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## Three essays in International Economics

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A thesis submitted in partial fulfillment of the requirements for the Doctor of Philosophy degree in Economics

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# Abstract

My thesis consists of three essays on International Economics. In the first two chapters, I study the role of domestic markets on the issuance of sovereign debt. In the third chapter, I evaluate the aggregate consequences of large devaluations on exporting dynamics.

Chapter 2 studies the episodes of sovereign default triggering banking crises. First, those episodes are characterized by an important exposure of domestic banks to government bonds. Therefore, a default triggers a credit crunch in the economy. Second, output and investment show a considerable drop and a protracted recovery after the default. In this chapter, I focus on the channel in which a default affects the capital accumulation financed by banks. I build a quantitative model to assess whether this channel can account for the joint dynamics of output and investment during empirical episodes where a default preceded a banking crisis. The model is calibrated to reproduce the empirical moments of banks' bondholding exposure and capital accumulation ex-ante to default in those economies that experienced a joint default and banking crisis. The model reproduces the untargeted dynamics of macroeconomic and financial variables during a default. Finally, I use the model to evaluate the ex-ante trade-off when a government issues government debt to banks. By issuing more debt, they decrease the incentives to default but it crowds-out capital accumulation in the economy. Also, I show that the crowding-out effect is lower for economies with a banking system that has more access to deposits.

Chapter 3 analyzes the trade-offs that a government faces when deciding whether to issue debt through domestic and foreign markets under limited commitment. I find empirical evidence showing a negative correlation between the exposure of domestic banks to government bondholdings with the interest rate spread compensating for the risk of default. In order to rationalize this fact, I develop a quantitative model where government chooses the optimal amount of debt issued to international investors and domestic banks and cannot discriminate across investors. The stock of debt held by foreign investors vis-a-vis the stock held by banks is meaningful to determine default incentives. While a repudiation of debt decreases the amount that should be paid by foreign lenders, the default is costly for domestic private intermediation. As a result, bond price worsens with the increase of foreign debt, while it improves with domestic debt. I parametrize the model to resemble the banking sector exposure to government bonds and default frequency of an emerging economy. The model is close to reproduce the untargeted share of domestic to foreign debt observed in the data.

Chapter 4 studies the macroeconomic effects of large and persistent devaluations. In the data we observe that after a large devaluation, exports have a sluggish reaction and start to increase after several years. I show that this pattern characterizes the devaluation observed in real exchange rate of Colombia in 2014. I build a quantitative model of a small open economy featuring costs for incumbent and new exporters. A share of the cost is paid by importing goods from the rest of the world. Therefore, in this stylized model, I introduce the feature that exporters are also intensive importers. This resembles a feature of the Colombian data where firms that account for 90 % of the exports are also intensive importers. Both elements affect the dynamics of the extensive margin for exporters. I solve the model and reproduce a large devaluation event that matches the dynamics observed in the data for real exchange rate and interest rates. I show that the model is able to reproduce the sluggish reaction of net exports.

The model is calibrated to match the steady state of several moments of the Colombian economy for the period of 1980-2012. In particular, I calibrate the parameters dominating probability distribution of the continuation and sunk costs to match the continuing rate of exporters and the exit rate. I solve the model using local projection methods. I use the solution of the model to find the optimal path of shocks to resemble a RER devaluation and the increase in international interest rate. I show that the model is able to match the dynamics of the elasticity of exports to RER.

## Summary for the Lay Audience

My thesis consists of three essays on International Economics related to sovereign default and banking crises, domestic debt, and large devaluations.

Chapter 2 studies the episodes of sovereign default triggering banking crises. Those episodes are characterized by an important exposure of domestic banks to government bonds. Therefore, a default triggers a credit crunch in the economy. I focus on the channel in which a default affects the capital accumulation financed by banks. I build a quantitative model to assess whether this channel can account for the joint dynamics of output and investment during empirical episodes where a default preceded a banking crisis. I use the model to evaluate the ex-ante trade-off when a government issues government debt to banks. By issuing more debt, they decrease the incentives to default but it crowds-out capital accumulation in the economy.

Chapter 3 analyzes the trade-offs that a government faces when deciding whether to issue debt through domestic and foreign markets under limited commitment. I find empirical evidence showing a negative correlation between the exposure of domestic banks to government bondholdings with the interest rate spread compensating for the risk of default. In order to rationalize this fact, I develop a quantitative model where government chooses the optimal amount of debt issued to international investors and domestic banks and cannot discriminate across investors. The model is close to reproduce the untargeted share of domestic to foreign debt observed in the data.

Chapter 4 studies the macroeconomic effects of large and persistent devaluations. In the data we observe that after a large devaluation, exports have a sluggish reaction and start to increase after several years. I build a quantitative model of a small open economy featuring costs for incumbent and new exporters to rationalize this fact. In the model, sunk costs affect the decisions of exporters to participate in international markets. Therefore, those costs represent a friction for participation. I solve and simulate the model to replicate the sluggish reaction of the elasticity of exports with respect to the real exchange rate. In the data we observe that after a large devaluation, exports have a sluggish reaction and start to increase after several years. I build a quantitative model of a small open economy featuring costs for incumbent and new exporters to rationalize this fact. In the model, sunk costs affect the decisions of exporters to participate in international markets. Therefore, those costs represent a friction for participation. I solve and simulate the model to replicate the sluggish reaction of the elasticity of exports with respect to the real exchange rate.

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# Chapter 1

## Introduction

My thesis consists of three chapters related to topics in international economics. In the first chapter, I study the importance of the credit–investment channel to explain the aggregate consequences of a sovereign default that triggers a banking crisis. The second chapter also focuses on the sovereign-bank nexus. In particular, I study the role of debt held by domestic banks in public debt sustainability. The last chapter explores the effects of entry costs for new exporters to explain the sluggish reaction of exports to real exchange rate (RER) devaluation.

Sovereign defaults that lead to banking crises are distinguished by a deep drop in output and protracted recovery. In these events, most public debt is issued through domestic markets, while 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. According to the model, banks invest in capital and buy bonds issued by a benevolent government, and they are financially constrained to issue deposits based on the value of their net worth. During sovereign default, a bank's investment in capital drops as its net worth decreases. I calibrate the model to match the fraction of bank assets held as government bonds, the mean investment to gross domestic product (GDP), and the investment volatility of economies that experience distress in domestic credit after a default. The model is able to reproduce the untargted observed dynamics of output, investment, consumption, deposits, and bank assets around default events.

In Chapter 2, I also 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 the ex-post cost of default. An increase of 50% in the share of bonds among banks' assets decreases the probab-

ity 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%. I demonstrate that, based on the data, the disruption in capital accumulation is reduced in economies with higher access to domestic deposits. In the model, economies with greater ability to issue deposits have more resources to lessen the crowding-out effect of sovereign debt in bank balance sheets.

In Chapter 3, I continue studying the sovereign-bank nexus. However, I here focus on the role domestic debt issuance plays in public debt sustainability. In particular, I study an environment in which the government is not able to discriminate across bondholders, meaning it is costly to default to foreign investors, as this also affects domestic banks. By issuing more domestic debt, a government increases its incentives to repay and improve its borrowing conditions. I study whether this channel can explain the structure of domestic to foreign debt issued by governments. I also develop a model of sovereign default that incorporates both domestic banks and foreign investors. The model is calibrated to simulate the default rate and the average bondholding exposure of the banking system for an emerging economy. I show that the model can simultaneously replicate the untargeted structure of foreign to domestic debt as well as several business cycle statistics.

I also provide a rationale for the negative empirical correlation between the sovereign spread and the stock of domestic debt held by different countries. In the model, the variation in the bondholding exposure of the banking system allows to replicate this negative relationship. A government with higher bondholding exposure has lower incentives to default, as this can trigger a credit crunch in the economy. First, the sovereign spread decreases with the lower willingness to default. Second, the government issues more domestic debt, as it can in this way strategically improve the cost of foreign borrowing. I go on to document evidence showing that domestic banks' balance sheets are highly exposed to local government bonds. On average, a domestic bank maintains around 12% of its balance sheet as sovereign debt and holds 25% of the total stock of public debt. Given such exposure, it is estimated that, during sovereign default episodes, domestic credit decreases by 4% of GDP on average. In addition, I empirically demonstrate that the risk of sovereign default implied from bond prices is negatively correlated with the exposure of domestic banks' balance sheets to local government bonds. A rationale for the latter relationship is that investors consider that the willingness to default decreases with the risk of triggering a decrease in credit intermediation.

In Chapter 4, I study the importance of frictions to new exporters to explain the sluggish dynamics of exports after a RER devaluation, focusing on the case of Colombia in 2014. At that time, the RER was devaluated by 40%, and the exports showed an increase after several quarters. I develop a quantitative model according to which sunk costs affects firms' decisions to become exporters. Exporters are also intensive importers, as they must finance a share of their costs with external goods. The reaction of exports to a devaluation may be dampened for two reasons. First, sunk costs reduce the willingness of firms to operate abroad. Second, as exporters are intensive importers, their costs increase substantially upon a devaluation. The model is calibrated to match the steady state of several moments of the Colombian economy for the period of 1980–2012. I solve the model using local projection methods and use the solution to determine the optimal shock path to represent an RER devaluation and the resulting increase in the international interest rate. I show that the model is able to match the dynamics of the elasticity of exports to RER.

# Chapter 2

## Domestic Debt, Financial Intermediaries, and the Dynamics of Investment

### 2.1 Introduction

Recent empirical studies have documented particular regularities in default events that precede an episode of domestic credit distress.<sup>1</sup> 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

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<sup>1</sup>See Asonuma and Trebesch (2016), Balteanu and Erce (2018), and Asonuma et al. (2020).



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.

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 volatil-

ities 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 chapter 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.

## 2.2 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 intermedi-

aries. 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.

### 2.2.1 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  $\beta$ . 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  $\pi$  the net dividends that the household receives from its shares on financial intermediaries, by  $\pi$  and by  $\tau$  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

$$\begin{aligned} \max_{c_t, l_t, d_{t+1}} \mathbb{E} \sum_{t=0}^{\infty} \beta^t u(c, l) \\ \text{s.t.} \\ c_t + \frac{d_{t+1}}{r_t} = d_t + (1 - \tau_t)w_t l_t + \pi_t + \Phi(k_{t+1}, k_t). \end{aligned}$$

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

### 2.2.2 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.<sup>2</sup>

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  $\pi_t^b$  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:

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

where  $\lambda$  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

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<sup>2</sup>These assumptions prevents the banker to over accumulate wealth and do not need external funding.

balance sheet of each period. The problem can be characterized as follows:

$$\begin{aligned}
 & \max_{b_{i+1}, k_{i+1}, d_{i+1}} \mathbb{E} \sum_{i=t}^{\infty} \Lambda_{t,i+1} \psi^{i-t} \{ (1 - \psi) n_{i+1} + \psi \pi_{i+1}^b \} \\
 & \text{s.t.} \\
 & \quad q_{i+1} b_{i+1} + k_{i+1} = \frac{d_{i+1}}{r_i} + n_i - \pi_i^b \\
 & \quad d_{i+1} = \lambda n_i \\
 & \quad n_{i+1} = b_{i+1} + R_{i+1} k_{i+1} - d_{i+1}
 \end{aligned}$$

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

### 2.2.3 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  $y_t = z_t F(k_t, l_t)$ . 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

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

### 2.2.4 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  $i_t = k_{t+1} - (1 - \delta)k_t + \Phi(k_{t+1}, k_t)$ .

### 2.2.5 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  $\{g, \tau, b\}_{t=0}^{\infty}$  satisfy the government's budget constraint.

The aggregate resource constraint holds.

Market clearing for bonds, deposits, capital, labor.

### 2.2.6 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 value function we can obtain that bankers' dividends  $\pi^b$  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:

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

and the value for repayment solves

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

and the value for default solves

$$\begin{aligned}
 V^{NR}(k, d, z) &= \max_{c, k', d', l} \left\{ u(c, l) + \beta E[\theta V^{NR}(k', d', z') + (1 - \theta)V(b', k', d', z')] \right\} \\
 \text{Resource} & \\
 \text{s.t.constraint} & : \quad zF(k, l) = c + i + g \\
 & \quad k' = (1 - \delta)k + i - \Phi(k', k) \\
 \text{Government} & \\
 \text{budget} & : \quad g = (1 - \tau)wl \\
 \text{constraint} & \\
 \text{Competitive} & : \quad \left\{ \begin{aligned} r &= \beta \frac{\mathbb{E}u'_c(c', l')}{u'_c(c, l)} \\ R &= zF_K(k, l) + (1 - \delta) \\ w &= zF_L(k, l) \\ \frac{d'}{r} &= \lambda N \\ k' &= \frac{d'}{r} + N \\ N &= \psi(Rk - d) - (1 - \psi)\bar{n}. \end{aligned} \right. \\
 \text{equilibrium} &
 \end{aligned}$$

**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.

## 2.3 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 3.1. The country utility function considers the following specification:

$$u(c, n) = \frac{(c - \frac{n^\omega}{\omega})^{1-\psi}}{1-\psi} \quad (2.1)$$

where the  $\sigma$  is the coefficient of risk aversion, which is set to 2 (as is standard in quantitative macroeconomics).<sup>3</sup> The parameter  $\omega$  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  $\frac{1}{\omega} = 2$ .<sup>4</sup>

The firm follows a constant return to scale technology:

$$F(k, n) = k^\alpha l^{1-\alpha} \quad (2.2)$$

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:

$$\log z_t = \rho_z \log z_{t-1} + \epsilon_t \quad (2.3)$$

with  $\epsilon_t \stackrel{\text{iid}}{\sim} N(0, \sigma_z^2)$ . I calibrated the parameters for TFP following the strategy of incorporating capital in a sovereign default model calibrated for emerging economies (see Roldan-Pena,

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<sup>3</sup>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.

<sup>4</sup>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.

2011; Gordon and Guerron-Quintana, 2017; Park, 2017). On the one hand, the persistence process was settled at  $\rho_z=0.95$ , 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).<sup>5</sup> The bankers' survival rate was set at  $\psi = 0.97$ , which is consistent with the findings of Bocola (2016) and Gertler and Kiyotaki (2010).<sup>6</sup> I calibrated the parameter for the bank's financial frictions  $\lambda$  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  $\delta$  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 is in the study of Gordon and Guerron-Quintana (2017)

$$\Phi(k', k) = \frac{\Theta}{2}(k' - k)^2, \quad (2.4)$$

where the parameter affecting the cost  $\Theta$  was set at 7 in order to match the volatility of the

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<sup>5</sup>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)

<sup>6</sup>In this model, the size of the parameter  $\psi$  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  $\psi$  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.

investment to volatility of output of 3.91 in the sample.

The value for the probability to reentry to financial markets after a default  $\theta$  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).<sup>7</sup>

The discounting parameter  $\beta$  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.<sup>8</sup>

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.

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<sup>7</sup>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).

<sup>8</sup>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 2.1: Parameters used in the model

Parameter	Value	Source
<b>Literature</b>		
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
<b>Calibrated</b>		
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 %
Cost of default	$\min\{z, 0.95\}$	Annual default rate 2.5 %
Government expenditure	$g = 0.09$	Government expenditure to GDP 14 %
Discount factor	$\beta = 0.976$	12 % of bank's balance sheet exposure
Adjustment cost capital accumulation	$\Theta = 7$	Investment to output volatility 4.25

## 2.4 Results

### 2.4.1 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.

### 2.4.2 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.<sup>9</sup> 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

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<sup>9</sup>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.

Table 2.2: Simulations:Data and Model

<b>Non-Target Statistics</b>	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
<b>Target statistics</b>		
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.

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.<sup>10</sup>

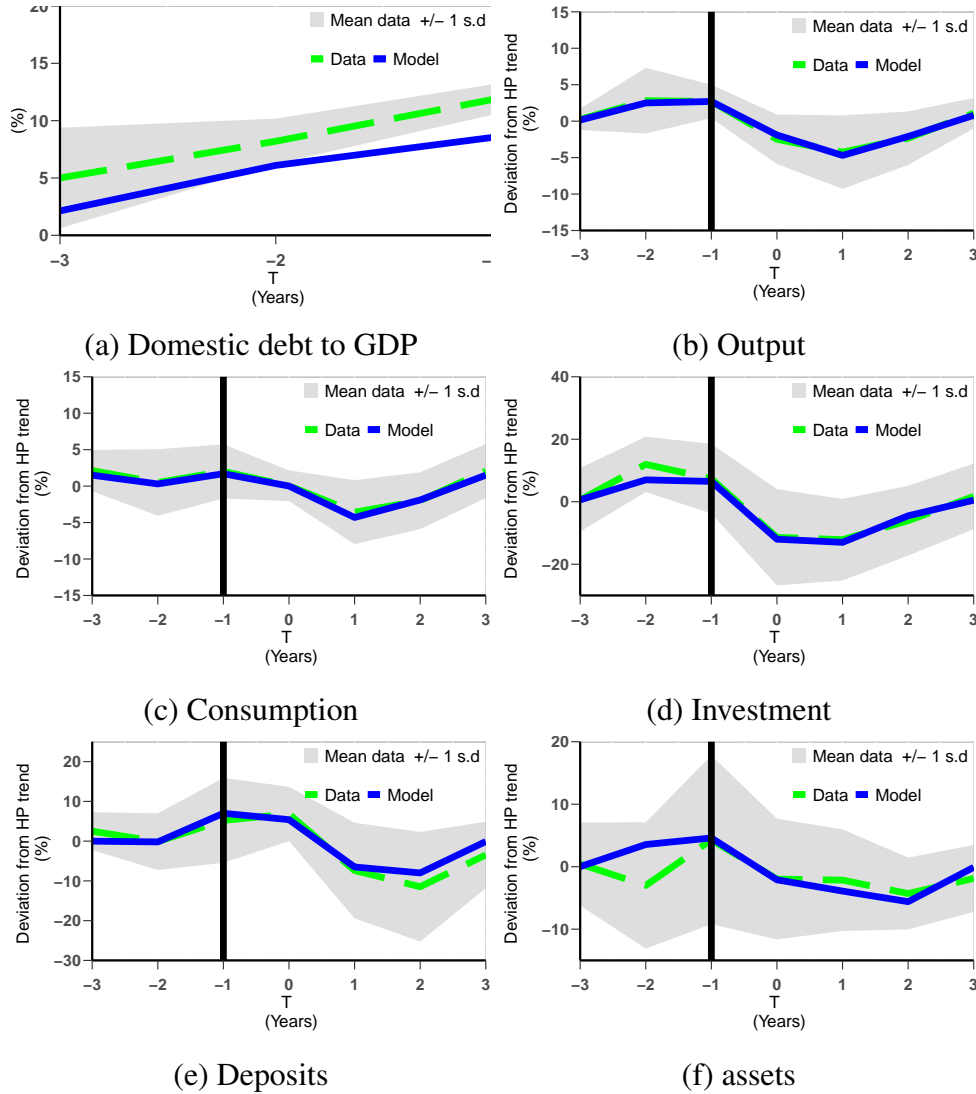
<sup>10</sup>In other classifications, it is difficult to differentiate the affect that external defaults have against domestic defaults. Sturzenegger and Zettelmeyer (2006) brought a detailed narrative regarding the unfolding at the run-up and aftermath of a sovereign default. They detailed that, while 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.



Figure 2.1 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 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 2.1: Simulations: Default events.



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 blue line 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  $\pm 1$  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 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;

$$\begin{aligned} \Delta \left( \frac{inv_{i,t}}{y_{i,t}} \right) = & \beta_1(\text{Default}^{CD}_{i,t-1}) + \beta_2(\text{Default}^{CD}_{i,t-1}) \cdot (\text{Bondholdings}_{i,t-1}) \\ & \beta_3(\text{Default}_{i,t-1}) + \beta_4(\text{Default}_{i,t-1}) \cdot (\text{Bondholdings}_{i,t-1}) \\ & + \beta_5(\text{Bondholdings}_{i,t-1}) + \alpha_i + \nu_t + \mathbf{X}'_{i,t-1}\gamma + \epsilon_{i,t}. \end{aligned} \quad (2.5)$$

where the  $i$  superscript identifies countries, 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.<sup>11</sup> I allow the interaction and the testable implication 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.  $\beta_2 < 0$  and  $\beta_4 < 0$ ).

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<sup>11</sup>While it is difficult to describe a causality from default and bank exposure on credit on credit, I intend 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.

Panel (a) in table (2.3) shows the estimates for (3.1) 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 (2.3) shows the estimates for

Table 2.3: Regression: Investment and on Default and Bondholdings

<b>Panel a: Investment deviation to HP-filtered trend</b>				
	(1)	(2)	(3)	(4)
$(\text{Default}_{i,t-1}^{CD}) \cdot (\text{Bondholdings}_{i,t-1})$	-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

<b>Panel b: Investment to GDP</b>				
	(1)	(2)	(3)	(4)
$(\text{Default}_{i,t-1}^{CD}) \cdot (\text{Bondholdings}_{i,t-1})$	-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.

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

### 2.4.3 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.

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 2.4, I study the importance of bondholdings' exposure in the model. I recalibrate the model 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 2.4: Simulation: Increase in bondholding exposure

	<b>Panel a: Government bonds to bank's assets</b>	
	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 2.5 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 2.5 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  $\lambda$  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 2.5: Simulation: Increase in deposits-to-GDP

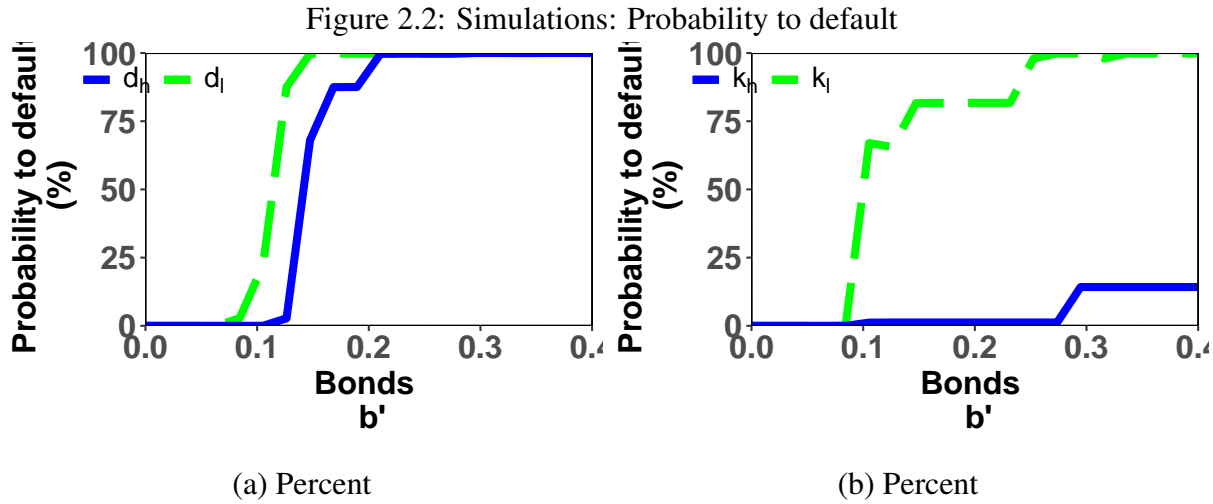
	<b>Data</b>		<b>Model</b>	
	Low	High	Low	High
Mean deposits to GDP	0.15	0.34	0.15	0.32
Mean Investment to GDP	0.19	0.22	0.17	0.28
Investment std. dev. to GDP std. dev.	4.81	3.68	3.53	3.71
Consumption std. dev. to GDP std. dev.	1.52	1.42	2.45	2.10
Probability to default	-	-	7.8	1.28

In the table we recalibrate the model to match the statistic related to the column Data. I recalibrate the model with the parameter  $\lambda$  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  $\lambda$  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 2.2. 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.



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.

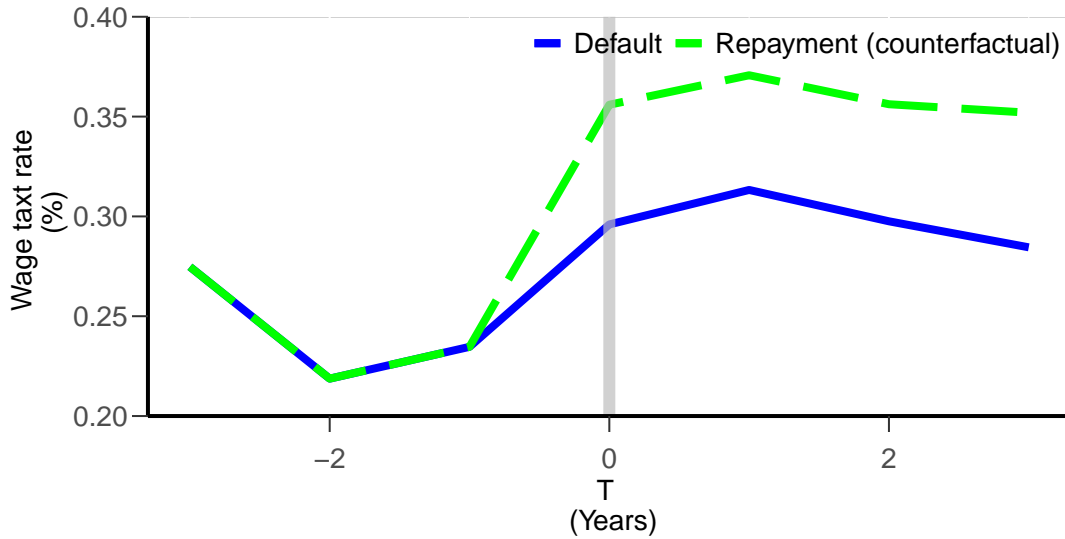
#### 2.4.4 Tax adjustment during the default episode

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 2.3 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.<sup>12</sup>

<sup>12</sup>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.



Figure 2.3: Simulations: Labor tax around a default episode.



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.

## 2.5 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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# Chapter 3

## Domestic debt and public debt sustainability

### 3.1 Introduction

In this chapter, I quantitatively study the role of domestic debt issuance in public debt sustainability and develop a model of sovereign default that incorporates both domestic banks and foreign investors. According to the model, the government cannot discriminate across bondholders. Therefore, it is costly to default to foreign investors, as this also affects domestic banks. By issuing more domestic debt, a government increases its incentives to repay and improve its borrowing conditions. The model is calibrated to simulate the default rate and the average bondholding exposure of the banking system for an emerging economy. I show that the model can simultaneously replicate the untargeted structure of foreign to domestic debt as well as several business cycle statistics.

I also provide a rationale for the empirical relationship according to which the sovereign spread is negatively correlated with the stock of domestic debt held by different countries. In the model, the variation in the bondholding exposure of the banking system allows for this negative relationship to improve. A government with higher bondholding exposure has lower incentives to default, as this can trigger a credit crunch in the economy. First, the sovereign spread decreases with the lower willingness to default. Second, the government issues more domestic debt, as it can in this way strategically improve the cost of foreign borrowing.

I go on to document evidence showing that domestic banks' balance sheets are highly exposed to local government bonds. On average, a domestic bank maintains around 12% of its

balance sheet as sovereign debt and holds 25% of the total stock of public debt. Given such exposure, it is estimated that, during sovereign default episodes, domestic credit decreases by 4% of GDP on average. In addition, I empirically demonstrate that the risk of sovereign default implied from bond prices is negatively correlated with the exposure of domestic banks' balance sheets to local government bonds. A rationale for the latter relationship is that investors consider that the willingness to default decreases with the risk of triggering a decrease in credit intermediation.

I further build a model considering previous empirical evidence. In the model, final goods producers face intra-period working capital constraints. Domestic banks use their assets, including government debt, to issue loans for financially constrained firms. Banks' bond holdings are risky, as a government can default its debt. In the case of default, banks' assets are reduced, producing a credit crunch in the economy.

A benevolent government issues short-term debt to international investors and domestic banks, but it cannot discriminate among domestic and foreign bondholders. As a result, it issues a single bond, and its price compensates the marginal foreign investors for the risk of default. In turn, the probability to default is determined by the structure of the debt held by foreign investors and domestic banks. While the repudiation of debt decreases the amount that foreign lenders should pay, the default is costly for private domestic intermediation. As a result, the bond price worsens with the increase of foreign debt, while it improves with increases in domestic debt.

Two benefits are considered in the decision to issue domestic debt. First, the decision can be rationalized as saving resources for future returns. Given the use of debt for final goods production, the benefit of investing in domestic bonds is that, in repayment states, they provide future resources and liquidity to financially constrained firms. Second, given that decisions are centralized, the government can internalize how domestic bond holdings are dealt with and improve the price of bonds sold to foreign investors.

I calibrate the model to an emerging economy, matching the annual default rate and average bank balance sheet exposure to government bonds. The model fits several standard business cycle moments and shows that interest rate spread decreases with the share of debt held by banks. In particular, the model is close to replicating the structure of domestic and foreign debt observed in the data. I extend the benchmark model to allow for risk premiums affecting interest rate spreads. The structure of domestic and foreign debt is preserved when introducing

this element, which adjusts for the level of sovereign spreads.

I demonstrate use of the model, showing that it can reproduce the negative relationship between sovereign spreads and the domestic stock of debt. I recalibrate the model over the average bondholding exposure to match a grid of stock of debt and compute the associated interest rate spread. In line with the evidence observed in the empirical section, I show quantitatively that this relationship is negative.

**Related Literature.** This paper is related to several strands of research connecting sovereign debt and banking crises. The first strand studies the interaction of banking sectors and strategic government sovereign debt repayment through the use of quantitative models à la Eaton and Gersovitz (1981). In an important study, Sosa-Padilla (2018) study the cost that the default has on domestic credit intermediation through the damage done to banking balance sheets in a closed economy where domestic banks are the only source of demands for bonds. In this previous paper, benefits from the default arise because the government decreases its tax rate. With regard to this point, I extend the work of Sosa-Padilla (2017) by adding international investors and inducing the government to make optimal decisions on the bank's bond holding, while the previous model incorporated banks operating in competitive equilibrium. In my model, the benefits of default result from debt not being repaid to international investors. Crucially, unlike Sosa-Padilla (2018), my model assumes that the government solves an optimal portfolio of two different assets and evaluates the benefits versus the costs. One benefit of issuing domestic debt is thus that it improves the cost of borrowing from external investors.

Perez et al. (2015) developed a model according to which banks that do not have opportunities to invest in productive projects use bonds as an asset to retain their current resources and obtain liquidity in the future. During a default, endogenous costs occur because of the default's effect on balance sheets, and more banks decide to invest in bonds instead of productive opportunities. My study differs from Perez et al. (2015) in two respects. First, in my model, endogenous costs only arise through the default's effect on balance sheets, allowing me to simplify the model and consider government centralization of banks' bond holdings. Second, the government internalizes the effect of domestic bond holdings on costs.

Other papers have also analyzed the effect of sovereign debt on banks. For example, Bocola (2016) evaluated the effect of sovereign risk on banks' lending conditions. In this previous paper, the economy was considered closed, and sovereign risk was modeled exogenously. In addition, the banking sector was considered endogenous capital accumulation. The paper went

on to study how sovereign risk affected banks' balance sheets and lending conditions. In contrast, my model considers an open economy banking sector with an intra-period balance sheet effect. More importantly, in contrast to Bocola (2016), who included an exogenous source of sovereign risk, my model endogenizes the decision to default.

Another strand of related literature includes studies that explore the connections among sovereign debt, banks, and debt sustainability. Gennaioli et al. (2014) studied the importance of introducing sovereign debt in the domestic banking sector for debt sustainability. This paper introduced a finite-horizon model and developed the theoretical implications that domestic bond holdings have for debt sustainability. Acharya and Rajan (2013) developed a finite-horizon model according to which government myopia due to political changes induces limited commitment to repay foreign debt. These authors also mention that a tax policy forcing domestic banks to hold debt could decrease the problems regarding limited commitment. Chari et al. (2014) developed a model according to which financial repression is optimal because it induces banks to maintain domestic reserves for government borrowing to mitigate the worsening of financial conditions in foreign markets (in particular, the financial repression during sudden stop episodes). In contrast to these theoretical studies, my model provides a quantitative framework to explore the role of domestic debt in debt sustainability and can be compared with empirical data.

The paper is structured as follows: Section 2 provides empirical evidence of several channels incorporated in my model. Section 3 presents the theoretical model to be used for quantitative purposes. Section 4 shows the quantitative analysis. Finally, Section 6 gives the project's conclusions.

## 3.2 Empirical evidence

In this section I show three empirical facts related to the importance of the sovereign-banking connection. The purpose is to provide evidence of the importance of domestic debt under the assumption that a government cannot discriminate between domestic and foreign investors. The first fact shows that banks' balance sheets are highly exposed to sovereign debt. The second evidence shows that in episodes of default such exposure affect the flow of private credit in the domestic economy. Third, I show that sovereign spreads, associated with the risk of default, are negatively correlated with domestic's banks exposure. I connect these facts, by suggesting that these lines of evidence are related to the idea that a government will pay a lower cost for its debt because defaulting is costly for banks' intermediation purposes.



**Banks' bondholdings.** Banks are significant holders of the total amount of government debt and show high exposure of their balance sheets to this asset. I show that such exposure can be important to disrupt domestic credit intermediation in case of default. First, in cross-section, there are several countries where the banking system is a major holder of domestic debt issued by the local government. Second, the observed levels of banks' balance sheet exposure to public debt are significant.

Figure B.1 shows the importance of domestic debt as a share of total public debt for several countries.<sup>1</sup> Panel (a) shows that around 50% of the total share of the debt is in the hands of domestic holders: the central bank, private banks, and non-bank intermediaries. In addition, around two-thirds of the sample of countries have over half of the total debt as domestic debt. Panel (b) shows that around 40% of domestic debt is held by private banks.

Figure B.2 shows a measure of the exposure of banking systems to government debt for several countries.<sup>2</sup> It consists of the ratio of intermediary banks' net claims to the government as a fraction of their total net assets, capturing the share of consolidated financial system balance sheets that are exposed to an outright government default. Panel (a) shows the average exposure for several countries. On average, in the sample, a country's banking system shows an exposure of around 12% of the balance sheet. Panel (b) shows the evolution of the average bank's exposure over a country-year average. This graph shows that, on average, the banking exposure to public debt fluctuated between 10% to 14%.<sup>3</sup>

The exposure of the banking systems to sovereign debt is significant when considering the BIS regulation framework for settling limits for the exposure of a bank to risky assets: each country considers maximum exposure to one single asset in the range of 10% to 25% (see Committee et al., 2014).<sup>4</sup> However, this comparison should include additional adjustments to be valid. While the regulatory framework considers assets valued by its risk-weights, imposed

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<sup>1</sup>I used the database from Arslanalp and Tsuda (2014) where they estimated the share of sovereign bond holdings in the hands of different types of investors. These estimates considered a sample from 2004 to 2016 and included 24 countries from Asia, Latin America, Eastern Europe, the Middle East, and Africa.

<sup>2</sup>This measure is commonly used in the literature to measure banks' exposure to sovereign debt as it has been documented by Kumhof and Tanner (2005); Gennaioli et al. (2014) and Asonuma et al., 2015.

<sup>3</sup>While the bank's exposure measure has a straightforward definition, its construction from International Financial Statistics (IFS) data from IMF is not explained. I used data from two IFS surveys: Other Depository Survey and Other Financial Corporations Survey. This construction is validated when comparing panel (b) with the corresponding measure in Gennaioli et al. (2018), figure 1, showing a similar level and dynamics.

<sup>4</sup>Usually public debt issued by a local government avoids this regulation as such bonds are considered safe assets.

by the national regulation, the measures presented above did not consider such weights, as the data from IFS avoided these measures in their valuation of assets. Therefore, once risk-weights are considered, the exposure could be smaller. In order to show how reliable is the exposure of the banking system to government debt, I explored data from the European Banking Union stress-tests. This data set provides measures of sovereign exposures in fully loaded assets and risk-weighted assets.

The data showed that banks' exposures to sovereign risk are important using any definition of their assets. Figure B.3 shows the sovereign exposure for several countries as a share of total assets on the balance sheet. Panels (a) and (b) display the sovereign exposure using fully loaded assets (FLA) and risk-weighted assets (RWA) as the denominator for several European economies under the stress test for 2014 and 2016, respectively. While in 2014, the FLA mean exposure (11.7%) was below the RWA exposure (13.14%), during 2016, the 14.7% FLA exposure was close to the 14.6% RWA exposure. In both measures, the average sovereign exposure remained similar to the 12% observed across countries using IFS data. Panels (d) and (e) display a scatter plot of sovereign exposure using FLA and RWA. Countries on the left of the 45-degree line showed lower exposures in RWA than FLA. In 2014, most countries were to the right of the 45-degree line, whereas in 2016, any pattern remained unclear, as most countries aligned around the 45-degree line. Therefore, excepting France, in 2016, sovereign exposures as a share of RWA did not appear to be lower than FLA exposures. This evidence supported the use of IFS data as a source to demonstrate the high exposure of banks' balance sheets.

**Domestic credit markets.** I quantify the effect of a default on domestic credit flow as evidence of the consequences of high exposures. Therefore, I show how banks' bondholding exposure could have real consequences in case of default. In particular, I show that private credit flow decrease after a sovereign default. Furthermore, this effect is more substantial in economies with higher exposure in their balance sheet to government bonds as those examined above.

Figure B.4 shows the average change in credit to GDP after default episodes, as weighted by GDP. Figure B.4, panel (a) shows that during default, the country-year annual change in credit is around 0.45% of GDP, contrasting with a credit level of 0.91% to GDP during no-default country-year observations. Therefore, comparisons across default and no-default episodes tentatively revealed that credit flow was lower when the government defaulted its debt. Figure B.4, panel (b) shows the change in credit flow during episodes of default in country-years with above, and below, median bond holdings. The figure shows that for country-years with bond

holding levels below (above) the median, credit flow increased (decreased) by 0.80% (0.50%) of GDP. This evidence suggested the existence of a potential balance sheet channel where higher exposure to bonds in default is translated into credit costs.

Previous evidence suggesting that a balance sheet channel operated in default episodes was not conclusive because other shocks and events that can affect the supply and demand of credit during a default must be controlled. In the following section, I control for different shocks and provide an estimate of the impact of default on the flow of credit. The data is annual from 1980 to 2005. I used the following pooled OLS regression to test the implications:

$$\begin{aligned} \Delta(\text{Private Credit})_{i,t} = & \beta_1(\text{Sovereign default}_{i,t-1}) \\ & + \beta_2(\text{Sovereign default}_{i,t-1}) \cdot (\text{Bondholdings}_{i,t-1}) \\ & + \alpha_i + \nu_t + X'_{i,t-1}\gamma + \epsilon_{i,t}. \end{aligned} \quad (3.1)$$

I tested two versions of this model to explain the effects of a default on private credit growth. In the first, I omitted the interaction term between sovereign debt and banks bond holdings ( $\beta_2 = 0$ ). In this specification, a decrease in credit on episodes of sovereign default ( $\beta_1 < 0$ ) was tested. In the second version, I allowed the interaction and the testable implication of private credit decreasing, after default, in countries with banks more exposed to sovereign debt ( $\beta_2 < 0$ ).

Each term in the specification of (3.1) deserves special description. While the term  $\alpha_i$  controlled for fixed effects across countries,  $\nu_t$  captured elements of common time variations across countries, such as commodity price shocks. The term  $X_{i,t-1}$  refers to control variables affecting credit supply and demand during episodes of sovereign default. By controlling for conditions correlated to default events, unexpected effects of a default on credit could also be captured.<sup>5</sup> By using GDP growth, unemployment, and inflation, I controlled for adverse economic conditions that affect the demand for credit and the distress that could trigger default episodes.

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<sup>5</sup>Unexpected effects of a sovereign default are difficult to capture because the event is endogenous to economic conditions. Yeyati and Panizza (2011) document that output contractions precede defaults and that the negative effect of the default on output could be driven by the anticipation of this event, unconditional on its validation. However, a default could also be triggered by episodes of economic distress where a government is unwilling to repay because debt repudiation is optimal. Therefore, several of the control variables were intended to capture the economic conditions endogenous to the default. I am testing the hypothesis to measure the effect of a default on credit once its validation has affected the balance sheet. While it is difficult to describe a causality between default and bank exposure on credit, I intend to capture a prevailing negative correlation once other economic conditions are accounted for.

I considered 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, depreciation was also associated with a potential default. In addition, I considered episodes of sudden stops affecting the supply of credit for private agents, including the banking and public sectors. Finally, I controlled for the existence of a banking crisis before the default event, as these states affect credit before the government realizes debt repudiation.

Table B.1 reports the regression estimates. The baseline estimates are presented in column (1) and show that credit growth decreases in an episode of sovereign default. In particular, these estimates implied that after default, private credit drops by 1% of GDP. In column (2), the interaction term between bank bond holdings and the default is negatively correlated with private credit flow. The coefficient was marginally statistically significant. In a default event, the marginal effect of a 10% increase in the exposure of the banking system to bond holdings decreases credit flow by 3.1% of GDP, the net effect is 3.6%.<sup>6</sup>

**Sovereign spreads and domestic debt.** I find evidence that sovereign interest rate spreads are negatively correlated with the amount of government debt held by domestic investors. In particular, this relationship prevails if the amounts held by domestic banks are considered.

As debt sustainability depends on the default's costs and assumes that the government cannot discriminate across the debt holders, the debt structure between domestic and foreign investors could be considered in the cost of sovereign debt. Since defaulting to domestic debt holders can be considered an ex-post cost, investors' expected yield could decrease, as there is a lower risk of default. However, as defaulting to foreign agents can be considered an ex-ante benefit, investors' expected yield could increase as the risk of default increases.

I tested whether the structure of bond holdings was important to explain the yields observed in the data across emerging economies. I used data for sovereign spreads from JP-Morgan Emerging Market Bond Index (EMBI) and for the structure of investors I follow Arslanalp and Tsuda (2014) that estimated the amount of sovereign debt in the hands of foreign and domestic holders.<sup>7</sup> The data frequency is quarterly and comprise information from 2004 to 2016.

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<sup>6</sup>The net decrease in private credit includes the marginal and direct effects of a default and the exposure of the banking system.

<sup>7</sup>Foreign debt holders comprise three categories: banks, non-banks, official sources. Domestic holders are comprised of banks, non-banks, and the central bank.

First, I used the following pooled OLS regression to test whether sovereign yields are negatively (positively) associated with the amount of debt held by domestic (foreign) investors

$$S_{i,t} = \alpha_i + \beta_1 \frac{B_{i,t-1}^D}{y_{i,t-1}} + \beta_2 \frac{B_{i,t-1}^F}{y_{i,t-1}} + \beta_3 \hat{y}_{i,t-1} + X'_{i,t-1} \gamma + \nu_t + \epsilon_{i,t}, \quad (3.2)$$

where  $S_{i,t}$  is the sovereign spread for a country  $i$  at time  $t$ ,  $\frac{B_{i,t-1}^D}{y_{i,t-1}}$  is the amount of debt-to-GDP in the hands of domestic holders,  $\frac{B_{i,t-1}^F}{y_{i,t-1}}$  is the amount of debt-to-GDP in the hands of foreign holders,  $\hat{y}_{i,t-1}$  is the country's GDP gap  $i$ , the term  $\alpha_i$  controls for fix effects across countries,  $\nu_t$  captures elements of common time variation across countries, and  $X'_{i,t-1}$  is a vector of variables controlling for global factors.

The coefficients of interest are  $\beta_1$ ,  $\beta_2$ , and  $\beta_3$ . For domestic and foreign debt holders, a negative (positive) value on the associated coefficient  $\beta_1$  and  $\beta_2$ , respectively, indicated that the change sovereign risk premium, captured by the sovereign spread, decreases (increases) with the number of bonds held by each type of holder. Finally, a negative value for  $\beta_3$  indicated that sovereign risk decreased when the output gap was positive.

The results of the regression estimates (3.2) are presented in column 1 of Table (B.2). While the estimate for  $\beta_1$  was significantly negative, the estimate for  $\beta_2$  was positive but not significant. In addition, the GDP gap coefficient was negative but not significant.<sup>8</sup>

Second, I exploited the database details from Arslanalp and Tsuda (2014) that estimated the amount of government debt held by different types of banking and non-banking investors. I used these estimates to run an alternative version of regression (3.2) where I split the amount of debt held by domestic and foreign holders. The following pooled OLS regression shows the alternative version associating spreads with the residency of the debt holder

$$S_{i,t} = \alpha_i + \sum_{D \in \{b,n\}} \beta^D \cdot \frac{B_{i,t-1}^D}{y_{i,t-1}} + \sum_{F \in \{b,n\}} \beta^F \cdot \frac{B_{i,t-1}^F}{y_{i,t-1}} + \beta_3 \hat{y}_{i,t-1} + X'_{i,t-1} \gamma + \nu_t + \epsilon_{i,t}, \quad (3.3)$$

where  $S_{i,t}$  is the sovereign spread for a country  $i$  at time  $t$ ,  $y_{i,t-1}$  is the country's GDP gap in  $i$ , the term  $\alpha_i$  controls for fix effects across countries,  $\nu_t$  captures elements of common time variation across countries, and  $X'_{i,t-1}$  is a vector of variables controlling for global factors.  $\frac{B_{i,t-1}^D}{y_{i,t-1}}$  ( $\frac{B_{i,t-1}^F}{y_{i,t-1}}$ ) is the amount of debt-to-GDP in the hands of domestic (foreign) holders of type  $D$  that can be

<sup>8</sup>While the coefficient was not statistically significant, this last result could hint that sovereign risk decreases as economic conditions improve, as expected by the theory connecting default risk with income fluctuations.

different sources: banking ( $b$ ) and non-banking ( $n$ ).

The results of the regression estimates (3.3) are presented in column 2 of Table (B.2). The only stock of bonds that is statistically significant to explain the spread in the pooled regression is  $\beta^b < 0$ .

### 3.3 Model

**Agents.** There are four types of domestic agents in the economy (firms, households, and the sovereign government) and one abroad (international investors). Firms operate a technology transforming hired labor into a final consumption good. Households are inhabited by two agents, workers, and bankers. There is full risk insurance across agents. Workers supply labor and return their wages to the household. Each period, bankers use the household's assets to invest in company loans and government bonds and transfer the dividends back to the household.

**State.** There are two endogenous state variables in this economy, the stock of public debt  $B$  and the stock of total domestic debt  $b$ , and one exogenous state variable, TFP shock  $z$ . Note that the government decides to issue debt to international investors  $b^{*'}$  and domestic banks  $b'$ . Moreover, the stock of government debt  $B'$  is the sum of both types of debt. Therefore, the problem remains the same, as the government chose the total stock of debt  $B'$  and the stock of domestic debt  $b'$ , where the foreign debt was computed by subtracting domestic debt from total debt ( $b^{*'} = B' - b'$ ).<sup>9</sup>

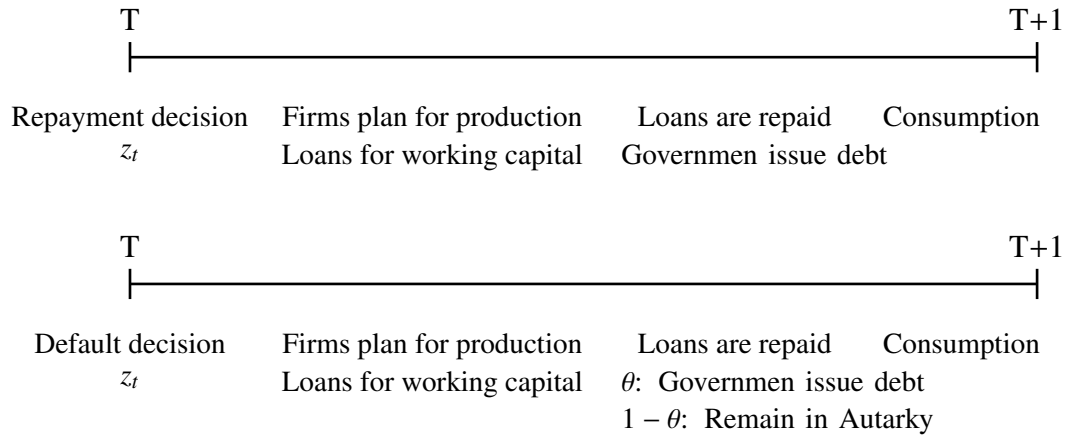
**Timing of events.** At the beginning of the period, a Total Factor Productivity (TFP) shock  $z_t$  is realized, and the government decides whether to repay or default on domestic and foreign debt. The timing is similar to Sosa-Padilla (2018). The top panel in fig:timeline represents the timing after a repayment decision. After the government's decision, firms decide their production plan and demand banks loans to fill their working capital requirements. Bankers use their endowment and the stock of debt repaid in the period in order to finance company loans. Before the end of the period, loans are repaid, and the government issue one-period debt to international investors and domestic banks. At the end of this period, households receive income from bankers' dividends, workers' wages, and transfers from the government.

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<sup>9</sup>Other studies analyzing the stock of foreign and domestic debt used the same strategy (Perez et al., 2015); Balke et al. (2016)).

In the case of default, the timeline of events proceeds as in the bottom panel of 3.1. After a default, firms decide on a production plan that requires working capital. However, banks can fund this requirement only through their endowment because they lose their accumulated government bonds. Before the end of the period, the governments finish (continue) the financial autarky with the probability  $\theta$  ( $1 - \theta$ ) and are able (not) to issue debt to foreign markets and domestic banks. In newly accessing financial markets, they can issue debt to foreign and domestic markets. At the end of the period, households consolidate the income of bankers and workers and, in case of not being in financial autarky, receive transfers from the government.

Figure 3.1: Timeline within period after a government's decision



### 3.3.1 Decision problems

#### Households

The representative household has a continuum of members of measure unity. Within the household, there are  $1 - f$  workers and  $f$  bankers. Workers supply labor  $n_t$  to firms at wage rate  $w_t$  and return the payment  $w_t n_t$  to the household. Bankers operate as financial intermediaries, facilitating resources to firms and the government. Every period, bankers receive an endowment  $A$  and bond holdings  $b$  from previous investments to provide loans to firms at the beginning of the period and the government at the end of the period.

Within the household, there is perfect consumption insurance. Each period, identical households choose consumption  $c_t$ , labor supply  $n_t$ , and government bonds  $b_{t+1}$  to maximize discounted lifetime utility. The preferences are time separable, and each period is discounted by the factor  $\beta$ . The period utility function  $u(\cdot)$  considered preferences  $u(c_t - g(n_t))$ , where  $g(\cdot)$

was the disutility to labor supply. In addition, in each period, households received an endowment  $A$  that is used by bankers to start operations.

These households take as given the wage rate  $w_t$ , profits from banks  $\pi_t^f$ , and transfers from the government  $T_t$ .<sup>10</sup> The household's dynamic problem can be expressed as:

$$\begin{aligned} \max_{c_t, n_t, b_{t+1}} \quad & \mathbb{E} \sum \beta^t u(c_t - g(n_t)), \\ \text{s.t.} \quad & c_t = w_t n_t + \pi_t^f + T_t \\ & \pi_t^f = (1 + r_t)(A + b_t) - q(B_{t+1}, b_{t+1}, z_t) b_{t+1} \end{aligned}$$

where  $T_t$  denotes the government transfers,  $r_t$  is the interest rate paid by intratemporal loans, and  $q(B_{t+1}, b_{t+1}, z_t)$  is the international bond price.

### Firms

Firms produce final goods with technology  $z_t F(N_t)$  where they use labor  $N_t$  and face TFP shock  $z_t$ . Firms face working capital constraints to pay a share  $\gamma$  of the payroll in advance (before production). Working capital requirements are financed through bank loans that are repaid at the end of the period. The firms' problem is:

$$\max_N z_t F(N_t) - w_t N_t - r_t \gamma w_t N_t.$$

### International investors

Competitive international investors are deep-pocket risk neutral. Investors buy one-period government bonds  $b^*$  at cost  $q(B_{t+1}, b_{t+1}, z_t)$  and discount future payments at the international free interest rate  $r_t^*$ .

### Government

Each period, the government decides whether to default  $d_t$  or repay  $(1 - d_t)$  on the public stock of debt. In repayment, the government has access to international markets and can issue total debt  $B_{t+1}$  at cost  $q(B_{t+1}, b_{t+1}, z_t)$ , it is divided between debt held by international investors  $b_{t+1}^*$  and debt held by domestic bankers  $b_{t+1}$ . In addition, the government has to repay one-period

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<sup>10</sup>As is standard in quantitative models following Eaton-Gersovitz, households could not issue private debt directly, but the government chose the optimal amount of debt and repayment decisions. As I describe later, funds from borrowing are received in the form of transfers to households.



government debt issued in the previous period  $B_t$ . The proceeds from repayments and issuing new debt are transferred to the households

$$T_t = (1 - d_t)(q(B_{t+1}, b_{t+1}, z_t)B_{t+1} - B_t),$$

where  $T_t$  is the transfer received by households.

In the case of default, the government repudiates the total stock of debt  $B_t$  but cannot issue new debt  $B_{t+1}$ . At the end of the period, the government can recover access to international markets with probability  $(1 - \theta)$  with zero debt to repay.

### 3.3.2 Recursive government problem

A government can solve the households' problem by choosing to default  $d$  or repay  $(1 - d)$

$$V(B, b, z) = \max_{d \in \{0,1\}} (1 - d)V^R(B, b, z) + dV^D(z),$$

where  $V^D(z)$  is the value function for choosing to default and  $V^R(B, b, z)$  is the value function for choosing to repay.

In the case of repayment, the government maximizes the households' lifetime utility by choosing the optimal stock of total debt  $B'$ , the optimal amount of domestic debt  $b'$ , and labor supply  $n_t$  given the firms' working capital constraints. The problem is represented by

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

s.t.

$$B + T = q(B', b', z)B'$$

$$n = \left( \frac{A + b}{\gamma} \right)^{\frac{1}{\omega}}$$

$$c = zF(n) + T + \pi^f$$

$$r = \frac{zF_n}{b + A} - \frac{1}{\gamma}$$

$$w = \frac{zF_n}{1 + \gamma r}$$

$$\pi^f = (b + A)(1 + r) - q(B', b', z)b',$$

where the first constraint represents government's household transfers policy. The second constraint combines labor supply. The third equation represents the households' budget constraints. The fourth equation considers the equilibrium intra-period interest rate for working

capital needs. The fifth constraint is the equilibrium wage rate for labor supply. Finally, the last constraint represents the bank dividends paid to households.

The value of default is represented by

$$\begin{aligned}
 V^D(z) &= \max_{c,n,l,S} u(c,n) + \beta \mathbb{E}[\theta V(0,0,z') + (1-\theta)V^D(z')] \\
 \text{s.t.} \\
 n &= \left(\frac{A}{\gamma}\right)^{\frac{1}{\omega}} \\
 c &= zF(n) + \pi^f \\
 r &= \frac{zF_n}{A} - \frac{1}{\gamma} \\
 w &= \frac{zF_n}{1 + \gamma r} \\
 \pi^f &= (A)(1 + r)
 \end{aligned}$$

where the first equation represents the optimal conditions for labor supply within constrained loans for working capital under default. The second equation introduces the feasibility constraint and does not consider government transfers. The third and fourth equations consider the constrained equilibrium interest rate and wage rate, respectively. Finally, the last equation introduces bank dividends in autarky.

As in Arellano and Ramanarayanan (2012), the default policy can be characterized by a default set in terms of

$$D(B', b') = \{z \in [\underline{z}, \bar{z}] : V^D(z) \geq V^R(B', b', z)\},$$

where  $\underline{z}$  and  $\bar{z}$  represent the upper and lower bounds of TFP realizations. In addition, let the complement of this set represent the repayment policy.

$$R(B, b) = \{z \in [\underline{z}, \bar{z}] : V^R(B', b', z) > V^D(z)\}.$$

In the case of repayment, the optimal new total debt issued by the government  $B'$  and the optimal debt issued to domestic banks  $b'$  can be represented by rules mapping the current state of tomorrow's optimal borrowing

$$B' = \tilde{B}(B, b, z)$$

$$b' = \tilde{b}(B, b, z).$$

Using these elements, and given that international investors are deep pocket risk-neutral and operate in a competitive environment, the equilibrium cost function can be written as

$$q(B', b', z) = \int_{R(B^{B'}, b')} \frac{f(z', z)}{1 + r^*} dz'.$$

**Markov equilibrium.-** The relevant state variables are  $B$ ,  $b$ , and  $z$ , and in recursive Markov equilibria, all decisions are functions of this state. A recursive equilibrium for this economy is (i) a set of policy functions for consumption  $\tilde{c}(B, b, z)$ , new issuances of total debt  $\tilde{B}(B, b, z)$ , new issuances of domestic debt  $\tilde{b}(B, b, z)$ , repayment sets  $R(B, b)$ , and default sets  $D(B, b)$ , and (ii) price functions for short-term debt, such that

- 1.- Taking as given the bond price function  $q(B', b', z)$ , the policy functions  $\tilde{c}(B, b, z)$ ,  $\tilde{B}(B, b, z)$ , and  $\tilde{b}(B, b, z)$ , repayment sets  $R(B, b)$ , and default sets  $D(B, b)$  satisfy the borrower's optimization problem.
- 2.- The bond price functions  $q(B', b', z)$  satisfy the bond price equilibrium equation.

**Optimality conditions.** I analyzed the optimality conditions of the government to illustrate the benefits of issuing more debt domestically. As an illustration, I assumed that the distribution function  $f$  was continuous and that the bond cost schedule and value function were differentiable. Therefore, the optimality first-order conditions of the government's problem were  $q(B', b', z)$ , such that the following conditions hold

$$b' : u'(c)q(B', b', z) = \beta \int_{R(B^{B'}, b')} u'(c') [z' F_{N'} + 1] f(z', z) dz' + \frac{\partial q(B', b', z)}{\partial b'} (B' - b')$$

$$B' : u'(c)q(B', b', z) = \beta \int_{R(B^{B'}, b')} u'(c') f(z', z) dz' + \frac{\partial q(B', b', z)}{\partial B'} (B' - b').$$

This equation represents the optimality condition of accumulating debt held by domestic bankers. The left hand side of the equation shows the households' costs for accumulating domestic assets, valued as foregone consumption in the present. The right hand side of the equation represents the benefits of accumulating government debt in repayment states. The first term shows that domestic bonds provide additional consumption and an additional source of liquidity in the financial system, as bonds can be used for working capital loans. The second term shows how domestic debt holdings affect the value of external debt issued in the present.

As I demonstrate in the quantitative analysis, the bond price schedule increases with additional domestic bonds, i.e.,  $\frac{\partial q(B', b', z)}{\partial b'} > 0$ , as the government has fewer incentives to default when debt is held domestically and can trigger a decrease in working capital loans.

Equation (3.3.2) represents the optimality condition of issuing total government debt (combining domestic and foreign assets). The term in the equation's left side represents the increase in consumption from borrowing today. The first term in the equation's right side represents the consumption foregone in future repayment states. The second term shows how debt issuance affects the value of external debt issued in the present. In the quantitative section, I demonstrate the term  $\frac{\partial q(B', b', z)}{\partial B'} < 0$ . Intuitively, as total debt increases due to debt issuance to foreign investors (holding domestic debt constant), there are more incentives to default.

## 3.4 Quantitative analysis

### 3.4.1 Computation

I solved the recursive equilibrium numerically with value function iteration around discretized grids of total government assets, domestic assets, and an exogenous TFP shock. As in Hatchondo et al. (2010), I solved the finite-horizon model with backward induction. I iterate the solution over several periods such that in the last iteration, in transition from the second to the first period, the difference of the value function and bond price of both periods was lower than  $1e-6$ .

### 3.4.2 Calibration

The benchmark calibration was based on quarterly data from Argentina. The set of parameters is described in 3.1.

The country utility function follows the specification of Greenwood et al. (1988):

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

where the labor share parameter in the benchmark calibration is  $\alpha = 1$ .

The firm technology follows a decreasing return to scale technology:

$$F(N) = N^\alpha$$

Table 3.1: Parameters

Parameter	Value	Source
Risk aversion	$\sigma = 2$	RBC literatue
Risk-free interest rate	$r^* = 0.017\%$	US
Curvature of labor disutility	$\omega = 1.83\%$	Frisch Labor elasticity
TFP process	$\sigma_z = 3.4\%, \rho_z = 0.96$	Argentina's GDP
Reentry probability	$\theta = 0.1$	Tree-year exclusion
Share of the wage bill financed	$\gamma = 0.52$	Argentina's data
Discount factor	$\beta = 0.8$	Default rate 3 %
Cost of issuing equity	$A = 0.356$	Bank exposure 12 %
Firms' Tecnology	$\alpha = 0.66$	

where the labor share parameter in the benchmark calibration is  $\alpha = 0.66$ .

Productivity shock follows an AR(1) process:

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

with  $\epsilon_t \stackrel{iid}{\sim} N(0, \sigma_z^2)$ . The process was calibrated to the quarterly real GDP from Argentina's Ministry of Economy and Finance (MECON) for the period 1980Q1–2005Q4. The productivity process obtained features  $\rho_z=0.96$  and  $\sigma_z^2 = 3.4$ . The banks' endowment A was calibrated to maintain exposure of the balance sheet  $\frac{b}{A+b}$  as 12%.

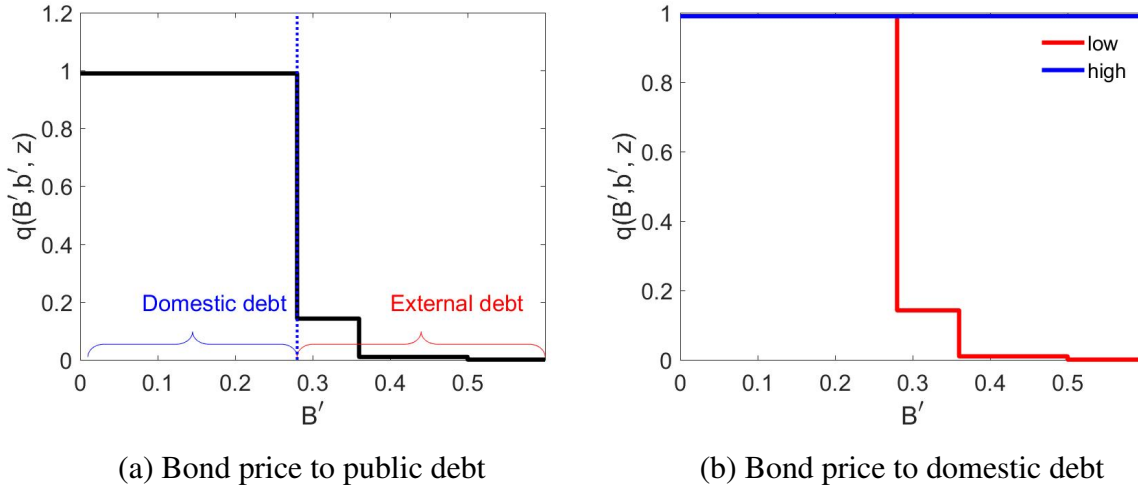
The parameter for the government discount factor  $\beta$  was set at 0.80 in accordance with quarterly calibration used in other quantitative studies. I used the U.S. quarterly interest rate for the risk-free interest rate. The working capital parameter was taken from Sosa-Padilla (2018) who estimated that 0.3% of the wage bill is financed by working capital.

The probability value for re-entry to the financial markets after a default  $\theta$  was set at 0.10, consistent with exclusion of three years. This parameter was set following previous literature. Other quantitative studies calibrated this parameter for a range from 2 to 6 years of exclusion, consistent with empirical estimates across a sample of default episodes (Richmond and Dias, 2009; Gelos et al., 2011).<sup>11</sup>

<sup>11</sup>While Dias and Richmond (2009) provided estimates of the average (median) time of exclusion between 5.7

### 3.4.3 Bond prices and policy functions

Figure 3.2: Price schedule



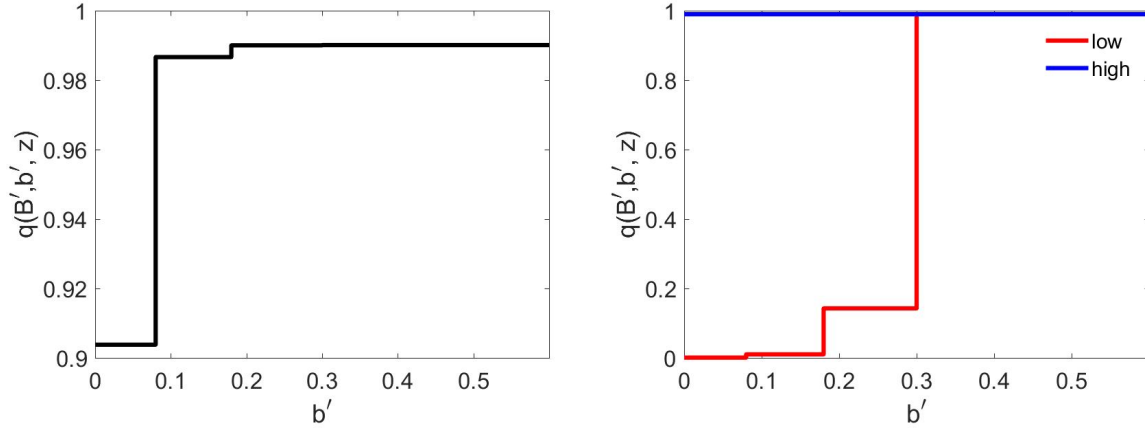
Source: Author's calculations. Panel (a) shows the price schedule with respect to total government's debt at different levels of the productivity shock. Each price schedule consider constant the level of debt held by domestic banks. Panel (b) shows the price schedule with respect to debt issued domestic holders at different levels of the productivity shock. Each price schedule consider constant the level of total government debt.

In this subsection, I examine the properties of the numerical solution of the calibrated model. Figure 3.2 plots the bond price concerning public debt ( $B$ ) for a fixed level domestic debt ( $b$ ).<sup>12</sup> Panel (a) shows that the bond price schedule decreased for total government debt (i.e.  $\frac{\partial q(B', b', z)}{\partial B'} < 0$ ). The dotted vertical line is fixed at the stock of domestic debt chosen by the government. Therefore, the price schedule after this line represents the bond price schedule associated with external debt. However, when the stock of public debt is entirely domestic, the price of issuing bonds does not show any risk as it is costly to default on domestic households. When the government starts to issue debt to international investors, issuing bonds reflects the risk of default as the government can benefit from not repaying international investors. In the panel (b) plots the price schedule of total government debt for a country with high and low TFP shock in the current period. A good (bad) TFP shock improves (worsens) the bond price

(3) years, Gelos et al., 2011 found that on average, it took around 2–4.5 years to recover partial market access. Quantitative studies analyzing sovereign default on external debt had targeted an average exclusion around 3–6 years (Arellano and Ramanarayanan, 2012; Cuadra et al., 2010; Mendoza and Yue, 2012). In studies considering domestic defaults, the estimates vary between 1.25–4 years (Malucci, (2015); Sosa-Padilla, 2018; Perez et al., 2015).

<sup>12</sup>Domestic debt was set at the simulated average debt.

Figure 3.3: Price schedule



(a) Bond price to public debt

(b) Bond price to domestic debt

Source: Author's calculations. Panel (a) shows the price schedule with respect to total government's debt at different levels of the productivity shock. Each price schedule consider constant the level of debt held by domestic banks. Panel (b) shows the price schedule with respect to debt issued domestic holders at different levels of the productivity shock. Each price schedule consider constant the level of total government debt.

schedule.

Figure 4.1 shows the bond price concerning domestic debt for a fixed level of total government debt.<sup>13</sup> Panel (a) shows that bond price increased as domestic debt increased (i.e.  $\frac{\partial q(B', b', z)}{\partial b'} > 0$ ). When government debt is issued to domestic holders, a non-discriminatory default becomes costly. Panel (b) plots the price schedule of domestic debt for a country with high and low TFP shock in the current period. A good (bad) TFP shock improves (worsens) the bond price schedule.

I simulated the numerical solution of the model to analyze the model economy's stationary distribution. I conducted 1,000 simulations with 10,000 periods in each simulation. I then extracted the last 500 observations of each simulation. Finally, I logged and HP filtered the simulated series. The stationary distributions were averages over simulated variables.

**Data.** The data used to compare the model is from different sources. Output, consumption, and trade balance were seasonally adjusted from 1980-Q1 to 2005-Q4 with data from MECON. The bond spread data is from J.P. Morgan's Emerging Markets Bond Indices (EMBI) for Argentina from 1994Q1 to 2002Q1. Following the strategy of Sosa-Padilla (2018), I computed the average total debt to GDP, domestic to GDP debt, and external debt from Reinhart and Ro-

<sup>13</sup>Total government debt was set at the simulated average debt.

Table 3.2: Data and Moments

Non-Target Statistics	Data	Benchmark	Risk Premia
Consumption std./Output std. ratio	1.03	1.01	1.023
Bond spreads std.	2.47	1.58	2.66
Average bond spread	6.21	1.24	5.12
<u>Correlation with Output:</u>			
Labor	0.96	0.93	0.91
<u>Correlation with Bond spreads:</u>			
Output	-.52	-0.36	-0.12
Labor	-0.45	-0.35	-0.10
<u>Debt statistics:</u>			
Total Debt/GDP (%)	41.30	62.71	12.82
Domestic debt/GDP (%)	11.32	20.10	4.22
External debt/GDP (%)	29.98	42.61	6.60
<u>Target statistics</u>			
Default frequency	3	2.98	2.98
Average exposure(%)	12	12	12

The table reports the statistics for Argentina observed in the data and reproduced by the model. All variables are logged and then de-trended using the Hodrick-Prescott filter, with a smoothing parameter of 1600.



goff (2011). I did not measure the average exposure for Argentina, but I used the mean cross-country banks' exposure to government debt constructed as in Kumhof and Tanner (2005).<sup>14</sup>

**Benchmark model.** The second column of 3.2 shows the long-run moments for the benchmark calibration. The model reproduces that around 42 % of total debt is held by domestic banks compared with 37 % in the data. However, in this model, total debt sustainability was higher than in the data. The domestic debt is higher than what we observe in data which implies an important motive to use it. In addition, external debt was higher, supporting the idea that higher domestic debt can improve repayment credibility and increase external debt.

The excess volatility of consumption to output was slightly lower than in data. In this model, the endogenous cost of default and the high persistence of TFP shock imply that good (bad) states prevail in the future. In addition, the bond price schedule improved (worsened) in good (bad) states. Therefore, given the high discounting implies a desire for consumption smoothing, the government borrowed to front-load consumption in good times. However, in bad states, the government decreased its consumption as borrowing became costly. Nonetheless, the existence of domestic debt introduced a counterbalance as it improved borrowing conditions. In turn, this last effect could be behind the limited excess of volatility with respect to the data.

Expected sovereign spreads were positive but not close to those observed in the data. In addition, the spreads' volatility was below that observed in the data. The possibility of issuing domestic debt decreased the probability of default. Therefore, conditional on observing positive domestic debt, the bond price schedule for total debt payment improves compared to a situation with no domestic debt. This effect could also influence the expected spread volatility.

The model also reproduced a negative correlation between spread concerning labor supply and output. A bad shock increased the spread, and given its persistence, it became costlier to issue any debt in future periods. As it became costlier for the government to issue domestic debt for liquidity purposes, domestic bonds decreased, and its availability to provide working capital negatively impacted labor and output.

**Risk premia.** In the benchmark calibration there is low level of the sovereign spread contrasting with ability of the model to reproduce the structure of foreign to domestic debt. A

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<sup>14</sup>In the case of Argentina, anecdotal evidence from Mishkin (2006) mentioned that banks' exposure were 10%, increasing to 25% before the 2001 default.

common concern is that risk premia can be an important driver of sovereign spreads (Longstaff et al. (2011); Borri and Verdelhan (2009)). Therefore, once it is considered, the ability of the model to reproduce the share of domestic to total debt can disappear. In this section, I introduce a risk premia to the model, to evaluate the how it affects the role of domestic debt.

Several studies involving quantitative models of sovereign default introduced risk premia through a pricing kernel  $M(z', z)$ . I followed the specification and parametrization of Arellano and Ramanarayanan (2012). In this specification the price of government debt is:

$$q(B', b', z) = \int_{R(B', b')} M(z', z) f(z', z) dz'. \quad (3.4)$$

I considered a pricing kernel where foreign investors' marginal utility increased where the probability of repayment was low. As explained in Arellano and Ramanarayanan (2012), this negative covariation was costed in the asset and required a lower price (higher premium). I modified the model and introduced the price in (3.4). The model was then re-calibrated for those parameters, targeting the average exposure and default frequency.

The variation of the model of time-varying risk premia through a pricing kernel for international investors. Following Arellano and Ramanarayanan (2012), the pricing kernel specification took the form

$$M(z_t, z_{t+1}) = \exp(-r^* - \gamma_t \epsilon_{t+1} - \frac{1}{2} \gamma_t^2 \sigma_z^2) \quad (3.5)$$

where  $\gamma_t = \alpha_0 + \alpha_1 \log z_t$ ,  $r^*$  is the risk-free interest rate,  $\epsilon_{t+1} = \log z_{t+1} - \rho_z \log z_t$ . The parameter  $\gamma_t$  represents the market price of risk. A high enough  $\alpha_0 > 0$  can impose  $\gamma_t > 0$  on average. Moreover,  $\alpha_1 < 0$  imposes higher risk premium when the economy faces low TFP shock. I used the parameterization in Arellano and Ramanarayanan (2012),  $\alpha_0 = 11$  and  $\alpha_1 = -141$ .<sup>15</sup>

The third column of shows the moments for the modified version with a risk premium. While the moment matched several business cycle statistics, it had problems reproducing the negative relationship between bond spreads, output, and labor. More importantly, in this economy, the government decreased its total debt, unsurprisingly, as shocks to risk premium caused the worst conditions for borrowing.<sup>16</sup> However, the relative importance of domestic debt remained, as almost 33% of debt was domestic with respect to 27 % in the data. Again, this

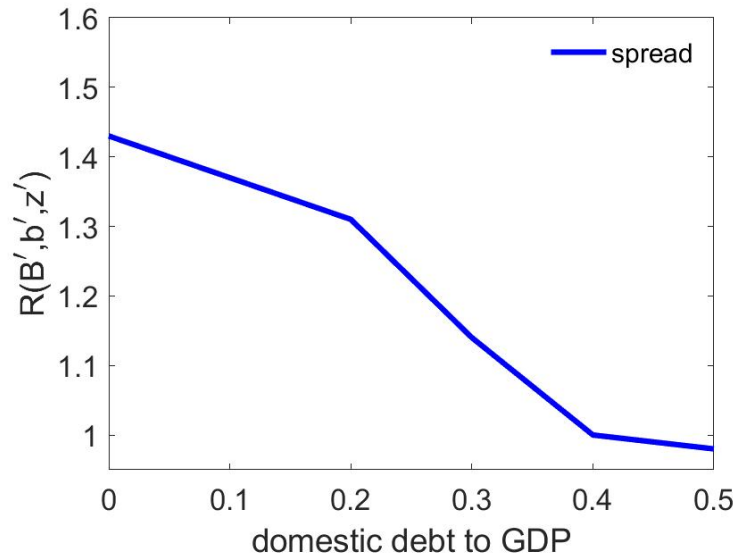
<sup>15</sup>While Arellano and Ramanarayanan (2012) pinned down  $\alpha_0$  and  $\alpha_1$  from Longstaff et al. (2011) for estimates of Brazil's pricing kernel, I used the same parametrization for Argentina, as it shares several characteristics with Brazil. In addition, this has been repeated in other studies Lopez-Martin et al. (2017).

<sup>16</sup>The low level of indebtedness was also found in Arellano and Ramanarayanan (2012)

shows that domestic debt is still an asset that governments use for future liquidity.

**Sovereign spreads and bondholdings.** In the empirical section, I showed that in the data there is a negative relationship between the sovereign spread and the stock of debt-to-GDP held by domestic banks. This property can be reproduced in the model by varying the banks' balance sheet. By varying the parameter  $A$ , I can solve the model over a grid of exposure of banks to government bonds  $\frac{b'}{A+b'}$ . As shown before, this statistic dominates the preference of the government to issue debt to domestic markets. As can be observed in Figure 3.4 this relationship is negative as in the data.<sup>17</sup>

Figure 3.4: Spreads and domestic debt



Source: Author's calculations. This plot shows the model recalibrated to match different levels of domestic debt-to-GDP. The vertical axis shows the spread for each level of domestic debt.

## 3.5 Conclusions

In this paper, I showed empirical evidence about the relationship between sovereign debt and banks. First, I showed that banks' balance sheets are highly exposed to sovereign debt. Second, credit decrease in episodes of default and this cost increase with exposure of the banking system. Third, government spreads for default are negatively correlated with bondholdings. The empirical evidence suggest that while banks' bond exposure is costly in case of a default,

<sup>17</sup>This exercise involved solving the model to match an equidistant grid of domestic debt-to-GDP

the exposure increase the probability of repayment ex-ante. The first two empirical facts suggest that sovereign default are costly in terms of its effect on bank's balance sheets. The third empirical fact suggest that the sovereign risk decrease with the stock of debt held by banks.

I propose a quantitative model of sovereign default with domestic banks and international investors. In this setup, the government can internalize the effect that issuing domestic debt in bond prices. This effect allows the government to issue more external debt at better price. I calibrated and solved the model using for an emerging economy. I found that the model replicated the untargeted structure of domestic to foreign debt observed in the data. The model is able to reproduce the negative relationship between the stock of debt held by domestic banks and sovereign spread.

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# Chapter 4

## Real Exchange Rate devaluations, exports dynamics and global firms

### 4.1 Introduction

In this chapter, I study the reasons why exports do not increase after a real exchange rate devaluation. I develop a quantitative model according to which sunk costs affect firms' decisions to become exporters. In addition, exporters are also intensive importers, as they must finance a share of their costs with external goods. The reaction of exports to a devaluation may be dampened for two reasons. First, sunk costs reduce the willingness of firms to operate abroad. Second, as exporters are intensive importers, their costs increase substantially upon a devaluation. I solve the model and simulate the real exchange devaluation in Colombia during 2014. Further, I demonstrate that, with these two elements, the model can reproduce the staggered reaction of exports.

Colombia suffered a RER devaluation in the third quarter of 2014, and the elasticity of exports to RER remained staggered for at least five quarters after the devaluation. Simultaneously, there was sharp increase in the cost of foreign borrowing as the US began to increase its interest rates. A particular element of the Colombian economy is that its exporters are global firms. That is, firms that are also intensive importers account for 90 % of the total exports, see Sandoval-Hernandez (2021).

In this study, I build a small open economy (SOE) model considering exporting firms that can incorporate both types of shock. In the model, there is a continuum of firms that, for each period, determines whether it is optimal to export to the rest of the world. Incumbent and new

exporters face a sunk cost to sell products abroad. To capture the idea of exporters being global firms, I allow that a share of the costs must be imported. Each incumbent (new) exporter decides whether to remain (participate) in international markets by evaluating the future stream of net profits vis-à-vis not participating.

During a devaluation, the future stream of profits for an exporter increases. Hence, there is a potential increase in the measure of exporters. However, export costs operate as a friction for the devaluation to allow for an increase of the extensive margin. Further, as a share of these costs must be financed with imports, the incentives to become an exporter decrease.

**Related literature.** This paper contributes to several strands of the literature. First, it considers a strand of the literature that studying the dynamics of exports to large devaluations and changes in trade barriers (see Alessandria et al., 2013; Alessandria and Choi, 2007; and Lopez-Martin et al., 2019). In this study, I extend the work of Alessandria et al. (2013) and introduce firms that are also intensive importers. This feature is particular of the structure of Colombia as shown by (Sandoval-Hernandez, 2021) as an important share of exporters are global firms. I show that this feature is important to reproduce the staggered reaction of exports.

My work is in the line of Blaum et al. (2018). By using data from Mexico at the firm level, this paper finds that an important share of exporters are also importers. Sandoval-Hernandez (2021) showed that this characteristic is also found in Colombia. Furthermore, Roberts and Tybout (1997) shows empirically that sunk costs are important to explain Colombia's exporter entry decisions. Combining both parts of the literature, I introduce this feature in a stylized aggregate model as a requirement to pay a share of the sunk costs with imports. Sunk costs paid in terms of imports had been also introduced in the lines of Lopez-Martin et al. (2019).

The SOE economy developed in this chapter is in the lines of standard real business cycle models (see Mendoza, 1991; Garcia-Cicco et al., 2010; and Neumeyer and Perri, 2005). In the model, the external real interest rate plays an important role as it affects the returns of being an exporter in the next period. Alessandria et al. (2013) showed that during large devaluations the real interest rate increases sharply. This feature is present also in the devaluation in Colombia in 2014. Therefore, by rising the international interest rate, the future benefits of being an exporter decrease during a devaluation. Also, I extend the standard international RBC model by introducing a global demand for exports which is a function of the extensive margin.

**Layout** This chapter is organized as follows. In section 2, I present the model and the equi-



librium of the economy. In section 3, I discuss the parametrization of the model. In section 4, I present the quantitative results related to the simulation of the devaluation event, and in section 5, I discuss concluding remarks.

## 4.2 Model

### 4.2.1 Households

There is a continuum of identical households. The households value consumption  $C$  and dislike labor  $L$  according to the utility function  $u(C, L)$  and discount the future with discount factor  $\beta$ . Also, the households can save through one-period bonds that pay an interest rate of  $R$  at period  $t + 1$ . Labor is supplied to good firms in exchange for a wage rate of  $w$ . The households are the owners of the exporting firms. Therefore, I denote  $\Pi$  are the net dividends that the households receive from their shares in exporting firms. Households make plans for consumption, labor supply, and savings to maximize their lifetime utility. Therefore, they solve the following problem

$$\begin{aligned} \max_{C_t, L_t, B_{t+1}} \quad & \sum_{t=0}^{\infty} \beta^t u(C_t, L_t) \\ \text{s.t.} \quad & P_t C_t + B_{t+1} = w_t L_t + \Pi_t + B_t(1 + R_t). \end{aligned}$$

In this setup, I assume that the households' utility function can be represented with Greenwood et al. (1988) preferences

$$u(C, L) = \frac{(C - \lambda L^\eta)^{1-\sigma}}{1-\sigma}$$

where  $\sigma$  represents the coefficient of risk aversion, the parameter  $\eta$  controls the curvature of the labor disutility and  $\lambda$  sets the intensity for labor disutility. Also, we consider that interest rates from international markets can be represented by

$$R_{t+1} = \rho_R R_t + \epsilon_{t+1}^R \quad \epsilon_{t+1}^R \sim N(0, 1).$$

The optimality conditions of the households' problems are:

$$\begin{aligned} \frac{u_{C,t}}{P_t} &= \frac{u_{L,t}}{w} \\ \frac{u_{C,t}}{P_t} &= \beta \mathbb{E} [(1 + R_{t+1}) u_{C,t}] \end{aligned}$$

where  $U_{c,t}$  represents the marginal utility for consumption and  $U_{L,t}$  the marginal utility for labor.

### 4.2.2 Domestic Market: local producers and importers

**Final goods.** The final goods consumed by households  $C_t$  are produced by combining intermediate input from domestic producers  $y_t^d$  and from imports  $y_t^m$  from the rest of the world. This final good is produced by using a Constant Elasticity of Substitution (CES) technology

$$C(y_t^d, y_t^m) = \left[ (y_t^d)^{\frac{\gamma-1}{\gamma}} + \phi (y_t^m)^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}$$

with the elasticity of substitution across home and foreign imports  $\gamma$  and bias for foreign input  $\phi$ . The problem of a final good producer is to minimize its expenditure on intermediate inputs to produce a unit of the final good

$$\min_{y_t^d, y_t^m} p_t^d y_t^d + p_t^m y_t^m$$

st.

$$C(y_t^d, y_t^m) \geq 1$$

where  $p_t^m$  and  $p_t^d$  are cost of imports and domestic intermediate goods, respectively. From the firm's problem we can obtain that the relative demand for inputs satisfies

$$\frac{p_t^m}{p_t^d} = \phi^{\frac{1}{\gamma}} \left( \frac{y_t^m}{y_t^d} \right)^{-\frac{1}{\gamma}}.$$

Also, from the value of the problem we can see that the optimal price index for the final goods satisfies

$$P = \left[ (p^d)^{1-\gamma} + (p^m)^{1-\gamma} \right]^{\frac{1}{1-\gamma}}.$$

### 4.2.3 Intermediate goods.

We assume that domestic intermediate goods are produced with a constant returns to scale technology

$$y_t^d = z_t l_t^d$$

where  $l_t^d$  is labor hired in the home country and  $z_t$  is a technology shock that follows the process

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

We assume that the market is competitive, therefore, the price of the intermediate goods are equal to the wage rate

$$p_t^d = w_t.$$

#### 4.2.4 Foreign Market: Exporters decisions

**Exporting decision.** In this economy, the number of exporters comes from two types of firms: old exporters ( $ox$ ) and new exporters ( $nx$ ). While old exporters are firms that participated during the period  $t - 1$  selling their products abroad, new exporters face the decision to export without any participation in the previous period. Therefore, at period  $t$ , old exporters obtain profits  $\pi$  from previous operations but new exporters will obtain profits until the next period.

We assume that each type of firm faces operating costs as an exporter. Old exporters must pay continuation costs  $\kappa_{ox}$  to remain operating but they avoid such costs in case they leave the exporting sector. New exporters must pay fixed costs  $\kappa_x$  to start operations in foreign markets. The cost  $\kappa_i$  for each type of exporter  $i \in \{ox, nx\}$  are identically independently distributed with an accumulated probability function  $F_i(\kappa_i)$ . A share  $\delta$  of these costs has to be bought in the domestic market and a share  $(1 - \delta)$  has to be part of the imports. Finally, units of labor required are rationalized to meet those costs.

The dynamic problem exporting decision for each type of firm is described below. Old exporters have to decide whether to remain operating at cost  $\delta \frac{w\kappa_{ox}}{z} + (1 - \delta)p_m\kappa_x$  or take their profits and become a non-exporter

$$V_{ox}(\kappa, R, z) = \max_{x, nx} \left\{ \pi - \frac{w}{z} \delta \kappa_{ox} - p_m(1 - \delta)\kappa_x + \mathbb{E} \left[ \frac{V_{ox}(\kappa', R', z')}{1 + R'} \right], \pi + \mathbb{E} \left[ \frac{V_{nx}(\kappa', R', z')}{1 + R'} \right] \right\}.$$

In the case of a non-exporter considering operating abroad, they have to decide whether it is worthwhile paying the fixed costs and obtaining a discounted future stream of profits, or to remain as a non-exporting firm

$$V_{nx}(\kappa, R, z) = \max_{x, nx} \left\{ -\frac{w}{z} \delta \kappa_{ox} - p_m(1 - \delta)\kappa_x + \mathbb{E} \left[ \frac{V_x(\kappa', R', z')}{1 + R'} \right], \mathbb{E} \left[ \frac{V_{nx}(\kappa', R', z')}{1 + R'} \right] \right\}.$$

In both problems  $V_{ox}$  denotes the value of being an old exporter and  $V_{nx}$  is the value of being a new exporter.

The decision to remain as an exporter, or to become a new exporter, is determined by both the continuation and fixed costs. In particular, exporters willing to remain participating in the

international markets or to become new exporters, are those whose costs are lower than the excess of returns of being an exporter,

$$\kappa_i \left( \frac{w}{z} \delta + p_m (1 - \delta) \right) \leq \mathbb{E} \left[ \frac{V_x(\kappa', R', z') - V_{nx}(\kappa', R', z')}{1 + R'} \right] \text{ for } i \in \{ox, nx\}.$$

From these expressions we can observe there is a cost  $\bar{\kappa} = \bar{\kappa}_{nx} = \bar{\kappa}_{ox}$  that characterizes the marginal exporter willing to participate in international markets. Therefore, the distribution of the costs  $F_i(\kappa) \in \{ox, nx\}$  determines the amount of exporters in the period  $t + 1$ .

Formally, the number of firms willing to export in the next period  $N_{t+1}$  is determined by the amount of old exporters remaining  $F_{ox}(\kappa)N_t$  and the amount of non-exporters that find it profitable to enter into international markets  $F_{nx}(\kappa)[1 - N_t]$ . The laws of motion for exporters can be determined as

$$N_{t+1} = F_{ox}(\kappa)N_t + F_{nx}(\kappa)[1 - N_t]$$

### 4.2.5 Demand for exports

We assume the rest of the world produces final goods by using intermediate goods from their own region  $y_i^*$  and from abroad, i.e. Colombia,  $y_i$ . We denote  $\theta$  as the constant elasticity of substitution of varieties coming from the same region. Also, we denote  $\gamma$  as the constant elasticity of substitution across intermediate goods coming from different regions. The production function for final goods can be described as:

$$y^* = \left\{ \left[ \int_0^1 (y_i^*)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1} \frac{\gamma-1}{\gamma}} + \left[ \int_0^N (y_i)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1} \frac{\gamma-1}{\gamma}} \right\}^{\frac{\gamma}{\gamma-1}}.$$

We assume final goods markets is competitive. Therefore the final good producer's problem is to maximize there profits by choosing  $(y_i^*, y_i)$  and taking prices as given satisfy the solution of the problem

$$\max_{y_i^*, y_i} P^* y^* - \int_0^1 p_i^* y_i^* di - \int_0^N p_i y_i di.$$

where from the optimality conditions we can derive the following demand functions

$$\begin{aligned} y_i^* &= (p_i^* P^*)^{-\theta} (P^* P^*)^{-\gamma} y^* \\ y_i &= (p_i P)^{-\theta} (P P^*)^{-\gamma} y^* \end{aligned}$$

where the price indexes satisfy

$$\begin{aligned} P^* &= (p^{*1-\gamma} + p^{1-\gamma}) \\ p^* &= \left( \int_0^1 p_i^{*1-\theta} di \right)^{\frac{1}{1-\theta}} \\ p &= \left( \int_0^N p_i^{1-\theta} di \right)^{\frac{1}{1-\theta}}. \end{aligned}$$

Where  $P^*$  is the final good price index,  $p^*$  is a price index of the goods produced in the rest of the world and  $p$  is a price index of the goods imported from home.<sup>1</sup>

In this setup, we combine the definition of the price indexes to express the individual demand for Colombian intermediate goods as

$$y_i = (p_i p)^{-\theta} (p P^*)^{-\gamma} y^*.$$

In addition, we assume that there is no heterogeneity in the production therefore the price index for exports coming from Colombia can be expressed as

$$P = N^{\frac{1}{1-\theta}} p_x.$$

Therefore the demand for exports can be expressed as

$$\begin{aligned} X &= \int_0^N y_i di \\ &= N^{\frac{\theta-\gamma}{1-\theta}} (\bar{p}_x)^{-\gamma} y^*. \end{aligned}$$

#### 4.2.6 Exporter problem.

The problem for firms  $i$  exporting, is maximizing their profits  $\pi_i$  considering they have market power to set their price  $p_i^x$  and that they can hire labor from the domestic market. We assume that the production of domestic goods can be characterized as constant returns to scale technology

$$y_i^x = (z l_i^x)^\alpha$$

where  $z$  is a technology shock. Therefore, the firms have to solve the following problem

$$\max_{p_i^x} \{p_i^x y_i^x - w l_i^x\}$$

and the solution to this problem provides the following solution for the price

$$p_i^x = \frac{\theta}{1-\theta} \frac{w}{\alpha z} (y_i^x)^{\frac{1}{\alpha-1}}$$

and the individual profits can be represented by

$$\pi_i = \left[ \frac{\theta}{\theta-1} \frac{1}{\alpha} - 1 \right] \frac{w}{\alpha z}.$$

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<sup>1</sup> See the appendix to follow the derivation of the demand functions and price indexes.

### 4.2.7 A competitive equilibrium

For this economy, a competitive equilibrium is supported by allocations  $\{L_t, C_t, B_{t+1}, y_{t,t}^d, y_{t,t}^m, y_{t,t}^x, l_t^d, l_t^x, \Pi_t\}$  and prices  $\{p_t^d, p_t^m, p_t^x\}$  are such that:

- Given  $(P_t, w_t, R_t)$ , allocations  $(C_t, L_t, B_{t+1})$  solves the households' problem.
- Given  $(p_t^d, p_t^m)$ , allocations  $(y_t^m, y_t^x)$  solves the final goods producers problem.
- Given  $(p_t^x, P_t^*, w_t)$  and  $\bar{\kappa}$ , allocations  $(y_t^x, l_t^x, \Pi_t)$  solves the exporting firms' problem.
- Allocations solve the exporting firms' problem.
- Satisfy market clearing conditions for labor, exports and aggregate resource constraintA full stop is needed at the end of the equations.

$$L_t = N_t l_t^x + l_t^d + \delta N_t \int_0^{\kappa^*} \frac{\kappa}{z_t} dF_{ox}(\kappa) + \delta(1 - N_t) \int_0^{\kappa^*} \frac{\kappa}{z_t} dF_{nx}(\kappa)$$

$$N_t(z_t l_t)^\alpha = N_t^{\frac{\theta-\gamma}{1-\theta}} (p_t^x) y_t^*$$

$$p_t X_t - p_t^m M_t = B_t + (1 + R_{t+1}) B_{t+1}$$

## 4.3 Parametrization

**Event study** I study the event of the real exchange rate (RER) devaluation that occurred in Colombia in the third quarter of 2014. I focused on the dynamics of the RER up to four years after the devaluation started. The RER devaluated almost to 40 % and the international interest rate increased in almost 50 basis points. This event can be explained by international conditions the economy confronted at the time. On the one hand, there was drop in the price of oil that is an important commodity for Colombia. On the other hand, emerging economies struggled with the increase of interest rates in the United States (US).

**Solution method** I focus on the aggregate consequences of the devaluation in the dynamics of the exporting sector. I solved the model using local perturbation methods and then proceeded in two steps to evaluate the aggregate dynamics around a devaluation. First, I found a sequence of shocks to TFP  $\{\epsilon^z\}$  and international interest rates  $\{\epsilon_R\}$  in order to replicate the path of the real exchange rates  $\frac{p_t^m}{p_t^d}$  and international interest rates  $R_t$ . Second, given the shocks replicating the devaluation episodes, I replicated the dynamics of the remaining endogenous variables of the model.<sup>2</sup>

**Calibration.** In this section, I discussed the strategy for the parametrization of the model. One set of parameters was taken from the quantitative macroeconomic literature. The other set of parameters were calibrated to match the value of endogenous variables in the steady state of the model. The model was solved using perturbation methods and it is simulated on a quarterly basis. Table 4.1 summarizes the parametrization of the model. The solution of the equilibrium of the model in a steady state is shown in the appendix.

The parameter for risk aversion was set  $\sigma$  at 2. The parameter  $\eta$  controls the curvature of the labor disutility and was set at 1.5, which is consistent with the Frisch wage elasticity of the labor supply of  $\frac{1}{\eta} = 2$ . The parameter that controls the elasticity of substitution across intermediate goods  $\gamma$  was set at 1.5. The ratio of profits to payroll was set at 1.25.<sup>3</sup>

Most of the parameters obtained from data were set to attain the equilibrium in the steady state. I set the parameters for the share of firms exporting as  $N_{ss} = 0.40$  and the exit rate of

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<sup>2</sup>This procedure relies on the state space representation of the model's solution given a first order approximation.

<sup>3</sup>This parameter is used to solve the steady state. The steady state is not sensitive to this parameter in values from around one to three.

Table 4.1: Parameters

Literature		
Parameter	Value	Source
CRRA preferences	$\sigma = 2$	Macroeconomic Literature
Curvature of labor disutility	$\eta = 1.5$	Frisch Labor elasticity of 2
Elasticity of Substitution accross exports	$\theta_z = 3$	Markup of 50%
Debt to Imports in steady state	$\frac{B_{ss}}{M_{ss}} = 3$	Average Debt to Imports 1980-2014
Elasticity of substitution across intermediate inputs	$\gamma = 1.5$	

Targeted moments		
Parameter	Value	Target
Exporters' technology	$\alpha = 0.352$	$\frac{p_{ss}^x}{p_{ss}^d} = 0.55$
Labor disutility intensity	$\lambda = 3.201$	Hours worked $L = \frac{1}{3}$
Adjustment in the cumulative prob. <i>no</i>	$\psi_{ox} = 2.681$	Stock of exporters $N^{ss} = 0.25$
Adjustment in the cumulative prob. <i>nx</i>	$\psi_{nx} = 0.10$	Exit rate $1 - F_{nx}(\kappa_{ss}) = 0.015$
Domestic production bias	$\phi = 0.15$	Labor in exporting sector $\frac{N_{ss}l_{ss}^x}{l_{ss}^d + N_{ss}l_{ss}^x}$
Probability function parameter	$\nu = 0.07$	Average exports after depreciation
Share of costs bought abroad	$\delta = 0.4$	Average imports after a depreciation

new exporters at 1.5 %.<sup>4</sup> I set a functional form for the probability distribution of the sunk and continuation costs to make the model tractable and target both statistics. The functional form is described as

$$F(\kappa) = \left( \frac{\kappa}{\psi_i \nu} \right)^{\frac{1}{\nu-1}}$$

with  $\psi \in \{ox, nx\}$ .<sup>5</sup> In the calibration, the parameter  $\psi_{ox}$  will allow me to target  $N_{ss}$  and the parameter  $\psi_{nx}$  will allow me to target the exit rate  $1 - F(\kappa_{ss})$ . The parameter  $\nu$  controlled the average response of exports after the devaluation episode. The intensity of sunk costs  $\delta$  financed with foreign goods is set at 0.4 in order target a level of imports after a depreciation.

The targeted relative price of exports to domestic goods  $\frac{p_x}{p_d}$  was set at 0.55 according to the relative production price index of the US to the consumer price index in Colombia. By setting this relative price, the model determines the curvature in the production of exporting goods  $\alpha$ .

<sup>4</sup>I use the database from (Sandoval-Hernandez, 2021) to compute those statistics.

<sup>5</sup>Alessandria et al. (2013) use a similar probability function which is helpful to make the model parsimonious.



The parameter  $\phi$  controls the ratio of labor used in exports with respect to domestic and was set at 10%.  $\lambda$  was set to adjust the labor supply to be consistent with 1/3. Finally, the ratio of debt to imports was set at 3.5% consistent with the data of Colombia in the period of 1980–2014.

## 4.4 Results

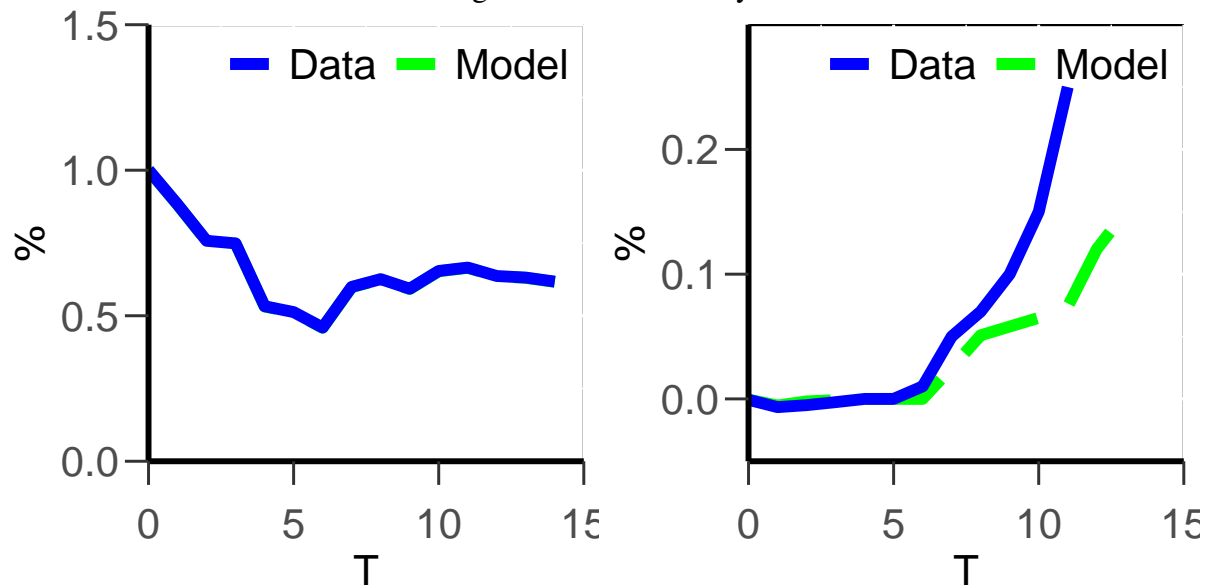
Figure 4.1 shows the dynamics of the RER and elasticity of exports to RER in Colombia in the third quarter of 2014. Panel (a) shows the depreciation of the RER. In this case, we use shocks that replicates exactly the dynamics of the model. Hence, the model and the data show does not differ. Panel (b) shows the elasticity of exports to a devaluation in the RER. This plot contrasts the model with the data. The data shows a sluggish increase in the elasticity of exports, as it takes several years to become positive. The model can recover this feature. The model makes a good fit because we consider that exporters require a share of imports to start operations. The beginning of the devaluation shows exporters require imports to operate, making it costly. Consequently, exports do not react in the first quarter. However, as the devaluation is stronger, future profits overcome the cost of imports.<sup>6</sup>

There are three channels operating for the staggered reaction of exports. First, the direct effect of sunk costs dominates the entry decision of exporters. It makes them avoid the entry to international market. Second, as a share of the sunk costs have to be paid as international goods, the devaluation increases the cost of being exporter. Third, future profits are discounted highly given the increase in the exchange rate. All these effects starts to disappear once the RER rebounds.

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<sup>6</sup>This feature is particular of the Colombian exporting sector as 90% of the exports are produced by firms that are also intensive importers.

Figure 4.1: Event Study



(a) Real Exchange Rate

(b) Elasticity of exports to RER

Source: Author's calculations.

## 4.5 Conclusions

In this chapter, I studied the role of entry costs in exporting decisions to explain the sluggish reaction of the exports after a large devaluation. I developed a SOE quantitative model with sunk cost for the continuation (entry) decisions of incumbent (new) exporters. Exporters are active importers as a share of those costs must be financed with imports from the rest of the world.

In the model developed in this chapter, during a large devaluation the future profits of a firm willing to export increase. However, the incumbent (new) exporter must pay an entry cost to operate abroad. In addition, a share of those entry cost must be imported as we consider that exporters are global firms (ie. intensive importers). This requirement decreases the benefits to become exporter. I calibrated the model to match the average extensive margin in normal times and the exit rate of exporters. Upon a devaluation the frictions over the extensive explains the sluggish reaction of the elasticity of exports to RER. I replicated a devaluation event in the third quarter of Colombia in 2014. I obtained the sequence of shocks in TFP and interest rate that replicates a RER devaluation. I compute the dynamics of the elasticity of exports to RER over five years with respect to the observed with the data. The model is able to reproduce the staggered response of the elasticity of exports with respect to RER.

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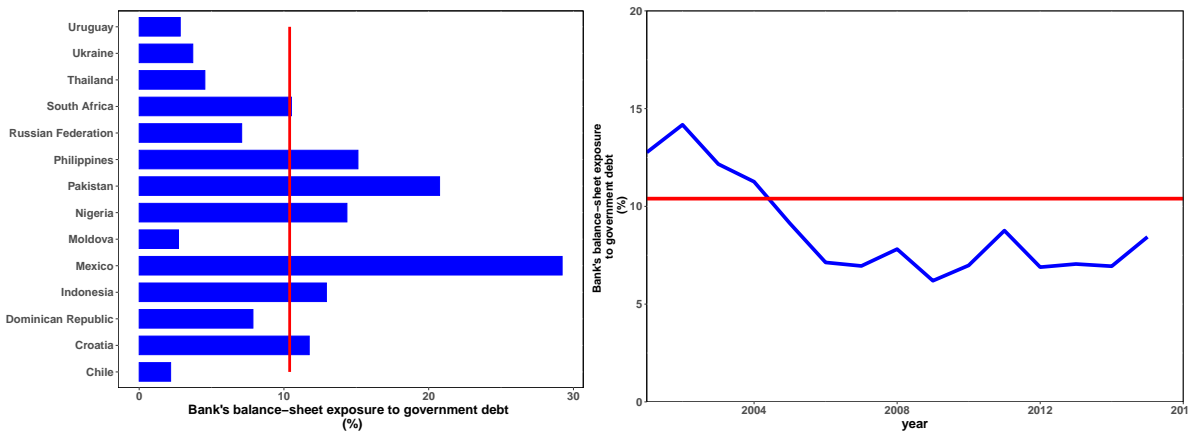
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# Appendix A

## Appendix for chapter 2

### A.1 Domestic banks' balance sheet exposure to sovereign debt

Figure A.1: 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.

### A.2 Defaults events

**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).

## A.3 Proof proposition 1

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

$$\begin{aligned}
 V_t^b &= \max_{b_{i+1}, k_{i+1}, d_{i+1}} \mathbb{E} \sum_{i=t}^{\infty} \Lambda_{t,i+1} \psi^{i-t} \{(1 - \psi)n_{i+1} + \psi \pi_{i+1}^b\} \\
 \text{s.t.} \quad & q_{i+1} b_{i+1} + k_{i+1} = \frac{d_{i+1}}{r_i} + n_i - \pi_i^b \\
 & d_{i+1} = \lambda n_i \\
 & n_{i+1} = b_{i+1} + R_{i+1} k_{i+1} - d_{i+1}.
 \end{aligned}$$

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

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

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:

$$\begin{aligned}
 v(n, \mathbf{S}) &= \max_{b', k', d'} \mathbb{E} \Lambda(\mathbf{S}, \mathbf{S}') \{(1 - \psi)n' + \psi v(n', \mathbf{S}')\} \\
 \text{s.t.} \quad & q(b', k', d', z') b' + k' = \frac{d'}{r} + n' \\
 & d' = \lambda n' \\
 & n' = (1 - D(b', k', d', z')) b' + R k' - d'.
 \end{aligned}$$

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

$$\begin{aligned}
 v(n, \mathbf{S}) &= \max_{b', k', d'} \mathbb{E}\{\Lambda(\mathbf{S}, \mathbf{S}') [1 - \psi + \psi\alpha(\mathbf{S}')] n'\} \\
 \text{s.t.} \\
 q(s')b' + k' &= \frac{d'}{r} + n' \\
 d' &= \lambda n' \\
 n' &= (1 - D(b', k', d', z'))b' + Rk' - d'.
 \end{aligned}$$

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

$$n' = R \left[ \left(1 - \frac{\lambda}{r}\right)n - qb' \right] + b' - \lambda n \quad (\text{A.1})$$

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

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

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

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

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

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

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

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

## A.4 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 parallelized 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  $\mathbb{E}V_T^{NR}(d'_i, k'_i, z')$

4.- 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:

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

s.t.

$$zF(k, l) = c + k' + (1 - \delta)k - \Psi(k', k)$$

$$g + b = (1 - \tau)wl + qb'$$

$$\mathbb{E} \frac{c'}{u_c} = r$$

$$R = zF_K(k, l) + 1 - \delta$$

$$w = zF_l(k, l)$$

$$\frac{d'}{r} = \lambda N$$

$$k' + qb' = d + N$$

$$N = \psi(Rk + b - d) - (1 - \psi)\bar{n}$$

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

4.1.2- 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  $V^{NR}_{T-1}(b_i, k_i, d_i, z_i)$  from:

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

s.t.

$$zF(k, l) = c + k' + (1 - \delta)k - \Psi(k', k)$$

$$g = (1 - \tau)wl$$

$$\mathbb{E} \frac{\beta u_{c'}}{u_c} = r$$

$$R = zF_K(k, l) + 1 - \delta$$

$$w = zF_l(k, l)$$

$$\frac{d'}{r} = \lambda N$$

$$k' = d + N$$

$$N = \psi(Rk - d) - (1 - \psi)\bar{n},$$

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

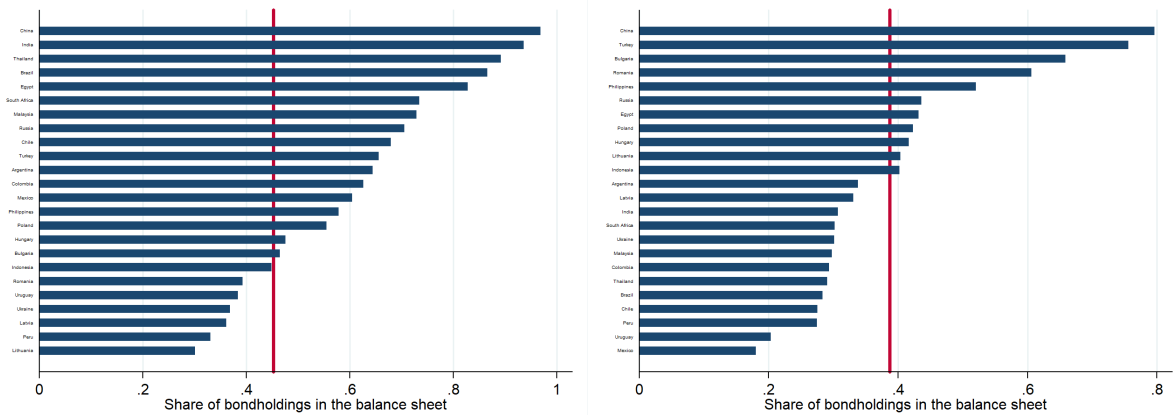
6.- Repeat 2 to 5 for T large enough value functions and bond price converge.

# Appendix B

## Appendix for chapter 3

### B.1 Figures

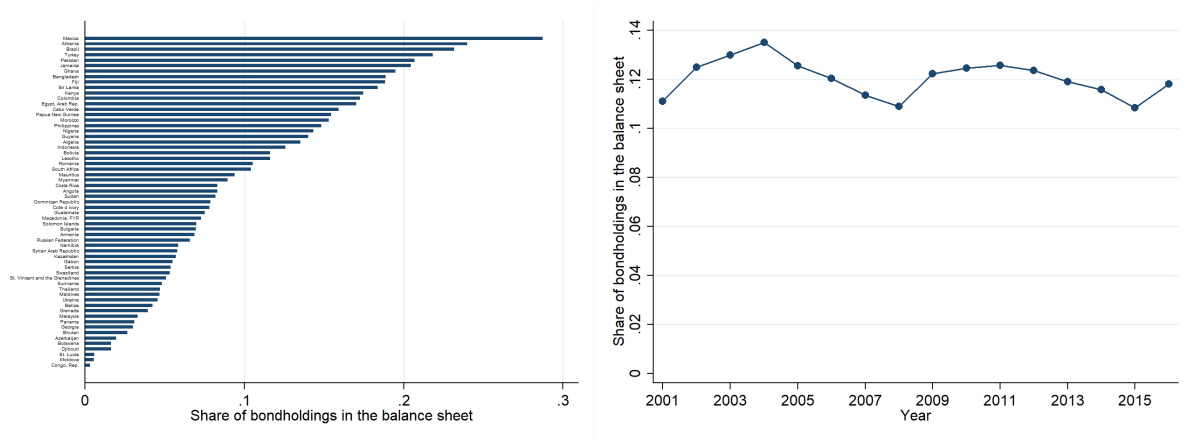
Figure B.1: Domestic debt



(a) Share of debt held by domestic agents from total debt. (b) Share of debt held by domestic banks from total debt held by domestic holder.

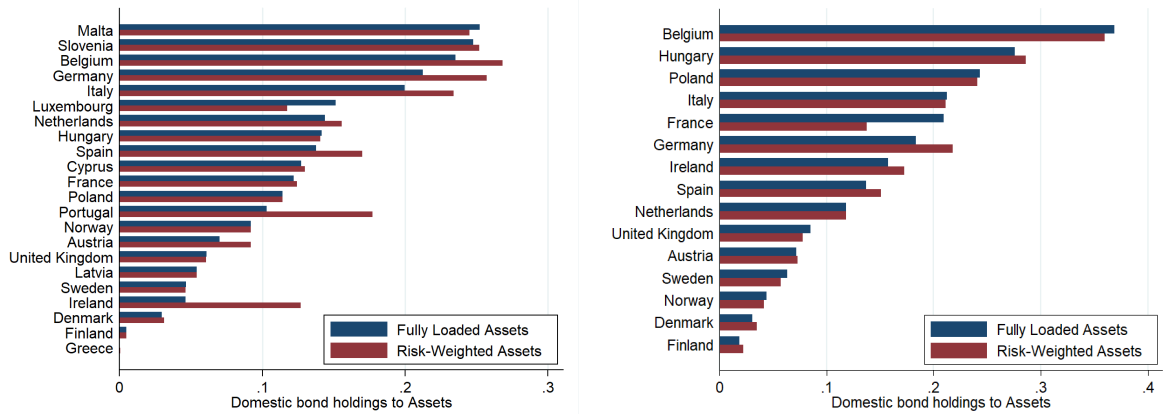
Source: Author's calculations. Panel (a) shows the average share of debt held by domestic agents. Panel (b) shows the average share of domestic debt held by banks. The average takes country-year observations for a set of countries from 2001 to 2016. The red line shows the average share across countries.

Figure B.2: Domestic bank’s bondholdings



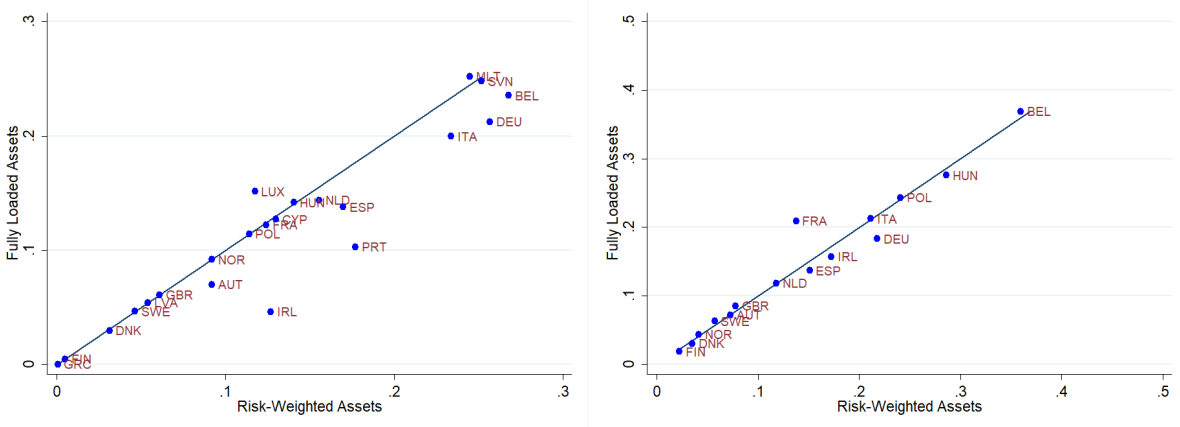
(a) Average bank’s bondholdings by country. (b) Average country-year bank’s bondholding. Source: International Financial Statistics and author’s calculations. The figure plots the banking system bondholdings over 2001–2016 for all country-years covered by both as weighted by GDP.

Figure B.3: Bank's sovereign exposure to assets



(a) Sovereign bond holdings to assets, 2014.

(b) Sovereign bond holdings to assets, 2016.

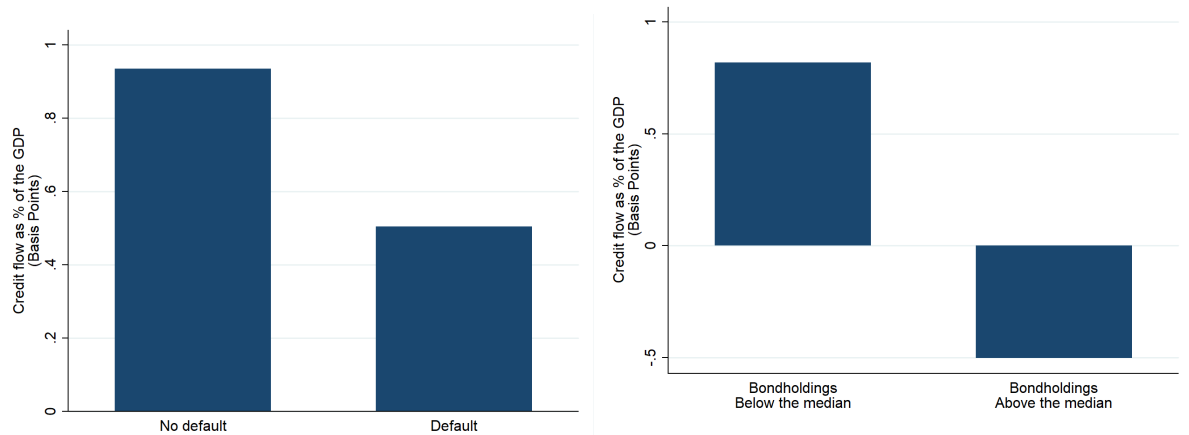


(c) Sovereign bond holdings to assets, 2014.

(d) Sovereign bond holdings to assets, 2016.

Source: European Banking Authority and author's calculations. Panel (a) and (b) plots the aggregate sovereign exposure to different measures of bank's balance sheet. Panel (c) and (d) reproduce an scatter plot comparing the balance sheet exposure using different definitions of the balance sheet. Notice that measures around the 45 show that the effect of balance sheet in sovereign exposure is not important. Fully loaded assets refers to assets without using any measure of risk on bank's balance sheet. Risk-weighted assets refers to assets without using regulatory risk weights on bank's balance sheet.

Figure B.4: Flow of credit



(a) Flow of credit conditional on the event.

(b) Flow of credit during a default conditional on the level of bond holdings.

Source: International Financial Statistics and author's calculations. Panel (a) shows the average change in credit flow during years where default or no default were observed. Panel (b) compares the credit flow for countries with bondholdings above and below the median. The average takes country-year observations for a set of countries from 1980 to 2005.

## B.2 Tables

Table B.1: Private credit flow in a sovereign default episode

	(1)	(2)
	Private Credit	Private Credit
Default <sub><i>t</i>-1</sub>	-0.00693*** (0.001)	-0.00822*** (0.002)
Default <sub><i>t</i>-1</sub> · Bondholdings <sub><i>t</i>-1</sub>		-0.310*** (0.052)
Banking Crisis <sub><i>t</i>-1</sub>	-0.00664 (0.575)	-0.00700 (0.589)
GDP Growth p.c. <sub><i>t</i>-1</sub>	0.00157*** (0.000)	0.000160 (0.775)
Unemployment <sub><i>t</i>-1</sub>	-0.00557*** (0.266)	0.00477 (0.588)
Inflation <sub><i>t</i>-1</sub>	0.000000637 (0.286)	0.0000729 (0.380)
Depreciation <sub><i>t</i>-1</sub>	0.0429** (0.029)	0.0896** (0.029)
Sudden Stop <sub><i>t</i>-1</sub>	0.00205 (0.689)	-0.0120 (0.149)
Openness <sub><i>t</i>-1</sub>	-0.0116* (0.098)	-0.0449 (0.241)
Bondholdings		0.0305 (0.301)
<i>N</i>	782	200
<i>R</i> <sup>2</sup>	0.148	0.110

The table reports the coefficients from OLS panel regressions of the different variables on the private credit flow to GDP. The analysis cover a set of countries advanced and emerging countries over the 1980 to 2005 period. The standard errors are clustered at the country level. The \*\*\*, \*\*, and \* denote significance at 0.01, 0.05, and 0.10 levels respectively.

Table B.2: Average share of the balance sheet held in bonds (2004-2017)

	(1)	(2)
	spreads	spreads
Bond holdings foreign	0.00745 (0.469)	
Bond holdings foreign nonbanks		0.0354 (0.191)
Bond holdings foreign banks		-0.0214 (0.108)
Bond holdings domestic	-0.0432*** (0.001)	
Bond holdings domestic nonbanks		-0.0214 (0.108)
Bond holdings domestic banks		-0.0828*** (0.007)
GDP Gap	-0.00368 (0.492)	-0.00293 (0.547)
VIX	0.101 (0.123)	0.106* (0.084)
Fed fund rate	-2.063*** (0.000)	-2.095*** (0.000)
<i>N</i>	688	688
<i>R</i> <sup>2</sup>	0.148	0.110

]The table reports the coefficients from OLS panel regressions of the amount of debt held by different types of investors, output, global risk aversion (VIX), and Fed fund rate on the change in the spreads. The analysis cover quarterly data for a set of emerging countries from 2004 to 2016 period. The standard errors are clustered at the country level. The \*\*\*, \*\*, and \* denote significance at 0.01, 0.05, and 0.10 levels respectively.

# Appendix C

## Appendix for chapter 4

### C.1 Global demand for exports from home

In this section we develop the demand for exports from the rest of the world and price indexes in the rest of the world described in the model. The problem in the rest of the world is to solve

$$\max_{y_i^*, y_i} P^* y^* - \int_0^1 p_i^* y_i^* di - \int_0^N p_i y_i di$$

where the final good production function is defined as

$$y^* = \left\{ \left[ \int_0^1 (y_i^*)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1} \frac{\gamma-1}{\gamma}} + \left[ \int_0^N (y_i)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1} \frac{\gamma-1}{\gamma}} \right\}^{\frac{\gamma}{\gamma-1}}.$$

**Price indexes for intermediate goods.** From the first order conditions, we can obtain:

$$\begin{aligned} P^* y^*^{\frac{\gamma}{\gamma-1}-1} \left( \int_0^1 (y_i^*)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1} \frac{\gamma-1}{\gamma}-1} (y_i^*)^{-\frac{1}{\theta}} - p_i^* &= 0 \\ P^* y^*^{\frac{\gamma}{\gamma-1}-1} \left( \int_0^N (y_i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1} \frac{\gamma-1}{\gamma}-1} (y_i^*)^{-\frac{1}{\theta}} - p_i &= 0 \end{aligned}$$

from these first order condition we can find an expression for the term containing the integral across intermediate goods:

$$\begin{aligned} P^* y^*^{\frac{1}{\gamma}} \left( \int_0^1 (y_i^*)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\gamma(1-\theta)}} &= \left( \int_0^1 p_i^{*1-\theta} di \right)^{\frac{1}{1-\theta}} \\ P^* y^*^{\frac{1}{\gamma}} \left( \int_0^N (y_i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\gamma(1-\theta)}} &= \left( \int_0^N p_i^{1-\theta} di \right)^{\frac{1}{1-\theta}}. \end{aligned}$$

In this case, we define the price index for intermediate goods produced in the rest of the world as  $p^* \equiv \left( \int_0^1 p_i^{*1-\theta} di \right)^{\frac{1}{1-\theta}}$  and the price index for goods imported from the home country  $p \equiv$



$$\left( \int_0^N p_i^{1-\theta} di \right)^{\frac{1}{1-\theta}}.$$

**Demand for intermediate goods.** Replacing these expression in the first order conditions, we can set the expressions for the individual demand for intermediate goods:

$$\begin{aligned} y_i^* &= (p_i^* p^*)^{-\theta} (p^* P^*)^{-\gamma} y^* \\ y_i &= (p_i p)^{-\theta} (p P^*)^{-\gamma} y^*. \end{aligned}$$

**Price indexes for final goods.** The price index for the final goods  $P^*$  can be derived from the zero profit condition for benefits and using the demand function for intermediate goods.

$$\begin{aligned} P^* &= \int_0^1 p_i^* y_i^* di + \int_0^N p_i y_i di \\ &= \int_0^1 p_i^* \left( \frac{p_i^*}{p^*} \right)^{-\theta} \left( \frac{p^*}{P^*} \right)^{-\gamma} di + \int_0^N p_i \left( \frac{p_i}{p} \right)^{-\theta} \left( \frac{p}{P^*} \right)^{-\gamma} di \\ &= \left( \frac{p^*}{P^*} \right)^{-\gamma} \int_0^1 \frac{p_i^{*1-\theta}}{p^{*-\theta}} di + \left( \frac{p}{P^*} \right)^{-\gamma} \int_0^N \frac{p_i^{1-\theta}}{p^{-\theta}} di \\ P^{*1-\gamma} &= p^{*1-\gamma} + p^{1-\gamma} \\ P^* &= \left( p^{*1-\gamma} + p^{1-\gamma} \right)^{\frac{1}{1-\gamma}} \end{aligned}$$

**Demand for exports from home.** In this section, we assume that exporting firms are homogeneous and set the same price in international markets, that is  $p_i = p_x$ . Therefore the price index for exports to the rest of the world is

$$\begin{aligned} P &= \left( \int_0^N p_i^{1-\theta} di \right)^{\frac{1}{1-\theta}} \\ &= \left( \int_0^N p_x^{1-\theta} di \right)^{\frac{1}{1-\theta}} \\ &= N^{\frac{1}{1-\theta}} p_x. \end{aligned}$$

Therefore, the demand for intermediate goods can be characterized as

$$\begin{aligned}
 X &= \int_0^N y_i di \\
 &= \int_0^N \left( \frac{p_i}{p} \right)^{-\theta} \left( \frac{p}{p^*} \right)^{-\gamma} y^* di \\
 &= N^{\frac{\theta}{1-\theta}} \left( \frac{N^{\frac{1}{1-\theta}} p_x}{p^*} \right)^{-\gamma} y^* \\
 &= N^{\frac{\theta-\gamma}{1-\theta}} \left( \frac{p_x}{p^*} \right)^{-\gamma} y^* \\
 &= N^{\frac{\theta-\gamma}{1-\theta}} (\bar{p}_x)^{-\gamma} y^*
 \end{aligned}$$

where  $\bar{p}_x$  represents the terms of trade between the home country and the rest of the world.

## C.2 Steady state solution

- 1.- We set the share of the exporting sector as  $\bar{N}_{ss}$  and the probability for the cost of continuing exporters at  $F_{1,ss}(\kappa^*)$ . From these targets we can find

$$F_{0,ss}(\kappa^{ss}) = \frac{1 - F_{1,ss}}{1 - N_{ss}} N$$

where  $F_{0,ss}$  is the probability for the sunk cost of new exporters in steady state. Using the value for  $F_{0,ss}$ , we let the the cost of the marginal exporter to be according this probability

$$\kappa^{ss} = \nu f_0 (F_{0,ss})^{\nu-1}.$$

therefore,  $\kappa^{ss}$  is a parameter that must be adjusted to attain the target for  $\bar{N}_{ss}$ . In turn, given a fixed  $\kappa$  and the functional form of the cumulative probabilities, we have to fix  $\left( \frac{f_0}{f_1} \right)^{\frac{1}{\nu-1}}$  to maintain the target  $F_{1,ss}$  as follows

$$\begin{aligned}
 F_{1,ss} &= \left( \frac{\kappa^*}{f_1 \nu} \right)^{\frac{1}{\nu-1}} \\
 &= \left( \frac{F_{0,ss}^{\nu-1} f_0 \nu}{f_1 \nu} \right)^{\frac{1}{\nu-1}} \\
 \Rightarrow \frac{F_{1,ss}}{F_{0,ss}} &= \left( \frac{f_0}{f_1} \right)^{\frac{1}{\nu-1}}
 \end{aligned}$$

- 2.- We target the mark-up of the exporting firms  $\frac{\pi_{ss}}{w_{ss} l_{x,ss}}$  and find  $f_0$  that allows the equilibrium in steady state to hold. First, notice that we can find an expression for  $\frac{\pi_{ss}}{w_{ss} l_{x,ss}}$  as

function of  $\kappa_{ss}$ . From the definition of the cost for the marginal exporter we can obtain the relationship

$$\frac{\pi}{w} = \left[ \beta^{-1} - \left( \frac{\nu-1}{\nu} \right) [F_{1,ss} - F_{0,ss}] \right] \kappa_{ss}$$

and from the labor market clearing condition we can find an expression for labor supply in the exporting sector

$$l_{x,ss} = (\bar{L} - \frac{N}{\nu} \kappa) \frac{LR}{N}$$

where  $LR \equiv \frac{Nl_{x,ss}}{l_d + Nl_{x,ss}}$ . By combining both expressions, we can set a function where the marginal cost depends of  $\kappa_{ss}$ . Recall from previous step that  $\kappa$  depends on  $f_0$ , therefore we set this parameter to solve

$$\min_{f_0} \left\| \frac{\pi_{ss}}{w_{ss}l_{ss}}(f_0) - \frac{\pi_{ss}}{w_{ss}l_{x,ss}} \right\|.$$

- 3.- We find  $\alpha$  such that we can target  $\frac{\bar{p}_{x,ss}}{w_{ss}}$ . First, notice exporters' profits and the targeted  $\frac{\pi_{ss}}{w_{ss}l_{x,ss}}$

$$\begin{aligned} \pi_{ss} &= \left[ \frac{\theta-1}{\theta} \frac{1}{\alpha} - 1 \right] w_{ss}l_{ss} \\ \Rightarrow \frac{\theta-1}{\theta} \frac{1}{\alpha} &\equiv \frac{\pi_{ss}}{w_{ss}l_{x,ss}} + 1 \end{aligned}$$

from the optimal price for an exporting firm we can find

$$\begin{aligned} p_{x,ss} &= \left[ \frac{\theta-1}{\theta} \frac{1}{\alpha} \right] w_{ss}l_{ss}^{1-\frac{1}{\alpha}} \\ \Rightarrow \frac{\bar{p}_{x,ss}}{w_{ss}} &= \left[ \frac{\pi_{ss}}{w_{ss}l_{x,ss}} + 1 \right] l_x^{1-\frac{1}{\alpha}} \\ \Rightarrow \alpha &= \frac{1}{1 - \frac{\ln\left(\frac{\bar{p}_{x,ss}}{w_{ss}}\right) - \ln\left[\frac{\pi_{ss}}{w_{ss}l_{x,ss}} + 1\right]}{\ln l_{x,ss}}} \end{aligned}$$

- 4.- In order to match the mark-up from the price equation, we set  $\theta$  such that

$$\theta = \frac{1}{1 - \alpha \left[ \frac{\pi_{ss}}{w_{ss}l_{x,ss}} + 1 \right]}$$

- 5.- By using the targeted ratio  $\frac{B_{ss}}{M_{ss}}$  we solve for domestic goods  $D_{ss}$ , imports  $M_{ss}$ , exports  $X_{ss}$ , and debt  $B_{ss}$ . We set  $p_{ss}^m = 1$  and the solution of the equilibrium is described as

follows

$$\begin{aligned}
l_{dss} &= \left( \frac{1}{\omega} N_{ss} l_{ss} - N_{ss} l_{ss}^x \right) \\
D_{ss} &= l_{ss}^d \\
M_{ss} &= \left( \left( \omega^{frac{1}{\gamma}} \right) \left( D_{ss}^{1/\gamma} \right) \frac{1}{\frac{\frac{p_{ss}^x}{p_{ss}^d} N_{ss} y_{ss}}{(1-(1-R_{ss})\frac{b}{M})}} \right)^{\frac{\gamma}{(1-\gamma)}} \\
p_x X_{ss} &= \left( 1 - (1 - R_{ss}) \frac{b}{M} \right) M_{ss} \\
B_{ss} &= \frac{b_{ss}}{M_{ss}} M_{ss} \\
p_d^{ss} &= \left( \omega^{-\frac{1}{\gamma}} \right) \left( \frac{M_{ss}}{D_{ss}} \right)^{\frac{1}{\gamma}} \\
p_{ss}^x &= p_{ss}^x p_{ss}^d \\
w_{ss} &= p_s^d \\
P_{ss} &= (p_{ss}^d)^{1-\gamma} + \omega)^{\frac{1}{(1-\gamma)}} \\
\pi_{ss}^n &= \frac{\pi}{w} w_{ss} \\
\Pi_{ss} &= N_{ss} \pi_{ss}^n - w_{ss} N_{ss} \\
C_{ss} &= \frac{w_{ss}}{P_{ss}} L_{ss} + \frac{\Pi_{ss}}{P_{ss}} - \frac{B_{ss}}{P_{ss}} + \frac{B_{ss}}{P_{ss}} \frac{1}{R_{ss}} \\
\lambda &= \frac{1}{\eta} \frac{w_{ss}}{P_{ss}} L_{ss}^{1-\eta} \\
y_{ss}^f &= \frac{y_{ss}}{\frac{\nu-1}{\nu} w_{ss} \kappa_{ss} (F_{ss}^{nx} - F_{ss}^{ox})} \\
Y_{ss} &= D_{ss} + \frac{\theta}{\theta-1} \frac{p_x}{p_d} N_{ss} y_{ss} \\
NX_{ss} &= \frac{p_{ss}^x X_{ss} - M_{ss}}{p_{ss}^x X_{ss} + M_{ss}}
\end{aligned}$$

# Curriculum Vitae

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