competitive equilibrium} & : \begin{cases} r = \beta \frac{\mathbb{E}u'_c(c',l')}{u'_c(c,l)} \\ R = zF_K(k,l) + (1-\delta) \\ w = zF_l(k,l) \\ d' = \lambda N \\ k' = \frac{d'}{r} + N \\ N = \psi(Rk - d) - (1-\psi)\bar{n}. \end{cases} \end{array}$$

Recursive Markov Equilibrium. In this economy a recursive equilibrium are government policy functions $D(b,k,d,z)$, borrowing decisions $B(b,k,d,z)$, value functions $V(b,k,d,z)$, $V^R(b,k,d,z)$, $V^{NR}(k,d,z)$, and the bond price schedule $q(b,k,d,z)$ such that: (i) the policy and the value functions satisfy its optimization problem; (ii) the government's debt price schedule satisfy $q(b,k,d,z) = \frac{\mathbb{E}[\hat{\Lambda}(b',k',d',z')[1-D(b',k',d',z')]}{\mathbb{E}[\hat{\Lambda}(b',k',d',z')R(b',k',d',z')]}$, (iii) the competitive equilibrium conditions are satisfied.

3 Parametrization

In this section, I discuss the strategy for the parametrization of the model. One set of parameters was taken from the quantitative macroeconomic literature. The other sets of parameters were calibrated to match a set of moments from emerging economies that had experienced a sovereign default followed by an episode of distress in credit intermediation as defined by Balteanu and Erce (2018) for the period of 1980–2005 (this sample is described in the appendix). The model was solved on a quarterly basis and the set of moments computed from the simulations were adjusted to represent the annual realization from the data. Accordingly, the stock variables represent the current realization and the flow variables were adjusted to represent the average during the last four quarters.

The set of parameters are described in table 1. The country utility function considers the following specification:

$$u(c,n) = \frac{(c - \frac{n^{\omega}}{\omega})^{1-\psi}}{1-\psi} \tag{1}$$

where the σ is the coefficient of risk aversion, which is set to 2 (as is standard in quantitative macroeconomics).[3] The parameter ω controls the curvature of the labor disutility and is set at 1.5, which is consistent with a Frisch wage elasticity of labor supply of $\frac{1}{\omega} = 2$. [4]

The firm follows a constant return to scale technology:

$$F(k,n) = k^{\alpha} l^{1-\alpha} \tag{2}$$

where the capital share parameter in the benchmark calibration is $\alpha = 0.36$ – as is standard in the literature.

The TFP shock follows an AR(1) process:

$$\log z_t = \rho_z \log z_{t-1} + \epsilon_t \tag{3}$$

[3]The specification removes the wealth effect on labor supply. Otherwise, episodes of default, which are accompanied by a fall in TFP or consumption, would reflect an increase in labor supply.

[4]Other studies of sovereign default that consider capital as a factor of production function calibrate the Frisch wage elasticity at the level of 2 as in the study of Pei (2016) and of 0.85 as in the study of Gordon and Guerron-Quintana (2017). With respect to other studies that considered only labor as the unique factor of production, the range can be described as follows, while Mendoza and Yue (2012) targeted an elasticity of 2.2, Sosa-Padilla (2018) and Cuadra et al. (2010) considered an elasticity of 0.667 and 0.689, respectively.

with $\epsilon_t \overset{\text{iid}}{\sim} \text{N}(0,\sigma_z^2)$. I calibrated the parameters for TFP following the strategy of incorporating capital in a sovereign default model calibrated for emerging economies (see Roldan-Pena, 2011; Gordon and Guerron-Quintana, 2017; Park, 2017). On the one hand, the persistence process was settled at ρ_z=0.95, which is line with values used in other studies. On the other hand, the standard deviation of the TFP was set at $\sigma_z = 2.1\%$, which is consistent with the volatility of output at $\sigma_z = 2.4\%$ – the average standard deviation of the emerging economies experiencing domestic credit distress after a default measured with data from the International Financial Statistics (IFS) database.

The transferring to entering bankers was set to 0.003, which is consistent with the perfect interbank market parameter as shown in the study of Gertler and Kiyotaki (2010).[5]. The bankers' survival rate was set at $\psi = 0.97$, which is consistent with the findings of Bocola (2016) and Gertler and Kiyotaki (2010).[6] I calibrated the parameter for the bank's financial frictions λ to match the deposits to the GDP average of 0.32 for the sample in the study of Balteanu and Erce (2018) using data from the Global Financial Development Database (GFDD) from the World Bank. The parameter g was set to match the government expenditure to GDP average of 15 % as observed in the IFS.

The capital depreciation rate δ was set at 0.0425 (17 % annual rate) to target a level of investment-to-GDP of 0.22 as observed in the GFDD for upper–middle income countries. I used this parameter to target such statistics in line with those found by Gordon and Guerron-Quintana (2017) and Pei (2016). Also, the functional form for capital adjustment was set as

[5]The parameter for the transferring for entering bankers remained low in order to not affect the aggregate implications of the model during default events. This parameter can resemble the period by period endowment that bankers received in the findings of Sosa-Padilla (2018). In fact, for this author, this parameter was important for measuring the exposure of the bank to sovereign risk. It can affect the size of the credit crunch and output drop. In the section designed for default events, we observed that the model was able to capture the drop in output observed in the model as well as without any parameter having driven this fall as shown in the study of Mendoza and Yue (2012) and Sosa-Padilla (2018)

[6]In this model, the size of the parameter ψ impacts the size of the banking net worth that can be used as collateral $\psi N + (1 - \psi)\bar{n}$. A decrease in the survival rate increases the share of the net worth, which is composed of a constant endowment that the new banker receives. I tried to maintain a high enough banking survival rate ψ in order to avoid $\bar{n}$ playing a role in the credit contraction. In general, other studies use a high value for this parameter as shown in the study of (Bocola, 2016), who estimated this parameter for Italy, (Gonzalez-Aguado, 2019), who used this parameter for bankers in emerging economies, and Perez, who used it to calibrate the share of debt held by banks.

is in the study of Gordon and Guerron-Quintana (2017)

$$\Phi(k', k) = \frac{\Theta}{2}(k' - k)^2, \tag{4}$$

where the parameter affecting the cost Θ was set at 7 in order to match the volatility of the investment to volatility of output of 3.91 in the sample.

The value for the probability to reentry to financial markets after a default θ was set at 0.10, which is consistent with an exclusion of three years. This parameter was set in accordance with previous studies considering domestic defaults the estimate vary between 1.25-4 years (see Sosa-Padilla, 2018, Perez et al., 2015, and Pei, 2016).[7]

The discounting parameter β was set at 0.976 to match the annual default rate of 2.5 %. I considered a nonlinear cost of default $min\{z, 0.95\}$ over the TFP as was demonstrated in the study of (Arellano, 2008) to calibrate an average of 12 % balance sheet exposure of domestic banks to government bonds using data from the IFS. This measure consisted of the ratio of an intermediary bank's net claims to government as a fraction of its net total assets. This captured the share of the consolidated financial system balance sheet, which is exposed to an outright default from government.[8]

On the one hand, this moment is important because it sets the average exposure of the balance sheet to the sovereign bond, which is the risky asset. On the other hand, it establishes the average target at which sovereign debt crowd-outs investment.

[7] Other quantitative considering the exclusion from international financial markets calibrate this parameter in order to be consistent with a range from 2-6 years, which is consistent with empirical estimates across a sample of episodes of default (see Richmond and Dias, 2009 and Gelos et al., 2011). While Richmond and Dias (2009) provided estimates of the average (median) time of exclusion between 5.7 (3) years, Gelos et al. (2011) found that, on average, it took around two to 4.5 years to recover partial market access. Quantitative studies analyzing sovereign default on external debt had targeted an average exclusion of around three–six years (see Arellano and Ramanarayanan, 2012, Cuadra et al., 2010, and Mendoza and Yue, 2012).

[8] I constructed this measure following the method of Kumhof and Tanner, 2005, which is commonly used by several studies (see Gennaioli et al., 2014, Gennaioli et al., 2018, and Asonuma et al., 2015).

Table 1: Quarterly Parameters used in the model

Parameter	**Value**	**Source**
Literature		
Bank's initial net worth	$\bar{n} = 0.003$	Gertler and Kiyotaki (2010)
Capital share	$\alpha = 0.3\%$	Standard
Curvature of labor disutility	$\omega = 1.5$	Frisch Labor elasticity
TFP process	$\rho_z = 0.95$	Emerging economies
Calibrated		
TFP Volatility	$\sigma_z = 2.1\%$	Output volatility 1.5 %
Depreciation rate	$\delta = 0.0425$	Capital to GDP 21 %
Collateral constraint	$\lambda = 0.3$	Deposits to GDP 25 %
Discount factor	$\beta = 0.976$	Annual default rate 2.5 %
Government expenditure	$g = 0.09$	Government expenditure to GDP 14 %
Discount factor	$min\{z, 0.95\}$	12 % of bank's balance sheet exposure
Adjustment cost capital accumulation	$\Theta = 7$	Investment to output volatility 4.25

4 Results

4.1 Simulations results

The model was able to reproduce targeted moments along with a set of untargeted moments. The model shows that, on average, one-third of the observed domestic debt can be issued. The ability of the model to obtain that level of domestic debt is related to the endogenous cost of default. As default triggers a decrease in net worth, it directly affects capital for the next period and its ability to raise deposits in the following periods. The difference between the saving and the lending rate is close to what it is observed in the data. On the part of the lending rate R, this spread incorporates the effect of the crowding-out of capital investment. The model demonstrates that consumption is more volatile than output as is usual in emerging economies and what is found in other studies of sovereign default. The correlation of output with consumption, deposits, and investment is closely related to the data. Finally, the hours worked are closely related to the standard of one-third of the total amount of time.

Table 2: Data and Moments

Non-Target Statistics	Model	Data
Mean domestic debt to GDP	0.10	0.17
Mean spread $E(R-r)$	6.71	6.94
Consumptions's standard to output's standard deviation	2.10	1.47
Correlation consumption and output	0.98	0.60
Correlation deposits and output	-0.04	-0.01
Correlation investment and output	0.38	0.50
Worked hours	0.31	0.33
Target statistics		
Mean Investment to GDP	0.22	0.21
Standard deviation of output	2.72	2.58
Investment standard deviation to GDP standard deviation	3.74	4.25
Bank's balance-sheet exposure	0.12	0.12
Mean deposits to GDP	0.22	0.25
Government's expenditure to GDP	0.18	0.14
Periods of exclusion (years)	2.9	3
Probability to default	2.7	2.5

All variables are logged and then de-trended using the Hodrick-Prescott filter, with a smoothing parameter of 6.25.

4.2 Dynamics around events of associated

In this section we study the model's ability to match the macroeconomic dynamics around episodes of default that could lead to a disruption in the intermediation of the domestic credit. In particular, I follow the work of Balteanu and Erce (2018), which identified events of sovereign default that were followed by a banking crisis in a period of up to three years. A default window considers three years in the run-up to default, the year of the default, and three years in the aftermath of the default. In these default event windows, I have contrasted the evolution of several observed variables by means of the simulations of the calibrated model.

Given the features of the model, I considered the default event classification used by Balteanu and Erce (2018) as a reasonable empirical benchmark for several reasons. First, it showed empirical evidence that suggested that, unlike default events not followed by a domestic credit distress, in the run-up, banks were highly exposed to government debt, and the default triggered a systemic loss on banks' balance sheets. Therefore, this suggests that the main force triggering a banking crisis is the effect on the balance sheet caused by default.[9] Second, the definition of a banking crisis considers that there exists a major decrease in the external funding of banks through deposits. This is featured and included in the model, and its dynamics can be compared with the data. Third, the empirical evidence suggested that these episodes showed a limited capital account openness. These authors mentioned that in this context, governments rely more on domestic markets to issue debt. This is important as the model features a closed economy, and in these events, domestic and external debt accounts for 75 and 25) % of the total public debt, respectively.[10]

Figure 1 plots the dynamics around a three-year window of a default followed by a banking crisis in the data and in the model. In this window, the time at zero implies the moment of default. While the negative periods imply the years in the run-up to default, the positive periods show the aftermath of the default. The green dotted lines show the deviation HP-filtered trend except for the labor supply and balance sheet, which are reported in levels. The shaded areas correspond to the intervals plus and minus one standard deviation from the mean. The solid blue lines are predicted by the model. Finally, the solid black bar at -1 shows the date at which the output reached a maximum prior to default.

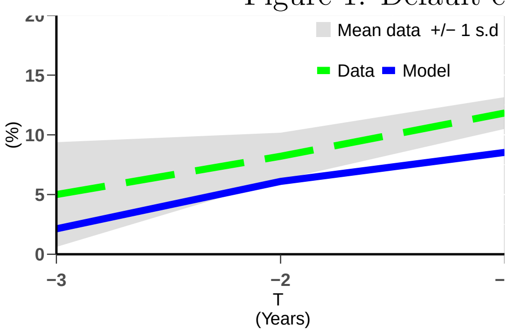
The model is able to replicate the dynamics of several macroeconomic and financial variables. It can replicate the boom and bust dynamics in the run-up and in the aftermath of default. The timing of the model allows for these dynamics to be matched. First, as default reduces a bank's net worth, investment drops at T=0; therefore, output and consumption drop until $T = 1$. Second, as the net worth decreases in $T = 0$, the external deposits that have to be paid in $T = 1$ fall. The decrease in deposits affects the accumulation of new

[9]This dynamic is consistent with the evidence shown in the study of Gennaioli et al. (2018). In a complementary paper, Gennaioli et al. (2014) provided evidence showing that, upon default, a banking system highly exposed to government debt was associated with an important decrease in the credit flow of the economy.

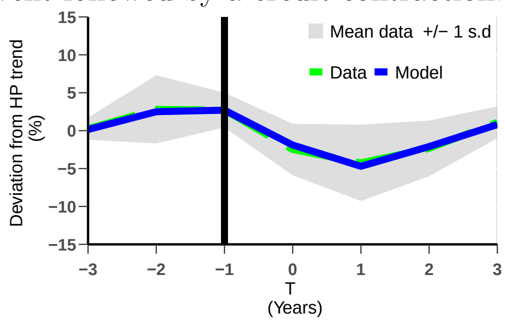
[10]In other classifications, it is difficult to differentiate the affect that external defaults have against domestic defaults. Sturzenegger and Zettelmeyer (2006) brought a detailed narrative regarding the unfolding at the run-up and aftermath of a sovereign default. They detailed that, while there existed a differentiated treatment of domestic and foreign debt holders in the default of Argentina in 2001 and Ecuador in 1999, these countries defaulted on both types of debt in a short period of time.

capital goods in $T = 1$, which affects deposits issued in $T + 2$. In the plot, total assets drop at T=0 and continue to fall until $T = 2$. The model reproduces the first fall as the effect of a default on a bank's balance sheet. As capital is the only asset during default, the model reproduces this dynamic as a lag with respect to investment.

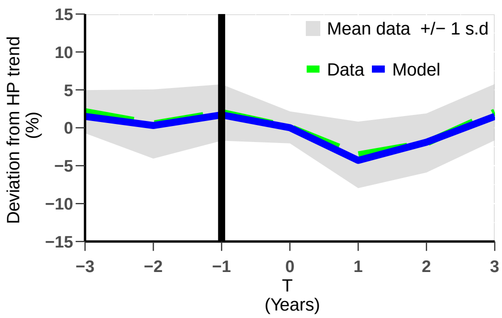
Figure 1: Default event followed by a credit contraction.



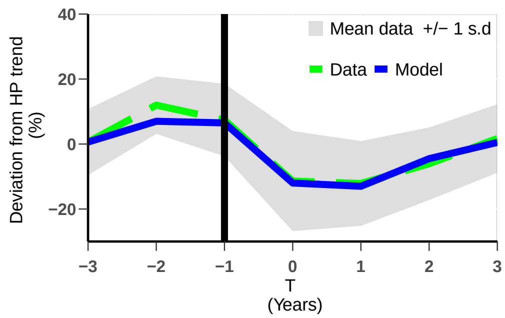
(a) Domestic debt to GDP



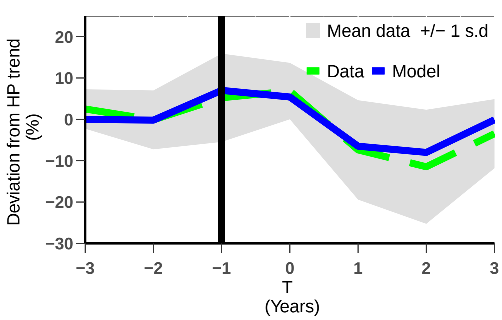
(b) Output



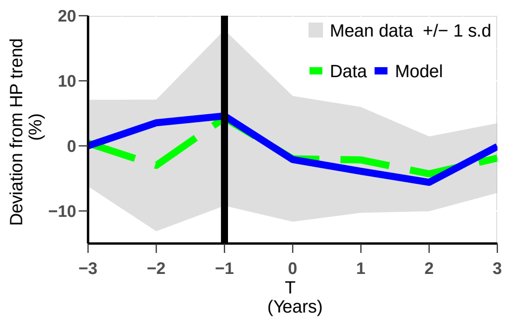
(c) Consumption



(d) Investment



(e) Deposits



(f) assets

Source: Global Financial Database, International Financial Statistics, and author's calculations. Default event which is followed by a banking crisis given the database of Balteanu and Erce (2018). The solid blueline corresponds to the mean trajectory of the calibrated model's simulated at the default event. The green dashed line corresponds to the mean trajectory observed in the data at different default events followed by a banking crisis at the dates described in Balteanu and Erce (2018). The gray shadow area corresponds the interval of +/- ones standard deviation around the mean of the data. The solid black line at T=-1 is the moment at which the output find its highest realization previous to the default.

I examine empirically whether, during a default, a bank's balance sheet exposure to the government's debt triggers adverse effects on investment. I follow the strategy shown by Gennaioli et al. (2014) to test whether a bank's balance sheet exposure is associated with a disruption on private credit markets. This strategy consists of regressing the variable expected to be disrupted on the event of default, the government's bondholdings as a share of the bank's balance sheet, and the interaction of both variables in the year previous to default.

I use a panel of countries including middle-income and high-income countries during the years between 1980–2005 using data from GFDD. The default events are those considered by Balteanu and Erce (2018). As a dependent variable, I consider two measures of investment: 1) investment as a deviation of the HP-filtered trend and 2) investment-to-GDP in annual growth rates. By using investment as a deviation of the HP-filtered trend, I test whether the model's predictions can be observed in the observed data. By using the investment-to-GDP, I use a similar variable to that used by Gennaioli et al. (2014), and I test if the exposure to the government's bonds affect the level capital formation in economies experiencing default.

In terms of the empirical strategy, I depart from that used by Gennaioli et al. (2014) by separating default events of those where the default was followed by a contraction in domestic credit from those where the default did not affect credit. The specification of the regression is as follows;

$$\begin{aligned}\Delta\left(\frac{inv_{i,t}}{y_{i,t}}\right) = \quad & \beta_1(\text{Default}^{CD}{}_{i,t-1}) + \beta_2(\text{Default}^{CD}{}_{i,t-1})\cdot(\text{Bondholdings}_{i,t-1}) \\ & \beta_3(\text{Default}_{i,t-1}) + \beta_4(\text{Default}_{i,t-1})\cdot(\text{Bondholdings}_{i,t-1}) \\ & + \beta_5(\text{Bondholdings}_{i,t-1}) + \alpha_i + \nu_t + \text{X}'_{i,t-1}\gamma + \epsilon_{i,t}.\end{aligned} \tag{5}$$

where the i superscript identifies countes, the t superscript identifies years, and the CD superscript represents the default events with credit distress after the default – as identified by Balteanu and Erce (2018). The bank's balance sheet exposure is measured as discussed in the calibration. In addition, I use control for shocks that affect the supply and demand for credit during episodes of default.[11]. I allow the interaction and the testable implication

[11]While it is difficult to describe a causality from default and bank exposure on credit on credit, I intend

is that investment as a deviation to HP-filtered trend (investment to GDP) decrease after default in countries with banks more exposed to sovereign debt (i.e. $\beta_3 < 0$).

Panel (a) in table (3) shows the estimates for (5) when the dependent variable is an investment that deviates from the HP-trend. In this regression, we can observe that the interaction is statistically significant, and its range is around -0.19 to -0.24. With this estimate, the impact of a default when banks hold an exposure of 12% is around a 2.28% to 2.88% drop of investment as deviation of its HP-filter. Panel (b) in table (3) shows the estimates for (5) when the dependent variable is the investment to GDP. In this regression, we can observe that the interaction is statistically significant, and its range is around -0.0351 to -0.076. With this estimate, the impact of a default when banks hold an exposure

Table 3: Regression: Investmentand on Default and Bondholdings

	Panel a: Investment deviation to HP-filtered trend			
	(1)	(2)	(3)	(4)
$(\text{Default}^{CD}_{i,t-1})\cdot(\text{Bondholdings}_{i,t-1})$	-0.195**	-0.190**	-0.241***	-0.230***
Observations	1470	1470	1470	1300
Country Fixed Effects	No	Yes	No	Yes
Annual Time Effects	No	No	Yes	Yes

	Panel b: Investment to GDP			
	(1)	(2)	(3)	(4)
$(\text{Default}^{CD}_{i,t-1})\cdot(\text{Bondholdings}_{i,t-1})$	-0.0586**	-0.0351**	-0.0760***	-0.0291***
Observations	1504	1504	1504	1472
Country Fixed Effects	No	Yes	No	Yes
Annual Time Effects	No	No	Yes	Yes

The specification which include country fixed effects and annual time effects includes controls. The specification without controls remains statistically significant in the interaction term for bond-holdings and default.

to capture a negative correlation that prevails once other economic conditions are accounted for. By using GDP growth, unemployment, and inflation, I control for the adverse economic conditions that affect the demand for credit and the distress that could trigger default episodes. I consider exchange rate depreciation as this could affect the balance sheet of non-banking private agents and their demand for credit. Given that governments could issue debt in foreign currency, a depreciation is also associated with a potential default. I also consider episodes of sudden stops that affect the supply of credit for private agents, including the banking and public sectors. Finally, I control for the existence of a banking crisis previous to the default event as these had an effect on credit prior to the realization of the government's debt repudiation.

of 12% is a drop of around 0.421% to 0.912% in the investment to GDP.

4.3 Sensitivity analysis: distortions in capital accumulation

I analyze how the default incentives and capital accumulation interact in the model. On the one hand, sovereign borrowing affects capital accumulation by reducing banks' resources that can be used for investment. At the same time, capital is an asset that can be used for insurance against TFP shocks. Therefore, sovereign borrowing affects the accumulation of assets that can be used for consumption smoothing (see Gordon and Guerron-Quintana, 2017; Pei, 2016. In the model, sovereign borrowing is a costly process that, by affecting capital accumulation, decreases the ability of the government to smooth consumption. On the other hand, by increasing the cost of default, a higher issuance of sovereign debt decreases the default probability.

In this section, I quantitatively evaluate the ex-ante effects of government borrowing vis-a-vis its effects ex-post in the model. I recalibrate the model in order to target a moment that affects government borrowing ex-ante while retaining all the other parameters of the benchmark calibration. In particular, in order to measure the ex-ante effects of default, I focus on how capital accumulation statistics, namely, mean investment to GDP and the volatility ratio of investment to GDP, can be affected by the new targeted moment. In order to measure the effects on consumption smoothing, I compute the volatility ratio of consumption to GDP. In order to measure the ex-post cost of default, I use the drop in output.

First, I evaluate how an increase in the banks' bondholdings as a share of total assets affects ex-ante investment, the volatility ratio of investment to GDP, and consumption to GDP. I contrast these effects with an adjustment in the probability to default. Second, I provide evidence that economies with high access to deposits show higher investment and a lower volatility ratio of investment to GDP and consumption to GDP. I recalibrate the model to match deposits to GDP and show that the model is able to reproduce this pattern. I explain the quantitative properties of the model that allow for the reproduction of this empirical pattern.

Bondholdings In Table 4, I study the importance of bondholdings' exposure in the model.

The discount parameter β is set at 0.9427 in order to match a share of bondholdings to total assets at 0.20. The model predicts that investment to GDP decreases from 0.22 to 0.18 as more assets are used to finance government borrowing. The volatility ratio of investment to GDP and consumption to GDP increases by 40 % and 54 %, respectively. This increase in the volatility ratio implies that more debt is absorbed by banks and that this issuance disrupts the flow of funds more frequently. As a consequence of the lower capital accumulation, the insurance that capital provides in fluctuations of GDP decreases. For these reasons, the model predicts that the volatility ratio of consumption to GDP increases.

Table 4: Model recalibration

	Panel a: Government bonds to bank's assets	
	Benchmark	High
	0.12	0.18
Mean Investment to GDP	0.22	0.18 ↓
Investment std. dev. to GDP std. dev.	3.74	4.63 ↑
Consumption std. dev. to GDP std. dev.	2.10	2.38 ↑
Probability to default	2.7	1.01 ↓

In the table we recalibrate the model to match the statistic related to the column High. In panel A, I recalibrate the model to match an exposure of 0.20 which is associate with a change in the persistence parameter. In order to compare for the excess of volatility with respect to GDP, I recalibrate the standard deviation of the TFP shock.

Deposits The first two columns from Table 5 show the conditional moments for a high and low level of deposits to GDP that was observed in the sample of countries from the data. In order to determine if a country is part of the group of high or low level, I computed the mean deposits to GDP for each country around the sample period and sorted the observations above or below the median as high or low, respectively. The conditional moments are the mean investment to GDP, volatility ratio of investment to GDP, and volatility ratio of consumption to GDP for each group (i.e. high or low). The third and fourth columns of Table 5 show moments simulated by a calibration of the model in order to target the high and low level of deposits to GDP by modifying the parameter for the financial friction .

The data shows that economies with high or low access to deposits to GDP observe higher or lower capital accumulation and a lower or higher volatility ratio of investment to

GDP and consumption to GDP, respectively. The model is able to recover the same feature. This feature highlights the role of capital as an asset for consumption smoothing. In the model, the economy has a higher access to deposits as it increases the share of net worth λ that can be used as a collateral. Ex-ante banks expand the resources available that can be used for investments and for bond purchases. As can be observed, with a higher access to deposits, the capital accumulation increases. Also, the volatility ratio of investment to GDP decreases as bond issuance has lower distortions in this economy. Hence, the volatility ratio of consumption to output also decreases as capital is used as an insurance against TFP shocks.

Table 5: Model predictions

	Data		**Model**	
	Low	High	Low	High
Mean deposits to GDP	0.15	0.34	0.15	0.32
Mean Investment to GDP	0.19	0.22	0.17	0.28
Investment std. dev. to GDP std. dev.	4.81	3.68	3.53	3.71
Consumption std. dev. to GDP std. dev.	1.52	1.42	2.45	2.10
Probability to default	-	-	7.8	1.28

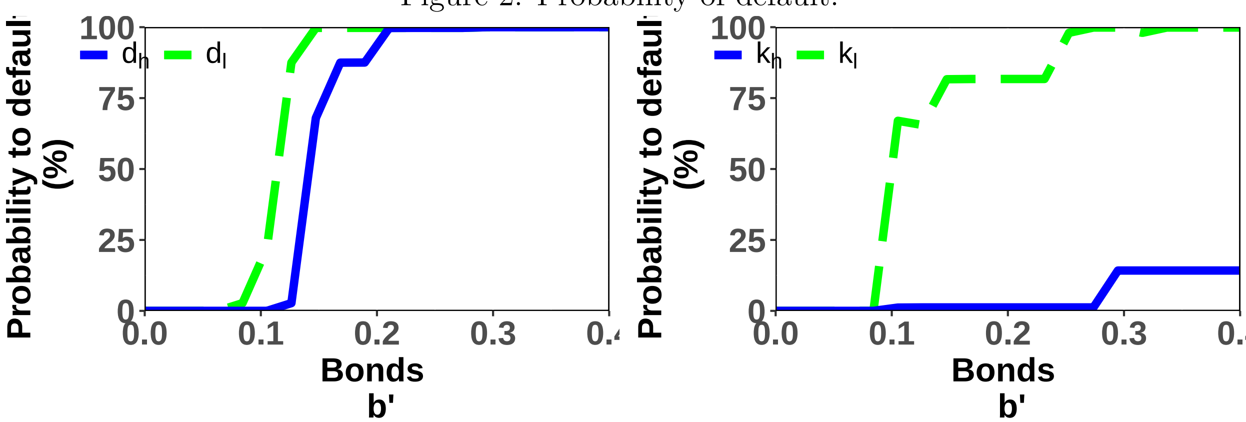
In the table we recalibrate the model to match the statistic related to the column Data. I recalibrate the model with the parameter λ to match countries with low deposits to GDP and high deposits to GDP. In order to compare for the excess of volatility with respect to GDP, I recalibrate the standard deviation of the TFP shock.

The ex-post cost of default also changes when the economy faces different targeted levels of deposits. The probability to default decreases as the economy has higher assets to deposits. This is for two reasons. First, in the model, a higher level of collateral λ used for deposits introduces a higher credit disruption in the economy. Therefore, it is costly for the government to decrease the supply of external funds when this provides an important share of resources in order to invest and to buy bonds. Second, as the economy has more capital, the economy has more resources to repay. In the current case, as more deposits decrease the crowding-out of capital, it allows for the accumulation of a higher stock of capital.

The two effects can be illustrated in Figure 2. Panel (a) shows the default probability when banks issue high and low claims from a household's deposits, which hold capital, and the

TFP at the median level of the grid on its respective dimension. The solid and dotted lines show the probability of default for a high or low level of deposits, respectively and which are values above or below the mean level of deposits in the grid, respectively. In this plot, the probability to default for a high level of deposits is always below that for a low level of capital. The government will try to avoid default when the level of external finance is high. Panel (b) shows the default probability when the economy accumulates a high or low level of capital, holding deposits and the TFP at the median level of the grid on its respective dimension. The solid and dotted lines show the probability of default for a high or low level of capital accumulated above or below the mean capital in the grid, respectively. The probability to default for a high level of capital is always below that for a low level of capital. As mentioned above, a higher stock of capital allows the government to repay with higher probability.

Figure 2: Probability of default.



(a) Percent

(b) Percent

Source: Author's calculations. Probability of default in the model along different levels of government's debt. Panel (a) shows the probability of default when the economy face high and low levels of deposits. Panel (b) shows the probability of default when the economy face high and low levels of aggregate capital.

4.4 Tax adjustment during the default episode

The simulations of the numerical solution show that during a default episode, the government is able to cushion a sudden increase in the labor tax in order to repay its debt and maintain its level of expenditure g. Figure 3 shows the dynamics of the labor tax rate in equilibrium vis-a-vis the tax rate that arise in cases of repaying and continuing to issue debt around the default window. The solid and dotted lines show the dynamics of the equilibrium and counterfactual tax rates in cases of default and repayment, respectively. Once default is announced, the tax rate suddenly increases in both cases, but the adjustment is lower in the default equilibrium by 6 %. This difference in the adjustment is almost constant in the aftermath of default. In this setup, the government uses default as a mechanism to avoid a sudden increase in the wage rate tax.[12]

Figure 3: Labor tax around a default episode.

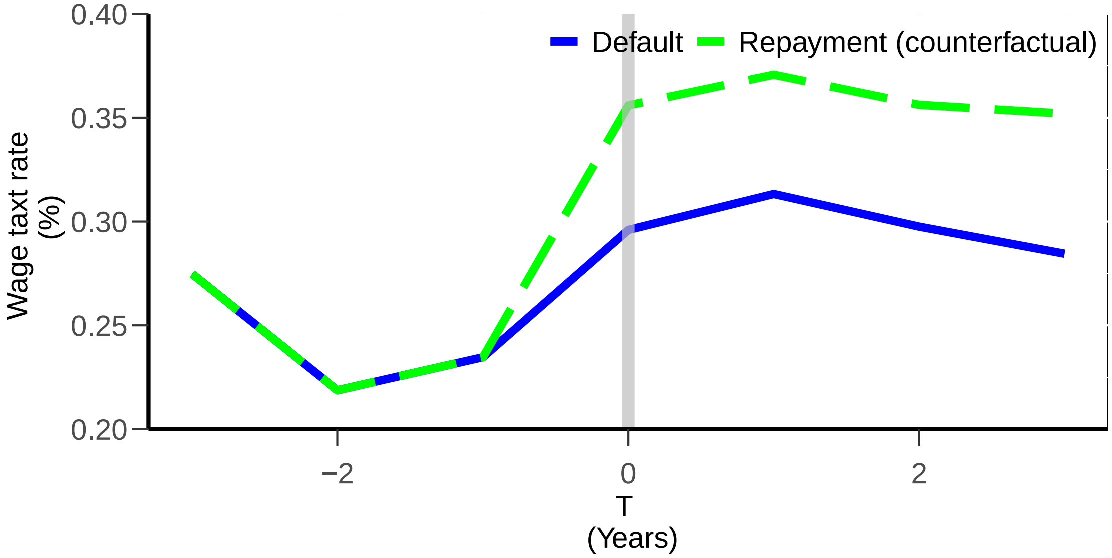


Figure 4: Percent

Source: Author's calculations. Labor tax rate during a default episode. The solid line in black shows the tax rate that the government impose in equilibrium in case of a default. The dotted line in blue shows the tax rate that arise in case of repaying its debt instead of defaulting.

[12]The adjustment in tax rates is a similar property to that shown by Sosa-Padilla (2018). In fact, this author quantified that, for Argentina's default in 2001, the government should have levied a tax 20 % higher in case of repayment. Also, contrary to my findings that wage rates increase even around default, this author believed that the wage rate should decrease in a default.

5 Conclusion

In this paper, I studied how capital accumulation can be disrupted by a sovereign default through financial intermediation. I explored these consequences in a model that combined capital accumulation, sovereign default, and financial frictions. In the model, banks make investment decisions for capital accumulation in the economy. Governments can only sell bonds to banks; hence, the resources used for buying bonds crowd-out investment. Banks can accumulate net worth and issue it as a collateral for receiving deposits from households. During a sovereign default, a bank's net worth decreases, its ability to issue deposits also decreases, and it adjusts its investments in new capital goods.

I calibrated the model to match the moments of a set of economies that experienced a default followed by a credit disruption. I have shown that the calibrated model can reproduce the untargeted dynamics around default of output, investment, deposits, and assets for these economies. After the default, capital is the only asset in a bank's balance sheet; therefore, the dynamics of assets and deposits are driven by capital accumulation after default. I provided empirical evidence that supports the fact that, during a default, capital accumulation is negatively correlated with the ratio of bonds to assets held by banks.

I used the calibrated model to show how ex-ante to a default, sovereign debt decreases capital accumulation and increases investment volatility. In fact, this suggests that disrupting capital accumulation decreases its ability to insure against TFP shocks. Therefore, the model shows the volatility ratio of consumption to GDP increases, which is associated with a lesser ability to smooth consumption.

Finally, I demonstrated, in the sample of economies considered, that those with lower or higher access to deposits face lower or higher capital accumulation and higher or lower volatility ratio of investment to GDP and consumption to GDP, respectively. The model was able to reproduce this fact by considering the ability of capital to be used as an insurance against TFP shocks. In the model, a lower access to deposits implied that resources available for a bank's operations decrease. In fact, banks invest less in capital as they have to buy bonds. In turn, as banks are constrained in the use of funds, bond issuance produces investments that become more volatile with respect to GDP. As capital is reduced and its accumulation becomes more volatile, the ability of capital to insure the economy against shocks to TFP is reduced.

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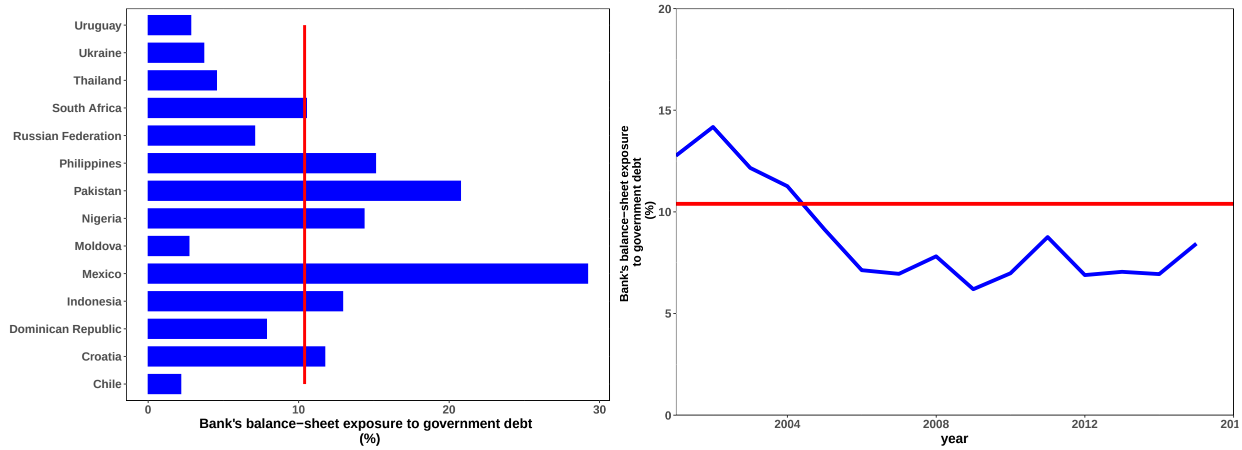
A Domestic bank's balance sheet exposure to sovereign debt

Figure 5: Domestic bank's bondholdings



(a) Average bank's bondholdings by country. (b) Average country-year bank's bondholding.

Source: International Financial Statistics and author's calculations. The figure plots the banking system bondholdings over 2001–2016 for all country-years covered by both as weighted by GDP.

B Defaults events and data sources

Default events. Albania(1991), Argentina (1989,2001), Armenia (1994), Azerbaijan(1994), Bolivia 1986, Brazil (1990), Cameroon (1985), Costa Rica (1984), Ghana 1979, Jordan 1989, Panama (1987), Peru (1983), Russia (1998), Turkey (1982), Ukraine (1998).

C Proof proposition 1

Proof proposition 1 First, rewrite the banker problem in recursive form. The banker problem in sequential form is

$$V_t^b = \max_{b_{i+1},k_{i+1},d_{i+1}} \mathbb{E}\sum_{i=t}^{\infty} \Lambda_{t,i+1}\psi^{i-t}\{(1-\psi)n_{i+1} + \psi\pi_{i+1}^b\}$$

s.t.

$$q_{i+1}b_{i+1} + k_{i+1} = \frac{d_{i+1}}{r_i} + n_i - \pi_i^b)$$

$$d_{i+1} = \lambda n_i$$

$$n_{i+1} = b_{i+1} + R_{i+1}k_{i+1} - d_{i+1}.$$

In this case the objective function of the bankers' problem can be written as

$$V_t^b = \max_{b_{i+1},k_{i+1},d_{i+1}} \mathbb{E}\Lambda_{t,t+1}\{(1-\psi)n_{t+1} + \psi\pi_{t+1}^b + \psi\left[\sum_{i=t+1}^{\infty} \Lambda_{t+1,i+1}\psi^{i-t}\{(1-\psi)n_{i+1} + \psi\pi_{i+1}^b\}\right]\}$$

$$V_t^b = \max_{b_{i+1},k_{i+1},d_{i+1}} \mathbb{E}\Lambda_{t,t+1}\{(1-\psi)n_{t+1} + \psi\pi_{t+1}^b + \psi V_{t+1}^b\}$$

In this problem a banker that remain in such activities has no incentives to provide dividends to its household $\pi_{t+1}^b = 0$ as it can save that amount and decrease the need for external deposits in the future. Now, rewriting the problem the sequential problem a recursive problem. Let the state to be represented as $\mathbf{S} = (b, k, d, z)$ and the banker's net worth with n. The Bankers' dynamic problem can be written as:

$$v(n,\mathbf{S}) = \max_{b',k',d'} \mathbb{E}\Lambda(\mathbf{S},\mathbf{S}')\{(1-\psi)n' + \psi v(n',\mathbf{S}')\}$$

s.t.

$$q(b',k',d',z')b' + k' = \frac{d'}{r} + n'$$

$$d' = \lambda n'$$

$$n' = (1 - D(b',k',d',z'))b' + Rk' - d'.$$

Second, I guess that the banker value function is linear in n and derive the bond price in equilibrium. Assume that the value function is linear $v(n, \mathbf{S}) = \alpha(\mathbf{S})n$ where $\alpha(\mathbf{S}')$ is the marginal value of the bankers' wealth. The problem can be expressed as

$$v(n, \mathbf{S}) = \underset{b',k',d'}{max} \mathbb{E}\{\Lambda(\mathbf{S}, \mathbf{S}') \left[1 - \psi + \psi\alpha(\mathbf{S}')\right] n'\}$$

$$\text{s.t.}$$

$$q(s')b' + k' = \frac{d'}{r} + n'$$

$$d' = \lambda n'$$

$$n' = (1 - D(b', k', d', z'))b' + Rk' - d'.$$

By substituting the constraint on deposits in the banker balance sheet $k' = \left(1 + \frac{\lambda}{r}\right) n - qb'$ and by introducing this expression on the law of motion of net worth

$$n' = R\left[\left(1 - \frac{\lambda}{r}\right) n - qb'\right] + b' - \lambda n \tag{6}$$

which an expression on bonds and current net worth, by introducing this expression on the value function, we obtain:

$$v(n, \mathbf{S}) = \underset{b'}{max} \mathbb{E}\left\{\hat{\Lambda}(\mathbf{S}, \mathbf{S}')[(R\left(1 - \frac{\lambda}{r}\right) - \lambda)n + \left[1 - D(b', k', d', z') - R(\mathbf{S}')q(\mathbf{S}')\right] b']\right\}$$

where the adjusted discounted factor is $\hat{\Lambda}(\mathbf{S}, \mathbf{S}') = \mathbb{E}\Lambda(\mathbf{S}, \mathbf{S}')[\psi + (1 - \psi)\alpha(\mathbf{S}')]$. From the first order conditions we obtain that

$$q(\mathbf{S}') = \frac{\mathbb{E}[\hat{\Lambda}(\mathbf{S}, \mathbf{S}') \left[1 - D(b', k', d', z')\right]}{\mathbb{E}[\hat{\Lambda}(\mathbf{S}, \mathbf{S}')R(\mathbf{S}')]}.$$

In the paper we will let the bond price to be expressed as

$$q(b', k', d', z') = \frac{\mathbb{E}[\hat{\Lambda}(b', k', d', z') \left[1 - D(b', k', d', z')\right]}{\mathbb{E}[\hat{\Lambda}(b', k', d', z')R(b', k', d', z')]}.$$

Finally, the guess is verified as with the first order the condition, the value function becomes

$$v(n, \mathbf{S}) = \mathbb{E} \sum_{t=0}^{\infty} \hat{\Lambda}(\mathbf{S}, \mathbf{S}')[(R\left(1 - \tfrac{\lambda}{r}\right) - \lambda)n].$$

D Numerical solution

Setup in order to solve the model. Grids $[z_i \times b_i \times k_i \times d_i]$, where capital and deposits are around their $k_i \in [0.5k^{ss}, 1.5k^{ss}]$ and $d_i \in [0.5d^{ss}, 1.5d^{ss}]$. The grid for (k_i, d_i) grids are equally spaced at 25 points. The productivity shock is around a grid of 40 points. The grid for bonds is b_i grid is set at 100 points. The model is parellalized with MPI at 20 cores in Fortran.

0.- Solve for period T considering terminal conditions for value functions and bond price.

1.- For a given state $[z_i \times b_i \times k_i \times d_i]$ solve for (d_i', k_i') the system of equations (bankers balance sheet and aggregate resource constraint) such that (d_i', k_i') solves

1.1.- In case of repayment, set the state $[z_i \times b_i \times k_i \times d_i] \times [b_i' \times z_i']$ solve for (d_i', k_i') the system of equations (bankers balance sheet and aggregate resource constraint) such that (d', k') solves

$$0 = f^R(k', d')$$

1.2.- In case of default, set the state $[z_i \times b_i \times k_i \times d_i] \times [z_i']$ solve for (d_i', k_i') the system of equations (bankers balance sheet and aggregate resource constraint) such that (d_i', k_i') solves

$$0 = f^{NR}(k', d')$$

2.- For a given state $[z_i \times b_i \times k_i \times d_i]$,

2.1.- In case of repayment, set the state $[z_i \times b_i \times k_i \times d_i] \times [b_i' \times z_i']$ and use piecewise cubic splines to interpolate the value functions at T over the solution (d', k') to obtain value functions $V_T(b_i, k', d', z_i)$.

2.2.- In case of default, set the state $[z_i \times b_i \times k_i \times d_i] \times [z'_i]$ and use piecewise cubic splines to interpolate the value functions at T over the solution (d', k') to obtain value functions $V_T^{NR}(k', d', z_i)$.

3.- Compute the expected values of the value functions at T with Tauchen quadrature.

3.1.- In case of repayment, set the state $[z_i \times b_i \times k_i \times d_i] \times [b'_i \times z'_i \times k' \times d']$ and compute $\mathbb{E}V_T^R(b'_i, d'_i, k'_i, z')$

3.2.- In case of default, set the state $[z_i \times b_i \times k_i \times d_i] \times [z'_i \times k' \times d']$ and compute $\mathbb{E}V_T^{NR}(d'_i, k'_i, z')$

Given $[z_i \times b_i \times k_i \times d_i]$, solve for Value functions in $T-1$

4.1.1- In repayment, for each (b'_i) we have the optimal policy k', d' and the expected value function $\mathbb{E}V^R(b'_i, k', d', z')$, therefore we can compute $V_{T-1}^R(b_i, k_i, d_i, z_i)$ from:

$$
\begin{aligned}
V^R(b,k,d,z) =& \max_{c,k',b',d',l} \{u(c,l) + \beta \mathbb{E}[V(b',k',d',z')]\} \\
& \text{s.t.} \\
zF(k,l) =& c + k' + (1-\delta)k - \Psi(k',k) \\
g + b =& (1-\tau)wl + qb' \\
\mathbb{E}\frac{c'}{u_c} =& r \\
R =& zF_K(k,l) + 1 - \delta \\
w =& zF_l(k,l) \\
\frac{d'}{r} =& \lambda N \\
k' + qb' =& d + N \\
N =& \psi(Rk + b - d) - (1-\psi)\bar{n}
\end{aligned}
$$

Evaluate the optimal $V^R(b,k,d,z)$ by evaluating each (b_i').

4.- In default, we have the optimal policy k', d' and the expected value function $\mathbb{E}V^R(b_i', k', d', z')$ and $\mathbb{E}V^{NR}(b_i', k', d', z')$, therefore we can compute $V_{T-1}^{NR}(b_i, k_i, d_i, z_i)$ from:

$$
\begin{aligned}
V^{NR}(b,k,d,z) =& \max_{c,k',d',l} \left\{ u(c,l) + \beta\mathbb{E}[^{NR}(b',k',d',z') + (1-\theta)V^R(b',k',d',z')] \right\} \\
& \text{s.t.} \\
zF(k,l) =& c + k' + (1-\delta)k - \Psi(k',k) \\
g =& (1-\tau)wl \\
\mathbb{E}\frac{\beta u_{c'}}{u_c} =& r \\
R =& zF_K(k,l) + 1 - \delta \\
w =& zF_l(k,l) \\
\frac{d'}{r} =& \lambda N \\
k' =& d + N \\
N =& \psi(Rk - d) - (1-\psi)\bar{n},
\end{aligned}
$$

5.- Compute the bond price $q_{T-1}(b_i, k_i, d_i, z_i)$

6.- Repeat 2 to 5 for T large enough value functions and bond price converge.