Sovereign Debt, Domestic Banks and the Provision of Public Liquidity*

Diego J. Perez **Paolo Varraso**

New York University and NBER Tor Vergata University

September 16, 2025

Abstract

This paper develops a model to study how a default can affect the domestic economy and the government's ability to provide liquidity. Banks that do not have good investment opportunities invest in public debt. After a default the government's ability to credibly issue debt is undermined. A scarcer supply of public debt makes banks substitute away from government securities to investments in their less productive projects. A quantitative analysis of the model for Argentina can generate a deep and persistent fall in output post-default, which induces repayment incentives to sustain significant levels of external public debt. We provide empirical support for the model's mechanism and use the model to analyze different policies that regulate banks' holdings of public debt.

Keywords: Sovereign default, public debt, banks, liquidity.

---

*Diego Perez (diego.perez@nyu.edu): New York University, Department of Economics and NBER. Paolo Varraso (paolo.varraso@uniroma2.it): Tor Vergata University, Department of Economics and Finance. We thank Manuel Amador, Luigi Bocola, Sebastian Di Tella, Alessandro Dovis, Andres Drenik, Simon Gilchrist, Mark Gertler, Pablo Kurlat, Monika Piazzesi, Pablo Ottonello, Guido Sandleris, Martin Schneider, Alonso Villacorta, Mark Wright, and seminar participants at various institutions for useful comments and suggestions. We acknowledge financial support from the Kapnick Foundation through a grant to Stanford Institute for Economic Policy Research.

1. Introduction

Sovereign governments borrow from international investors and domestic residents. Most of the domestic investors are financial institutions that actively manage their public bond holdings based on their idiosyncratic needs. In this context, it is well understood that the government can provide liquidity to the domestic financial system by issuing public debt, and affect the investments of banks and macroeconomic outcomes. What is less understood is how is the ability of the government to provide liquidity affected by a sovereign default.

This paper proposes a quantitative theory to explore how a default can affect the domestic economy and the government's ability to provide liquidity. In the model, banks that do not have good investment opportunities invest in public debt to transfer their wealth across time. A default undermines the government's ability to provide liquidity domestically by issuing public debt. A scarcer domestic supply of public debt makes banks substitute away from the use of government securities to investments in their less productive projects. A quantitative analysis of the model for Argentina shows that this mechanism can generate a deep and persistent fall in output comparable in magnitude to the negative balance-sheet effect of the default. Our analysis also sheds light on the effects of regulating banks' holdings of public debt.

The theoretical framework features an economy with heterogeneous banks and a government that can issue external and domestic public debt and choose to default on it ex-post. Banks can invest in projects with idiosyncratic productivity, lend to the government or lend to other banks. They finance these investments by accumulating net worth and borrowing from other banks subject to financial frictions. In this economy, the government can provide liquidity to the domestic financial system by issuing public debt, and induce a better allocation of resources in the economy. Consider a situation in which various banks invest in projects with differing productivities which require labor as input. If the government increases the supply of public debt, the additional units of debt will be bought by those banks with low-productivity investment opportunities, which have low expected returns. By purchasing public debt these banks reduce their demand for labor, reduce wages, and allow banks with high-productivity investment projects, which are borrowing-constrained, to hire more labor.

The government's ability to provide liquidity is undermined after a default and this generates an output cost through a liquidity channel. Following a default, the government is able to credibly issue less debt without increasing subsequent default risk. This induces a shortage of public debt that is detrimental for economic activity. Consider a bank with low-productivity investment projects that finds it profitable to invest in public debt. After a default the aggregate supply of public debt is endogenously low and so is its return; therefore, this bank will now prefer to finance its low-productivity projects. These projects demand labor, which is now allocated to projects that are, on average, of lower productivity. This in turn, translates into a lower level of aggregate output. A default also negatively affects output through a balance-sheet channel. The banks' net worth is hit by a default, which reduces their ability to raise funds, prevents the flow of resources to productive investments and further reduces the level of output.

The presence of these effects gives rise to an internal cost of default that the government takes into account when making repayment decisions. The optimal repayment decision entails a trade-off. On the one hand, a default precipitates an endogenous output cost, and a temporary exclusion from external financial markets. On the other hand, by defaulting, the government saves resources from being paid back to foreign investors. The default also induces internal redistribution from bond holders (bankers) to taxpayers (workers). The attractiveness of default thus depends on the residence composition of the government's creditors.

We provide empirical evidence from Argentina that is in line with the model's predictions. First, we collect panel data on individual banks' balance sheets and show that there is selection in the banks that purchase government bonds. In particular, we show that those banks that are more exposed to public debt are banks that, on average, have lower returns on their investment. The selection in the banks that acquire public debt is at the core of the model's mechanism, as it is necessary for the government to be able to provide liquidity. Second, we show that the dynamics of banking-related variables following the sovereign default of December 2001 were consistent with the main mechanism of the model. In particular, we show that the default was followed by a drop in interbank lending, a period of low real interest rates, and lower and more dispersed returns of bank investments.

The model is calibrated to the Argentinean economy using aggregate macroeconomic and micro banking data for Argentina for the 1994-2012 period. The model reproduces several salient features of emerging markets' business cycles, such as the high variability of consumption and the counter-cyclicality of the trade balance and interest rate spreads, the observed composition of public debt, and key moments of banking-related variables.

We use the calibrated model to quantify the output costs of a default. We estimate a deep and persistent output cost of default, which is approximately half of the observed output drop in Argentina following the default in December 2001. We then disentangle the output cost and find that both the liquidity and balance-sheet effects are important drivers. The liquidity effect is as relevant as the well-understood balance-sheet effect, which the literature has estimated to be quantitatively important (Gennaioli, Martín and Rossi, 2014; Bocola, 2016; Sosa Padilla, 2018). The output costs of default provides the government with incentives to repay debt, which allows for credibly issuing significant levels of external debt.

We then use our framework to identify the determinants of the output costs of default. Our analysis highlights two key dimensions. First, the persistence of idiosyncratic investment opportunities in banks. The output cost of default is attenuated when these are persistent. This is because a default mostly affects banks that were exposed to public debt, which are low-productivity banks, and their effect on output is lower if these banks are expected to continue to have a low productivity. Second, the extent of domestic financial repression. The output costs of default are stronger when banks are repressed on the set of assets they can invest in. When banks have more asset options the role of liquidity provision of public debt is undermined and so is the liquidity channel of a default.

Finally, we use the model to study the effects of domestic policies that regulate banks' holdings of public debt. We analyze two commonly discussed policies: a subsidy on banks' purchases of public debt, and a minimum requirement of public debt holdings in banks. We show that these policies have different effects on economic activity. The subsidy expands economic activity through a selection effect. It induces banks with low productivities to hold public debt instead of investing in their technologies, and thus crowds out low-productivity banks from production, freeing up labor for high-productivity banks. On the other hand, a minimum requirement contracts economic activity through a negative effect on the allocation of labor. It forces high-productivity banks to use resources to buy public debt that would otherwise be invested in high-productivity technologies.

One novel feature of the model is the role of heterogeneity in banks. This feature gives rise to a role of the government as a provider of liquidity through debt issuance, and helps understand how the output cost of default can be a result of misallocation of resources (or a drop in the aggregate-TFP component of output). Additionally, the presence of heterogeneity implies that different policies that target banks' holdings of public debt may have significantly different effects.

Related Literature. This paper builds upon the literature on sovereign default and is closely related to a rising theoretical and quantitative literature that studies the interaction between defaults, banks and credit. It also relates to the literature that studies fiscal policy in economies with heterogeneous agents.

Following the original framework of sovereign defaultable debt developed in Eaton and Gersovitz (1981), a body of literature has studied the quantitative dynamics of sovereign debt and sovereign defaults. Arellano (2008) and Aguiar and Gopinath (2006) analyzed quantitative models of sovereign debt and business cycles in emerging economies that can account for the tight empirical link between spreads and economic activity, documented in Uribe and Yue (2006), among others. Several studies have extended the defaultable debt framework to study different aspects related to sovereign debt.[1] One of the findings of this literature is that reputational costs in the form of exclusion from financial markets cannot

[1] Some recent applications and related work include Hatchondo and Martinez (2009), Benjamin and Wright (2009), Yue (2010), Broner, Martín and Ventura (2010), D'Erasmo (2011), Chatterjee and Eyigungor (2012), Arellano and Ramanarayanan (2012), Du and Schreger (2018), D'Erasmo and Mendoza (2016), Bocola and Dovis (2016), Hatchondo, Martinez and Sosa-Padilla (2016), D'Erasmo and Mendoza (2017), Na, Schmitt-Grohé, Uribe and Yue (2018), Ottonello and Perez (2018) and Bianchi, Hatchondo and Martinez (2018). Passadore and Xu (2018) study a model with default and illiquidity risk. In their case, illiquidity refers to search frictions in secondary markets, a different concept than the one stressed in this paper.

quantitatively account for observed levels of external borrowing and that a source of domestic cost of default is necessary to reconcile observed levels of external debt with low frequencies of default.[2] Mendoza and Yue (2012) first developed a model that endogenizes the output cost of default. In their model a default restricts external credit for firms and induces them to substitute imported inputs for domestic ones that are imperfect substitutes. The analysis here is complementary to theirs as it sheds light into the mechanisms that can trigger a decline in credit following a sovereign default.

The paper also relates to the literature that studies the role of domestic public debt. One strand of this literature argues that sovereign debt can be used to provide public liquidity. Woodford (1990) and Holmström and Tirole (1998) show that there is room for an active management of liquidity through the issuance of government securities in heterogeneous-agents economies with financial frictions in the private sector. A strand of the literature has studied different aspects related to the provision of public liquidity.[3] Another strand of the literature analyzes the government's default incentives when debt can be held both domestically and abroad (for example, Kremer and Mehta, 2000; Broner, Martin and Ventura, 2008; Broner *et al.*, 2010; Broner and Ventura, 2011). Brutti (2011) develops a theory that links a sovereign default with a private liquidity crisis. This paper contributes to this literature by quantitatively analyzing how the government's ability to provide liquidity can be endogenously undermined after a default. The role of liquidity emerges because the model features heterogeneous banks. In this sense, the emphasis in the link between sovereign risk and heterogeneity echoes the work of Arellano, Bai and Bocola (2017), who study the feedback between sovereign risk and economic activity and argue that heterogeneity in firms plays a key role in the transmission mechanism.

This work is most closely related to the literature that studies the interaction between default, banks and domestic credit. A significant body of empirical research has documented that sovereign and banking crises tend to occur jointly (for example, Borensztein and Panizza,

[2] Several theoretical papers analyze the role of reputational costs in generating commitment to repay (see, for example, Bulow and Rogoff (1989), Chari and Kehoe (1993) and Chari, Dovis and Kehoe (2018)).

[3] Kiyotaki and Moore (2005) discuss the role of public liquidity and studies its effect on asset prices. Aiyagari and McGrattan (1998) study how public debt can alleviate financial frictions and crowd-out capital. Angeletos, Collard, Dellas and Diba (2013) analyze the optimal fiscal policy in these types of economies.

2009; Reinhart and Rogoff, 2011; Kalemli-Ozcan, Reinhart and Rogoff, 2016; Gennaioli, Martin and Rossi, 2018).[4] Motivated by this evidence, Gennaioli *et al.* (2014) develop a theory in which a sovereign default can weaken the balance sheet of banks, causing a decrease in lending, a banking crisis, and a decline in economic activity. Other papers that explore the balance-sheet channel and its effect economic activity, employment, and corporate and sovereign risk include Basu (2009), Mengus (2018), Moretti (2021), Mallucci (2022), and Balke (2023). Another set of papers provide empirical support for the balance-sheet channel of sovereign default (for example, Gennaioli *et al.*, 2018; Buera and Karmakar, 2021; Baskaya, Hardy, Kalemli-Ozcan and Yue, 2024).

Within this literature, two closely related papers are Bocola (2016) and Sosa Padilla (2018), who develop quantitative macro models to analyze the effects of sovereign risk and default on banks and the economy. Bocola (2016) shows that an increase in sovereign risk, even in the absence of default, can trigger a contraction in credit and a recession. He estimates the strength of this mechanism in the context of the European debt crisis. Sosa Padilla (2018) analyzes how the default-induced drop in output due to a negative effect on banks' balance sheets, can affect the incentives of the government to repay. In addition to the well-understood negative balance-sheet effect of a default on banks, this paper analyzes a liquidity channel through which a default affects the domestic economy. The contribution of this paper is to perform a quantitative analysis of how the government's ability to provide liquidity is undermined after a default and how this can shape the government's incentives to repay.

Finally, this paper is also related to the work of Chari *et al.* (2018) that study the optimal degree of financial repression on banks when the government lacks commitment to repay their debt. Both in their paper and in this paper, the desirability of enhancing the banks' exposure to sovereign debt arises because this enhances the credibility of the government to repay debt. Our paper complements the findings of their paper by showcasing the differential effects of imposing a minimum requirement of public debt and a subsidy on banks' purchases of public

[4] A related empirical literature studies the costs of default (see the survey by Panizza, Sturzenegger and Zettelmeyer, 2009, and references therein). Hébert and Schreger (2017) empirically identify a negative causal effect of sovereign default on equity returns of Argentine firms, particularly so in financial firms.

debt that arise because of banks' selection into buying public debt.

Layout. The remaining of the paper is organized as follows. Section 2 presents the model setup and characterizes the equilibrium. Section 3 presents supporting empirical evidence using banks micro data. Section 4 presents the quantitative analysis of the model, and estimates the ouput cost of default and its effect on government incentives. Section 5 studies domestic policies that regulate banks holdings of public debt. Finally, section 6 concludes.

2. A Model of Sovereign Debt and Heterogeneous Banks

In this section we formulate and characterize a dynamic model of a small open economy to study the interaction between heterogeneous banks and a sovereign government that lacks commitment to repay debt.

2.1. Environment

There are four types of agents in the economy: workers, bankers, the government and foreign investors. We describe them below.

Workers. There is a continuum of identical workers of measure unity. Workers are risk averse and their preferences are defined over an infinite stream of non-storable consumption

$$U^w = \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t u\left(C_t^w\right) \right], \tag{1}$$

where $\beta \in (0,1)$ is the discount factor, C_t^w is consumption of the representative worker in period t and $u(\cdot)$ is increasing and concave. Workers supply a fixed amount of labor in a competitive labor market and are hand-to-mouth consumers that do not make any savings decision. Let w_t be the wage paid to each worker in period t and τ_t the lump sum taxes paid to the government, the budget constraint of an individual worker is given by

$$C_t^w = w_t - \tau_t, \tag{2}$$

where the individual labor supply is normalized to one.

Bankers. There is a representative household with a continuum of heterogeneous bankers of measure unity. Each banker operates a bank and transfers the proceeds from their banking activity to the household. The bankers' household is risk averse and its preferences are given by

$$U^b = \mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t u(C_t^b)\right], \tag{3}$$

where C_t^b is consumption of bankers in period t. The income of the bankers' household includes dividend payments from all individual banker. Thus, the budget constraint of the bankers' household is given by

$$C_t^b = \int_{i\in[0,1]} div_{i,t}\mathrm{d}i, \tag{4}$$

where $div_{i,t}$ is the dividend payments from banker i at period t. Every banker has access to a constant-returns-to-scale production technology. The technology is stochastic and uses labor $l_{i,t+1}$ chosen in period t to deliver

$$A_{t+1}z_{i,t}l_{i,t+1}$$

units of consumption in period $t+1$, where A_{t+1} is an aggregate productivity shock and $z_{i,t}$ is an idiosyncratic productivity shock. The aggregate shock is subject to trend shocks

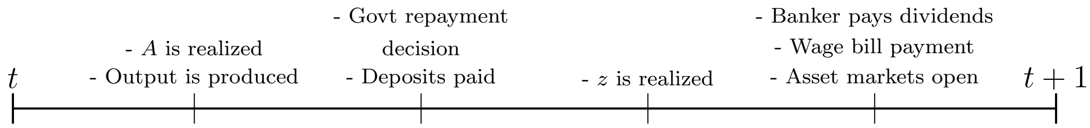
$$A_t = \exp(g_t)A_{t-1}$$

where g_t follows a Markov process with transition probability $f(g_{t+1}, g_t)$. The idiosyncratic shock $z_{i,t}$ is known to each banker at period t, and is iid with cumulative distribution function $G(z)$. Since idiosyncratic shocks are independent across bankers and there is a continuum of bankers, $G(z)$ is also the realized fraction of bankers with idiosyncratic shock below z.

In order to hire labor, banks need to pay the wage bill $w_t l_{i,t+1}$ in period t before production takes place.[5] In addition to the production technology, bankers have access to two asset

[5] This timing assumption gives rise to heterogeneous portfolio decisions and a need for banks to obtain

Figure 1: Timing of events for a banker



markets: the public debt market and the interbank market. Public debt is a risky one-period security that pays one unit of consumption in the following period if the government repays and zero if the government defaults. Interbank deposits are riskless one-period securities that pay one unit of consumption in the following period. In summary, banks can lend to or borrow from other banks, invest in their production technology by hiring labor and buy public debt. The timeline of events for an individual banker within a period is depicted in Figure 1.

Let $\{l_{i,t}, b^d_{i,t}, d_{i,t}\}$ be the claims on labor, the stock of public debt and the stock of interbank deposits with which banker i comes into period t. Then the amount of consumption goods a banker obtains in a period (net worth) is given by the net repayments on these claims

$$n_{i,t} = A_t z_{i,t-1} l_{i,t} + \iota_t b^d_{i,t} + d_{i,t} \tag{5}$$

where $\iota_t \in \{0, 1\}$ indicates whether the government defaults or repays its debt in period t, respectively. Every period bankers transfer a fraction $1 - \sigma$ of their net worth to the household as dividend payments, $div_{i,t} = (1 - \sigma)n_{i,t}$. The net worth that is left over from consumption, plus the goods a banker borrows from other banks (if any), can be used to invest in the productive technology, buy public debt or lend to other banks. Let q^b_t, q^d_t be the price of public debt and interbank deposits, respectively, then the banker's balance sheet is given by

$$\sigma n_{i,t} = w_t l_{i,t+1} + q^b_t b^d_{i,t+1} + q^d_t d_{i,t+1}. \tag{6}$$

Note that $d_{i,t+1} \leq 0$ indicates borrowing from other banks.

The interbank credit market is subject to a financial friction. We assume that the

credit to produce, as banks need to finance their wage payments with previously accumulated net worth or loans.

amount of borrowing that any banker can raise through interbank loans is capped by a multiple of its own post-consumption net worth

$$q_t^d d_{i,t+1} \geq -\kappa\sigma n_{i,t}. \tag{7}$$

This type of financial friction is commonly used in quantitative models of credit markets. It can be micro-founded by an agency problem in which the banker has the ability to run away with a fraction of his assets and transfer them to their own household.[6] Finally, we also assume that bankers cannot take short positions in public debt

$$b_{i,t+1}^d \geq 0. \tag{8}$$

Each banker's objective is to maximize the value of dividend payments to its household

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \Lambda_{0,t}(1-\sigma) n_{i,t} \right], \tag{9}$$

where $\Lambda_{t,s} \equiv \beta^{s-t} u'(C_s^b)/u'(C_t^b)$ is the stochastic discount factor of the bankers' household. The banker's problem is then to choose a sequence $\{l_{i,t}, b_{i,t}^d, d_{i,t}\}_{t=1}^{\infty}$ that maximizes (9), subject to (5)-(8), given an initial level of net worth n_0 and idiosyncratic productivity z_0.

Government. The sovereign government issues one-period zero-coupon bonds that pay one unit of consumption next period when the government repays. These securities can be purchased by domestic banks and/or foreign investors. Financial markets are segmented: the government is the only agent that has access to foreign borrowing from external investors. Foreign investors are risk-neutral and can borrow and lend at a constant risk-free interest rate R.

[6] For a micro-foundation of this type of financial frictions see, for example, Bernanke and Gertler (1989), Holmstrom and Tirole (1997), Kiyotaki and Moore (1997), Bernanke, Gertler and Gilchrist (1999), Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). Chari *et al.* (2018) provide a microfoundation for the particular constraint used in (7). To ensure that bankers will always have enough consumption goods to pay back its deposits it is necessary to assume that the minimum realization of the aggregate shock A is bounded above.

The government lacks commitment to repay its debt and can choose to default on its entire stock of public debt. Let B_t the stock of total public debt due at period t. The government budget constraint is given by

$$q_t^b B_{t+1} + \tau_t = \iota_t B_t. \tag{10}$$

The government is benevolent and its objective is to maximize a weighted average of the lifetime utility of workers and bankers,

$$\alpha U^w + (1-\alpha)U^b,$$

where $\alpha \in (0,1)$ is the weight assigned to workers. To do so it chooses the total stock of public debt, lump sum taxes to households and repayment decisions.

We analyze an equilibrium with trigger strategies, in which a relevant state variable of the economy is an indicator of whether the economy is open or closed. When the economy is open, public debt can be purchased by domestic bankers and/or foreign investors. When the economy is closed, public debt can only be purchased by domestic bankers. The economy alternates endogenously between these two states depending on the repayment decisions of the government. If the government chooses to default when the economy is open, the economy switches to being closed and the government loses access to the market for external credit for a stochastic number of periods. While the economy is closed the government can still choose debt issuance and repayment decisions optimally. A default in the closed economy is not punished further, and the government can still issue debt in the same period it defaults. The economy switches back to being open with probability ϕ and, when it does so, the government gains access to external financial markets and starts with zero external public debt.

2.2. Discussion of Assumptions

This section discusses the assumptions that underlie the setup. In this model bankers represent a consolidation of the financial and productive sector of the economy and we assume that they have access to a production technology that is subject to aggregate and idiosyncratic risk. Our baseline specification assumes that idiosyncratic shocks are independent over time, which allows for analytical expressions for the allocations of the competitive equilibrium, given government policies, and avoids carrying the distribution of banks' portfolios as a state variable, thereby making the solution to the model more computationally feasible. In Section 4, we analyze a model extension with persistent idiosyncratic shocks, and underscore the relevance of the shocks' persistence for our main quantitative results. In that section we also analyze a model extension with stationary aggregate productivity shocks, instead of trend shocks as in the baseline model.

We assume that international financial markets are segmented (see Maggiori, 2022, for a survey of research on imperfections in international capital markets). Domestic banks can invest in their own investment projects, and buy public debt or interbank deposits, but cannot invest in foreign assets. The three modeled investment alternatives cover most of the banks' balance sheets in the Argentinean data.[7] In Section 4, we analyze a model extension in which banks can also invest in a risk-less storage technology with decreasing returns, and find that the liquidity cost of a sovereign default is lower than in the baseline model but still quantitatively important.

The assumption that interbank deposits are risk-less is motivated by the fact that we did not observe systemic defaults in the interbank market following the sovereign default. By focusing on interbank loans as the source of financing for banks, the model abstracts from the presence of household deposits. Introducing deposits is computationally challenging because it would require increasing the state space, quickly running into the course of dimensionality. An interesting extension worth analyzing is the joint modeling of banks' and government's default decisions. One example of such avenue of work is Acharya, Drechsler and Schnabl (2014), that develop a model with bank deposits to study the interaction between bank-runs and sovereign debt crises.

[7] In the data, the sum of public debt holdings, interbank loans and total loans account for roughly 70% of total banks' assets. Additionally, banks do not accumulate sizable holdings of foreign assets. These type of assets account for only 4% of total assets of banks. The presence of currency risk, transaction costs, and bank regulation have been proposed as potential explanations of this pattern (see, for example, Coval and Moskowitz (1999)).

Finally, we assume that the government is not allowed to default selectively on only one type of debt. This assumption is important since, as will become clear later, the government may have ex-post incentives to default on its external debt and repay its domestic debt. In practice sovereign governments often contain cross-default clauses (see, for example, IMF, 2002; Hatchondo *et al.*, 2016). These clauses state that a default in any government obligation constitutes a default in the contract containing that clause. For examples of theories in which external debt can be sustained even if governments are allowed to default selectively, see Broner and Ventura (2011) and Chari *et al.* (2018). For a similar reason, we also assume that bankers do not receive fiscal transfers or pay taxes. If the government could make transfers to banks, it would be able to replicate a selective default on external debt by defaulting on the total public debt and bailing out banks. This assumption is also in line with the fact that tax payments by the banking industry account for a small fraction of total tax collection.

2.3. Equilibrium Characterization

In this section we define and characterize the competitive equilibrium for a government policy. We analyze optimal government policies in the next section.

We focus in equilibria in which bankers follow cutoff rules to determine their portfolio choices and later argue that the unique solution to the bankers' problem is of this type. Denote $\underline{z}$ a threshold level of productivity above which banks invest in their own technology. Additionally, let A_{-1} indicate the level of aggregate productivity in the previous period, $B^d = \int_i b_i^d \mathrm{d}i$ the aggregate stock of domestic public debt and $B^x = B - B^d$ the stock of external public debt (public debt held by foreign investors).[8] The aggregate state of the economy is $\mathbf{s} = (s, e)$ where $s = \left(A_{-1}, g, \underline{z}, B^d, B^x\right)$ and $e \in \{o, c\}$ indicates whether the

[8]For any variable x of an individual banker define its aggregate counterpart as

$$X \equiv \int_i x_i \mathrm{d}i = \int_{n,z} x(n, z) \mathrm{d}\mathcal{G}(n, z),$$

where $\mathcal{G}(n, z)$ is the endogenous distribution of net-worth and idiosyncratic productivity. We adopt a similar notation for aggregate variables of workers. Since workers are identical, in this case aggregate variables will coincide with individual variables.

economy is open ($e = o$) or closed ($e = c$). The relevant state for the private allocations is the augmented state $\tilde{\mathbf{s}} = (\mathbf{s}, B', \iota)$ that also includes the current government policies. A competitive equilibrium is given by workers' and bankers' consumption, bankers' portfolio choices and prices such that the labor market, the interbank market and the market of public debt clear, given government policies. We provide a formal definition of equilibrium in Appendix A.

The way the public debt market is different depending on whether the economy is open or closed. The government chooses a total debt issuance. In states in which the economy is closed ($e = c$), the price adjusts so that the entire stock of government debt is purchased by bankers. In states in which the economy is open ($e = o$), public debt is priced by foreign investors $\left(q^b(s, B') = \frac{\mathbb{E}[\iota(\mathbf{s}')|\tilde{\mathbf{s}}]}{R}\right)$ and the amount of external public debt is determined as the residual between the total stock of public debt and the domestic public debt demanded by banks at that price.[9]

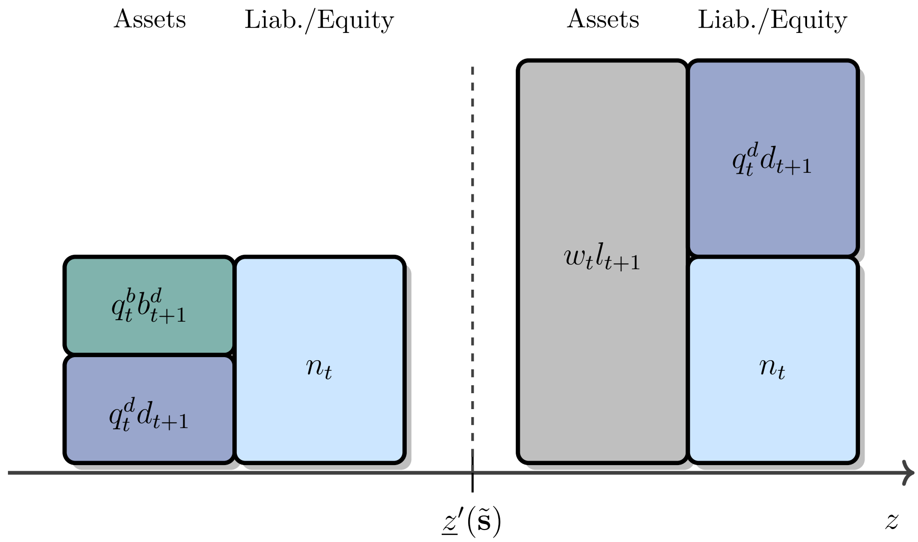
We now characterize the competitive equilibrium. In any equilibrium with positive investment in public debt, public debt and interbank deposits have the same risk-adjusted expected return.[10] The individual banker's problem is linear in its net worth and its solution involves corners that depend on the level of idiosyncratic productivity. Bankers with productivity than a threshold choose to borrow in the interbank market up to their constraint and invest the amount borrowed plus all their net worth in their production technology by hiring labor. Bankers with lower productivity than the threshold are indifferent between lending to other bankers and investing in public debt. An illustration of the solution to the banks' portfolio problem is depicted in Figure 2.

---

[9]Another possibility in the open economy is that there is no external debt ($B^{d'}(\tilde{\mathbf{s}}) = B'$). In this case the equilibrium price of public debt should clear the market domestically and also be such that foreign investors are not willing (or at least indifferent) to buy public debt $\left(q^b(s, B') \geq \frac{\mathbb{E}\left[\iota(\mathbf{s}')|\tilde{\mathbf{s}}\right]}{R}\right)$. In the model's simulations this case does not occur and the equilibrium always features positive external debt when the economy is open. From now onwards we focus on this case.

[10]If it is strictly lower all banks would want to borrow from other banks and invest in public debt, but then the interbank market of deposits would not clear. If it is strictly higher then no bank would buy public debt.

Figure 2: Solution to Banks' Portfolio Problem



The recursive representation of the banker's problem can be found in Appendix A, and has as idiosyncratic states (n, z). A formal characterization of its solution is stated in the following proposition. Denote $R^x(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')$ the realized return of asset x, and $\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')$ the augmented stochastic discount factor of bankers (defined below). Additionally, let $\underline{z}'(\tilde{\mathbf{s}})$ be a threshold productivity level such that the risk-adjusted expected return of investing in the production technology is the same as the risk-adjusted expected return of lending to other banks, i.e., $\mathbb{E}\left[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')R^l(\underline{z}(\tilde{\mathbf{s}}); \tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\right] = \mathbb{E}\left[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\right]$.

***Proposition* 1.** *In any equilibrium with positive holdings of public debt, the price of inter-bank deposits is given by* $q^d(\tilde{\boldsymbol{s}}) = q^b(\tilde{\boldsymbol{s}})\frac{\mathbb{E}[\Omega(\tilde{\boldsymbol{s}}, \tilde{\boldsymbol{s}}')]}{\mathbb{E}[\Omega(\tilde{\boldsymbol{s}}, \tilde{\boldsymbol{s}}')\iota(\tilde{\boldsymbol{s}}')]}$. *Additionally,*

- *Bankers with* $z > \underline{z}'(\tilde{\boldsymbol{s}})$ *prefer to borrow up to their constraint* $q^d(\tilde{\boldsymbol{s}})d' = -\kappa\sigma n$, *invest everything in the productive technology* $w(\tilde{\boldsymbol{s}})l' = (\kappa + 1)\sigma n$ *and not buy any public debt* $b^{d'} = 0$.

- *Bankers with* $z \leq \underline{z}'(\tilde{\boldsymbol{s}})$ *are indifferent between borrowing to other banks and investing in public debt* $q^d(\tilde{\boldsymbol{s}})d' = x \in [0, \sigma n]$, *and* $q^b(\tilde{\boldsymbol{s}})b^{d'} = \sigma n - x$ *and do not invest in labor* $l' = 0$.

Additionally, the value function of bankers is linear in net worth $v(n, z; \tilde{\boldsymbol{s}}) = \nu(z; \tilde{\boldsymbol{s}})n$, where

$$\nu(z; \tilde{\boldsymbol{s}}) = (1-\sigma) + \sigma \mathbb{E}\left[\Omega(\tilde{\boldsymbol{s}}, \tilde{\boldsymbol{s}}')R^d(\tilde{\boldsymbol{s}}, \tilde{\boldsymbol{s}}')\left[1 + (\kappa+1)\left(\max\left\{\frac{R^l(z; \tilde{\boldsymbol{s}}, \tilde{\boldsymbol{s}}')}{R^d(\tilde{\boldsymbol{s}}, \tilde{\boldsymbol{s}}')} - 1, 0\right\}\right)\right]\right], \quad (11)$$

and the augmented stochastic discount factor is given by $\Omega(\tilde{\boldsymbol{s}}, \tilde{\boldsymbol{s}}') = \Lambda(\tilde{\boldsymbol{s}}, \tilde{\boldsymbol{s}}')\mathbb{E}_{z'}[\nu(z', \tilde{\boldsymbol{s}}')]$.

All proofs can be found in Appendix A. The proposition has the following corollary regarding the relationship between banks' exposure to public debt and returns.

***Corollary* 1.** *The model predicts a decreasing relationship between public debt holdings and expected returns on assets. It also predicts a decreasing relationship between public debt holdings and investment in their productive projects.*

These relationships are a necessary ingredient for public debt to play the role of liquidity provision, and we empiricaly test them in Section 3.

We now characterize the aggregate allocations in a competitive equilibrium. Because idiosyncratic shocks are iid, it suffices to keep track of the aggregate level of domestic public debt B^d, the threshold productivity $\underline{z}$ and government policies to determine the laws of motion of private allocations. Using market clearing in the interbank market, the aggregate net worth of bankers measured before dividend payments is given by $N(\tilde{\mathbf{s}}) = \left(A\mathbb{E}\left[z|z > \underline{z}\right] + \iota B^d\right)$. The labor market clearing condition is given by

$$(\kappa+1)\sigma N(\tilde{\mathbf{s}})\left[1 - G\left(\underline{z}'(\tilde{\mathbf{s}})\right)\right] = w(\tilde{\mathbf{s}}), \quad (12)$$

which states that the total internal and external resources from producing banks should equal the wage bill. The demand for labor depends positively on the aggregate level of bankers net worth and negatively on the fraction of bankers that choose not to invest in their production technology, $G\left(\underline{z}'(\tilde{\mathbf{s}})\right)$. The green line of Figure 3 depicts this condition on the $(\underline{z}', w)$ space.

The threshold productivity of the banker that is indifferent between investing in her production technology and investing in public debt (or lending to other bankers) is determined by the risk-adjusted expected return on public debt

$$\mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')A'\right]\frac{\underline{z}'(\tilde{\mathbf{s}})}{w(\tilde{\mathbf{s}})}=\mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')R^b(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right]. \tag{13}$$

Higher wages, everything else equal, increase the threshold productivity since it is costlier to hire labor and therefore less profitable to invest in their own technology. The blue line of Figure 3 plots this condition. The equilibrium wage and cutoff productivity are determined at the intersection of both lines, for given levels of the aggregate net worth and expected returns on public debt.

In states in which the economy is open the expected return on public debt is determined by the international risk-free rate R and the aggregate stock of domestic public debt is determined as a residual of the net worth of those bankers with low productivity that did not lend to other bankers[11]

$$q^b(\tilde{\mathbf{s}})B^{d'}(\tilde{\mathbf{s}})=\sigma N(\tilde{\mathbf{s}})\left[G(\underline{z}'(\tilde{\mathbf{s}}))(1+\kappa)-\kappa\right]. \tag{14}$$

In those states in which the economy is closed, equation (14) determines the equilibrium price of public debt for a given government policy of domestic public debt issuance.

The following proposition formalizes the above-mentioned characterization of prices and aggregate allocations in a competitive equilibrium.

Proposition 2. *For any equilibrium with positive domestic holdings of public debt, wages and the threshold productivity solve (12) and (13), for a given expected return on public debt. For states in which the economy is open ($e=o$) and the price of debt is $q^b(\tilde{\boldsymbol{s}})=\frac{\mathbb{E}[\iota(\tilde{s}')|\tilde{s}]}{R}$, the law of motion for domestic public debt debt solves (14). For states in which the economy is closed ($e=c$), the level of domestic public debt is determined by the government policy, and the price of public debt solves (14).*

Finally, combining the budget constraints (2), (4) and (10) with (12)-(14), we can express

[11]Note that for the stock of domestic public debt to be non-negative we must have $G(\underline{z}'(\tilde{\mathbf{s}}))\geq\frac{\kappa\sigma}{\kappa\sigma+1}$. If this condition does not hold, then the equilibrium is with $B^{d'}(\tilde{\mathbf{s}})=0$ and $\mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right]>\mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')R^b(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right]$. This case does not occur in equilibrium in the simulations of the model.

aggregate consumption workers and bankers as

$$C^w(\tilde{\mathbf{s}}) = \sigma A\mathbb{E}\left[z|z > \underline{z}\right] - (1-\sigma)\iota(\tilde{\mathbf{s}})B^d - \iota(\tilde{\mathbf{s}})B^x + q^b(\tilde{\mathbf{s}})B^{x\prime}, \tag{15}$$

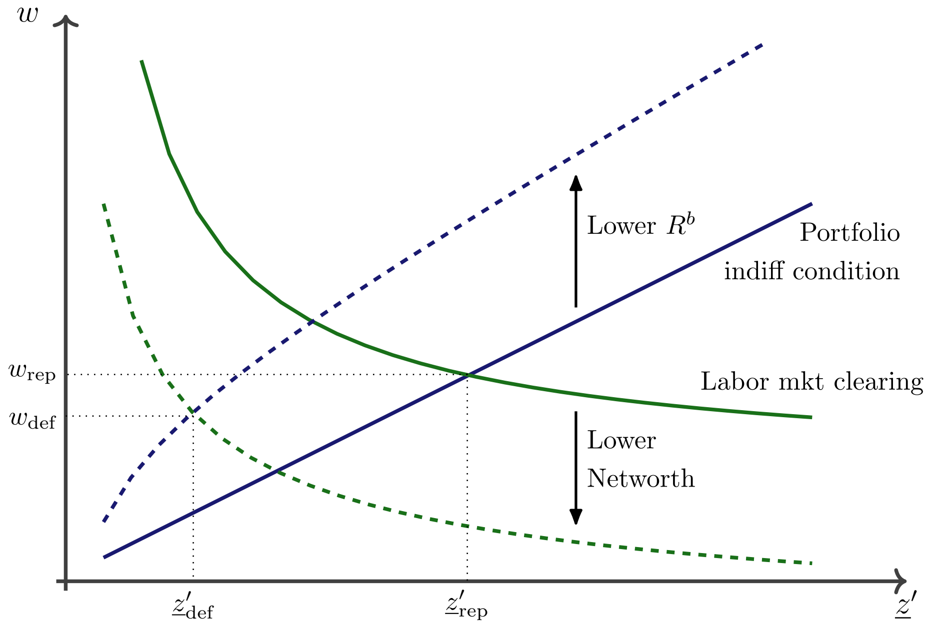
$$C^b(\tilde{\mathbf{s}}) = (1-\sigma)A\mathbb{E}\left[z|z > \underline{z}\right] + (1-\sigma)\iota(\tilde{\mathbf{s}})B^d, \tag{16}$$

where aggregate output is given by $A\mathbb{E}\left[z|z > \underline{z}\right]$. Note that output $A\mathbb{E}\left[z|z > \underline{z}\right]$ depends on the cutoff productivity $\underline{z}$ and is shared among workers and bankers. Additionally, the external debt is useful to allocate consumption of workers inter-temporally. Finally, a default on both domestic and external debt, constitutes a redistribution from foreign investors and bankers, to workers.

Public liquidity and sovereign default. One of the roles of public debt in this economy is to provide liquidity to the domestic financial system. By liquidity we refer to the availability of instruments that can be used to transfer wealth across periods (see, Woodford, 1990; Holmström and Tirole, 1998). In this economy individual banks view the availability of public debt as an exogenous technology at which they can transfer resources across time at a given expected return. This investment vehicle is attractive for banks with low productivity that cannot obtain high returns by hiring labor and investing in their productive technology. From an aggregate perspective, the availability of public debt provides liquidity value to the domestic economy as it allows low-productivity banks to invest their net worth in an asset with an attractive risk-adjusted return while they wait for a high productivity draw in the future. The liquidity value of public debt is positively related to its risk-adjusted return. As its return increases, public debt provides a higher liquidity value as it screens away low-productivity banks from investing in their own technology, which in turn frees-up labor for high-productivity banks, improves the allocation of inputs and increases output. Given the efficient screening effect, the government can induce a more efficient allocation of labor if increasing debt issuance increases its equilibrium return.

A default affects output through two channels: a liquidity channel that operates through its effect on the return of public debt, and a balance-sheet channel that operates through

Figure 3: The Output Cost of Default: Equilibrium Characterization



Notes: This figure illustrates the equilibrium determination of wages and the cutoff productivity using equations (12) and (13). It also shows how the equilibrium is affected by a sovereign default.

its effect on the banks' networth and on the return on public debt. As will be clear later, a default undermines the government's ability to issue public debt domestically, and lowers its rate of return. A lower return of public debt induces low-productivity banks to invest in their technologies, which in turn lowers average labor productivity. Mathematically, this channel operates by shifting the blue line in Figure 3 to the left, implying a lower threshold productivity for any given wage.[12]

The balance-sheet channel operates through a lower networth of banks exposed to public debt. These banks can raise less resources in the interbank market and reduce the levels of investment in their productive technology, thereby reducing aggregate labor demand, lowering wages. This in turn induces low-productivity to invest in their projects lowering average labor productivity. This channel operates by shifting the green line to the left, implying a lower wage for any given threshold productivity.

One implication of the model is that the reduction in output following a default is due

[12]The blue dotted line is nonlinear because the return of public debt in the closed economy is endogenous and depends on $\underline{z}$ because it affects the demand for public debt.

to a misallocation of labor. After a default more bankers with lower productivities engage in production, leading to higher cross-sectional dispersion of the marginal product of labor.

2.4. Optimal Government Policies

We now define the government's problem. Given its lack of commitment, the government chooses its policy rules at any given period taking as given the policy rules that represent future governments' decisions, and a recursive equilibrium is characterized by a fixed point in these policy rules.

Denote $\underline{z}'(s, e; B', \iota)$ and $B^{d'}(s, e; B', \iota)$ the competitive equilibrium allocations associated to current government policies $\{B', \iota\}$ and future government policies $\{\mathcal{B}'(\mathbf{s}), \mathcal{I}(\mathbf{s})\}$. These allocations satisfy the conditions stated in Proposition 2. Denote W^e for $e = o, c$, the value for the government of being in an open ($e = o$) or closed ($e = c$) economy. These value functions solve

$$W^o(A_{-1}, g, \underline{z}, B^d, B^x) = \max_{\iota \in \{0,1\}} \iota W^{or}(A_{-1}, g, \underline{z}, B^d, B^x) + (1 - \iota) W^{od}(A_{-1}, g, \underline{z}), \tag{17}$$

$$W^c(A_{-1}, g, \underline{z}, B^d) = \max_{\iota \in \{0,1\}} \iota W^{cr}(A_{-1}, g, \underline{z}, B^d) + (1 - \iota) W^{cd}(A_{-1}, g, \underline{z}), \tag{18}$$

where W^{er} and W^{ed} denote the value of repaying and defaulting, respectively, in economy $e = o, c$. The value of repaying in the open economy is given by

$$W^{or}(A_{-1}, g, \underline{z}, B^d, B^x) = \max_{B'} \alpha u(C^w) + (1 - \alpha) u(C^b) + \beta \mathbb{E}\left[W^o(A, g', \underline{z}', B^{d'}, B^{x\prime}) | s\right] \tag{19}$$

subject to

$$\begin{aligned}
C^w &= \sigma A \mathbb{E}\left[z | z > \underline{z}\right] - (1 - \sigma) B^d - B^x + q^b(s, B^{x\prime}) B^{x\prime} \\
C^b &= (1 - \sigma) A \mathbb{E}\left[z | z > \underline{z}\right] + (1 - \sigma) B^d \\
\underline{z}' &= \underline{z}'\left(s, o; B', 1\right) \\
B^{d'} &= B^{d'}\left(s, o; B', 1\right) \\
B^{x\prime} &= \max\{B' - B^{d'}, 0\}.
\end{aligned}$$

The value of repaying in the closed economy is given by

$$W^{cr}(A_{-1}, g, \underline{z}, B^d) = \max_{B^{d'}} \alpha u(C^w) + (1-\alpha)u(C^b) \tag{20}$$
$$+ \beta \mathbb{E}\left[\phi W^o(A, g', \underline{z}', B^{d'}, 0) + (1-\phi) W^c(A, g', \underline{z}', B^{d'})\right]$$

subject to

$$C^w = \sigma A \mathbb{E}\left[z | z > \underline{z}\right] - (1-\sigma) B^d$$
$$C^b = (1-\sigma) A \mathbb{E}\left[z | z > \underline{z}\right] + (1-\sigma) B^d$$
$$\underline{z}' = \underline{z}'\left(s, c; B^{d'}, 1\right).$$

Finally, the value of defaulting on debt when the economy is open and closed are given by

$$W^{od}(A_{-1}, g, \underline{z}) = W^{cr}(A_{-1}, g, \underline{z}, 0) - \delta + \epsilon_o, \tag{21}$$
$$W^{cd}(A_{-1}, g, \underline{z}) = W^{cr}(A_{-1}, g, \underline{z}, 0) + \epsilon_c, \tag{22}$$

where $\delta > 0$ is a disutility cost of defaulting when the economy is open; and ϵ_o, ϵ_c are additive taste shocks that are independently normally distributed with zero mean and variance σ_ϵ. We introduce the disutility cost and taste shocks to the repayment decision, which are common in the literature and help better match the data (see, e.g., Dvorkin, Sánchez, Sapriza and Yurdagul, 2021).[13] When choosing to repay or default when the economy is open the government faces a trade-off: a default redistributes resources from foreign investors and bankers to workers, and entails costs in terms output, utility and a reversion to the closed economy. When the economy is closed, the repayment/default decision trades-off redistribution from bankers to workers with the output costs.

A recursive equilibrium with optimal government policies is defined as the competitive equilibrium associated with the policies that solve the government problem given future policies that are consistent with optimal ones. Appendix A provides the formal definition.

[13] These shocks also form part of the state vector but, to keep notation simple, we do not explicitly include because they only introduce noise to the default decision.

The model is solved using a global solution that uses projection methods. The competitive equilibrium given any government policy is solved using Euler equation iteration and the government problem is solved using value function iteration methods. Appendix C.1 describes the numerical solution algorithm.

3. Supporting Empirical Evidence

In this section, we provide empirical evidence in support of the model predictions stated in Corollary 1, which state that banks with less attractive investment opportunities tend to purchase more public debt. We also analyze the dynamics of banking-related variables during an episode of default.

We collected micro-data on individual banks' balance sheets in Argentina for the period 1999-2010 at an annual frequency. The data comes from the Central Bank of Argentina that requires all banks to report their balance sheet information. The full dataset contains data balance sheets from 115 financial institutions. Each balance sheet contains disaggregated information about the assets and liabilities of banks as well as their profits, income and expenditures. We provide further details in the description of the data and the construction of variables in Appendix B.

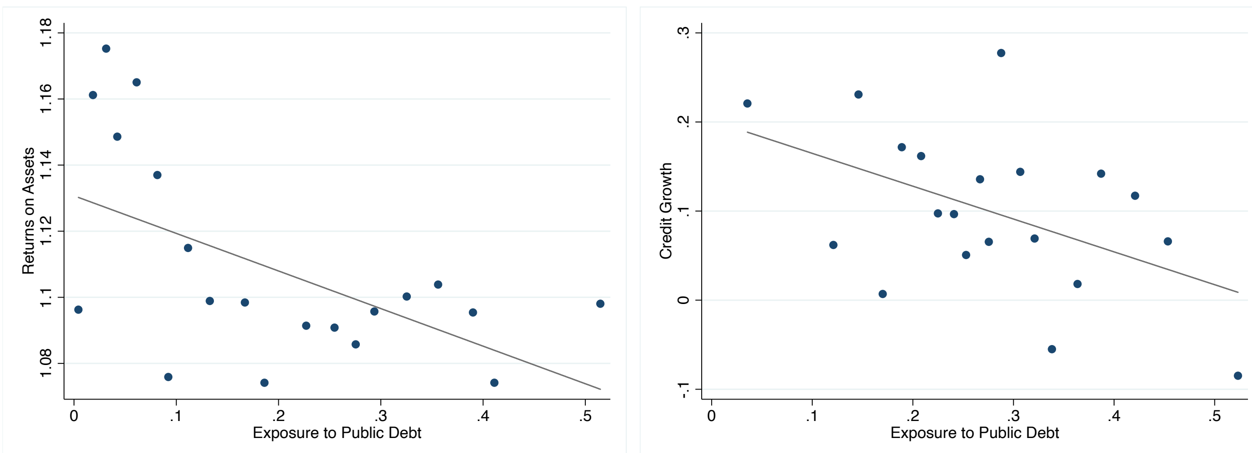
To test the first prediction of Corollary 1, we construct measures of banks' performance and analyze their relationship with their exposure to public debt. The baseline measure of performance is the return on financial assets, defined as the ratio between annual income from financial sources to the book value of total financial assets. The baseline measure of exposure to public debt is the ratio of the sum of claims on the public sector and public securities to total assets. According to the model's predictions, those banks that have less attractive investment opportunities are more willing to buy public debt.[14] Panel (a) of Figure

[14] In the data, the asset composition of banks include both public debt and productive technology (proxied by credit to the private sector). In the model, due to the constant-returns-to-scale assumption, banks either invest in public debt and interbank deposits, or invest all their resources in productive technology. The strong dichotomy is not crucial for the model's main mechanism. A model with decreasing returns to scale would retain the model's main mechanisms and deliver interior asset composition for some banks, at the expense of significantly increasing the difficulty of its numerical solution.

4 shows a scatter plot of the average return on assets over time and the average exposure to public debt for each bank in the sample.[15] As illustrated by the line of best fit, there is a negative relationship between the average return on assets and average exposure to public debt. This negative relationship is statistically significant.

Figure 4: Selection in Banks' Holdings of Public Debt

(a) Public Debt and Returns **(b)** Public Debt and Credit Growth



Notes: Panel (a) shows a bin scatterplot of the average exposure to public debt over years for a given bank (in the horizontal axis) and the average annual gross return on financial assets over years for a given bank (in the vertical axis). Each dot corresponds to a binscatter of observations at the bank level. Panel (b) shows a bin scatterplot of the exposure to public debt in a given bank-year (in the horizontal axis) and the log change in credit to the private sector in in a given bank-year. Each dot corresponds to a binscatter of observations at the bank-year level. See Appendix B for details on the construction of these variables.

Panel (b) of Figure 4 uses the panel data to show that banks with higher exposure to public debt tend to have lower growth rates in credit to the private sector, which proxies investment in productive opportunities. This relationship is also in line with the second prediction of Corollary 1, indicating a substitution between public debt and credit to private sector at the bank level.

In Appendix B, we analyze the robustness of these relationships and test further predictions of the model. First, we show that the negative relationship between banks' returns and public debt exposure is still present when we control for the observed volatility of banks'

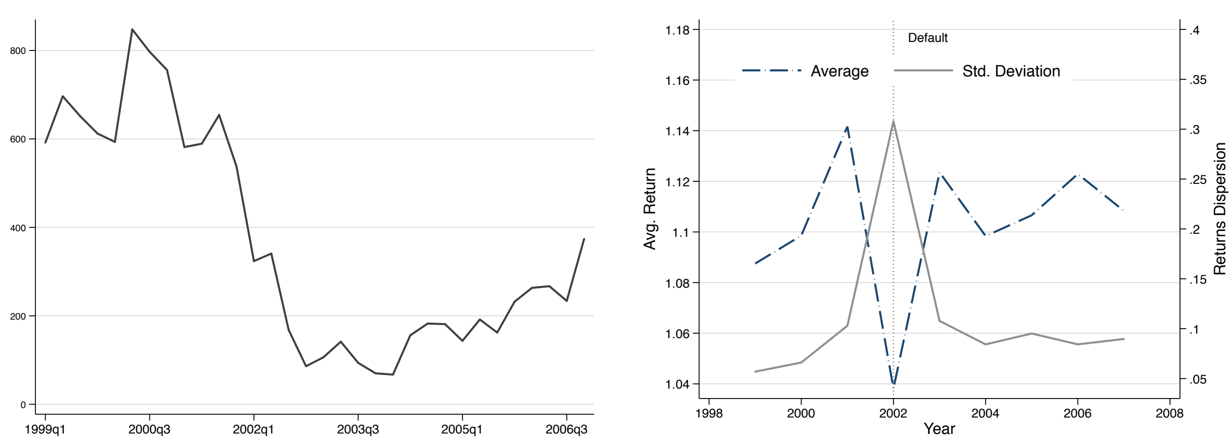
[15]We average the data across time since the model's prediction relates to expected returns rather than realized returns. The negative relationship between returns and exposure to public debt does not reflect the mechanical channel of low realized returns during the default period of 2002-05, since banks were allowed to value government debt at par during this period. In Appendix B, we also compute average returns excluding the default period and find similar results.

return on assets, ruling out the possibility of higher returns only reflecting higher risk. Second, we show that this relationship is robust to using the data without averaging across time, and to considering alternative measures of banks' performance and exposure to public debt. Third, we show that the relationship between public debt exposure and credit growth is robust to including bank and time fixed effects. Finally, also consistent with the model's predictions, we find a negative empirical relationship between exposure to public debt and bank leverage.

We then focus on the dynamics of banking-related variables around episodes of default. According to our quantitative model, a default is followed by lower expected risk-adjusted returns from lending to other banks, which in turn leads to lower volumes of interbank lending, and lower and more dispersed returns of bank investments. As shown in Panel (a) Figure 5, interbank loans dropped significantly after the default. Additionally, Panel (b) shows that realized average bank returns dropped significantly and its cross-sectional dispersion increased following the default.

Figure 5: Bank Dynamics Around a Default Episode

(a) Interbank Lending **(b)** Average Returns & Returns Dispersion



Notes: Panel (a) shows the evolution of total interbank loans, expressed in thousands of Jan-99 Argentine pesos. Panel (b) shows the evolution of the cross-sectional average (left axis) and standard deviation (right axis) of the annual returns on financial assets around the default of December 2001. See Appendix B for details on the construction of these variables.

In Appendix B, we also analyze the dynamics of bank credit growth following the 2001 default in the microdata. According to the theory, it should be low-productivity banks that invest relatively more than high-productivity banks following a default. We test this prediction in the data and show that banks with high pre-default returns experienced relatively lower credit growth following the default.

The evidence on more dispersed bank returns and higher credit growth for low-return banks is also consistent with other studies that document larger degrees of misallocation in Argentina in the same period. Kehoe (2007) argues that most of the drop of output in the Argentinean crisis was due to a fall in measured total-factor-productivity (TFP). Additionally, Sandleris and Wright (2014) use firm-level data to show that of the fall in measured TFP in Argentina, most of it was due to labor misallocation.

4. Quantitative Analysis

This section performs a quantitative analysis of the model by calibrating it to the Argentinean economy for the period 1994-2012. We consider the Argentinean economy during this period to be an interesting case for study because it displayed significant levels of external and domestic public debt, and included one of the largest sovereign defaults in history followed by a period of exclusion from external financial markets. In December 2001 the Argentinean government explicitly defaulted on \$95 billion of external debt which represented 37% of its annual GDP. Additionally, by imposing a unfavorable swaps and the conversion of dollars to pesos of its domestic debt it also implicitly defaulted on the outstanding stock of domestic debt at that time. The default was followed by a period of exclusion from external financial markets until Argentina reached a swap agreement with creditors in June 2005.[16]

4.1. Calibration and validation

One period in the model corresponds to one quarter. The instantaneous utility function for workers and bankers is assumed to be

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma}.$$

[16]See Sturzenegger and Zettelmeyer (2008) for an analysis of the Argentinean sovereign default.

Additionally, we assume that idiosyncratic productivity shocks z are distributed Pareto with shape parameter λ, and that the growth rate of the aggregate productivity is approximated with a log-normal AR(1) process with long run mean μ_g and persistence coefficient ρ_g, i.e.

$$g_t = (1-\rho_a)\left(\ln \mu_a - \frac{1}{2}\frac{\sigma_a^2}{1-\rho_a^2}\right) + \rho_a g_{t-1} + \sigma_a \varepsilon_t, \qquad \varepsilon_t \sim N(0,1).$$

The model is parametrized by government- and preferences-specific parameters $(\alpha, \beta, \gamma, \delta, \sigma_\epsilon, \phi, R)$, and bank-related parameters $(\sigma, \kappa, \lambda, \mu_a, \rho_a, \sigma_a)$. A subset of them are externally set and the remaining are calibrated. The model parameter values are summarized in Table 1. The risk aversion coefficient γ is set to 2 and the risk-free interest rate is set to $R = 1.005$, which are standard in quantitative business cycle studies. The reentry probability to external financial markets is set to 0.063 which implies an average period of exclusion of four years, which is consistent with the median period of exclusion from international credit markets found in Dias and Richmond (2008) and also in the range of estimates of Gelos, Sahay and Sandleris (2011). We set the value of the discount factor to $\beta = 0.9$, which is in the range of discount factors considered in quantitative models of sovereign default. Low discount factors are needed to generate defaults in equilibrium.

Table 1: Calibrated Parameters Baseline

Panel A: Externally Set			Panel B: Calibrated		
Parameter		Value	Parameter		Value
Risk aversion coefficient	γ	2.00	Growth rate autocorrelation	ρ_a	0.45
Risk free interest rate	R	1.01	Std. deviation of growth shocks	σ_a	0.02
Reentry probability	ϕ	0.90	Shape of idiosyncratic prod. dist.	λ	3.27
Discount factor	β	0.06	Bankers survival probability	σ	0.77
Banks LC constraint	κ	7.50	Utility weight of workers	α	0.99
Average growth rate	μ_a	1.01	Std. deviation of default disutility	σ_ϵ	0.08
			Average default disutility	δ	0.53

Notes: This table reports values for two subsets of parameters. Panel A reports externally set parameters, while Panel B reports parameters calibrated to match data moments.

The parameters of the exogenous process for aggregate productivity were calibrated to match the standard deviation and autocorrelation of de-trended GDP in the model as well as the average quarterly growth rate. The corresponding estimated values are $\mu_g = 1.01$, $\rho_g = 0.5$ and $\sigma_g = 0.02$. The parameter κ in the banks' limited commitment constraint is set to 7.5, which corresponds to the maximum leverage that banks can take by regulation.

The remaining five parameters $(\alpha, \sigma, \lambda, \delta, \sigma_\epsilon)$ are jointly calibrated to match a set of moments related to public debt and the micro data on banks' balance sheets. These moments include the average stock of external and domestic public debt, the frequency of default, the average return on assets and the correlation of sovereign spreads and output. While all parameters affect all moments, σ and δ are mostly identified by the average domestic and external public debt levels, respectively; λ mostly affect the average banks' returns; and α and σ_ϵ are mostly identified by the frequency of default and the spread-output correlation. Panel (a) of Table 2 reports the targeted moments in the model and the data. All moments are correctly matched in the model.

Panel (b) of Table 2 compares the model moments with their data counterparts for those moments that were not targeted in the calibration. The model correctly captures the volatility and comovement of macroeconomic aggregates like output, consumption and the trade balance. In particular, it reproduces key business cycle patterns that are common in emerging economies like the excess volatility of consumption (i.e., consumption being roughly as volatile as output), and the countercyclicality of the trade balance. It underestimates the median spread and its volatility, which is expected given that investors are risk neutral (see Aguiar, Chatterjee, Cole and Stangebye, 2016; Morelli, Ottonello and Perez, 2019, for examples of papers studying the role of risk averse lenders and shocks to risk premia).

4.2. Output Costs of Default and Debt Sustainability

In this section, we conduct counterfactual exercises to quantify the output costs of default and assess their effect on equilibrium external debt. We also analyze the role of exclusion from financial markets.

Table 2: Targeted and Untargeted Moments

Panel A: Targeted Moments			Panel B: Untargeted Moments		
Statistic	Data	Model	Statistic	Data	Model
Avg. domestic public debt	35.0%	34.4%	Output std. dev.	2.9%	3.9%
Avg. external public debt	93.0%	89.8%	Consumption std. dev.	2.9%	4.7%
Frequency of default	0.7%	0.4%	Trade balance std. dev.	1.9%	2.2%
Avg. return on assets	3.8%	4.6%	Public debt std. dev.	7.7%	2.0%
Output growth std. dev.	2.1%	2.1%	Median spread	1.7%	0.4%
Output growth autocorr.	87.6%	87.4%	Spread std. dev.	1.5%	0.1%
Output - spread corr.	-40.9%	-38.8%	Output - consumption corr.	93.1%	47.3%
			Output - trade balance corr.	-27.1%	-6.2%
			Output - returns dispersion corr.	-28.7%	-15.2%
			Public debt - spread corr.	11.7%	76.7%

Notes: Data moments are computed with quarterly data for the period of 1994.Q1 - 2012Q4 excluding the the post-default period of 2001.Q4- 2005.Q3. To compute moments from the model, we simulate the economy over a long horizon and calculate average statistics, restricting attention to states in which the economy is open. Domestic public debt corresponds to banks' exposure to public debt, and is expressed in % of quarterly GDP. Trade balance, external debt, and total public debt are also expressed in % of quarterly GDP. Bank returns, measured as the return on assets (ROA), and the interest rate spread are computed in a quarterly basis. The first moment is the average for all variables except spreads, for which the median is reported. 'Output - returns dispersion corr.' corresponds to the time series correlation between output and the cross-sectional standard deviation of quarterly returns on assets. We provide further details on the data used in the calibration in Appendix C.

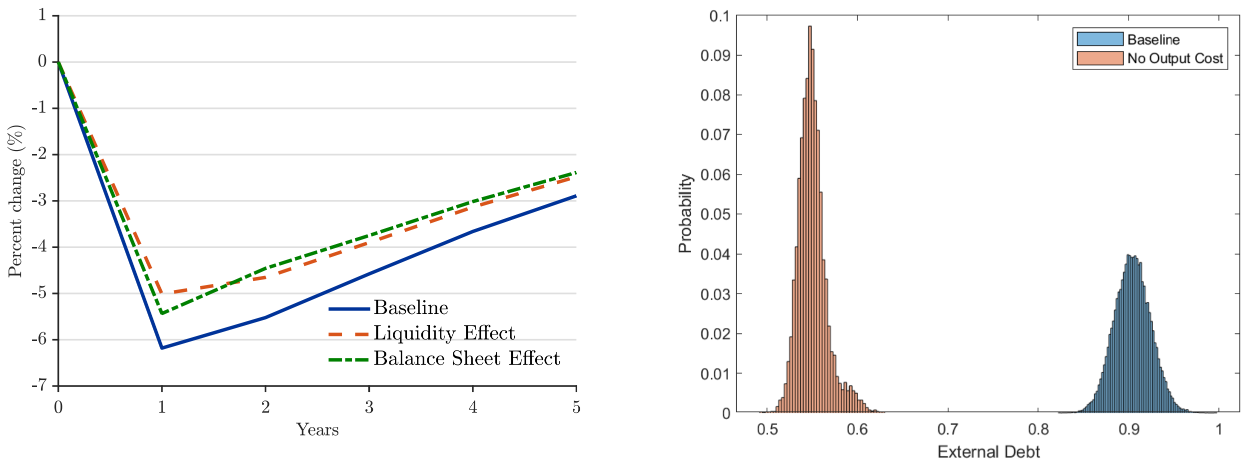
Quantifying the output costs of default. We first quantify the output costs of sovereign default and disentangle the role of different channels of transmission. Figure 6 depicts the percent drop in output that is due to a default decision for different horizons. Appendix C describes how we compute the output costs of default. Output falls over 6% on impact due to the default decision, and takes time to recover. Five years after the default output is approximately 3% below what it would be in the absence of a default. The output costs magnitudes are comparable to those estimated in Mendoza and Yue (2012). They find that a shift from imported to domestic inputs in the production function due to a sovereign default generates a drop of 5% in Argentinean output.

As explained in Section 2, the default affects output through two channels: a liquidity and a balance-sheet channel. We quantify the effects of the liquidity channel by computing

Figure 6: The Costs of Default: Output Dynamics and Debt Sustainability

(a) Output Costs of Default

(b) Output Costs and External Debt



Notes: Panel (a) illustrates the evolution of output following a default, disentangling the liquidity and balance-sheet channels. The solid blue line shows the average percent difference in output between default and repayment. The dashed orange line shows the corresponding difference when banks net worth is assumed to be unaffected by default, isolating the liquidity channel. The dash-dotted green line shows the difference when the return on public debt is held constant at its pre-default level, isolating the balance-sheet channel. Panel (b) displays the distribution of external debt as a share of quarterly GDP in the baseline model and in a counterfactual economy where default does not entail an output cost. We provide further details on how these figures are constructed in Appendix C.

the dynamics of $(\overline{z}, w)$ assuming that the net worth is not affected by the default, so that the only channel through which default affects output is the liquidity channel via the expected rate of return on public debt. Similarly, we quantify the effects of the balance-sheet channel by computing the dynamics of $(\overline{z}, w)$ assuming that the rate of return of public debt is the one prior to the default, so that the only channel through which default affects output is the balance-sheet. We provide further details on these counterfactual exercises in Appendix C. Panel (a) of Figure 6 shows that both channels are quantitatively important, with each of them accounting between 80 to 90% of the total drop in output at different horizons. The fact that both effects account for more than the total drop implies the presence of an attenuating interactive effect. This is because, following a default, the negative balance sheet effect reduces the demand for public debt, thereby putting upward pressures on expected returns of public debt. This, in turn, attenuates the effect of liquidity on output. The magnitude of the output cost of default is higher when banks hold more public debt, mostly because the balance-sheet effect scales with banks' exposure to public debt (see Appendix Figures C2 and C3). The quantitative relevance of the balance-sheet channel is in line with prior findings of Bocola (2016), although studied in the context of Italy. What is more novel from this analysis is that the liquidity effect is quantitatively sizeable.

Table 3: Macroeconomic Cost of Defaults

Variable	Horizon (Years)	Baseline Model	Persistent Idio. Prod.	Elastic Labor Supply	Storage Technology	Stationary Agg. Shocks	Data
Output	1	-5.0%	-3.4%	-3.2%	-1.6%	-4.4%	-11.2%
	2	-5.5%	-2.9%	-6.6%	-2.2%	-5.5%	-5.0%
	3	-4.3%	-1.9%	-6.4%	-1.6%	-4.9%	-1.2%
Wages	1	-6.8%	-18.7%	-6.6%	-11.0%	-10.1%	-7.4%
	2	-4.9%	-8.5%	-6.8%	-7.3%	-7.5%	-15.0%
	3	-3.3%	-6.1%	-5.3%	-3.5%	-6.4%	-7.5%
Bank Returns	1	-13.9%	-8.6%	-28.3%	2.7%	-4.6%	-9.1%
	2	-9.7%	-23.1%	-17.2%	1.1%	-7.2%	-1.6%
	3	-7.4%	-14.7%	-16.1%	3.7%	-5.7%	-3.8%

Notes: This table shows the dynamics of output, wages, and bank returns in the first three years after a default. For each model specification, we simulate the economy over a long horizon and identify states in which the government defaults while the economy is open. We then compute the average dynamics of output, wages, and returns across default episodes. Bank returns are measured as the average annual return on assets (ROA). In both the model and the data, output and wages are expressed as percentage deviations from an HP-filtered trend, while bank returns are expressed as percentage deviations from the average annual return in the year prior to default. All columns except the last one correspond to different model specifications. We provide further details how these dynamics are computed in Appendix C.

Table 3 and Appendix Figure C4 report the dynamics of other macroeconomic variables around a default. Banks' average returns on assets are lower and their cross-section dispersion increases in response to a default. The effect of a default on wages is qualitatively ambiguous due to the presence of two opposing effects. On the one hand, a default reduces the net worth of banks, which reduce their demand for labor and puts downward pressure on wages. On the other hand, the fact that banks with lower productivities in the margin decide to invest in their technology puts upward pressures on wages. As shown in the table, the former effect quantitatively dominates and wages drop significantly in the event of a default. For a similar reason, the volume of interbank credit also drops during defaults, due to banks having lower net worth, in spite of more low-productivity banks borrowing to invest in their technology. The last column of Table 3 reports the observed variation in these variables during the 2001 default episode. The model mechanisms can account for an important fraction of the observed contraction in output and wages during this episode. The unexplained component of the contraction in these variables may be due to other channels and policies that are not present in the model and occurred during the 2001 crisis (e.g. a bank run and exchange rate devaluation).

Effects on external debt. We also analyze how much external debt can be sustained because of the endogenous output cost of default. For this, we solve a counterfactual model in which the endogenous laws of motion are set so that there is no fall in output due to a default (see Appendix C for further details). Panel (b) of Figure 6 compares the histograms of external debt simulations in the baseline model and in the model without output costs of default. The average level of external debt in the model without output costs of default is 55% of quarterly GDP, compared to 90% in the baseline model. The government can still sustain some level of debt mainly because of the disutility costs of default. This result indicates that the presence of output cost of default allows the government to sustain a significant fraction of the observed levels of external debt.

The role of exclusion from financial markets. We analyze this by solving the model for different lengths of exclusion from international financial markets. When the length of exclusion is shorter the government's ability to provide liquidity upon default is less undermined, resulting in a milder drop in output. This allows the government issue less external debt. Appendix Figure C5 shows that the length of exclusion is a relevant determinant of the magnitude of the output cost of default and the level of external debt. In the extreme case when exclusion is only for a quarter ($\phi = 1$), the output cost of default is less than half of the baseline model and the level of external debt is two thirds of that in the baseline. This implies that the length of exclusion is quantitatively relevant for output dynamics following a default and for debt sustainability.

These results complement those from the literature on quantitative default models.

One commonly stressed results is that the punishment of financial autarky is quantitatively irrelevant, as it cannot generate enough commitment to sustain almost any external public debt (see, for example, Hatchondo, Martinez and Sapriza (2007)). In light of this, the literature commonly assumes that the economy suffers an output cost of default for as long as they are excluded from financial markets. This analysis provides a micro-foundation for this assumption by endogenously generating a depressed level of output while the economy is in external financial autarky, due to undermined liquidity provision while the economy is closed. It also argues that the quantitative irrelevance of financial exclusion is not robust once their effects on output are endogenized.

4.3. Model Extensions

In this section we analyze four extensions of our baseline model in which we introduce persistent idiosyncratic shocks, an elastic labor supply, an alternative asset in which banks can invest, and stationary aggregate shocks. The main takeaway from this analysis is that the magnitude of the output costs of default is sensitive to how we model the asset market and the idiosyncratic productivity process, but less so to the labor market and the aggregate shock process.

Persistent idiosyncratic shocks. In the main model extension, we introduce persistent idiosyncratic productivity shocks assuming that with probability $1 - p_z$ each bank keeps its idiosyncratic productivity from the previous period, and with probability p_z it draws a new productivity from a Pareto distribution. The baseline iid model corresponds to $p_z = 1$.

This model does not feature the aggregation properties of the baseline model, and the joint distribution of banks' assets and productivity becomes a state variable. We solve the model using Krusell and Smith (1998) techniques that approximate the distribution with relevant moments (see Morelli *et al.*, 2019, for an application of this method to sovereign debt models). Appendix D describes the solution method of this model extension. We calibrate p_z to match the autocorrelation of banks' returns, which is 20%. Table D.1 shows the calibrated parameters, and Table D.2 shows the targeted and untargeted moments.

The main quantitative takeaway from this model is that the persistence in idisyncratic shocks attenuates the output cost of default. This is because a default hits more adversely the holders of public debt, which are low-productivity banks. If shocks are persistent, these banks are more likely to be low-productivity banks in the future and less likely to participate in production. The quantitative estimates of the output cost of default in this model is 3.4% after 1 year, compared to 5.4% in the baseline model with i.i.d. shocks (see Table 3). The magnitude of the difference is not signicant because the calibrated process is mildly persistent, as infered by the low autocorrelation of returns.

Elastic labor supply. We now assume that workers' flow preferences are given by

$$u(c,l) = \frac{\left(c - \frac{l^{\omega}}{\omega}\right)^{1-\gamma}}{1-\gamma},$$

which give rise to an optimal labor supply of $L_t = w_t^{\frac{1}{\omega-1}}$. Because labor is chosen one period ahead, this model extension features labor as an additional state variable. We set $\omega = 5$, which corresponds to a Frisch elasticity of labor supply of 0.25–in line with estimates from the labor literature–, and recalibrate the remaining parameters. Appendix Tables D.1 and D.2 report the parameter values and the targeted moments.

Table 3 reports the output costs of default for various horizons. In this model extension output contracts due to a default because both labor and the cutoff productivity fall. The reduction in labor demand induced by the balance-sheet effect implies lower wages but also lower labor because labor supply is elastic. As a consequence, wages, and thus, the cutoff productivity fall less than in the baseline model, but the reduction in output is similar since the milder fall in the cutoff productivity is offset by the reduction in labor. We provide further details about this model extension in Appendix D.

Alternative assets. In this model extension we allow banks to invest in an additional asset that consists of a risk-free technolgy. Following Sosa Padilla (2018), we assume that there is a storage technology sector that takes aggregate loans K_{t+1} from banks in period

t promising a return R^k_{t+1} and uses a storage technology that delivers ξK^{ν}_{t+1} in $t+1$ with $\nu \in (0,1)$ and $\xi > 0$. Free entry into this sector implies the following zero profit condition $R^k_{t+1} = \xi K^{\nu-1}_{t+1}$. Appendix D describes this model extension in further detail.

This storage technology captures the possibility of banks using additional assets when they have poor investment opportunities. We parameterize the storage technology to match the share of external assets in banks' balance sheets. Appendix Tables D.1 and D.2 report the parameter values and the targeted and untargeted moments.

Table 3 reports the estimated output cost of default, which is approximately one third of the baseline one at all horizons. The lower output cost of default is due to an attenuation of the liquidity channel. In this model banks have an additional asset they can purchase following a default that is less price-sensitive to the default decision.

Stationary aggregate shocks. In this model extension we consider a stationary process for the aggregate productivity given by

$$\log A_t = \rho_a \log A_{t-1} + \varepsilon_{At}, \qquad \varepsilon_{At} \sim N\left(-\frac{\sigma_a^2}{2}, \sigma_a^2\right),$$

where ρ_a and σ_a^2 are calibrated to match the autocorrelation and volatility of output. Tables D.1 and D.2 report the parameter values and the model moments moments, and Appendix D provides further details in the model calibration. The estimated output costs of default are similar to those in the baseline model (see Table 3).

Sensitivity analysis. In Appendix C.4, we perform a sensitivity analysis of the main results with respect to key model parameters. We provide here a summary of our main findings for the parameters that are most particular to our model and refer the reader to the appendix for the analysis of more standard parameters.

A lower dispersion of bank productivities–i.e., a higher λ–mitigates output losses from default because changes in the composition of banks that produce do not significantly alter the average producitivity. With lower output costs of default, the government is able to sustain lower levels of external debt. Decreases in bankers consumption rates–i.e., a higher σ–

increases the stock of domestic debt. This affects repayment incentives through two opposing channels. First, it amplifies the output costs of default through a stronger balance-sheet effect, which leads to more incentives to repay. Second, with a higher domestic debt, the government can redistribute more from bankers to workers by defaulting, which leads to more incentives to default. Quantitatively, the first effect dominates and the government is able to sustain higher levels of external debt. Finally, a tighter leverage constraint–i.e., a lower κ–mostly reduces the average level of output as high-productivity banks can obtain less funds in the interbank market. The effects on output costs and government's incentives to default are quantitatively small.

5. Policy Analysis

This section studies the effects of policies designed to increase the banks' exposure to public debt, often referred to as financial repression policies. We analyze two policies: a subsidy on banks' purchases of public debt, and a minimum requirement of public debt holdings in banks. Both of them are commonly adopted in various countries.

We find that these policies have different effects on economic activity due to their effect on the selection of banks holding public debt. The subsidy increases output by inducing high-productivity banks into production, and the minimum requirement decreases output by crowding high-productivity banks out of production.

5.1. Subsidy on Public Debt

This policy is characterized by the parameter τ_b which is a proportional subsidy that banks face when acquiring sovereign debt, and is financed with lump-sum taxes on workers. We describe the banker's problem and characterize the competitive equilibrium in the economy with a subsidy in Appendix E. Panel (a) of Appendix Figure E.1 illustrates the effects of the subsidy. The subsidy distorts the portfolio indifference condition of the marginal bank, by making public debt a more attractive investment and moving the blue line to the right.

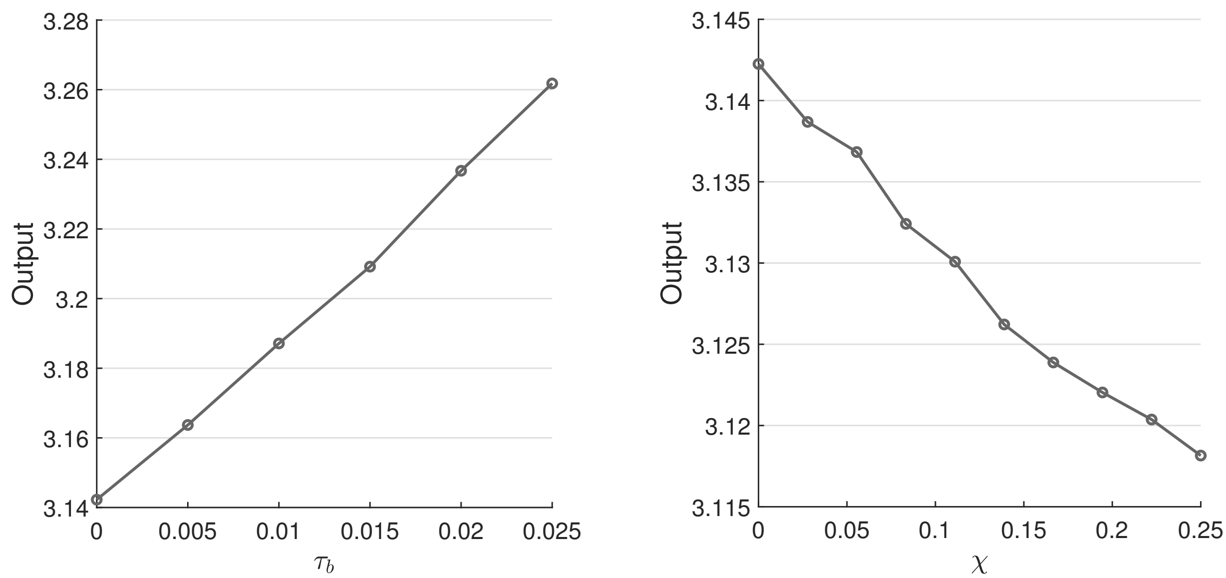
In particular, the cutoff productivity now satisfies the following condition

$$\mathbb{E}\left[\Omega(\tilde{\mathbf{s}}')A'\right]\frac{\underline{z}'(\tilde{\mathbf{s}})}{w(\tilde{\mathbf{s}})} = \mathbb{E}\left[\Omega(\tilde{\mathbf{s}}')\frac{\iota(\tilde{\mathbf{s}}')}{q^b(\tilde{\mathbf{s}})(1-\tau_b)}\right],$$

which is higher for any given wage and return on public debt. This reduces the demand for labor, reduces wages and allows banks with high productivity to hire more labor. Therefore, the policy induces a more efficient allocation of labor and higher levels of output. Figure 7a shows the average level of output in economies with different values of the subsidy τ_b.

Figure 7: Output Effects of Different Policies

(a) Subsidy on Public Debt **(b)** Minimum Requirement of Public Debt



Notes: Panel (a) shows the average level of output in economies with different values of subsidies to banks' holdings of public debt, τ_b. Panel (b) shows the average level of output in economies with different values of minimum requirements of public debt, χ.

5.2. Minimum Requirement on Public Debt Holdings

We also consider the implementation of a minimum requirement of public debt holdings in every bank. The policy is characterized by the parameter χ that specifies the minimum requirement of public debt as a share of each bank's net worth. The policy introduces the following additional constraint in the bank's problem A.1

$$q^b(\tilde{\mathbf{s}})b^d \geq \chi n$$

We describe the formal derivations of the solution to the banks' problem, as well as the equations that characterize the competitive equilibrium in Appendix E.

This constraint is not necessarily binding for low-productivity banks that are indifferent between buying public debt and lending to other banks. However, it is binding for high-productivity banks since they are forced to allocate part of their asset portfolio in public debt that would otherwise be invested it in their productive technology. A minimum requirement of public debt therefore crowds out investment in productive technology from high-productivity banks. This in turn reduces the demand for aggregate labor, which lowers wages and attracts low-productivity banks to invest in their technology (see Panel (b) of Appendix Figure E.1). As a result, the aggregate level of output falls as labor is allocated into technologies with lower productivities on average. Panel (b) of Figure 7 shows the average level of output in economies with different values of χ.

6. Conclusion

This paper develops a dynamic model of endogenous default with heterogeneous banks to explore how a sovereign default affects the domestic economy and the ability of the government to provide liquidity. When quantifying the model to match the Argentinean economy, we find that a default can generate a deep and persistent fall in output, which provides incentives for the government to credibly repay significant levels of external debt.

The main innovation relative to existing literature is the focus on bank heterogeneity. Modeling this feature gives rise to a new mechanism through which a default affects the economy, and also has novel implications for policy design. On the positive side, when banks are heterogeneous and subject to financial frictions public debt plays a liquidity role in the domestic economy, which varies with default. When there is a default, the government's ability to provide liquidity is undermined, which makes banks substitute away from the use of government securities to investments in their less productive projects, thereby lowering output by exacerbating misallocation.

On the normative side, we highlight that two commonly adopted policies that regulate banks' holdings of public debt (a minimum requirement and a subsidy on public debt) can have different effects on economic activity beacuse of their opposing effects on the selection of banks that purchase public debt. While subsidy on public debt may expand economic activity by crowding-out low-productivity banks from production, a minimum requirement can contract economic activity by forcing high-productivity banks to cut on their productive investments.

References

Acharya, V., Drechsler, I. and Schnabl, P. (2014). A pyrrhic victory? bank bailouts and sovereign credit risk. *The Journal of Finance*, **69** (6), 2689–2739.

Aguiar, M., Chatterjee, S., Cole, H. and Stangebye, Z. (2016). *Quantitative Models of Sovereign Debt Crises*, Elsevier, vol. 2.

— and Gopinath, G. (2006). Defaultable Debt, Interest Rates and the Current Account. *Journal of International Economics*, **69** (1), 64–83.

— and — (2007). Emerging Market Business Cycles: The Cycle Is the Trend. *Journal of Political Economy*, **115** (1), 69–102.

Aiyagari, S. R. and McGrattan, E. R. (1998). The Optimum Quantity of Debt. *Journal of Monetary Economics*, **42** (3), 447–469.

Alvarez-Parra, F., Brandao-Marques, L. and Toledo, M. (2013). Durable goods, financial frictions, and business cycles in emerging economies. *Journal of Monetary Economics*, **60** (6), 720–736.

Angeletos, G.-M., Collard, F., Dellas, H. and Diba, B. (2013). Optimal Public Debt Management and Liquidity Provision, nBER Working Paper No. 18800.

Arellano, C. (2008). Default Risk and Income Fluctuations in Emerging Economies. *The American Economic Review*, **98** (3), 690–712.

—, Bai, Y. and Bocola, L. (2017). Sovereign Default Risk and Firm Heterogeneity, manuscript.

— and Ramanarayanan, A. (2012). Default and the Maturity Structure in Sovereign Bonds. *Journal of Political Economy*, **120** (2), 187–232.

Balke, N. (2023). The Employment Costs of Sovereign Default, manuscript.

Baskaya, Y. S., Hardy, B., Kalemli-Ozcan, S. and Yue, V. (2024). Sovereign risk and bank lending: evidence from 1999 turkish earthquake. *Journal of International Economics*, **150**, 103918.

Basu, S. (2009). Sovereign Debt and Domestic Economic Fragility, manuscript.

Benjamin, D. and Wright, M. L. (2009). Recovery Before Redemption: A Theory of Delays in Sovereign Debt Renegotiations, manuscript.

Bernanke, B. and Gertler, M. (1989). Agency Costs, Net Worth, and Business Fluctuations. *The American Economic Review*, **79** (1), 14–31.

Bernanke, B. S., Gertler, M. and Gilchrist, S. (1999). The Financial Accelerator in a Quantitative Business Cycle Framework. *Handbook of Macroeconomics*, **1**, 1341–1393.

Bianchi, J., Hatchondo, J. C. and Martinez, L. (2018). International Reserves and Roll-Over Risk, forthcoming at *The American Economic Review*.

Bocola, L. (2016). The pass-through of sovereign risk. *Journal of Political Economy*, **124** (4), 879–926.

— and Dovis, A. (2016). Self-Fulfilling Debt Crises: A Quantitative Analysis, manuscript.

Borensztein, E. and Panizza, U. (2009). The costs of sovereign default. *IMF Staff Papers*, **56** (4), 683–741.

Broner, F., Martín, A. and Ventura, J. (2010). Sovereign Risk and Secondary Markets.

American Economic Review, **100** (4), 1523–1555.
— and Ventura, J. (2011). Globalization and Risk Sharing. *The Review of Economic Studies*, **78** (1), 49–82.
Broner, F. A., Martin, A. and Ventura, J. (2008). Enforcement problems and secondary markets. *Journal of the European Economic Association*, **6** (2-3), 683–694.
Brutti, F. (2011). Sovereign Defaults and Liquidity Crises. *Journal of International Economics*, **84** (1), 65–72.
Buera, F. and Karmakar, S. (2021). Real effects of financial distress: The role of heterogeneity. *The Economic Journal*, **132** (644), 1309–1348.
Bulow, J. and Rogoff, K. (1989). Sovereign Debt: Is to Forgive to Forget? *The American Economic Review*, **79** (1), 43–50.
Chari, V. V., Dovis, A. and Kehoe, P. J. (2018). On the Optimality of Financial Repression, manuscript.
— and Kehoe, P. J. (1993). Sustainable Plans and Debt. *Journal of Economic Theory*, **61** (2), 230–261.
Chatterjee, S. and Eyigungor, B. (2012). Maturity, Indebtedness, and Default Risk. *The American Economic Review*, **102** (6), 2674–2699.
Coval, J. D. and Moskowitz, T. J. (1999). Home bias at home: Local equity preference in domestic portfolios. *The Journal of Finance*, **54** (6), 2045–2073.
Den Haan, W. (2010). Assessing the accuracy of the aggregate law of motion in models with heterogeneous agents. *Journal of Economic Dynamics and Control*, **34** (1), 79–99.
D'Erasmo, P. (2011). Government Reputation and Debt Repayment in Emerging Economies, manuscript, University of Maryland, College Park.
— and Mendoza, E. (2017). Optimal domestic (and external) sovereign default, manuscript.
— and Mendoza, E. G. (2016). Distributional incentives in an equilibrium model of domestic sovereign default. *Journal of the European Economic Association*, **14** (1), 7–44.
Dias, D. A. and Richmond, C. (2008). Duration of Capital Market Exclusion: Stylized Facts and Determining Factors, manuscript.
Du, W. and Schreger, J. (2018). Sovereign Risk, Currency Risk, and Corporate Balance Sheets, manuscript.
Dvorkin, M., Sánchez, J. M., Sapriza, H. and Yurdagul, E. (2021). Sovereign debt restructurings. *American Economic Journal: Macroeconomics*, **13** (2), 26–77.
Eaton, J. and Gersovitz, M. (1981). Debt with Potential Repudiation: Theoretical and Empirical Analysis. *The Review of Economic Studies*, **48** (2), 289–309.
Garcia-Cicco, J., Pancrazi, R. and Uribe, M. (2010). Real business cycles in emerging countries? *American Economic Review*, **100** (5), 2510–2531.
Gelos, R. G., Sahay, R. and Sandleris, G. (2011). Sovereign Borrowing by Developing Countries: What Determines Market Access? *Journal of International Economics*, **83** (2), 243–254.
Gennaioli, N., Martín, A. and Rossi, S. (2014). Sovereign Default, Domestic Banks, and Financial Institutions. *The Journal of Finance*, **69** (2), 819–866.

—, Martin, A. and Rossi, S. (2018). Banks, government bonds, and default: What do the data say? *Journal of Monetary Economics*.

Gertler, M. and Karadi, P. (2011). A Model of Unconventional Monetary Policy. *Journal of Monetary Economics*, **58** (1), 17–34.

— and Kiyotaki, N. (2010). Financial Intermediation and Credit Policy in Business Cycle Analysis. *Handbook of Monetary Economics*, **3** (11), 547–599.

Guntin, R., Ottonello, P. and Perez, D. J. (2023). The micro anatomy of macro consumption adjustments. *American Economic Review*, **113** (8), 2201–2231.

Hatchondo, J. C. and Martinez, L. (2009). Long-duration Bonds and Sovereign Defaults. *Journal of International Economics*, **79** (1), 117–125.

—, — and Sapriza, H. (2007). Quantitative models of sovereign default and the threat of financial exclusion. *FRB Richmond Economic Quarterly*, **93** (3), 251–286.

—, — and Sosa-Padilla, C. (2016). Debt dilution and sovereign default risk. *Journal of Political Economy*, **124** (5), 1383–1422.

Hébert, B. and Schreger, J. (2017). The costs of sovereign default: Evidence from argentina. *American Economic Review*, **107** (10), 3119–45.

Holmstrom, B. and Tirole, J. (1997). Financial intermediation, loanable funds, and the real sector. *the Quarterly Journal of economics*, **112** (3), 663–691.

Holmström, B. and Tirole, J. (1998). Private and Public Supply of Liquidity. *Journal of Political Economy*, **106** (1), 1–40.

IMF (2002). The Design and Effectiveness of Collective Action Clauses, iMF Working Paper.

Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *American economic review*, **95** (1), 161–182.

Kalemli-Ozcan, S., Reinhart, C. and Rogoff, K. (2016). Sovereign debt and financial crises: Theory and historical evidence. *Journal of the European Economic Association*, **14** (1), 1–6.

Kehoe, T. J. (2007). What can we learn from the 1998-2002 depression in Argentina? *Great depressions of the twentieth century*.

Kiyotaki, N. and Moore, J. (1997). Credit Cycles. *Journal of Political Economy*, **105** (2), 211–248.

— and — (2005). 2002 Lawrence R. Klein Lecture Liquidity and Asset Prices*. *International Economic Review*, **46** (2), 317–349.

Kremer, M. and Mehta, P. (2000). *Globalization and international public finance*. Tech. rep., National Bureau of Economic Research.

Krusell, P. and Smith, A. A., Jr (1998). Income and wealth heterogeneity in the macroeconomy. *Journal of political Economy*, **106** (5), 867–896.

Maggiori, M. (2022). International macroeconomics with imperfect financial markets. *Handbook of International Economics*, **6**, 199–236.

Mallucci, E. (2022). Domestic debt and sovereign defaults. *Journal of Money, Credit and Banking*, **54** (6), 1741–1775.

Mendoza, E. G. and Yue, V. Z. (2012). A General Equilibrium Model of Sovereign Default and Business Cycles. *The Quarterly Journal of Economics*, **127** (2), 889–946.

MENGUS, E. (2018). Honoring sovereign debt or bailing out domestic residents? the limits to bailouts. *Journal of International Economics*, **114**, 14–24.

MORELLI, J. M., OTTONELLO, P. and PEREZ, D. J. (2019). Global banks and systemic debt crises, manuscript.

MORETTI, M. (2021). The asymmetric pass-through of sovereign risk. *Manuscript, New York University*.

NA, S., SCHMITT-GROHÉ, S., URIBE, M. and YUE, V. (2018). The twin ds: Optimal default and devaluation. *American Economic Review*, **108** (7), 1773–1819.

OTTONELLO, P. and PEREZ, D. J. (2018). The Currency Composition of Sovereign Debt, manuscript.

PANIZZA, U., STURZENEGGER, F. and ZETTELMEYER, J. (2009). The economics and law of sovereign debt and default. *Journal of Economic Literature*, **47** (3), 651–98.

PASSADORE, J. and XU, Y. (2018). Illiquidity in Sovereign Debt Markets, manuscript.

REINHART, C. M. and ROGOFF, K. S. (2011). From Financial Crash to Debt Crisis. *The American Economic Review*, **101** (5), 1676–1706.

SANDLERIS, G. and WRIGHT, M. L. (2014). The Costs of Financial Crises: Resource Misallocation, Productivity, and Welfare in the 2001 Argentine Crisis. *The Scandinavian Journal of Economics*, **116** (1), 87–127.

SOSA PADILLA, C. (2018). Sovereign Defaults and Banking Crises, forthcoming at *Journal of Monetary Economics*.

STURZENEGGER, F. and ZETTELMEYER, J. (2008). Haircuts: Estimating Investor Losses in Sovereign Debt Restructurings, 1998–2005. *Journal of International Money and Finance*, **27** (5), 780–805.

URIBE, M. and YUE, V. Z. (2006). Country spreads and emerging countries: Who drives whom? *Journal of international Economics*, **69** (1), 6–36.

WOODFORD, M. (1990). Public Debt as Private Liquidity. *The American Economic Review*, **80** (2), 382–388.

YUE, V. Z. (2010). Sovereign Default and Debt Renegotiation. *Journal of International Economics*, **80** (2), 176–187.

Contents

A. Omitted Proofs and Additional Theoretical Results

A.1. Recursive Representation of Bankers' Problem

The banker's problem admits the following recursive representation which depends on future government policies $(\mathcal{B}'(\mathbf{s}), \mathcal{I}(\mathbf{s}))$ and on the law of motion of the aggregate state $\Gamma(\mathbf{s}', \mathbf{s}, B', \iota)$. Define $\tilde{\mathbf{s}} = (\mathbf{s}, B', \iota)$ the augmented aggregate state and $\tilde{\mathbf{s}}' = (\mathbf{s}', \mathcal{B}'(\mathbf{s}), \mathcal{I}(\mathbf{s})))$ next period's augmented aggregate state given future government policies. Denote $v(n, z; \tilde{\mathbf{s}})$ the value of an individual bank with net worth n, idiosyncratic productivity (for next period) z, in augmented aggregate state $\tilde{\mathbf{s}}$, that solves the bank's problem in recursive form. After knowing his idiosyncratic productivity, a banker faces the following recursive problem

$$v(n, z; \tilde{\mathbf{s}}) = \max_{l' \geq 0, b^{d'} \geq 0, d'} (1 - \sigma)n + \mathbb{E}\big[\Lambda(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')v(n', z'; \tilde{\mathbf{s}}')|\tilde{\mathbf{s}}\big] \tag{A.1}$$

subject to:

$$\sigma n = w(\tilde{\mathbf{s}})l' + q^b(\tilde{\mathbf{s}})b^{d'} + q^d(\tilde{\mathbf{s}})d', \tag{A.2}$$

$$n' = A'zl' + \iota(\tilde{\mathbf{s}}')b^{d'} + d', \tag{A.3}$$

$$q^d(\tilde{\mathbf{s}})d' \geq -\kappa\sigma n. \tag{A.4}$$

A.2. Definition of Competitive Equilibrium

Denote future government policy functions $(\mathcal{B}'(\mathbf{s}), \mathcal{I}(\mathbf{s}))$ and the law of motion of the aggregate state $\Gamma(\mathbf{s}', \mathbf{s}, B', \iota)$, which corresponds to the density function of state $\mathbf{s}'$ conditional on $(\mathbf{s}, B', \iota)$.

***Definition* 1.** *Given the augmented aggregate state $\tilde{\boldsymbol{s}} = (\boldsymbol{s}, B', \iota)$ and future government policies $\{\iota(\boldsymbol{s}), B'(\boldsymbol{s})\}$, a competitive equilibrium are workers' and bankers' consumption $\{C^w(\tilde{\boldsymbol{s}}), C^b(\tilde{\boldsymbol{s}})\}$, banker's allocations $\{l'(n, z; \tilde{\boldsymbol{s}}), b^{d'}(n, z; \tilde{\boldsymbol{s}}), d'(n, z; \tilde{\boldsymbol{s}})\}$ and value functions $v(n, z; \tilde{\boldsymbol{s}})$ for all z, lump-sum taxes $\tau(\tilde{\boldsymbol{s}})$, prices $\{q^d(\tilde{\boldsymbol{s}}), q^b(\tilde{\boldsymbol{s}}), w(\tilde{\boldsymbol{s}})\}$, the distribution of bankers $\mathcal{G}(n, z; \tilde{\boldsymbol{s}})$ and the law of motion of the aggregate state $\Gamma(\boldsymbol{s}', \boldsymbol{s}, B', \iota)$ such that:*

1. *Government policies and taxes satisfy the government budget constraint* (10)

2. *Given taxes and wages workers' consumption is consistent with its budget constraint* (2)

3. *Given prices, bankers' allocations and value functions solve the recursive banker's problem* (A.1)

4. *The labor market and the interbank deposit market clear*

$$\int l'(z,n,\tilde{\mathbf{s}})\mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}}) = 1, \tag{A.5}$$

$$\int d'(z,n,\tilde{\mathbf{s}})\mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}}) = 0 \tag{A.6}$$

5. *The public debt market clears*

for $e = o:$

$$\int b^{d'}(z,n,\tilde{\mathbf{s}})\mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}}) \leq B' \tag{A.7}$$

$$q^b(s,B') \geq \frac{\mathbb{E}\left[\iota(\boldsymbol{s}')|\tilde{\mathbf{s}}\right]}{R} \tag{A.8}$$

$$\left(\int b^{d'}(z,n,\tilde{\mathbf{s}})\mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}}) - B'\right)\left(q^b(s,B') - \frac{\mathbb{E}\left[\iota(\boldsymbol{s}')|\tilde{\mathbf{s}}\right]}{R}\right) = 0 \tag{A.9}$$

for $o = c:$

$$\int b^{d'}(z,n,\tilde{\mathbf{s}})\mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}}) = B' \tag{A.10}$$

6. *The joint distribution of net-worth and productivity evolves according to*

$$\mathcal{G}'(n',z';\tilde{\boldsymbol{s}}') = \iint_{(n,z):n'=\eta(n,z;\tilde{\mathbf{s}},\boldsymbol{s}')} \mathcal{G}(n,z;\tilde{\mathbf{s}})g(z')dndz$$

where $\eta(\cdot)$ *is consistent with the evolution of idiosyncratic net worth given by the banker's allocations and the law of motion of the aggregate state.*

7. *The law of motion of the aggregate state is consistent with current government policies and private allocations, i.e.*

- *e' evolves according to the transition probability*

$$\Pr(e' = o) = \begin{cases} 1 & \textit{if } e = o, \iota = 1 \\ 0 & \textit{if } e = o, \iota = 0 \\ \phi & \textit{if } e = c \end{cases}$$

- *A' evolves according to the conditional density $f(A', A)$*
- *$B^{d'}(\tilde{\boldsymbol{s}}) = \int b'^{b}(z, n, \tilde{\boldsymbol{s}}) \mathrm{d}\mathcal{G}(n, z; \tilde{\boldsymbol{s}})$, $B^{x\prime}(\tilde{\boldsymbol{s}}) = B' - B^{d'}(\tilde{\boldsymbol{s}})$ and the cutoff productivity $\underline{z}'(\tilde{\boldsymbol{s}})$ is given by the minimum productivity of a banker that chooses to invest in his own technology*

A.3. Proof of Proposition 1

We first conjecture that the value function is linear in net worth, i.e. $v(n, z; \tilde{\mathbf{s}}) = \nu(z; \tilde{\mathbf{s}})n$, then solve the portfolio problem of the banks and finally verify our conjecture. Using our conjecture and equation (A.2) to substitute away d' we can re-write the bankers' recursive problem as

$$\nu(z; \tilde{\mathbf{s}})n = \max_{l' \geq 0, b^{d'} \geq 0} (1 - \sigma)n + \mathbb{E}\big[\Lambda(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\nu(z'; \tilde{\mathbf{s}}')n' | \tilde{\mathbf{s}}\big] \tag{A.11}$$

subject to:

$$\begin{aligned} n' &= \left(R^l(z; \tilde{\mathbf{s}}, \tilde{\mathbf{s}}') - R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\right) w(\tilde{\mathbf{s}})l' + \left(R^b(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}') - R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\right) q^b(\tilde{\mathbf{s}})b^{d'} + R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\sigma n \\ (1 + \kappa)\sigma n &\geq w(\tilde{\mathbf{s}})l' + q^b(\tilde{\mathbf{s}})b^{d'} \end{aligned}$$

where $R^l(z; \tilde{\mathbf{s}}, \tilde{\mathbf{s}}') \equiv \frac{A'z}{w(\tilde{\mathbf{s}})}$, $R^b(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}') \equiv \frac{\mathcal{I}(\mathbf{s}')}{q^b(\tilde{\mathbf{s}})}$ and $R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}') \equiv \frac{1}{q^d(\tilde{\mathbf{s}})}$.

Consider the case in which the expected risk-adjusted return on deposits and public debt are the same$q^d(\tilde{\mathbf{s}}) = q^b(\tilde{\mathbf{s}})\frac{\mathbb{E}[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')]}{\mathbb{E}[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\iota(\tilde{\mathbf{s}}')]}$. This is true in equilibrium.

Given the constant returns to scale technology, the solution to the portfolio problem involves corners and depends on z.

- If $z > \underline{z}'(\tilde{\mathbf{s}})$: $\quad w(\tilde{\mathbf{s}})l' = (1 + \kappa)\sigma n \quad q^d(\tilde{\mathbf{s}})d' = -\kappa\sigma n \quad q^b(\tilde{\mathbf{s}})b^{d'} = 0$
- If $z \leq \underline{z}'(\tilde{\mathbf{s}})$: $\quad w(\tilde{\mathbf{s}})l' = 0 \quad q^d(\tilde{\mathbf{s}})d' = x \in [0, \sigma n] \quad q^b(\tilde{\mathbf{s}})b^{d'} = \sigma n - x$

This follows from substituting n' and noting the linearity of the problem on l' and b'.

Now we verify our conjecture of linearity. Substituting the solution to the problem in (A.11) the level of net worth scales away and we obtain a law of motion for the marginal value of one unit of net worth.

- For $z \leq \underline{z}'(\tilde{\mathbf{s}})$:

$$\nu(z;\tilde{\mathbf{s}}) = (1-\sigma) + \sigma\mathbb{E}\left[\Lambda(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\nu(z',\tilde{\mathbf{s}}')R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right]$$

- For $z > \underline{z}'(\tilde{\mathbf{s}})$:

$$\nu(z;\tilde{\mathbf{s}}) = (1-\sigma) + \sigma\mathbb{E}\left[\Lambda(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\nu(z',\tilde{\mathbf{s}}')R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\left[1+(\kappa+1)\left(\frac{R^l(z;\tilde{\mathbf{s}},\tilde{\mathbf{s}}')}{R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')}-1\right)\right]\right]$$

Combining these last two equations and using the definition of $\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')$ yields the last result of the proposition.

A.4. Proof of Proposition 2

The aggregate demand for labor is determined by the amount of resources that high productivity banks can raise in the interbank deposit market which is given by

$$\begin{aligned} w(\tilde{\mathbf{s}})L(\tilde{\mathbf{s}}) &= \int_{z>\underline{z}'(\tilde{\mathbf{s}})} (1+\kappa)\sigma n \mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}}) \\ &= \sigma N(\tilde{\mathbf{s}})(1+\kappa)\left[1-G(\underline{z}'(\tilde{\mathbf{s}}))\right] \end{aligned}$$

where the second equality uses the independence between the net worth with which banks arrive to the period and the level of idiosyncratic productivity. Given that the aggregate supply of labor is normalized to one, and using the market clearing condition, we obtain equation (12).

Now, we show that the price of deposits is given by $q^d(\tilde{\mathbf{s}}) = q^b(\tilde{\mathbf{s}})\frac{\mathbb{E}[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')]}{\mathbb{E}[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\iota(\tilde{\mathbf{s}}')]}$. First, note that market clearing in the interbank market implies that $q^d(\tilde{\mathbf{s}}) \leq q^b(\tilde{\mathbf{s}})\frac{\mathbb{E}[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')]}{\mathbb{E}[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\iota(\tilde{\mathbf{s}}')]}$, or equivalently, $\mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right] \geq \mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')R^b(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right]$. This is shown by contradiction. Suppose $\mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right] < \mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')R^b(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right]$, then any banker, regardless of his productivity, would borrow up to its constraint raising interbank deposits (some of them would use it to invest in their technology, others to buy public debt). This implies that the interbank market for deposits would not clear at that price.

Second, note that if $q^d(\tilde{\mathbf{s}}) < q^b(\tilde{\mathbf{s}})\frac{\mathbb{E}[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')]}{\mathbb{E}[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\iota(\tilde{\mathbf{s}}')]}$, public debt would have a lower risk-adjusted expected return than interbank deposits and no bank would hold public debt, contradicting the equilibrium with positive holdings of public debt.

Next, we prove that the law of motion for the threshold productivity and aggregate level of domestic debt solve (13)-(14) for those states in which the economy is open. Given that the risk-adjusted return of public debt and deposits is the same, the productivity level $\underline{z}'(\tilde{\mathbf{s}})$ that would make a bank indifferent between investing in their own technology and lending to other banker (or buying public debt) must deliver the same risk-adjusted return as the other two options

$$\mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')A'\right]\frac{\underline{z}'(\tilde{\mathbf{s}})}{w(\tilde{\mathbf{s}})} = \mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')R^b(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right]$$

According to proposition 1 the banks with $z < \underline{z}(\tilde{\mathbf{s}})$ are indifferent between buying public debt or lending to other banks. Therefore, the volume of interbank lending is demand-determined and the aggregate demand for public debt is determined residually

$$\begin{aligned} q^b(\tilde{\mathbf{s}})B^{d'}(\tilde{\mathbf{s}}) &= \int_{z\le \underline{z}'(\tilde{\mathbf{s}})} \sigma n \mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}}) - \int_{z>\underline{z}'(\tilde{\mathbf{s}})} \kappa\sigma n \mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}}) \\ &= \sigma N(\tilde{\mathbf{s}})\left[G(\underline{z}'(\tilde{\mathbf{s}}))(1+\kappa)-\kappa\right]. \end{aligned}$$

This is part of an equilibrium if within the bankers that are indifferent between buying public debt and lending to other bankers, there is enough resources to satisfy the demand for interbank lending at that price, or equivalently, if the residual demand for public debt is non-negative. This is true if the following inequality holds

$$G(\underline{z}'(\tilde{\mathbf{s}})) \ge \frac{\kappa}{1+\kappa}.$$

This is the assumption needed to obtain positive holdings of public debt in equilibrium.

Finally, for those states in which the economy is closed the last two equations also hold. The only difference is that (14) pins down the price of public debt, given that the aggregate stock of public debt held by bankers must be the same as the total stock of public debt issued by the government $B' = B^{d'}$.

A.5. Definition of Recursive Equilibrium Given Optimal Government Policies

***Definition* 2.** *A recursive equilibrium is a set of aggregate private allocations* $\{C^w(\tilde{\boldsymbol{s}}), C^b(\tilde{\boldsymbol{s}}), \underline{z}'(\tilde{\boldsymbol{s}}), B^{d'}(\tilde{\boldsymbol{s}})\}$, *prices* $\{q^d(\tilde{\boldsymbol{s}}), q^b(\tilde{\boldsymbol{s}}, B'), w(\tilde{\boldsymbol{s}})\}$, *government policy functions* $\{B'(\boldsymbol{s}), \iota(\boldsymbol{s})\}$ *and future government policy functions* $\{\mathcal{B}'(\boldsymbol{s}), \mathcal{I}(\boldsymbol{s})\}$ *such that:*

1. *Given government policies, aggregate private allocations and prices constitute a competitive equilibrium.*

2. *Given private allocations and future policies, the government policies solve the government problem (17)-(21).*

3. *Optimal government policies coincide with future policies* $\{\mathcal{B}'(\boldsymbol{s}), \mathcal{I}(\boldsymbol{s})\} = \{B'(\boldsymbol{s}), \iota(\boldsymbol{s})\}$.

B. Empirical Analysis

This appendix provides further details and additional results related to the empirical analysis of Section 3. We first describe the data used in the analysis. Second, we perform additional analysis related to the selection of banks into holding public debt. Finally, we carry out an analysis of the dynamics of credit during the Argentinean default of 2001.

B.1. Data Description

The micro-data on individual banks' balance sheet data comes from the Central Bank of Argentina. We collected data on all the balance sheets of financial institutions of Argentina for the period 1999-2010 each year. The dataset contains information on 115 institutions. The panel is unbalanced as the number of operating institutions was significantly reduced after the crisis of 2002. Each balance sheet contains disaggregated information about the assets and liabilities of banks as well as their profits, income and expenditures.

B.2. Robustness Analysis: Selection in Banks' Holdings of Public Debt

According to Corollary 1, a testable prediction is that banks with better investment opportunities choose to have a lower exposure to public debt.[17] This prediction is at the core of the liquidity channel of public debt. In Section 3, we show that the empirical evidence is supportive of this prediction.

In this section, we provide robustness analysis regarding the relationship between measures of banks' performance and exposure to public debt. We focus on measures of banks' performance and exposure to public debt. All variables are measured at book value. We consider two measures of banks' performance: return on assets and return on equity. We compute return on assets as the ratio of annual financial income to financial assets.[18] Return on equity is reported in the balance-sheet information and is measured as the ratio of annual profits to book value of equity. We also consider two measures of banks' exposure to public debt. The first measure is the ratio of loans to the non-financial public sector to total assets

[17] In the model, given the assumption of constant returns-to-scale, the relationship is dichotomic.

[18] We include in financial income the concept of 'other income' since some valuation losses associated to the sovereign default were assigned to this book concept.

(we refer to this measure as PD Exposure 1). The second measure is the ratio of the sum of loans to the non-financial public sector and public and private securities to total assets (we refer to this measure as PD Exposure 2). Both measures are complementary to each other. The first measure is more conservative, as it includes only loans to the public sector. The second is more comprehensive as it also includes securities. It also includes private securities given that the available data consolidates public and private securities together. However, this is less of a concern given that the public securities represent more than two thirds of the total securities traded domestically.

We estimate a set of regressions of measures of banks' performance on measures of exposure to public debt. We estimate two specifications: one which uses cross-sectional data by averaging individual banks' variables over time and one that uses the panel data without averaging over time.

Results are shown in Table B.1. Columns 1 and 2 show the estimates of a linear regression of bank's average return on assets on the first and second measure of exposure to public debt, respectively. Both specifications show a negative relationship between banks' performance and exposure to public debt that is statistically significant at the 5% level. Columns 3 and 4 show the same set of regressions as in the first two columns but adding the standard deviation of the time series of bank returns as an additional control variable. The motivation for adding this variable is to control for a potential relationship between average returns and risk. We find that the relationship between average returns and exposure to public debt is still negative in both specifications and significant at the 1% when the regressors is the second measure of exposure to public debt. Finally, columns 5 and 6 estimate the baseline regression with average returns computed excluding the default period of 2002-05. The motivation is to avoid any mechanic effect that may come from lower returns on larger holdings of public debt due to the default. Point estimates under these specifications are similar to those from the baseline specification.

We also estimate the baseline regression using panel data, instead of averaging variables across time for every bank. These specifications include year- and bank- fixed effects. We first use returns on equity as a measure of banks' performance. Results, reported in the first two columns of Table B.2, indicate a negative statistically significant relationship between banks' returns on equity and exposure to public debt. Columns 3 and 4 show the estimates

Table B.1: Cross Sectional Regressions: Banks' Returns & Exposure to Public Debt

	(1) RoA	(2) RoA	(3) RoA	(4) RoA	(5) RoA	(6) RoA
PD Exposure 1	-0.210**		-0.222**		-0.254***	
	(0.084)		(0.085)		(0.095)	
PD Exposure 2		-0.124**		-0.131***		-0.104**
		(0.048)		(0.049)		(0.045)
N	76	76	76	76	72	72
Specification	Baseline	Baseline	Cont: σ_RoA	Cont: σ_RoA	Exc. 2002-05	Exc. 2002-05

Notes: The dependent variable is the return on financial assets. The regressor is the ratio of claims to public sector to assets (PD Exposure 1) in odd columns and the ratio of the sum of loans to the non-financial public sector and public and private securities to assets (PD Exposure 2) in even columns. Columns (1)-(2) estimates the baseline specification with public debt exposure as independent variable. Columns (3)-(4) also include the standard deviation (across time) of return on assets as an additional control. Columns (5)-(6) estimates the baseline regression with average returns computed excluding the 2002-05 period. The estimation method used in all columns is OLS. Robust standard errors are in parentheses. $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

of the same regression with returns on assets as the dependent variable. In this case, the estimated coefficient losses significance.

Table B.2: Panel Regressions: Banks' Performance and Exposure to Public Debt

	(1) RoE	(2) RoE	(3) RoA	(4) RoA	(5) Δ Cred	(6) Δ Cred	(7) Leverage	(8) Leverage
PD Exposure 1	-1.048***		0.003		-1.404***		-8.788*	
	(0.332)		(0.093)		(0.462)		(4.596)	
PD Exposure 2		-0.388**		-0.057		-0.824***		-4.127
		(0.161)		(0.039)		(0.238)		(2.577)
N	496	495	500	499	407	406	496	495
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The dependent variable is the return on equity in columns (1)-(2), the return on financial assets in columns (3)-(4), the annual growth rate in credit to the private sector in columns (5)-(6), and leverage (defined as the ratio of assets to net worth) in columns (7)-(8). The regressor is the ratio of claims to public sector to assets (PD Exposure 1) in odd columns and the ratio of the sum of loans to the non-financial public sector and public and private securities to assets (PD Exposure 2) in even columns. The estimation method used in all columns is OLS. "Year FE" and "Bank FE" are year and bank dummy variables, respectively. Robust standard errors are in parentheses. $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

Another prediction of Corollary 1 is that banks with higher exposure to public debt should invest less in their productive projects. Columns 5 and 6 of Table B.2 estimates a panel regression where the dependent variable is the growth rate of credit to the private sector, which proxies banks' investment in their productive projects, on banks exposure to public debt. These regressions estimate a negative and statistically significant relationship between these variables, when we use both measure of exposure to public debt.

Finally, another prediction of the model is that banks with higher exposures to public debt choose lower leverage. We test this prediction by estimating a similar regression with leverage as the dependent variable. Consistent with the theory, the estimated coefficients are negative (see last two columns of Table B.2).

B.3. Bank Credit Dynamics During the 2001 Default

In this section, we study the heterogeneous dynamics of bank credit during the 2001 default. One prediction of the theory is that following a default, banks with low productivity enter production by investing in their projects. We test this prediction by analyzing whether banks with less attractive investment opportunities invest relatively more following a default. First, we identify banks with different investment opportunities through their average returns obtained pre-default.[19] We then analyze the differential growth rate in private credit after the default, by estimating

$$\Delta \text{Credit}_{i,t+h} = \alpha_h + \beta_h X_i + \epsilon_{ih}, \tag{B.1}$$

where i is a bank, t is the year before the default (2000), $h = 1, 2, 3$ is the number of years after t and X_i to measures of bank returns pre-default (either average return on equity or on assets for the period 1999-00). We estimate Jordà's 2005 local projections by estimating (B.1) each time for different h. Table B.3 reports the estimates of β_h. The estimates are negative and significant when regressed on pre-default returns on equity. These results suggest that banks with better productive opportunities decrease their credit relatively more following the default episode. When regressed on pre-default returns on assets, the estimate of β_h is negative and significant only in the first year.

[19] Since idiosyncratic returns are persistent in the data, pre-default returns are a good indicator of idiosyncratic investment opportunities, with higher-return banks being more likely to face better investment opportunities.

Table B.3: Regressions on Default Episode: Credit Growth and Ex-Ante Returns

	(1)	(2)	(3)	(4)	(5)	(6)
	Δ Cr 00-01	Δ Cr 00-02	Δ Cr 00-03	Δ Cr 00-01	Δ Cr 00-02	Δ Cr 00-03
RoE 1999-00	-1.076***	-0.731**	-0.925**			
	(0.256)	(0.342)	(0.388)			
RoA 1999-00				-2.952**	-1.349	0.876
				(1.318)	(1.640)	(1.906)
N	67	57	56	67	57	56

Notes: The dependent variable is the growth rate in credit to the private sector from 2000 to different years (2001-03). The independent variable is the average return on equity during 1999-2000 in the first three columns, and the average return on assets during 1999-2000 in the last three columns. The estimation method used in all columns is OLS. Standard errors are in parentheses. $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

C. Quantitative Analysis

C.1. Numerical Solution

C.1.1. De-trending of the Banker and Government Problem

First, we derive the de-trended recursive banker's problem and then the government problem. The state variables for the banks problem are given by $(n, z; A_{-1}, g, \underline{z}, B^d, B^x)$.[20] The banker's problem is given by

$$v(n_0, z_0; A_{-1}, g_0, \underline{z}_0, B_0^d, B_0^x) = \max_{\{n_t, l_t, b_t^d, d_t\}_{s=1}^{\infty}} \mathbb{E}_0 \sum_{t=1}^{\infty} (1-\sigma)\Lambda_{0,t} n_t, \tag{C1}$$

subject to

$$n_t = \prod_{s=0}^{t} R_s^d n_0 + \sum_{s=1}^{t} \prod_{u=s}^{t-1} R_u^d \left[\left(R_s^l - R_s^d\right) w_{s-1} l_s + \left(R_s^b - R_s^d\right) q_{s-1}^b b_s^d \right], \tag{C2}$$

$$q_t^b b_{t+1} \geq \kappa \sigma n_t, \tag{C3}$$

$$b_{t+1}^d \geq 0. \tag{C4}$$

Equation (C2) is obtained by iterating over the definition of net worth. Now, we argue that the constraint set of this maximization problem is homogeneous of degree one in $(n; A_{-1}, B^d, B^x)$. Consider a new initial state given by $(\alpha n, z; \alpha A_{-1}, g, \underline{z}, \alpha B^d, \alpha B^x)$ with $\alpha > 0$. Conjecture that new wages are given by αw_t and that q_t^d, q_t^b are not affected by the change in state. Then, given the balance-sheet constraints, it follows that if $\{n_t, l_t, b_t^d, d_t\}_{s=1}^{\infty}$ is feasible under the initial state, then $\{\alpha n_t, l_t, \alpha b_t^d, \alpha d_t\}_{s=1}^{\infty}$ is feasible under the new initial state $(\alpha n, z; \alpha A_{-1}, g, \underline{z}, \alpha B^d, \alpha B^x)$ with $\alpha > 0$. Given that the objective function is homogeneous of degree one on n_t, it follows that $v(\alpha n, z; \alpha A_{-1}, g, \underline{z}, \alpha B^d, \alpha B^x) = \alpha v(n_0, z_0; A_{-1}, g_0, \underline{z}_0, B_0^d, B_0^x)$.

Now consider the recursive problem of the banker. Consider $\alpha_t = (A_{t-1}\mu_g)^{-1}$ and denote $\hat{x} = (A_{t-1}\mu_g)^{-1} x$ the de-trended version of variable x, and $\hat{\mathbf{s}} = (g, \underline{z}, \hat{B}^d, \hat{B}^x)$. The normalization results in an aggregate productivity level with unconditional average of one.

[20] To simplify notation, we consider private allocations to depend only on the aggregate state. This already assumes that private allocations correspond to a recursive equilibrium in which government policies are optimal and depend on the aggregate state $\mathbf{s}$.

Conjecture that the price of debt is homogeneous of degree zero, i.e., $q^b(\hat{\mathbf{s}}) = q^b(\mathbf{s})$. Then, using the definition of the stochastic discount factor it can be shown that

$$\Lambda(\hat{\mathbf{s}}, \hat{\mathbf{s}}') = \Lambda(\mathbf{s}, \mathbf{s}') \exp(g)^{-\gamma}. \tag{C5}$$

Using the homogeneity of the bank's value function, we can obtain the de-trended bank's recursive problem

$$\begin{aligned} v(\hat{n}, z; \hat{\mathbf{s}}) &= (A_{-1}\mu_g)^{-1} v(n, z; \mathbf{s}) \\ &= (A_{-1}\mu_g)^{-1} \max_{l' \geq 0, b^{d\prime} \geq 0, d' \geq -\kappa n/q^d} (1-\sigma)n + \mathbb{E}\big[\Lambda(\mathbf{s}, \mathbf{s}') \left(\sigma v(n', z'; \mathbf{s}')\right) |\mathbf{s}\big] \\ &= \max_{l' \geq 0, \hat{b}^{d\prime} \geq 0, \hat{d}' \geq -\kappa \hat{n}/q^d} (1-\sigma)\hat{n} + \mathbb{E}\big[\Lambda(\mathbf{s}, \mathbf{s}') \exp(g) \left(\sigma v(\hat{n}', z'; \hat{\mathbf{s}}')\right) |\mathbf{s}\big] \\ &= \max_{l' \geq 0, \hat{b}^{d\prime} \geq 0, \hat{d}' \geq -\kappa \hat{n}/q^d} (1-\sigma)\hat{n} + \mathbb{E}\big[\Lambda(\hat{\mathbf{s}}, \hat{\mathbf{s}}') \exp(g)^{1-\gamma} \left(\sigma v(\hat{n}', z'; \hat{\mathbf{s}}')\right) |\mathbf{s}\big], \end{aligned} \tag{C6}$$

where in the third equality we use the definition of $\hat{n}'$ and the homogeneity of degree one of the value function, and in the third equality we use equation (C5).

Now, we derive the de-trended recursive problem for the government. Denote $\Phi(\mathbf{s}_t)$ the budget set of associated to the government problem. Using a similar argument, it can be shown that if $(\iota_t, C_t, \underline{z}_{t+1}, B^d_{t+1}, B^x_{t+1}) \in \Phi(\mathbf{s}_t)$ then $(\iota_t, \hat{C}_t, \underline{z}_{t+1}, \hat{B}^d_{t+1}, \hat{B}^x_{t+1}) \in \Phi(\hat{\mathbf{s}}_t)$. Then using homogeneity of degree $1-\gamma$ of the utility function, we can write the recursive problem of the government as

$$W^o(g, \underline{z}, \hat{B}^d, \hat{B}^x) = \max_{\iota \in \{0,1\}} \iota W^{or}(g, \underline{z}, \hat{B}^d, \hat{B}^x) + (1-\iota) W^{od}(g, \underline{z}), \tag{C7}$$

$$W^c(g, \underline{z}, \hat{B}^d) = \max_{\iota \in \{0,1\}} \iota W^{cr}(g, \underline{z}, \hat{B}^d) + (1-\iota) W^{cd}(g, \underline{z}). \tag{C8}$$

The value of repaying in the open economy is

$$W^{or}(g, \underline{z}, \hat{B}^d, \hat{B}^x) = \max_{\hat{B}'} \alpha u(\hat{C}^w) + (1-\alpha) u(\hat{C}^b) + \beta \exp(g)^{1-\gamma} \mathbb{E}\left[W^o(g', \underline{z}', \hat{B}^{d\prime}, \hat{B}^{x\prime}) |\hat{\mathbf{s}}\right], \tag{C9}$$

subject to

$$
\begin{aligned}
\hat{C}^w &= \sigma \frac{\exp(g)}{\mu_g} \mathbb{E}\left[z | z > \underline{z}\right] - (1-\sigma)\hat{B}^d - \hat{B}^x + q^b(\hat{\mathbf{s}}, \hat{B}^{x'})\hat{B}^{x'}, \\
\hat{C}^b &= (1-\sigma) \frac{\exp(g)}{\mu_g} \mathbb{E}\left[z | z > \underline{z}\right] + (1-\sigma)\hat{B}^d, \\
\underline{z}' &= \underline{z}'\left(\hat{\mathbf{s}}, o; \hat{B}', 1\right), \\
\hat{B}^{d'} &= B^{d'}\left(\hat{\mathbf{s}}, o; \hat{B}', 1\right), \\
\hat{B}^{x'} &= \max\{\hat{B}' - \hat{B}^{d'}, 0\}.
\end{aligned}
$$

The value of repaying in the closed economy is

$$
\begin{aligned}
W^{cr}(g, \underline{z}, \hat{B}^d) = \max_{\hat{B}^{d'}} \alpha u(\hat{C}^w) + (1-\alpha) u(\hat{C}^b) \\
+ \beta \exp(g)^{1-\gamma} \mathbb{E}\left[\phi W^o(g', \underline{z}', \hat{B}^{d'}, 0) + (1-\phi) W^c(g', \underline{z}', \hat{B}^{d'})\right],
\end{aligned}
\tag{C10}
$$

where

$$
\begin{aligned}
\hat{C}^w &= \sigma \frac{\exp(g)}{\mu_g} \mathbb{E}\left[z | z > \underline{z}\right] - (1-\sigma)\hat{B}^d, \\
\hat{C}^b &= (1-\sigma) \frac{\exp(g)}{\mu_g} \mathbb{E}\left[z | z > \underline{z}\right] + (1-\sigma)\hat{B}^d, \\
\underline{z}' &= \underline{z}'\left(\hat{\mathbf{s}}, c; \hat{B}^{d'}, 1\right).
\end{aligned}
$$

Finally, the value of defaulting on debt when the economy is open and closed are given by

$$
W^{od}(g, \underline{z}) = W^{cr}(g, \underline{z}, 0) - \delta + \epsilon_o, \tag{C11}
$$

$$
W^{cd}(g, \underline{z}) = W^{cr}(g, \underline{z}, 0) + \epsilon_c, \tag{C12}
$$

C.1.2. Numerical Algorithm

Denote $\hat{x} = \frac{x}{A_{-1}\mu_g}$ the de-trended version of variable x. Let $\hat{\mathbf{s}} = (\hat{\mathbf{s}}, e)$ denote the de-trended aggregate state, where $\hat{\mathbf{s}} = \left(g, \underline{z}, \hat{B}^d, \hat{B}^x\right)$. First, we solve for the set of competitive equilibrium given any *current* government policies $\left\{\hat{B}', \iota\right\}$, *expected* government policies

$\left\{\hat{\mathcal{B}}'(\hat{\mathbf{s}}), \mathcal{I}(\hat{\mathbf{s}})\right\}$ and associated functions of expected bankers' consumption and price of public debt $\left\{\hat{\mathcal{C}}^b(\hat{\mathbf{s}}), q^b(\hat{\mathbf{s}}, \hat{B}^{x'})\right\}$. For those states in which the economy is open $(e = o)$, the government debt policy is $\hat{B}' = \hat{B}^{x'} + \hat{B}^{d'}(\hat{\mathbf{s}})$ so there is no loss of generality to consider the policy as the choice of $\hat{B}^{x'}$. For those states in which economy is closed $(e = c)$, the government debt policy is $\hat{B}' = \hat{B}^{d'}(\hat{\mathbf{s}})$ so there is no loss of generality to consider the policy as the choice of $\hat{B}^{d'}$.

For those states in which the economy is open, finding the competitive equilibrium implies solving for equilibrium functions $\left\{\underline{z}'(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota), \hat{B}^{d'}(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota), \hat{N}(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota), \nu(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota)\right\}$, using the following set of equations

$$\underline{z}'(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota) = \left[(\kappa+1)\sigma\hat{N}\frac{\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\frac{\mathcal{I}(\hat{\mathbf{s}}')}{q^b(\hat{\mathbf{s}}, \hat{B}^{x'})}\right]}{\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\exp(g')\right]}\right]^{\frac{1}{1+\lambda}} \tag{C13}$$

$$q^b(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota)\hat{B}^{d'}(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota) = \sigma\hat{N}\left((1-\underline{z}^{-\lambda})(1+\kappa) - \kappa\right) \tag{C14}$$

$$\hat{N}(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota) = \left(\frac{\exp(g)}{\mu_g}\frac{\lambda\underline{z}}{\lambda-1} + \iota\hat{B}^d\right) \tag{C15}$$

$$\nu(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota) = (1-\sigma) + \sigma\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\frac{\mathcal{I}(\hat{\mathbf{s}}')}{q^b(\hat{\mathbf{s}}, \hat{B}^{x'})}\left[1 + \frac{(\kappa+1)}{\lambda-1}\underline{z}'(\hat{\mathbf{s}})^{-\lambda}\right]\right] \tag{C16}$$

where

$$\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}') = \beta\exp(g)^{1-\gamma}\left(\frac{\hat{\mathcal{C}}^b(\hat{\mathbf{s}}')}{\hat{C}^b(\hat{\mathbf{s}})}\right)^{-\gamma}\nu(\hat{\mathbf{s}}'). \tag{C17}$$

For those states in which the economy is closed $(e = c)$ the level of domestic public debt is chosen by the government, and the cutoff productivity solves the following non-linear equation

$$\underline{z}'(\hat{\mathbf{s}}; \hat{B}^{b'}, \iota)^{-(1+\lambda)}(\kappa+1)\frac{\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\mathcal{I}(\hat{\mathbf{s}}')\right]}{\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\exp(g)'\right]} = \frac{\left(\left(1-\underline{z}'(\hat{\mathbf{s}}; \hat{B}^{b'}, \iota)^{-\lambda}\right)(1+\kappa) - \kappa\right)}{B^{b'}}. \tag{C18}$$

Note that we have used the functional forms used in the calibration to substitute for $u(\cdot), G(\cdot)$ and we have also used the case of $\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')R^d(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\right] = \mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')R^b(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\right]$. Additionally, equation (C16) comes from solving the expectation over z' in equation (11).

The algorithm to solve for the competitive equilibrium given expected and current government policies follows these steps:

1. Generate a discrete grid for variable x state space $G_x = x_1, x_2, ...x_{N_x}$, for $x = g, \underline{z}, \hat{B}^d, \hat{B}^x$. The total aggregate state space is given by $\mathcal{S} = G_g \times G_{\underline{z}} \times G_{\hat{B}^d} \times G_{\hat{B}^x} \times \{o, e\}$.

2. Feed in some expected government policies $\left\{\hat{\mathcal{B}}^{x'}(\hat{\mathbf{s}}), \mathcal{I}(\hat{\mathbf{s}})\right\}$ for states in which $e = o$, and $\left\{\hat{\mathcal{B}}^{d'}(\hat{\mathbf{s}}), \mathcal{I}(\hat{\mathbf{s}})\right\}$ for states in which $e = c$.

3. For states in which $e = o$, conjecture functional forms $\mathcal{E}_1^o(\mathbf{s}, B^{x\prime}, \iota)$ and $\mathcal{E}_2^o(\mathbf{s}, B^{x\prime}, \iota)$ for all $(\mathbf{s}, B^{x\prime}, \iota) \in \mathcal{S} \times G_{\hat{B}^x} \times \{0, 1\}$, that will be guesses for $\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\frac{\mathcal{I}(\hat{\mathbf{s}}')}{q^b(\hat{\mathbf{s}}, \hat{B}^{x\prime})}\right]$ and $\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\exp(g')\right]$, respectively. For states in which $e = c$, conjecture functional forms $\mathcal{E}_1^c(\mathbf{s}, B^{d\prime}, \iota)$ and $\mathcal{E}_2^c(\mathbf{s}, B^{d\prime}, \iota)$ for all $(\mathbf{s}, B^{d\prime}, \iota) \in \mathcal{S} \times G_{\hat{B}^d} \times \{0, 1\}$, that will be guesses for $\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\mathcal{I}(\hat{\mathbf{s}}')\right]$ and $\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\exp(g')\right]$, respectively.

4. Solve for $\left\{\underline{z}'(\hat{\mathbf{s}}), \hat{B}^{d'}(\hat{\mathbf{s}}), \hat{N}(\hat{\mathbf{s}}), \nu(\hat{\mathbf{s}})\right\}$ using (C13)-(C18). For states in which $e = o$, check whether $\hat{B}^{d'}(\hat{\mathbf{s}}) \geq 0$ in every grid point (this ensures that we are under the equilibrium in which $q^d(\hat{\mathbf{s}}) = q^b(\hat{\mathbf{s}})\frac{\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\right]}{\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\iota(\hat{\mathbf{s}}')\right]}$).

5. Compute $\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\frac{\mathcal{I}(\hat{\mathbf{s}}')}{q^b(\hat{\mathbf{s}}, \hat{B}^{x\prime})}\right]$,$\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\mathcal{I}(\hat{\mathbf{s}}')\right]$ and $\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\exp(g')\right]$ using quadrature methods for computing expectations. For evaluation of the functions outside grid points we use piecewise linear interpolation.

6. If $\sup_{\mathbf{s}, B^{x\prime}, \iota}\left\|\mathcal{E}_1^o(\mathbf{s}, B^{x\prime}, \iota) - \mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\frac{\mathcal{I}(\hat{\mathbf{s}}')}{q^b(\hat{\mathbf{s}}, \hat{B}^{x\prime})}\right]\right\| < \epsilon$, $\sup_{\mathbf{s}, B^{x\prime}, \iota}\left\|\mathcal{E}_2^o(\mathbf{s}, B^{x\prime}, \iota) - \mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\exp(g')\right]\right\| < \epsilon$, $\sup_{\mathbf{s}, B^{d\prime}, \iota}\left\|\mathcal{E}_1^c(\mathbf{s}, B^{d\prime}, \iota) - \mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\mathcal{I}(\hat{\mathbf{s}}')\right]\right\| < \epsilon$, $\sup_{\mathbf{s}, B^{d\prime}, \iota}\left\|\mathcal{E}_2^c(\mathbf{s}, B^{d\prime}, \iota) - \mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\exp(g')\right]\right\| < \epsilon$ then the conjecture is an competitive equilibrium. If not, update (using some dampening) and start again from step two until convergence.

Given the set of competitive equilibria, the second part of the algorithm solves for the government problem, given its time inconsistency problem. We solve the recursive equilibrium by solving a fixed point between the expected government policies and the optimal one-period deviation policies that solve government problem (C7)-(C10) in its de-trended recursive representation.

The algorithm to solve for the recursive equilibrium follows these steps:[21]

1. For states in which $e = o$, conjecture expected policies $\left\{\hat{\mathcal{B}}^{x'}(\hat{\mathbf{s}}), \mathcal{I}(\hat{\mathbf{s}})\right\}$ and a price schedule for public debt $q^b(\hat{\mathbf{s}}, \hat{B}^{x'})$ for any $\hat{\mathbf{s}}$ in the previously defined state space $\mathcal{S}$. For states in which $e = c$, conjecture $\left\{\hat{\mathcal{B}}^{d'}(\hat{\mathbf{s}}), \mathcal{I}(\hat{\mathbf{s}})\right\}$.

2. Solve for the set of competitive equilibria given any possible current government policy and the conjectured expected government policy. This is done using the first part of the algorithm.

3. Solve for the recursive government problem (C7) - (C12). The problem is solved using value function iteration. The choice of external debt in the maximization problem is done over a finer grid to improve accuracy.

4. Compute $q^b(\mathbf{s}, \hat{B}^{x'}) = \mathbb{E}\left[\iota(\hat{\mathbf{s}}')|\hat{\mathbf{s}}\right]/R$ using quadrature methods.

5. If $\sup_{\mathbf{s}} \|\mathcal{X}(\mathbf{s}) - X(\mathbf{s})\| < \epsilon$ for $X = B^{x'}, q^b, B^{d'}$ (where $\mathcal{X}$ refers to the expected version of X) then stop. Otherwise update conjectures of expected policies and price of debt (using some dampening parameter) and start from the first step.

C.2. Data Used for Calibration

Below we denote the data sources for the macroeconomic variables used in the calibration:

- Output, consumption, exports and imports: These data are obtained from the Latin Macro Watch Dataset from the IDB. The data are at the quarterly frequency and seasonally adjusted.

- External public debt: These data are obtained from the Latin Macro Watch Dataset from the IDB. The data are at the quarterly frequency and expressed as % of annual GDP. We then express it as a fraction of quarterly GDP by multiplying it times four, to maket it comparable with the model.

[21] While we do not analytically show uniqueness of the equilibrium, the numerical solution always converge to the same solution for different initial guesses. See Bocola and Dovis (2016) for a quantitative analysis of a sovereign default model with multiple equilibrium.

- Banks' holdings of public debt: These data are obtained from Central Bank of Argentina. Its frequency is quarterly. We then express it as a fraction of quarterly GDP to maket it comparable with the model. We refer to this in the model as domestic public debt.

- Sovereign spreads: These data come from Datastream and correspond to the EMBI+ spread. Its frequency is daily and we take the quarterly average to compare it with the model.

- Banks' returns: These data are obtained from the micro data on banks. See Appendix B for further details.

The moments from the data were computed for the sample period 1994-2012, excluding the period 2002-2005 in which the Argentinean government was excluded from financial markets. We de-trend output and consumption data using an HP filter. The data expressed as a share of GDP is not detrended. Banks' returns and sovereign spreads data are not detrended.

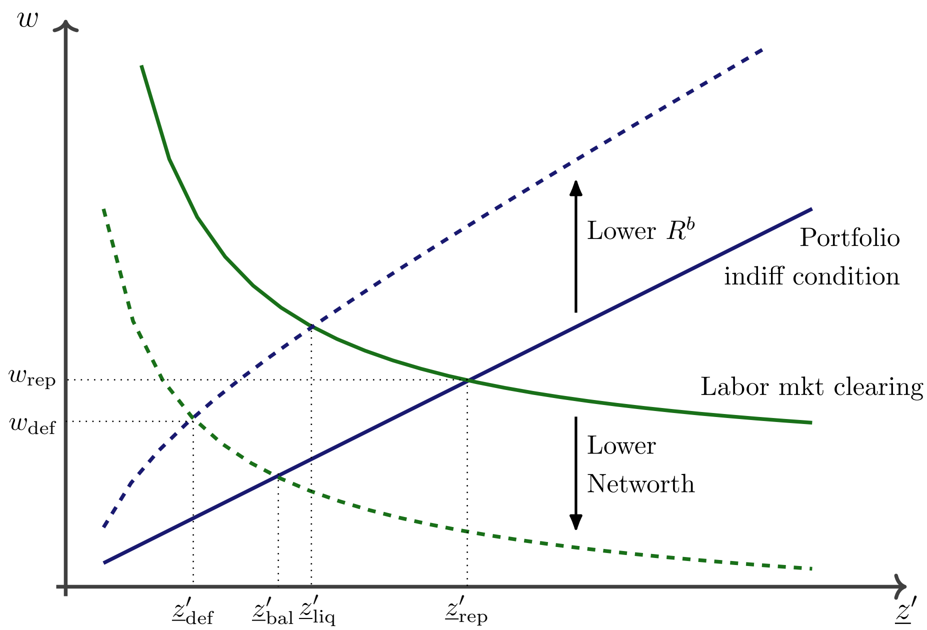
C.3. Additional Quantitative Results

This section provides further details on the counterfactual exercises from Section 4 and additional quantitative results.

Output costs of default. To quantify the output costs of default, we start from the average state in the ergodic distribution and compute the dynamics of output if the government chooses to repay (in this and the following periods) and under no further innovations to the aggregate productivity shock. We then compare them to the dynamics of output if the government chooses to default. Because the dynamics of output following a default depend on the realization of other shocks (i.e., when the economy reverts to being open and on the disutility costs of defaulting in the closed economy), we simulate various paths and compare the dynamics of output under repayment to the average path of output under default.

In addition, we use our model to disentangle the roles of the *balance-sheet channel* and the *liquidity channel*. Consider an open economy. If the government decides to *repay*, the

Figure C1: Characterization of Liquidity and Balance-Sheet Channels



*N*otes: This figure illustrates the equilibrium determination of wages and the cutoff productivity using equations (12) and (13). It also shows how the liquidity and balance-sheet effects are computed.

equilibrium is characterized by:

$$\underline{z}' = \frac{\mathbb{E}[\nu^e \iota']}{q^b} \cdot \frac{1}{\mathbb{E}[\nu^e A']} w, \tag{C19}$$

$$q^b = \frac{\mathbb{E}[\nu^e \iota']}{R}, \tag{C20}$$

$$w = (\kappa + 1)\sigma \left[A_t \frac{\lambda}{\lambda - 1} \, \underline{z} + \iota_t B_t^d \right] \left[1 - G(\underline{z}')\right]. \tag{C21}$$

If the government decides to *default*, the equilibrium is instead given by:

$$\underline{z}' = \frac{\mathbb{E}[\nu^e \iota']}{q^b} \cdot \frac{1}{\mathbb{E}[\nu^e A']} w, \tag{C22}$$

$$q^b = \frac{\sigma \left[A_t \frac{\lambda}{\lambda - 1} \, \underline{z} \right] (G(\underline{z}')(1 + \kappa) - \kappa)}{B^{b\prime}}, \tag{C23}$$

$$w = (\kappa + 1)\sigma \left[A_t \frac{\lambda}{\lambda - 1} \, \underline{z} \right] \left[1 - G(\underline{z}')\right]. \tag{C24}$$

To isolate the balance-sheet channel, we compute a counterfactual equilibrium where banks still suffer balance sheet losses—which in turn affect the wage—but the return on debt is the same as under repayment. The balance-sheet effect is then computed as follows:

$$\underline{z}'_{bal} = \frac{\mathbb{E}[\nu^e \iota']}{q^b_{bal}} \cdot \frac{1}{\mathbb{E}[\nu^e A']} w_{bal}, \tag{C25}$$

$$q^b_{bal} = \frac{\mathbb{E}[\nu^e \iota']}{R}, \tag{C26}$$

$$w_{bal} = (\kappa + 1)\sigma \left[A_t \frac{\lambda}{\lambda - 1} \underline{z}\right] \left[1 - G(\underline{z}'_{bal})\right]. \tag{C27}$$

Graphically, this corresponds to the intersection of the blue solid line and the green dotted line in Figure C1.

To isolate the liquidity channel, we compute a counterfactual equilibrium where the labor demand is the same as if the economy had not defaulted, but the return on public debt is computed under default. The liquidity effect is then computed as follows:

$$\underline{z}'_{liq} = \frac{\mathbb{E}[\nu^e \iota']}{q^b_{liq}} \cdot \frac{1}{\mathbb{E}[\nu^e A']} w_{liq}, \tag{C28}$$

$$q^b_{liq} = \frac{\sigma \left[A_t \frac{\lambda}{\lambda-1} \underline{z}\right] \left(G(\underline{z}'_{liq})(1+\kappa) - \kappa\right)}{B^{b\prime}}, \tag{C29}$$

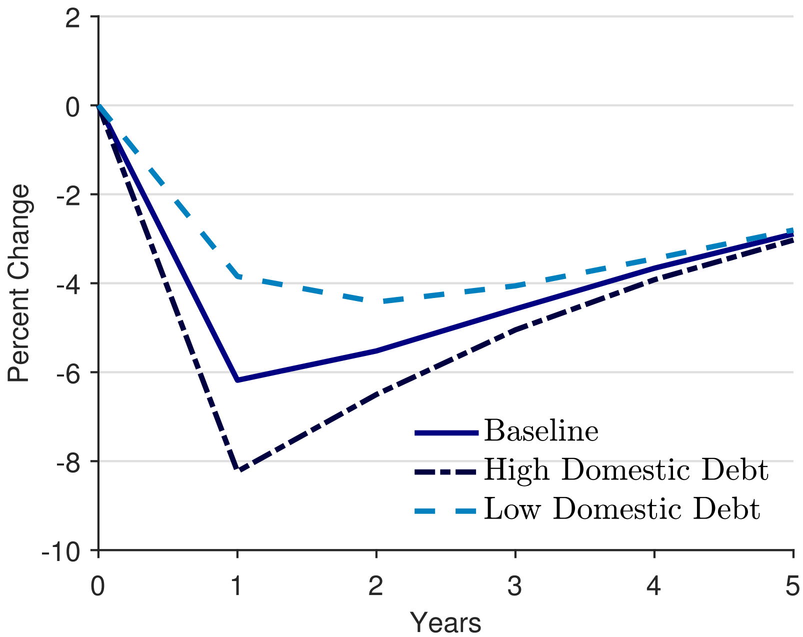
$$w_{liq} = (\kappa + 1)\sigma \left[A_t \frac{\lambda}{\lambda - 1} \underline{z} + \iota_t B^d_t\right] \left[1 - G(\underline{z}'_{liq})\right]. \tag{C30}$$

Graphically, this corresponds to the intersection of the blue dotted line and the green solid line in Figure C1.

Figure C2 shows the output cost of default for different initial levels of banks' holdings of public debt. The output costs of default are deeper when banks' exposure to public debt is larger. Figure C3 shows that the relevance of the balance-sheet effect in the output costs of default increases with the banks' exposure to public debt.

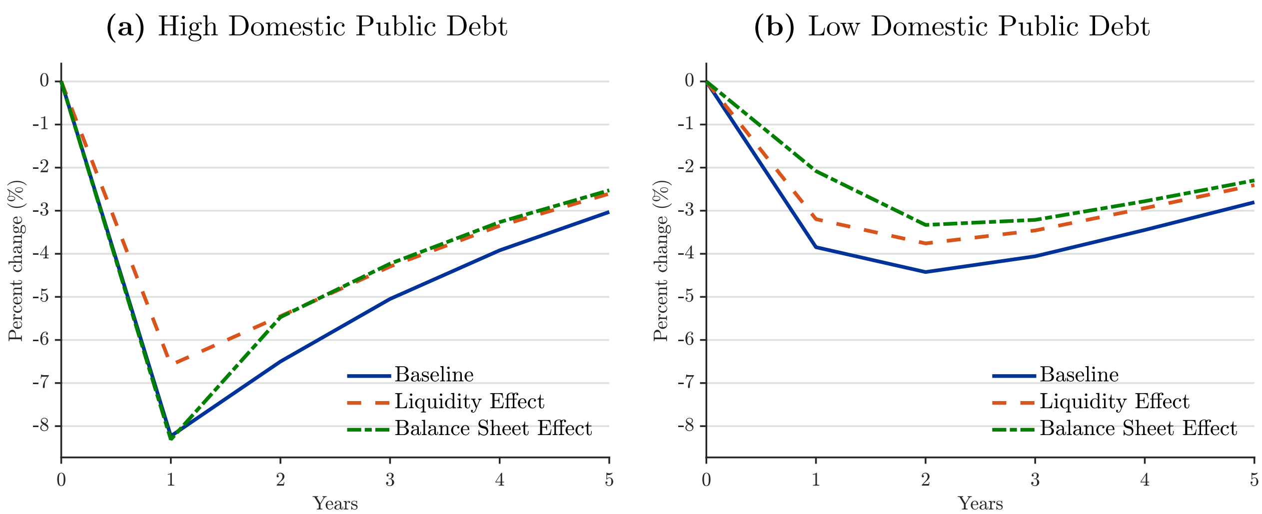
External debt sustainability. We assess how much external debt can be sustained because of the output cost of default by solving a counterfactual model that does not feature output costs of default. In this model, the laws of motion of $\left(\underline{z}, B^{b\prime}\right)$ are the same as in the open economy, which imply that output is not affected by a default decision. All other features of the model remain the same as in the baseline model.

Figure C2: Output Costs of Default: The Role of Domestic Public Debt



Notes: This figure shows the average percent difference of the evolution of output under a default and its evolution under a repayment decision starting from three different initial levels of domestic public debt: the average level in the simulations, 0.5 times the average, and 1.5 times the average.

Figure C3: Balance-sheet and Liquidity Effects: The Role of Domestic Public Debt



Notes: This figure illustrates the evolution of output following a default for different initial levels of domestic public debt, disentangling the liquidity and balance-sheet channels. Panel (a) corresponds to an initial debt level equal to 1.5 times the average, while Panel (b) corresponds to 0.5 times the average. The solid blue line shows the average percent difference in output between default and repayment. The dashed orange line shows the corresponding difference when banks net worth is assumed to be unaffected by default, isolating the liquidity channel. The dash-dotted green line shows the difference when the return on public debt is held constant at its pre-default level, isolating the balance-sheet channel.

Macroeconomic dynamics around a default. Figure C4 reports the dynamics of various macroeconomic variables around a default episode. These dynamics are obtained by simulating various paths for the economy, each lasting a sufficiently long time period. For each path, we identify episodes where the government defaults while the economy is open. We then construct 12-quarter event windows centered on the default event. Finally, we take averages across default episodes and across time paths for various macroeconomic variables.

The role of exclusion from financial markets. Figure C5 shows the on-impact output costs of default and the average equilibrium level of external debt debt in different model parameterizations that vary in the probability of re-entering international financial markets following a default.

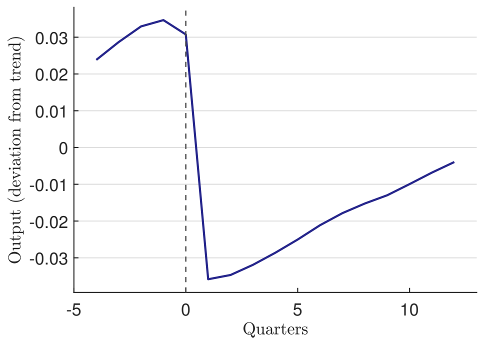
C.4. Sensitivity Analysis

This section analyzes the sensitivity of the main results to key parameters in the model. We consider the effects of different specifications for the discount factor of workers and bankers (parameter β), the degree of tightness of the limited commitment constraint of bankers (captured by parameter κ), the dispersion of idiosyncratic bank productivities (captured by the shape of the Pareto distribution of idiosyncratic productivities λ), the dividend payment rate of bankers (parameter σ), the weight of workers on the government preferences (parameter α) and the disutility cost of defaulting (parameter δ). Results are reported in Table C1. The first row shows the main summary statistics for the baseline model.

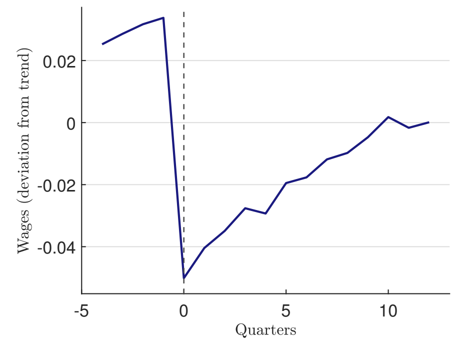
Rows 2 and 3 show the summary statistics for an alternative specification in which all the parameters of the model are the same as in the baseline case, except for the discount factor β. We consider two alternative values, $\beta = 0.85$, which is lower than the baseline value and $\beta = 0.95$ higher than the baseline value and in line with quantitative business cycle models. We find that the levels of external debt are smaller in the economy with a higher discount factor since the benefits of issuing debt to front-load consumption are lower. On the other hand, the levels of external debt in the economy with a lower discount factor are significantly higher than those of the baseline economy. This is due to the fact that for sufficiently low discount factors, the gains from front-loading consumption are high enough that the government finds it optimal to issue as much debt as it can credibly be repaid (i.e.,

Figure C4: Macroeconomic Dynamics During Default Episodes

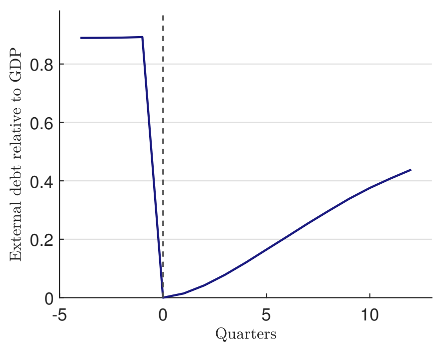
(a) Output



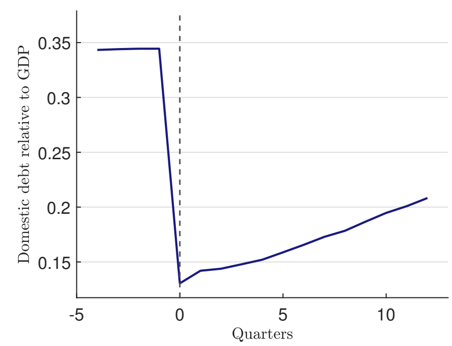
(b) Wages



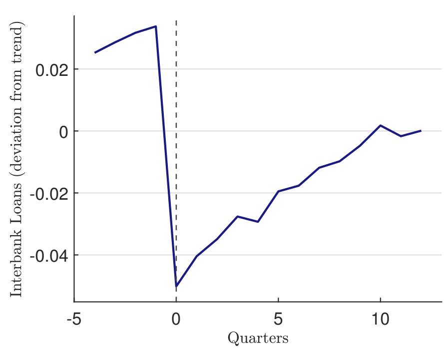
(c) External Public Debt



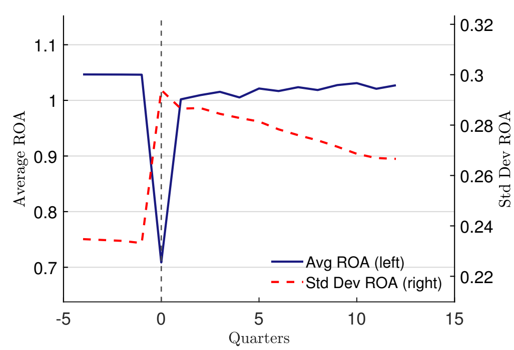
(d) Domestic Public Debt



(e) Interbank Credit

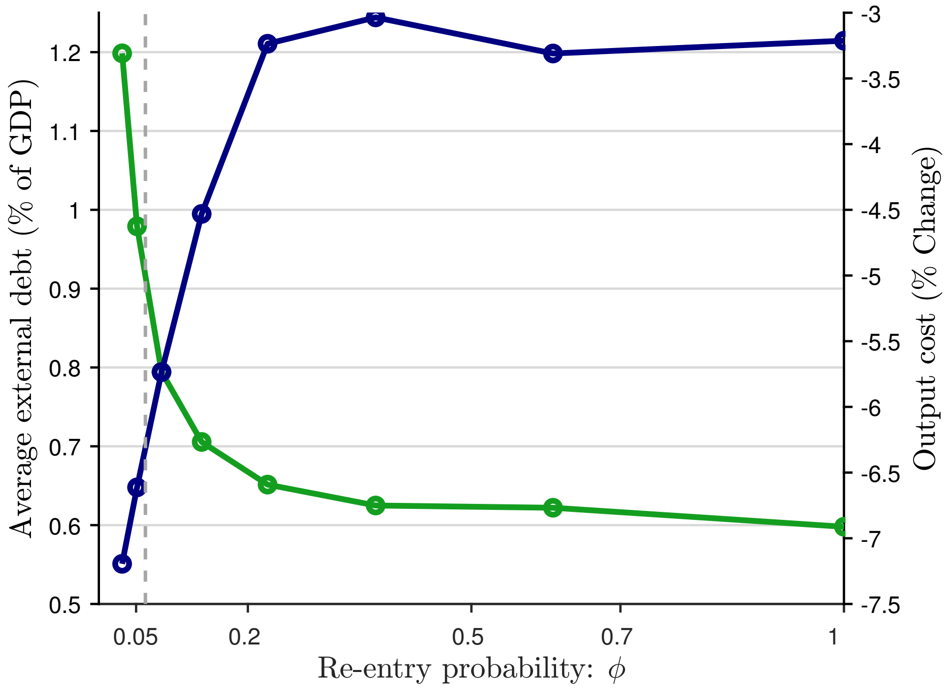


(f) Banks' Returns on Assets



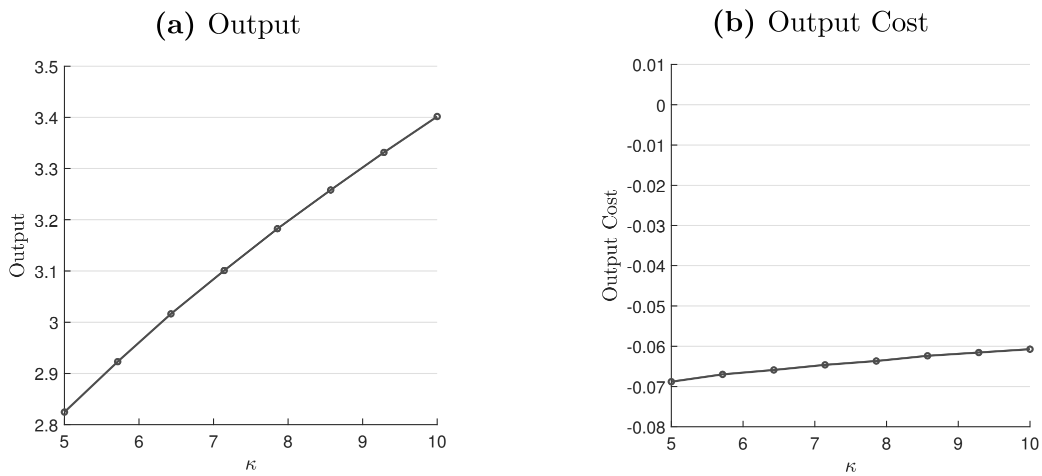
Notes: The dynamics of model variables are obtained by identifying episodes in which the government defaults while the economy is open and computing the average behavior of each variable around those episodes. output, wages and interbank credit are expressed as deviations from an HP trend. External and domestic public debt are expressed as a percentage of quarterly GDP. Banks returns on assets correspond to quarterly gross returns on assets, for which we compute the cross-sectional average and standard deviation.

Figure C5: Output Costs and External Debt: The Role of Exclusion



Notes: This figure shows the average level of external public debt as a share of GDP (left axis) and the average level of the output cost (right axis) in the simulations of various economies that differ in probability of re-entering international financial markets following a default, ϕ (shown in the x-axis).

Figure C6: Effects of κ on output and output cost.



Notes: Figures report output and output cost as a function of κ.

in the region close to the peak of the debt 'Laffer curve').

Rows 4 and 5 show the sensitivity to κ, which governs the strength of the banks' limited

Table C1: Sensitivity Analysis

Parametrization	Value	External Public Debt	Domestic Public Debt	Output Level	Output Cost of Default	Frequency of Default
Baseline Model	-	90.4%	34.9%	0.0%	-6.5%	0.4%
Discount Factor	Lower $\beta = 0.85$	153.6%	34.8%	-0.0%	-6.7%	0.3%
	Higher $\beta = 0.95$	40.8%	34.9%	0.0%	-5.8%	0.5%
Leverage Constraint	Tighter $\kappa = 5.00$	76.5%	34.9%	-10.1%	-6.9%	0.3%
	Looser $\kappa = 8.00$	90.7%	34.9%	1.8%	-6.3%	0.3%
Prod. Dispersion	Lower $\lambda = 3.10$	90.5%	42.2%	9.4%	-8.5%	0.3%
	Higher $\lambda = 3.70$	84.4%	18.6%	-17.3%	-1.9%	0.2%
Bankers Cons. Rate	Lower $\sigma = 0.73$	90.1%	14.2%	-6.5%	-1.5%	0.3%
	Higher $\sigma = 0.81$	123.6%	51.2%	5.2%	-9.4%	0.2%
Workers Weight	Lower $\alpha = 0.93$	161.9%	34.9%	0.0%	-3.9%	0.1%
	Higher $\alpha = 1.00$	84.9%	34.9%	0.0%	-6.5%	0.3%
Default Disutility	Lower $\delta = 0.46$	59.4%	34.9%	0.0%	-6.5%	0.8%
	Higher $\delta = 0.57$	109.7%	34.9%	-0.0%	-6.4%	0.3%

Notes: To compute moments from the model, we simulate the economy over a long horizon and calculate average statistics, restricting attention to states in which the economy is open. External and domestic public debt are expressed in % of quarterly GDP. The column 'Output level' shows the percent difference of the average level of output in each economy relative to that of the Baseline Model. The column 'Output cost of default' shows the average percent difference of between the level of output if the government repays and if the government defaults, for every time period in the simulations. Each row corresponds to the simulations of an economy in which one particular parameter is different than in the baseline calibration and all remaining parameters the same.

commitment constraint. The most salient effect of κ is on the average level of output. The economy with a tighter limited commitment constraint ($\kappa = 5$) has associated an average level of output that is 10.1% lower than in the baseline economy. Figure C6 shows the average level of output for different parameterizations of κ. Given a tighter limited commitment constraint banks with high productivities can borrow less from banks with low productivities and can demand less labor. This reduces equilibrium wages and attracts banks with lower productivities to invest in their technology. This, in turn, reduces the level of output since labor is allocated to technologies that are, on average, of lower productivity. Figure C6 also shows that the output cost of default decreases as κ increases but, quantitively, the magnitude of the output cost is not very sensitive to changes in κ.

Rows 6 and 7 show the sensitivity to the dispersion of idiosyncratic productivity, by analyzing economies with $\lambda = 3.1$ and $\lambda = 3.7$. A higher dispersion of productivities ($\lambda = 3.1$) implies that negative shocks to the financial system translate into shocks of larger magnitude to output. The reason is that idiosyncratic productivities are less concentrated and, hence, changes in the composition of banks that are using their production technology have large effects on the average productivity and hence on output. This implies a sovereign default has a larger effect on output (8.5% on impact, compared to 6.5% in the baseline economy). While the output cost of default rises, domestic public debt also increases due to higher domestic borrowing by banks. As these two forces push default incentives in opposite directions, variations in λ have a mild effect on external debt.

Rows 8 and 9 show the sensitivity to the rate of consumption of bankers $1 - \sigma$. A lower consumption rate (higher σ) increases the saving rate of bankers and hence increases the stock of domestic public debt. Facing a higher stock of domestic government debt, the government's incentives to repay are affected through two opposing channels. First, a larger exposure of banks to public debt increases the output costs of default through a stronger balance-sheet channel, as illustrated in Figures C2 and C3. This increases the incentives to repay debt. Second, with higher stocks of domestic debt the government can redistribute more from bankers to workers by defaulting. This increases the incentives to default, given the weight it assigns to workers. Quantitatively, the first effect dominates, which allows the government to credibly issue more external debt.

Rows 10 and 11 show the sensitivity to the weight α that the government assigns to workers in its utility function. This parameter governs the redistributive incentives of the government. Its effect is non-monotone on the level of external public debt that can be sustained in equilibrium. For high levels of α default is more attractive since it redistributes towards workers, and this reduces the level of external debt that can be sustained in equilibrium. On the other hand, high levels of α also undermines the ability of the government to credibly issue debt when the economy is closed and, hence, lowers the value of default making repayment under the open economy more attractive.

Finally, the last two rows show the sensitivity to the disutility cost of defaulting, δ. When this cost is lower, the frequency of default increases, 0.8% compared to 0.4% in the baseline economy. Moreover, as default becomes less costly, a lower level of external debt can be sustained relative to the baseline, 59.4% compared to 90.4%. The opposite occurs for higher disutility costs of deafulting.

D. Model Extensions

This appendix presents and solves a series of model extensions, which include an alternative calibration of the baseline model, the model with persistent idiosyncratic shocks, the model with elastic labor supply, the model with storage technology and the model with stationary aggregate shocks.

D.1. Model with Persistent Idiosyncratic Shocks

In this model extension, bankers draw a new idiosyncratic shock with probability p_z and keep its productivity from the previous period with probability $1 - p_z$. The baseline model corresponds to $p_z = 1$. The bankers' portfolio choices are unaffected by this extension and are still characterized by Proposition 1. However, this model extension does not feature the aggregation properties of the baseline model, and the joint distribution of banks' assets and productivity becomes a state variable. The equilibrium wages and domestic debt level solve

$$w = (\kappa + 1)\sigma \int_{\underline{z}'}^{z_H} n(z) dG(z),$$

$$q^b B^{b\prime} = \sigma \left(\int_{z_L}^{\underline{z}'} n(z) \mathrm{d}G(z) - \kappa \int_{\underline{z}'}^{z_H} n(z) \mathrm{d}G(z) \right),$$

and the cutoff productivity is determined by (13). Now output is determined by the cutoff productivity and the covariance of idiosyncratic productivities and labor choices: $y_t = A_t \left(\mathbb{E}[z|z > \underline{z}] + \mathrm{Cov}[z, l|z > \underline{z}] \right)$, which imply the following expression for workers' and bankers' consumption

$$C_t^w = \sigma A_t \left(\mathbb{E}[z|z > \underline{z}] + \mathrm{Cov}[z, l|z > \underline{z}] \right) - (1 - \sigma)\iota_t B_t^d + q_t^b B_{t+1}^x - \iota_t B_t^x$$
$$C_t^b = (1 - \sigma) A_t \left(\mathbb{E}[z|z > \underline{z}] + \mathrm{Cov}[z, l|z > \underline{z}] \right) + (1 - \sigma)\iota_t B_t^d.$$

Finally, the government problem is similar to that in the baseline model where the restrictions are the new equations that characterize the competitive equilibrium. The numerical algorithm used to solve the model with persistent idiosyncratic shocks is described in the following section.

Calibration. We follow a similar calibration strategy as the baseline model by targeting the same data moments. To calibrate p_z, we target the autocorrelation of banks' returns, which is 20% in the banks microdata. Table D.1 shows the calibrated parameters and Table D.2 shows the targeted and untargeted moments.

Table D.1: Model Extensions: Calibrated Parameters

Panel A: Externally Set					
Parameter		Persistent Idio. Prod.	Elastic Labor Supply	Storage Technology	Stationary Agg. Shocks
Risk aversion coefficient	γ	2.00	2.00	2.00	2.00
Risk free interest rate	R	1.01	1.00	1.00	1.01
Reentry probability	ϕ	0.06	0.06	0.06	0.06
Discount factor	β	0.90	0.90	0.90	0.90
Banks LC constraint	κ	7.50	7.50	7.50	7.50
Average growth rate	μ_a	1.01	1.01	1.00	
Labor supply	ω		5.00		
Storage technology, curvature	υ			0.99	
Panel B: Calibrated					
Parameter		Persistent Idio. Prod.	Elastic Labor Supply	Storage Technology	Stationary Agg. Shocks
Growth rate autocorrelation	ρ_a	0.45	0.45	0.45	1.00
Std. deviation of growth shocks	σ_a	0.02	0.02	0.02	0.03
Shape of idiosyncratic prod. dist.	λ	3.27	3.27	3.27	3.27
Bankers survival probability	σ	0.81	0.77	0.79	0.77
Utility weight of workers	α	0.92	0.95	0.93	0.97
Std. deviation of default disutility	σ_ϵ	0.01	0.06	0.25	0.09
Average default disutility	δ	0.00	0.34	0.90	0.58
Persistence of idiosyncratic prod.	p_z	0.81			
Storage technology, scalar, open economy	ξ			1.00	
Storage technology, scalar, closed economy	ξ_c			0.70	

Notes: This table reports values for two subsets of parameters corresponding to the model extensions described in Section 4.3. Panel A presents externally set parameters, while Panel B shows parameters calibrated to match data moments.

Counterfactual exercises. We conduct the same counterfactual exercises as in the baseline model. The output cost of default in this model is 3.4% after 1 year, compared to 5.4% in the baseline model (see Table 3). Output costs are lower in this model because a default affects less those banks that are more likely to produce. A default affects more low-productivity banks because they hold domestic public debt. If shocks are persistent, these banks are more likely to be low-productivity banks in the future and less likely to participate in production. This model also features drops in wages and banks' returns following

Table D.2: Model Extensions: Targeted and Untargeted Moments

Panel A: Targeted Moments					
Statistic	Data	Persistent Idio. Prod.	Elastic Labor Supply	Storage Technology	Stationary Agg. Shocks
Avg. domestic public debt	35.0%	37.1%	28.2%	25.8%	35.3%
Avg. external public debt	93.0%	84.5%	87.7%	91.6%	95.3%
Frequency of default	0.7%	0.6%	0.8%	0.4%	1.8%
Avg. return on assets	3.8%	2.3%	4.2%	4.0%	4.5%
Output growth std. dev.	2.1%	2.1%	2.3%	2.1%	2.7%
Output growth autocorr.	87.6%	86.0%	85.7%	87.0%	71.5%
Output - spread corr.	-40.9%	-22.2%	-44.0%	-49.9%	-24.0%
Return on equity autocorr.	20.0%	18.6%			
Share storage, open economy	12.0%			12.8%	
Share storage, closed economy	12.0%			12.7%	

Panel B: Untargeted Moments					
Statistic	Data	Persistent Idio. Prod.	Elastic Labor Supply	Storage Technology	Stationary Agg. Shocks
Output std. dev.	2.9%	3.6%	4.0%	3.8%	3.4%
Consumption std. dev.	2.9%	4.1%	4.9%	8.6%	5.6%
Trade balance std. dev.	1.9%	2.2%	3.5%	2.1%	5.0%
Public debt std. dev.	7.7%	1.8%	3.1%	1.7%	4.5%
Median spread	1.7%	0.3%	0.2%	0.7%	0.2%
Spread std. dev.	1.5%	0.1%	0.1%	0.1%	0.1%
Output - consumption corr.	93.1%	62.5%	52.4%	22.5%	91.4%
Output - trade balance corr.	-27.1%	-12.3%	9.9%	2.9%	-5.5%
Output - returns dispersion corr.	-28.7%	-5.9%	-10.9%	-8.1%	48.1%
Public debt - spread corr.	11.7%	58.1%	27.1%	59.4%	32.9%

Notes: Data moments are computed with quarterly data for the period of 1994.Q1 - 2012Q4 excluding the the post-default period of 2001.Q4- 2005.Q3. To compute moments from the model, we simulate the economy over a long horizon and calculate average statistics, restricting attention to states in which the economy is open. Domestic public debt corresponds to banks' exposure to public debt, and is expressed in % of quarterly GDP. Trade balance, external debt, and total public debt are also expressed in % of quarterly GDP. Bank returns, measured as the return on assets (ROA), and the interest rate spread are in a quarterly basis. The first moment is the average for all variables except spreads, for which the median is reported. 'Output - Returns dispersion corr.' corresponds to the time series correlation between output and the cross-sectional standard deviation of quarterly returns on assets. 'Share storage' refers to the share of bank asset porfolio in the storage technology, in the open and closed economy.

a default.

D.2. Numerical Solution of Model with Persistent Idiosyncratic Shocks

In the presence of persistent productivity shocks and aggregate uncertainty, the distribution of banks across productivity states and balance-sheet structures—an infinite-dimensional object—is a state variable in the government's problem. To solve for the equilibrium of the model numerically, we follow a common practice in the literature and approximate the distribution with a set of statistics that summarizes the relevant information. We reduce the dimensionality of the state space by tracking $y \equiv \mathbb{E}[zl \mid z > \underline{z}]$ and $\hat{B}^{d'}$, which are the two objects that enter the consumption equations.

We conjecture the following law of motions for output and domestic debt when $e = o$:

$$\hat{B}^{d'} = k_o^b + k_{go}^b g + k_{yo}^b y + k_{bo}^b \hat{B}^d \, \mathbb{I}_{\iota=1}, \tag{D.1}$$

$$y' = k_o^y + k_{go}^y g + k_{yo}^y y + k_{bo}^y \hat{B}^d \, \mathbb{I}_{\iota=1}. \tag{D.2}$$

In the closed economy ($e = c$), the equilibrium depends on the government's choice of next-period domestic debt $\hat{B}^{d'}$ and on the expected default probability. We therefore conjecture that the closed-economy equilibrium is a polynomial function of $\hat{B}^{d'} \, \mathbb{E}\left[\mathcal{I}(\hat{\mathbf{s}}')\right]$. Specifically, for every $\hat{B}^{d'}$, we assume that:

$$y'(\hat{B}^{d'}) = k_{c0}^y + k_{c1}^y \hat{B}^{d'} \, \mathbb{E}\left[\mathcal{I}(\hat{\mathbf{s}}')\right] + k_{c2}^y \left(\hat{B}^{d'} \, \mathbb{E}\left[\mathcal{I}(\hat{\mathbf{s}}')\right]\right)^2 + k_{c3}^y \left(\hat{B}^{d'} \, \mathbb{E}\left[\mathcal{I}(\hat{\mathbf{s}}')\right]\right)^3, \tag{D.3}$$

where $\hat{\mathbf{s}}' = \left(g', \underline{z}', \hat{B}^{d'}\right)$.

Numerical government problem. The government problem is to choose external debt and repayment decisions to maximize weighted average of utilities. After default the government loses access to external markets and reverts to the Markov equilibrium from the closed economy. The recursive problem is given by

$$W^o(g, \hat{B}^x, y, \hat{B}^d) = \max_{\iota \in \{0,1\}} \iota W^{or}(g, \hat{B}^x, y, \hat{B}^d) + (1-\iota) W^{od}(g, y) \tag{D.4}$$

$$W^c(g, y, \hat{B}^d) = \max_{\iota \in \{0,1\}} \iota W^{cr}(g, y, \hat{B}^d) + (1-\iota) W^{cd}(g, y) \tag{D.5}$$

The value of repayment in the open economy (and keeping access to external markets) is given by

$$W^{or}(g, \hat{B}^x, y, \hat{B}^d) = \max_{\hat{B}^{x'}} \alpha u(\hat{C}^w) + (1-\alpha)\hat{C}^b + \beta \exp(g)^{1-\gamma} \mathbb{E}\left[W^0(g', \hat{B}^{x'}, y', \hat{B}^{d'}) | \hat{\mathbf{s}}\right] \tag{D.6}$$

subject to

$$
\begin{aligned}
\hat{C}^b &= (1-\sigma)\frac{\exp(g)}{\mu_g}y + (1-\sigma)\hat{B}^d \\
\hat{C}^w &= \sigma\frac{\exp(g)}{\mu_g}y - (1-\sigma)\hat{B}^d + q^b(\hat{\mathbf{s}};\hat{B}^{x'})\hat{B}^{x'} - \hat{B}^x \\
\hat{B}^{d'} &= k_o^b + k_{go}^b g + k_{yo}^b y + k_{bo}^b \hat{B} \\
y' &= k_o^y + k_{go}^y g + k_{yo}^y y + k_{bo}^y \hat{B}
\end{aligned}
$$

The value of repayment in the closed economy is given by

$$
\begin{aligned}
W^{cr}(g,y,\hat{B}^d) = \max_{\hat{B}^{d'}} &\alpha u(\hat{C}^w) + (1-\alpha)\hat{C}^b \\
&+ \beta\exp(g)^{1-\gamma}\mathbb{E}\left[\phi W^o(g',0,y'(\hat{B}^{d'}),\hat{B}^{d'}) + (1-\phi)W^c(g',y'(\hat{B}^{d'}),\hat{B}^{d'})\right] \quad \text{(D.7)}
\end{aligned}
$$

subject to

$$
\begin{aligned}
\hat{C}^b &= (1-\sigma)\frac{\exp(g)}{\mu_g}y + (1-\sigma)\hat{B}^d \\
\hat{C}^w &= \sigma\frac{\exp(g)}{\mu_g}y - (1-\sigma)\hat{B}^d \\
y'(\hat{B}^{d'}) &= k_{c0}^y + k_{c1}^y\hat{B}^{d'}\,\mathbb{E}\left[\mathcal{I}(\hat{\mathbf{s}}')\right] + k_{c2}^y\left(\hat{B}^{d'}\,\mathbb{E}\left[\mathcal{I}(\hat{\mathbf{s}}')\right]\right)^2 + k_{c3}^y\left(\hat{B}^{d'}\,\mathbb{E}\left[\mathcal{I}(\hat{\mathbf{s}}')\right]\right)^3
\end{aligned}
$$

Finally, the values of default are given by

$$
W^{od}(g,y) = W^{cr}(g,y,0) - \delta + \epsilon_o, \quad \text{(D.8)}
$$

$$
W^{cd}(g,y) = W^{cr}(,g,y,0) + \epsilon_c. \quad \text{(D.9)}
$$

Krusell-Smith algorithm. Our algorithm then proceeds as follows:

1. Guess the vector of coefficients

$$
\mathbf{k}_j = \left(k_{o,j}^b,\ k_{go,j}^b,\ k_{yo,j}^b,\ k_{bo,j}^b,\ k_{o,j}^y,\ k_{go,j}^y,\ k_{yo,j}^y,\ k_{bo,j}^y, k_{c0,j}^y, k_{c2,j}^y, k_{c3,j}^y, k_{c4,j}^y\right)
$$

for $j = 0$.

2. Solve the recursive government problem (D.4) - (D.9), using value function iteration, given the forecasting rules

$$\hat{B}^{d'} = k_o^b + k_{go}^b g + k_{yo}^b y + k_{bo}^b \hat{B}^d \, \mathbb{I}_{\iota=1}, \tag{D.10}$$

$$y' = k_o^y + k_{go}^y g + k_{yo}^y y + k_{bo}^y \hat{B}^d \, \mathbb{I}_{\iota=1}, \tag{D.11}$$

$$y'(\hat{B}^{d'}) = k_{c0}^y + k_{c1}^y \hat{B}^{d'} \, \mathbb{E}\left[\mathcal{I}(\hat{\mathbf{s}}')\right] + k_{c2}^y \left(\hat{B}^{d'} \, \mathbb{E}\left[\mathcal{I}(\hat{\mathbf{s}}')\right]\right)^2 + k_{c3}^y \left(\hat{B}^{d'} \, \mathbb{E}\left[\mathcal{I}(\hat{\mathbf{s}}')\right]\right)^3 \tag{D.12}$$

for $j = 0$.

3. Simulate data from the model using the policy functions obtained in (2) for a given sequence of exogenous variables, $\tilde{g} \equiv \{g_t\}_{t=1}^T$, where T is the time length of the panel of model-simulated data. Estimate the parameters, $\mathbf{k}_{j+1}$, of the forecasting rules with model-simulated data. Defining $F_j(\tilde{s}^x)$ as the sequence of forecasts for the sequence $\tilde{s}^x$ implied by coefficients $\mathbf{k}_j$, compute the distance

$$\delta_{j+1} \equiv \|\tilde{F}_{j+1}(\tilde{s}^x) - F_j(\tilde{s}^x)\|.$$

4. Update the forecasting rules and iterate steps (2) and (3) for $j = 1, 2, 3, \ldots$, until δ_{j+1} is sufficiently small.

Details on simulation step. In order to update the forecasting rules we need to simulate the distribution of banks across productivity states and networth, $\Lambda \equiv H(n, z)$. To do so, we will consider equilibria in which all banks that do not invest in labor hold a same proportion of interbank deposits and government debt, i.e., $\frac{d}{b} = const$, for $z < \underline{z}$. We start from an initial distribution $H_0(n, z)$.

For every $t = 0, 1, 2, \ldots$, given the distribution at the beginning of the period $H_t(n, z)$ and given the aggregate state $\hat{\mathbf{s}} = \left(g, y, \hat{B}^d, \hat{B}^x, e \in \{o, c\}\right)$ we perform the following steps

1. We solve for the competitive equilibrium. depending on whether the economy is open or closed.

- If $e = o$, we first solve for $\underline{z}'$ using

$$\begin{aligned}\underline{z}' &= \frac{\mathbb{E}\left[\Omega(\underline{z}', \hat{\mathbf{s}}')\iota'(\hat{\mathbf{s}}')\right]}{q^b(\hat{\mathbf{s}}; \hat{B}^{x'})} \frac{(1+\kappa)\sigma \int_{\underline{z}'}^{z_H} n \mathrm{d}H_t(n,z)}{\mathbb{E}\left[\Omega(\underline{z}', \tilde{\mathbf{s}}')\exp(g')\right]} \\ &\sim R\frac{(1+\kappa)\sigma \int_{\underline{z}'}^{z_H} n(z) \mathrm{d}H_t(n,z)}{\mathbb{E}\left[\exp(g')\right]}\end{aligned}$$

where in the second line with used an implicit approximation that $\mathrm{Cov}(\Omega, \exp(g')) = 0$. Then we can compute w and y' as

$$\begin{aligned}w &= (1+\kappa)\sigma \int_{\underline{z}'}^{z_H} n \mathrm{d}H_t(n,z) \\ y' &= (1+\kappa)\sigma \int_{\underline{z}'}^{z_H} z\frac{n}{w} \mathrm{d}H_t(n,z)\end{aligned}$$

Finally, we obtain q^b from government policies.

- If $e = c$, we solve for $\underline{z}'$ using

$$\frac{\sigma\left(\int_{z_L}^{\underline{z}'} n\mathrm{d}H_t(n,z) - \kappa \int_{\underline{z}'}^{z_H} n\mathrm{d}H_t(n,z)\right)}{\hat{B}^{b'}}\underline{z}' = \frac{\mathbb{E}\left[\Omega(\underline{z}', \hat{\mathbf{s}}')\iota'(\hat{\mathbf{s}}')\right]}{\mathbb{E}\left[\Omega(\underline{z}', \tilde{\mathbf{s}}')\exp(g')\right]}(\kappa+1)\sigma \int_{\underline{z}'}^{z_H} n\mathrm{d}H_t(n,z)$$

or using a similar approximation

$$\frac{\sigma\left(\int_{z_L}^{\underline{z}'} n\mathrm{d}H_t(n,z) - \kappa \int_{\underline{z}'}^{z_H} n\mathrm{d}H_t(n,z)\right)}{\hat{B}^{b'}}\underline{z}' = \frac{\mathbb{E}\left[\iota'(\hat{\mathbf{s}}')\right]}{\mathbb{E}\left[\exp(g')\right]}(\kappa+1)\sigma \int_{\underline{z}'}^{z_H} n\mathrm{d}H_t(n,z).$$

Given $\underline{z}'$, we can then compute y' and the equilibrium prices.

2. Given the equilibrium objects $\underline{z}'$, w, x, q^b and q^d, compute banks' portfolio choises, l', $b^{d'}$ and d', for every idiosyncratic state $\{n, z\}$:

   - If $z > \underline{z}'$: $\quad wl' = (1+\kappa)\sigma n \quad q^d d' = -\kappa\sigma n \quad q^b b^{d'} = 0$
   - If $z \leq \underline{z}'$: $\quad wl' = 0 \quad q^d d' = x \in [0, \sigma n] \quad q^b b^{d'} = \sigma n - x$

3. Given the next-period aggregate state $\hat{\mathbf{s}}' = \left(g', y', \hat{B}^{d'}, \hat{B}^{x'}\right)$ and depending on whether the economy is closed or open, compute the government default decision, $\iota' \in \{0, 1\}$.

Then, for every idiosyncratic state $\{n, z\}$ compute next-period net worth as:

$$n' = \exp(g')zl' + \iota'(b^{d'} + d') \tag{D.13}$$

Finally, simulate z' from the exogenous process and compute the joint distribution of n' and z'. This gives us the $t+1$-distribution $H_{t+1}(n, z)$.

Accuracy. We analyze the goodness of fit of the assumed forecasting rule following Den Haan (2010), who suggests testing the accuracy of the forecast rule by performing a multiperiod forecasting without updating the endogenous state variable. This method does not adjust for deviations from the true endogenous state, and thus provides some sense of divergence in the model. We simulate a series of y and $\hat{B} = \hat{B}^d + \hat{B}^x$ under the true policy and compare it with a series of y^f and $\hat{B}^f$ under the multiperiod forecast of the policy based on the coefficients $\mathbf{k}$. The steps are as follows:

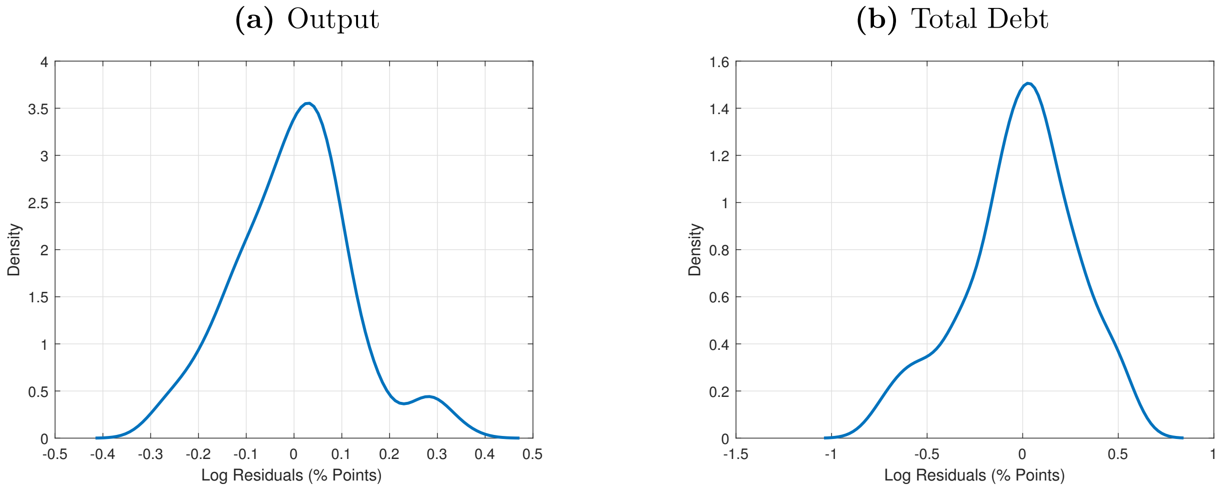
1. Draw a sample for the exogenous process $\tilde{g} \equiv \{g_t\}_{t=1}^T$.
2. Solve for the equilibrium output and debt. In particular, obtain a realization for $\{y_t, \hat{B}_t\}_{t=1}^T$.
3. Let $y_0^f = y_0$ and $\hat{B}_0^f = \hat{B}_0$ and construct $\{y_t^f\}_{t=1}^T$ and $\{\hat{B}_t^f\}_{t=1}^T$ using forcasting rules and government policies.
4. Construct a series for log residuals $\{\log(y_t) - \log(y_t^f)\}_{t=1}^T$ an $\{\log(\hat{B}_t) - \log(\hat{B}_t^f)\}_{t=1}^T$. Figure D.1 shows the estimated density for the entire time series of residuals for both output and total debt.

D.3. Model with Elastic Labor Supply

In this extension, the workers' flow preferences are given by

$$u(c, l) = \frac{\left(c - \frac{l^\omega}{\omega}\right)^{1-\gamma}}{1-\gamma},$$

Figure D.1: Fundamental Accuracy Plot



Notes: This figure shows the estimated density of the log residuals output and total debt. On the x-axis, we have the value for the log residual and on the y-axis the density value.

which rise to the following labor supply $L_t = w_t^{\frac{1}{\omega-1}}$. Because labor is chosen one period ahead, this model extension features labor as an additional state variable. Now the labor market clearing equation is

$$L_t = \frac{(\kappa+1)\sigma N_t}{w_t}\left[1 - G\left(\underline{z}_{t+1}\right)\right],$$

and output is given by $y_t = A_t \mathbb{E}\left[z | z > \underline{z}_t\right] L_t$. The reminder equilibrium conditions are similar to the baseline model with fixed supply.

Calibration and counterfactual exercises. We target the same moments as in the baseline model, and calibrate $\omega = 5$ so that the Frisch elaticity of labor supply is 0.25. In this model, the two channels through which a default affects output operate differently on labor. On the one hand, the negative balance-sheet effect induces a contraction in labor because it lowers its demand. On the other hand, the liquidity effect induces more banks to produce, which, in turn, increases the demand for labor. In the quantitative analysis, the contractionary effect predominates and labor falls following a default.

D.4. Model with Storage Technology

This model extension introduces a risk-free storage technology in which banks can invest their funds, in addition to public debt and interbank deposits. Following Sosa Padilla (2018), we assume there exists a representative firm that can create a risk-free asset out of a storage technology with decreasing returns to scale in the aggregate. The firm finances itself with loans from the banks that pay a rate return of R_t^s. The firm's profits are given by

$$\xi K_t^{\upsilon} - R_t^k K_t,$$

where K_t are the aggregate loans from banks and $0 < \upsilon < 1$. Free-entry on this business implies

$$\xi K_t^{\upsilon-1} = R_t^k.$$

The recursive banker's problem with the available storage technology is

$$v(n, z; \tilde{\mathbf{s}}) = \max_{l' \geq 0, b^{d'} \geq 0, k' \geq 0, d'} (1-\sigma)n + \mathbb{E}\big[\Lambda(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')v(n', z'; \tilde{\mathbf{s}}')|\tilde{\mathbf{s}}\big]$$

subject to:

$$\begin{aligned}
\sigma n &= w(\tilde{\mathbf{s}})l' + q^b(\tilde{\mathbf{s}})b^{d'} + q^d(\tilde{\mathbf{s}})d' + k'(\tilde{\mathbf{s}}), \\
n' &= R^l(z; \tilde{\mathbf{s}}, \tilde{\mathbf{s}}')w(\tilde{\mathbf{s}})l' + R^b(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')q^b(\tilde{\mathbf{s}})b^{d'} + R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')q^d(\tilde{\mathbf{s}})d' + R^k(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')k', \\
q^d(\tilde{\mathbf{s}})d' &\geq -\kappa\sigma n,
\end{aligned}$$

where k' is the banker's choice of loans to the storage technology firm and $R^k(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')$ is the return from those loans.

The solution to the bankers problem is similar to that of the baseline model, with the addition that all banks below the cutoff productivity can also invest in the storage technology. In equilibrium, the storage technology has the same risk-adjusted return as interbank deposits and public debt, i.e. $R^k(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}') = R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')$.

The new equations that characterize the competitive equilibrium are:

$$\begin{aligned}
w(\tilde{\mathbf{s}}) &= (\kappa+1)\sigma\left[A\mathbb{E}[z|z>\underline{z}]+\iota(\tilde{\mathbf{s}})B^d+\xi K^{\upsilon}\right]\left[1-G\left(\underline{z}'(\tilde{\mathbf{s}})\right)\right],\\
q^b(\tilde{\mathbf{s}})B^{b\prime}(\tilde{\mathbf{s}}) &= \sigma\left[A_t\mathbb{E}[z|z>\underline{z}]+\iota_t B^d_t+\xi K^{\upsilon}\right]\left(G(\underline{z}'(\tilde{\mathbf{s}}))(1+\kappa)-\kappa\right),\\
\mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')A'\right]\frac{\underline{z}'(\tilde{\mathbf{s}})}{w(\tilde{\mathbf{s}})} &= \mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\frac{\iota(\tilde{\mathbf{s}}')}{q^b(\tilde{\mathbf{s}})}\right],\\
K(\tilde{\mathbf{s}}') &= \left(\frac{\mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\frac{\iota(\tilde{\mathbf{s}}')}{q^b(\tilde{\mathbf{s}})}\right]}{\xi\mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right]}\right)^{\frac{1}{\upsilon-1}}.
\end{aligned}$$

Substituting the expressions for prices into workers' and bankers' budget sets, we can obtain expressions for their consumption

$$C^w(\mathbf{s}) = \sigma A\mathbb{E}\left[z|z>\underline{z}\right]-(1-\sigma)\iota(\mathbf{s})B^d+\sigma\xi K^{\upsilon}-K'(\mathbf{s})-\iota(\mathbf{s})B^x+q^b(\mathbf{s},B^{x\prime})B^{x\prime}(\mathbf{s}), \tag{D.14}$$

$$C^b(\mathbf{s}) = (1-\sigma)A\mathbb{E}\left[z|z>\underline{z}\right]+(1-\sigma)\iota(\mathbf{s})B^d+(1-\sigma)\xi K^{\upsilon}. \tag{D.15}$$

The introduction of the storage technology provides banks with an additional security in which they can invest their resources over time. This undermines the government's role of liquidity provision, and attenuates the effect that a default has on output through this channel. In the aggregate, the storage technology allows for inter-temporal transfer of resources. The government problem, omitted here for brevity, implies choosing debt issuance and repayment decisions subject to the expressions for consumption, given by (D.14) and (D.15), and the policies that characterize the competitive equilibrium.

Calibration. The numerical solution of this model extension is similar to that of the baseline model, with the additional complexity of the introduction of a new endogenous state variable, K. This extension also introduces two new parameters, ξ and υ. We set $\upsilon = 0.99$ which is the largest value for which we obtain numerical stability. We also allow ξ to vary when the economy is open and closed and calibrate their values so that the average stock of storage is 12% of quarterly GDP, which corresponds to the observed average net foreign assets held by banks. The remaining parameters are re-calibrated to match the same targeted moments as in the baseline model. Table D.1 reports the calibrated parameters and

Table D.2 the targeted and untargeted moments.

Counterfactual exercises. The fourth column of Table 3, show that the output costs of default are undermined when the banks have access to another asset. The output cost of default is 1.6% one year after default, compared to 5.4% in the baseline model. This is because the liquidity channel is attenuated given that banks have another alternative to public debt.

D.5. Model with Stationary Aggregate Shocks

Our baseline model features shocks to the growth rate of aggregate productivity. This choice is motivated by the literature that argues business cycles in emerging economies are well-characterized by trend shocks (see, for example, Aguiar and Gopinath, 2007; Guntin, Ottonello and Perez, 2023). Other strand of the literature argues that models with stationary productivity and financial shocks can also replicate business cycle patterns in emerging economies (see, for example, Garcia-Cicco, Pancrazi and Uribe, 2010; Alvarez-Parra, Brandao-Marques and Toledo, 2013). In this model extension, we assume that aggregate productivity shocks follow an autoregressive process in logs:

$$\log A_{t+1} = \rho_a \log A_t + \epsilon_t,$$

where $\epsilon_t \sim N(0, \sigma_a)$.

Calibration and counterfactuals. We calibrate ρ_a and σ_a to match the volatility and persistence of output (see Table D.1). Targeted and untargeted moments, reported in the fifth column of Table D.1, are very similar to those of the baseline model. Finally, the output costs of default are also similar to the baseline estimates with growth shocks (see Table 3). It follows that the assumption of aggregate shocks to the trend is not relevant for the quantitative results.

E. Policy Analysis

E.1. Economy with Subsidy on Banks' Purchases of Public Debt

The new government budget constraint is given by

$$q^b(\tilde{\mathbf{s}})\left(B^{d\prime}(\tilde{\mathbf{s}}) + B^{x\prime}(\tilde{\mathbf{s}})\right) + \tau(\tilde{\mathbf{s}}) = \iota(\tilde{\mathbf{s}})\left(B^d(\tilde{\mathbf{s}}) + B^x(\tilde{\mathbf{s}})\right) + \tau_b q^b(\tilde{\mathbf{s}})B^{d\prime}(\tilde{\mathbf{s}}).$$

The banker problem under the presence of the subsidy on public debt is

$$v(n, z; \tilde{\mathbf{s}}) = \max_{l' \geq 0, b^{d\prime} \geq 0, d'} (1-\sigma)n + \mathbb{E}\left[\Lambda(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')v(n', z'; \tilde{\mathbf{s}}')|\tilde{\mathbf{s}}\right]$$

subject to:

$$\begin{aligned}
\sigma n &= w(\tilde{\mathbf{s}})l' + q^b(\tilde{\mathbf{s}})(1-\tau_b)b^{d\prime} + q^d(\tilde{\mathbf{s}})d' \\
n' &= A'zl' + \iota(\tilde{\mathbf{s}}')\left(b^{d\prime} + d'\right) \\
q^d(\tilde{\mathbf{s}})d' &\geq -\kappa\sigma n.
\end{aligned}$$

Substituting out d' and conjecturing that the value function is linear in net worth, we can express the banker's problem as

$$\nu(z; \tilde{\mathbf{s}})n = \max_{l' \geq 0, b^{d\prime} \geq 0} (1-\sigma)n + \mathbb{E}\left[\Lambda(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\nu(z'; \tilde{\mathbf{s}}')n'|\tilde{\mathbf{s}}\right]$$

subject to:

$$\begin{aligned}
n' &= \left(R^l(z; \tilde{\mathbf{s}}, \tilde{\mathbf{s}}') - R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\right)w(\tilde{\mathbf{s}})l' + \left(R^b(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}') - R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\right)q^b(\tilde{\mathbf{s}})(1-\tau_b)b^{d\prime} + R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')q^d(\tilde{\mathbf{s}})\sigma n, \\
(1+\kappa)\sigma n &\geq w(\tilde{\mathbf{s}})l' + q^b(\tilde{\mathbf{s}})(1-\tau_b)b^{d\prime},
\end{aligned}$$

where $R^l(z; \tilde{\mathbf{s}}, \tilde{\mathbf{s}}') \equiv \frac{A'z}{w(\tilde{\mathbf{s}})}$, $R^b(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}') \equiv \frac{\mathcal{I}(\mathbf{s}')}{q^b(\tilde{\mathbf{s}})(1-\tau_b)}$ and $R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}') \equiv \frac{\mathcal{I}(\mathbf{s}')}{q^d(\tilde{\mathbf{s}})}$. Following the same argument as in Proposition 1 the solution of this problem in the relevant case of $q^d(\tilde{\mathbf{s}}) = q^b(\tilde{\mathbf{s}})(1-\tau_b)\frac{\mathbb{E}[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')]}{\mathbb{E}[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\iota(\tilde{\mathbf{s}}')]}$ is given by

- If $z > \underline{z}'(\tilde{\mathbf{s}})$: $\quad w(\tilde{\mathbf{s}})l' = (1+\kappa)\sigma n, \quad q^d(\tilde{\mathbf{s}})d' = -\kappa\sigma n, \quad q^b(\tilde{\mathbf{s}})(1-\tau_b)b^{d\prime} = 0$

- If $z \leq \underline{z}'(\tilde{\mathbf{s}})$: $\qquad w(\tilde{\mathbf{s}})l' = 0, \qquad q^d(\tilde{\mathbf{s}})d' = x \in [0, \sigma n], \qquad q^b(\tilde{\mathbf{s}})b^{d'} = \sigma n - x$

Substituting the solution into the objective function, we can verify our linearity guess:

- For $z \leq \underline{z}'(\tilde{\mathbf{s}})$:

$$\nu(z; \tilde{\mathbf{s}}) = (1-\sigma) + \sigma \mathbb{E}\left[\Lambda(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\nu(z', \tilde{\mathbf{s}}')R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\right]$$

- For $z > \underline{z}'(\tilde{\mathbf{s}})$:

$$\nu(z; \tilde{\mathbf{s}}) = (1-\sigma) + \sigma \mathbb{E}\left[\Lambda(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\nu(z', \tilde{\mathbf{s}}')R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\left[1 + (\kappa+1)\left(\frac{R^l(z; \tilde{\mathbf{s}}, \tilde{\mathbf{s}}')}{R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')} - 1\right)\right]\right]$$

Now we characterize the competitive equilibrium. The labor market clearing condition is given by

$$w(\tilde{\mathbf{s}}) = (\kappa+1)\sigma\left(\left[A\mathbb{E}[z|z > \underline{z}] + \iota(\tilde{\mathbf{s}})B^d\right]\right)\left[1 - G\left(\underline{z}'(\tilde{\mathbf{s}})\right)\right] \tag{E.1}$$

The total demand for public debt is determined residually

$$\begin{aligned}
q^b(\tilde{\mathbf{s}})(1-\tau_b)B^{b'}(\tilde{\mathbf{s}}) &= \int_{z<\underline{z}} \sigma n \mathrm{d}\mathcal{G}(n, z; \tilde{\mathbf{s}}) - \int_{z>\underline{z}} \kappa\sigma n \mathrm{d}\mathcal{G}(n, z; \tilde{\mathbf{s}}) \\
&= \sigma\left(\left[A_t\mathbb{E}[z|z > \underline{z}] + \iota_t B^d_t\right]\right)\left(G(\underline{z}'(\tilde{\mathbf{s}}))(1+\kappa) - \kappa\right).
\end{aligned}$$

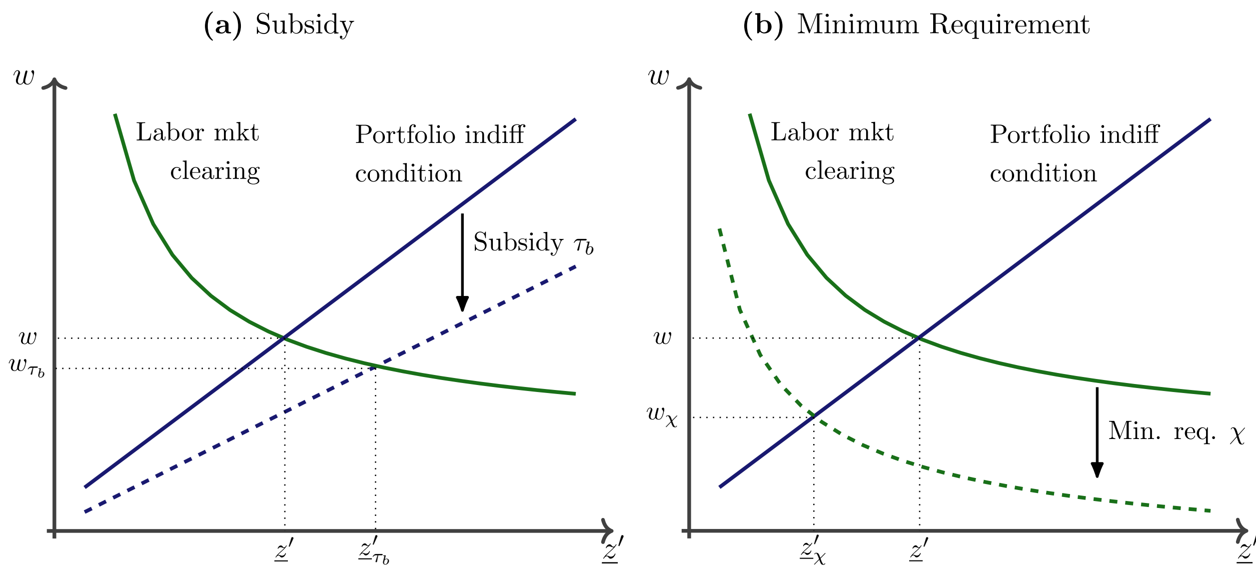
Finally, the cutoff productivity is determined by the banker that is indifferent between investing in his own technology and investing in public debt

$$\mathbb{E}\left[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')A'\right]\frac{\underline{z}'(\tilde{\mathbf{s}})}{w(\tilde{\mathbf{s}})} = \mathbb{E}\left[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\frac{\iota(\tilde{\mathbf{s}}')}{q^b(\tilde{\mathbf{s}})(1-\tau_b)}\right].$$

In those states in which the economy is open these equations determine the equilibrium level of the cutoff productivity and the stock of domestic public debt, for a given return of public debt. In those states in which the economy is closed, these equations determine the cutoff productivity and the equilibrium price of debt given that $B' = B^{d'}$.

Panel (a) of Figure E.1 shows how the competitive equilibrium allocations in the open economy are affected by the subsidy. The subsidy shifts the portfolio equal returns condition for the indifferent bank to the right (blue dotted line). This implies that the equilibrium cutoff productivity increases and wages decrease as low-productivity banks are induced into public debt and away from production. As a consequence, output increases.

Figure E.1: Equilibrium Effects of Subsidy and Minimum Requirement on Public Debt



Notes: This figure illustrates the equilibrium determination of wages and the cutoff productivity. It also shows how the equilibrium responds to an increase in the subsidy on banks purchases of public debt (Panel (a)) and to an increase in the minimum requirement on public debt (Panel (b)).

E.2. Economy with a Minimum Requirement of Public Debt in Banks

The banker problem under the presence of minimum requirement of public debt is

$$v(n, z; \tilde{\mathbf{s}}) = \max_{l' \geq 0, b^{d'} \geq 0, d'} (1-\sigma)n + \mathbb{E}\big[\Lambda(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')v(n', z'; \tilde{\mathbf{s}}')|\tilde{\mathbf{s}}\big]$$

subject to:

$$\sigma n = w(\tilde{\mathbf{s}})l' + q^b(\tilde{\mathbf{s}})b^{d'} + q^d(\tilde{\mathbf{s}})d'$$
$$n' = A'zl' + \iota(\tilde{\mathbf{s}}')\left(b^{d'} + d'\right)$$
$$q^d(\tilde{\mathbf{s}})d' \geq -\kappa\sigma n$$
$$q^b(\tilde{\mathbf{s}})b^{d'} \geq \chi\sigma n.$$

Substituting out d' and conjecturing that the value function is linear in net worth, we can express the banker problem as

$$\nu(z;\tilde{\mathbf{s}})n = \max_{l'\geq 0, b^{d'}\geq 0} (1-\sigma)n + \mathbb{E}\big[\Lambda(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\nu(z';\tilde{\mathbf{s}}')n'|\tilde{\mathbf{s}}\big]$$

subject to:

$$\begin{aligned} n' = &\left(R^l(z;\tilde{\mathbf{s}},\tilde{\mathbf{s}}') - R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right)w(\tilde{\mathbf{s}})l' + \left(R^b(\tilde{\mathbf{s}},\tilde{\mathbf{s}}') - R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right)q^b(\tilde{\mathbf{s}})b^{d'} + R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')q^d(\tilde{\mathbf{s}})\sigma n, \\ (1+\kappa)\sigma n \geq &w(\tilde{\mathbf{s}})l' + q^b(\tilde{\mathbf{s}})b^{d'}, \\ q^b(\tilde{\mathbf{s}})b^{d'} \geq &\chi\sigma n, \end{aligned}$$

where $R^l(z;\tilde{\mathbf{s}},\tilde{\mathbf{s}}') \equiv \frac{A'z}{w(\tilde{\mathbf{s}})}$, $R^b(\tilde{\mathbf{s}},\tilde{\mathbf{s}}') \equiv \frac{\mathcal{I}(\mathbf{s}')}{q^b(\tilde{\mathbf{s}})}$ and $R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}') \equiv \frac{\mathcal{I}(\mathbf{s}')}{q^d(\tilde{\mathbf{s}})}$. Following the same argument as in Proposition 1 the solution of this problem in the relevant case of $q^d(\tilde{\mathbf{s}}) = q^b(\tilde{\mathbf{s}})\frac{\mathbb{E}[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')]}{\mathbb{E}[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\iota(\tilde{\mathbf{s}}')]}$ is given by

- If $z > \underline{z}'(\tilde{\mathbf{s}})$: $\quad w(\tilde{\mathbf{s}})l' = (1+\kappa-\chi)\sigma n, \quad q^d(\tilde{\mathbf{s}})d' = -\kappa\sigma n, \quad q^b(\tilde{\mathbf{s}})b^{d'} = \chi\sigma n$
- If $z \leq \underline{z}'(\tilde{\mathbf{s}})$: $\quad w(\tilde{\mathbf{s}})l' = 0, \quad q^d(\tilde{\mathbf{s}})d' = x \in [0,(1-\chi)\sigma n], \quad q^b(\tilde{\mathbf{s}})b^{d'} = \sigma n - x$

Substituting the solution into the objective function, we can verify our linearity guess:

- For $z \leq \underline{z}'(\tilde{\mathbf{s}})$:
$$\nu(z;\tilde{\mathbf{s}}) = (1-\sigma) + \sigma\mathbb{E}\left[\Lambda(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\nu(z',\tilde{\mathbf{s}}')R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right]$$

- For $z > \underline{z}'(\tilde{\mathbf{s}})$:

$$\nu(z;\tilde{\mathbf{s}}) = (1-\sigma) + \sigma\mathbb{E}\left[\Lambda(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\nu(z',\tilde{\mathbf{s}}')R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\left[1 + (\kappa-\chi+1)\left(\frac{R^l(z;\tilde{\mathbf{s}},\tilde{\mathbf{s}}')}{R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')} - 1\right)\right]\right]$$

Now we characterize the competitive equilibrium. The labor market clearing condition is given by

$$w(\tilde{\mathbf{s}}) = (\kappa-\chi+1)\sigma\left(\left[A\mathbb{E}[z|z>\underline{z}] + \iota(\tilde{\mathbf{s}})B^d\right]\right)\left[1 - G\left(\underline{z}'(\tilde{\mathbf{s}})\right)\right] \tag{E.2}$$

To characterize market clearing in the public debt market we need to consider two cases: *i.* one in which the minimum requirement is not binding in the aggregate for those banks that do not invest in their technologies, and *ii.* another in which the minimum requirement is binding in the aggregate for those banks that do not invest in their technologies.

We first consider case *i.* In this case the total demand for public debt is given by

$$q^b(\tilde{\mathbf{s}})B^{b'}(\tilde{\mathbf{s}}) = \underbrace{\int_{z<\underline{z}} \sigma n \mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}}) - \int_{z>\underline{z}} \kappa\sigma n \mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}})}_{\text{Demand from low } z \text{ bankers}} + \underbrace{\int_{z>\underline{z}} \chi\sigma n \mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}})}_{\text{Demand from high } z \text{ bankers}}$$
$$= \sigma\left(\left[A_t\mathbb{E}[z|z>\underline{z}] + \iota_t B_t^d\right]\right)\left(G(\underline{z}'(\tilde{\mathbf{s}}))(1+\kappa-\chi) - \kappa + \chi\right).$$

In this case the cutoff productivity is determined by the banker that is indifferent between investing in his own technology and investing in public debt

$$\mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')A'\right]\frac{\underline{z}'(\tilde{\mathbf{s}})}{w(\tilde{\mathbf{s}})} = \mathbb{E}\left[\Omega(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\frac{\iota(\tilde{\mathbf{s}}')}{q^b(\tilde{\mathbf{s}})}\right]$$

In those states in which the economy is open these equations determine the equilibrium level of the cutoff productivity and the stock of domestic public debt, for a given return of public debt. In those states in which the economy is closed, these equations determine the cutoff productivity and the equilibrium price of debt given that $B' = B^{d'}$.

Panel (b) of Figure E.1 illustrates how the minimum requirement policy affects the allocations in the open economy. The policy reduces the demand for labor, shifting the labor market clearing condition to the left (green dotted line). This implies that wages decrease and so does the equilibrium cutoff productivity as low-productivity banks are induced into production. As a consequence, output decreases.

We now consider case *ii.* In this case the total demand for public debt is given by

$$q^b(\tilde{\mathbf{s}})B^{b'}(\tilde{\mathbf{s}}) = \int_{z,n} \chi\sigma n \mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}})$$
$$= \sigma\chi\left(\left[A_t\mathbb{E}[z|z>\underline{z}] + \iota_t B_t^d\right]\right).$$

In those states in which the economy is open this equation determines the equilibrium stock of domestic public debt, for a given return of public debt. In those states in which the economy is closed, it determines the equilibrium price of debt given that $B' = B^{d'}$. Finally, the cutoff productivity is such that the interbank market clears

$$G(\underline{z}'(\tilde{\mathbf{s}}))(1+\kappa-\chi)-\kappa+\chi=\chi.$$