TITULO: Soveriegn Debt, Domestic Banks and the Provision of Public Liquidity

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1. Introduction

Sovereign governments borrow not only from international investors but also from domestic residents. Most of these 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 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. After a default the government loses reputation and with it, its 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 these mechanisms can generate a deep and persistent fall in output, similar to the one observed in the data during the December 2001 default. Additionally, the presence of this endogenous output cost of default generates repayment incentives for the government that are strong enough to explain observed levels of external 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 finance projects with idiosyncratic productivity, lend to the government or lend to other banks. The joint analysis of domestic and external debt gives rise to a new insight that is the dual role of sovereign debt. First, public debt is a security that allows the government to transfer aggregate resources across time when the holders of this security are foreign investors. Second, it provides liquidity to the domestic financial system. By this I mean that the government can induce a better allocation of resources in the economy through its choices of debt issuance.

The provision of liquidity by issuing public debt arises due to the presence of financial frictions that prevent the banking sector from satisfying its demand for liquidity with privately issued securities. 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. This implies that the government can attain a more efficient allocation of resources in the domestic economy through its debt issuance choices.

The government's ability to provide liquidity is undermined after a default. By defaulting, a government loses its reputation and is able to credibly issue less debt without increasing subsequent default risk. This induces a shortage of public debt which is detrimental for economic activity. Consider a bank with low-productivity investment projects that finds 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 triggers a negative balance-sheet effect on banks, 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, a loss of reputation 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.

I provide empirical evidence from Argentina that is line with the model's predictions. First, I collect panel data on individual banks balance-sheets and show that there is selection in the banks that purchase government bonds. In particular, I show that those banks that are more exposed to public debt are banks that, on average, have lower returns on their investment. The presence of 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, I show that the dynamics of banking-related variables following the sovereign of December 2001 were consistent with the main mechanism of the model. In particular, I 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.Q1-2012.Q4 period. The model is able to explain 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, and approximates certain cross-sectional moments of banking-related variables. Additionally, the simulated output dynamics around episodes of sovereign default matches the observed behavior of output in Argentina during the 2001 default, both in terms of the magnitude of the recession and the dynamics of the recovery. I use the calibrated model to assess the relevance of the endogenous negative effect of default on the allocation of resources, through its effect on the financial system. I find that the endogenous output cost of default is deep and persistent. Additionally, it can account for half of the drop in output during a typical default episode, which leaves the other half explained by the fall in exogenous aggregate productivity that triggers the optimal default decision.

In the model, when the government defaults while the economy is open, it reverts to a closed economy for a stochastic number of periods. During these periods, the government can still issue debt and, importantly, default on it without any further punishment. This leads to an endogenous loss of reputation of the government. The strength of the reputation loss is thereby linked to the length of the period of exclusion from external financial markets. I analyze how relevant is the role of the length of exclusion and find that it plays a key role in determining the depth and persistence of output cost, as well as in determining the average levels of external debt. When the length of exclusion is larger the government's ability to provide liquidity is undermined, resulting in a deeper and more persistent drop in output. This lower level of output following a default enhances the government's commitment to credibly repay higher levels of external debt.

Finally, I use the model to study the effects of domestic policies that are targeted to address the government's lack of commitment problem. I analyze the case of two policies: the implementation of a subsidy on banks' purchases of public debt, and a minimum requirement of public debt holdings in banks. I find that the former is more effective in allowing for higher levels of external debt and is also welfare enhancing. The reason is that the subsidy, in addition to enhancing aggregate exposure of banks to public debt (thereby increasing the output costs of default), also induces a positive selection of banks into production. The subsidy induces banks with low productivities to hold public debt instead of investing in their technologies, and thus crowds-out low productivity banks from production. On the other hand, a minimum requirement induces a negative effect on the allocation of labor, by forcing high-productivity banks to use resources to buy public debt, that would otherwise be invested in high-productivity technologies.

One key feature of the model is the role of heterogeneity in banks, which has not been studied in most of the related literature. This feature gives rise to an active interbank market and therefore a role of the government as a provider of liquidity through debt issuance. It also helps understand how interbank lending is severely affected in episodes of default. Additionally, the presence of heterogeneity helps disentangle how two different policies that target the same aggregate exposure of bank holdings of public debt can differ in their effectiveness.

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 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 recent body of literature has studied the quantitative dynamics of sovereign debt and sovereign defaults. Arellano (2008) and Aguiar and Gopinath (2006) analyze sovereign debt and business cycle properties in emerging economies. Several studies have extended the 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 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 develop a model that endogenizes the output cost of default. In their model a default restricts external credit for firms and forces them to substitute imported inputs for domestic ones that are imperfect substitutes. The analysis here is complementary to theirs

[1]Some recent applications and related work include Hatchondo and Martinez (2009), Benjamin and Wright (2009), Yue (2010), Broner et al. (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), D'Erasmo and Mendoza (2017), Na et al. (2018), Ottonello and Perez (2018) and Bianchi et al. (2018). Passadore and Xu (2018) study a model with default and iliquidity risk. In their case, iliquidity refers to search frictions in secondary markets, a different concept than the one stressed in this paper.

[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 et al. (2018)).

as it sheds light into what are 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 sovereign debt as public liquidity. Woodford (1990) and Holmström and Tirole (1998) show that there is room for an active management of public 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] This paper contributes to this literature by studying how the government's ability to provide liquidity can be undermined after a default, and how this in turn serves as a commitment device to repay for the government.

This work is most closely related to the rising 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.[4] Motivated by this evidence, several papers argue that a sovereign default can weaken the balance-sheet of banks and explore its effect on government's commitment (for example, Gennaioli et al. (2014), Basu (2009), Mengus (2018) and Mallucci (2017)), and on the dynamics of employment (Balke (2018)). Arellano et al. (2017) study the feedback between sovereign risk and economic activity and argue that heterogeneity in firms plays a key role in the transmission mechanism. Two closely related papers are Bocola (2016) and Sosa Padilla (2018), that develop quantitative macro models to analyze the effects of sovereign risk and default on banks and the economy. Bocola (2016) argues that an increase in sovereign risk (even in the absence of default) can trigger a contraction in credit and a recession and analyze 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. I contribute to this literature by studying 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 closely related to the contemporaneous work of Chari et al. (2018) that study the optimal degree of financial repression on banks when the government lacks

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

[4] See, for example, Borensztein and Panizza (2009), Reinhart and Rogoff (2011), Kalemli-Ozcan et al. (2016) and Gennaioli et al. (2018). Hébert and Schreger (2017) empirically identify a negative causal effect of sovereign default on equity returns of Argentine firms, particularly so in financial firms.

commitment to repay their debt. Both in their paper and in this paper, the desirability of enhancing the banks' exposure to sovereign debt arises from the fact that this enhances the credibility of the government to repay debt. While they characterize the full optimal path of financial repression, I argue that imposing a minimum requirement of public debt does not achieve the same results as a subsidy on banks' purchases of sovereign debt, due to their effects on banks' selection into buying public debt.

Layout

The remaining of the paper is organized as follows. Section 2 presents the model setup and characterizes equilibrium. Section 3 discusses the model's mechanisms. Section 4 presents supporting empirical evidence using bank data. Section 5 analyzes the model's calibration, its business cycle properties and provides counterfactual exercises. Section 6 studies domestic policies aimed at addressing the government's lack of commitment problem. Finally, section 7 concludes.

2. A Model of Sovereign Debt and a Financial Sector

In this section I formulate a dynamic model of a small open economy enriched with a financial sector (along the lines of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011)) and a sovereign government that lacks commitment and has access to debt markets (as in Eaton and Gersovitz (1981)). There are four types of agents in the economy: workers, bankers, the government and foreign investors. I 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 representative household with a continuum of heterogeneous bankers of measure unity. Each banker operates a bank and transfers the proceedings 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 all dividend payments from each individual bankers. 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

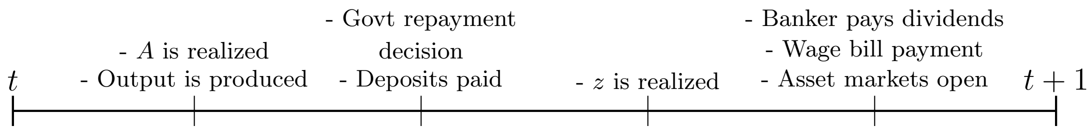
$$A_t = \exp(g_t) A_{t-1}$$

where g_t follows a Markov process with transition probability $f(g_{t+1}, g_t)$ with bounded support. 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. This assumption about the timing gives rise to a need for banks of obtaining credit to produce.

In addition to the production technology, bankers have access to two asset 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 also risky one-period securities that pay one unit of consumption in the following period, except in those states where there is sovereign default, in which they pay zero. In summary, banks can lend to or borrow from other banks, invest in

FIGURE 1. Timing of events for a banker



their production technology by hiring labor and buy public debt. The time line 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, $div_{i,t} = (1-\sigma)n_{i,t}$.[5] The net worth that is leftover 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. I assume that the amount of borrowing that any banker can raise through interbank loans is capped by a multiple of its own post-consumption net worth

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

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, I also assume

[5]This assumption can be micro-founded by making bankers exit their business with probability $(1 - \sigma)$ and allowing for the choice of dividend payments, which will be zero until they retire from business (see, for example, Gertler and Kiyotaki (2010)).

[6]For a micro-foundation of this type of financial frictions (and similar variants of it) that stem from agency problems and its role as an accelerator of macroeconomic shocks see, for example, Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Bernanke et al. (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

that bankers cannot take short positions on public debt

$$b^d_{i,t+1} \geq 0. \tag{8}$$

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 $\Lambda_{t,s} \equiv \beta^{s-t} u'(C^b_s)/u'(C^b_t)$ is the stochastic discount factor of the bankers' household. The banker's problem is then to choose a sequence $\{l_{i,t}, b^d_{i,t}, d_{i,t}\}_{t=1}^{\infty}$ 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 non-state-contingent bonds that pay one unit of consumption next period. These securities can be purchased by domestic banks and/or foreign investors. 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.

The government lacks commitment to repay its debt and can ex-post 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

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

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.

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

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 by $\frac{\kappa}{\kappa+1}\mathbb{E}[A]$.

economy is open, the economy switches to being closed and the government looses 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, as 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. This setup ties together access to external credit markets with government's reputation.

Discussion of Assumptions

This section discusses the assumptions that underlie the setup. Bankers are assumed to have access to a production technology. The banks in this economy represent a consolidation of the financial and productive sector of the economy. The production technology is subject to idiosyncratic productivity shocks and therefore banks face an idiosyncratic risk that is not insurable. These uninsurable shocks can represent geographic components or specific knowledge of bankers on certain types of industries that are subject to idiosyncratic shocks. A relevant assumption is that this idiosyncratic productivity process is independent over time. This assumption allows to avoid carrying the distribution of banks' portfolios as a state variable, thereby making the solution to the model computationally feasible. To the extent that idiosyncratic productivity is persistent, the quantitative balance-sheet effects of a default will be less severe.[7]

I assume the banks can invest in two securities (public debt and interbank deposits), as well as in their own investment projects. This assumption is based on technical reasons.[8] However, the above investment alternatives cover most of the banks' balance sheets in the case of Argentinean banks in the data.[9] The assumption that interbank deposits are not repaid in the state of a sovereign default is done for simplicity. A more standard assumption of risk-less interbank deposits could be adopted and the main theoretical and quantitative results would still carry through. This is due to the fact that a default on interbank loans does not affect the aggregate

[7]As it will be described in section 3, if idiosyncratic productivities are persistent, then banks that are more likely to be the most productive following a default are banks that were productive before a default and hence less exposed to sovereign debt.

[8]Adding an extra asset that banks could invest in would add an extra endogenous state variable, quickly running into the curse of dimensionality.

[9]In the data, the sum of public debt holdings, interbank loans and total loans account for roughly 70% of total banks' assets. Additionally, government securities and interbank loans constitute more than half of total liquid assets.

net worth of banks, which is the relevant variable, as opposed to its distribution, given the assumption that idiosyncratic productivity shocks are iid.

Implicit in the writing of the government budget constraint (10) is the assumption that the government is not allowed to default selectively on only one type on 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) and Hatchondo et al. (2016)). These clauses state that a default in any government obligation constitutes a default in the contract containing that clause.

Recursive Equilibrium

Equilibrium is defined in two steps. First, I define a *competitive equilibrium* for a given government policy. Second, I define a *Markov perfect equilibrium* as the competitive equilibrium associated to the government policies that are chosen optimally given its time inconsistency problem.

I 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. In particular, 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 (public debt held by bankers) and $B^x = B - B^d$ the stock of external public debt (public debt held by foreign investors).[10] 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 economy is open ($e = o$) or closed ($e = c$). Since I define equilibrium in two steps, the relevant state for the private allocations is the augmented state $\tilde{\mathbf{s}} = (\mathbf{s}, B', \iota)$ that 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. I provide a formal definition of equilibrium in Appendix A.

[10]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. I adopt a similar notation for aggregate variables of workers. Since workers are identical, in this case aggregate variables will coincide with individual variables.

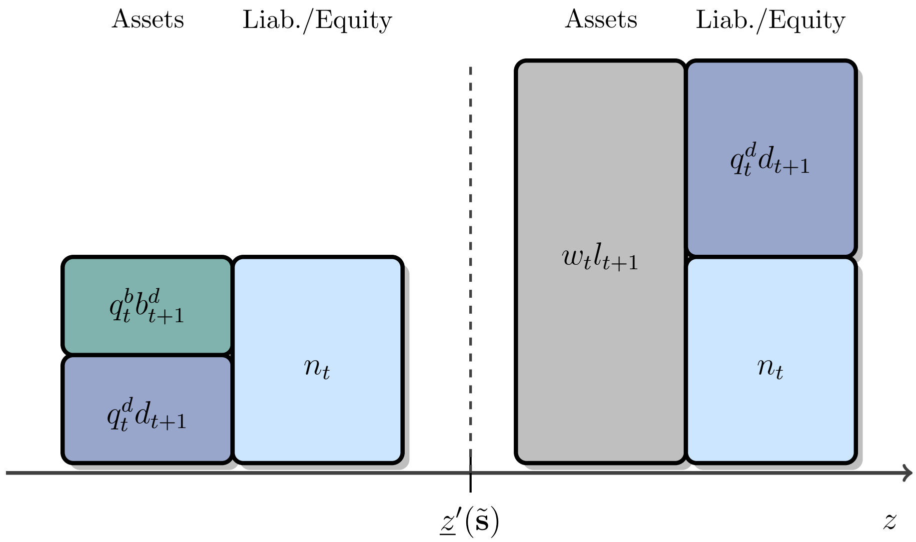
The way the public debt market is different depending on whether the economy is open or closed. For states in which the economy is closed ($e = c$), the entire stock of government debt is purchased by bankers. For states in which the economy is open ($e = o$), there are two possibilities. One possibility 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 $\left(q^b(s, B') \geq \frac{\mathbb{E}[\iota(\mathbf{s}')|\tilde{\mathbf{s}}]}{R}\right)$. The second case is that there is a positive amount of external public debt. In this case 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.[11]

I can now characterize the competitive equilibrium. Given that the payoffs to interbank deposits and public debt are the same in every state it must be the case that $q^b(\tilde{\mathbf{s}}) = q^d(\tilde{\mathbf{s}})$ for all states.[12] Given that the discount factor of the bankers' household is not affected by the portfolio choices of an individual banker, the individual banker's problem is linear in its net worth and its solution involves corners. The individual bankers' optimal portfolio choice depends on their idiosyncratic productivity z, wages, and the price of public debt and deposits. Bankers with high productivity 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 low productivity 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.

[11]In the model's simulations the equilibrium always corresponds to the second case in which the marginal investor is foreign. From now onwards I focus on that case.

[12]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. But no domestic debt in banks is a suboptimal debt issuance policy for the government as it is argued in the following section.

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). Also 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. *For states in which $q^b(\tilde{\boldsymbol{s}}) = q^d(\tilde{\boldsymbol{s}})$:*

– *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 $b^{d\prime} = 0$.*

– *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 $q^b(\tilde{\boldsymbol{s}})b^{d\prime} = \sigma n - x$ 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.

Given the characterization of the individual portfolio choices of banks I can characterize the aggregate allocations in a competitive equilibrium.

In this economy the joint distribution of net worth and idiosyncratic productivity follows an endogenous law of motion. Since idiosyncratic shocks are assumed to be iid there is no need to keep track of the entire distribution of net worth across banks but only of the aggregate level of domestic public debt B^d and the threshold productivity $\underline{z}$. Using the fact that z is drawn iid across banks, and using the market clearing condition for deposits I get an expression for the aggregate net worth of bankers measured before dividend payments, $N(\tilde{\mathbf{s}}) = \left(A\mathbb{E}\left[z|z>\underline{z}\right] + \iota B^d\right)$. The labor market clearing condition is given by

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

The demand for labor depends positively on the aggregate level of bankers net worth (which ultimately determines the volume of interbank lending) 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 threshold productivity of the banker that is indifferent between investing in his 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.

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[13]

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

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

The following proposition formalizes the above-mentioned characterization of prices and aggregate allocations in a competitive equilibrium. Let $\overline{q}(\tilde{\mathbf{s}})$ and its associated return a $\overline{R}(\tilde{\mathbf{s}},\tilde{\mathbf{s}}') =$

[13]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.

$\mathcal{I}(\tilde{\mathbf{s}}')/\overline{q}(\tilde{\mathbf{s}})$ be the price of debt such that its risk-adjusted expected return is the same as the risk-adjusted expected return of interbank deposits in an economy without public debt. Formally, $\overline{R}(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')$ satisfies

$$\mathbb{E}\left[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\overline{R}(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\right] = \mathbb{E}\left[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')A'\right] \frac{G^{-1}\left(\frac{\kappa}{\kappa+1}\right)}{\sigma N(\tilde{\mathbf{s}})}.$$

Proposition **2.** *For any state equilibrium wages solve* (12)*. For states in which the economy is open ($e = o$) and the price of debt is $q^b(\tilde{\boldsymbol{s}}) < \overline{q}(\tilde{\boldsymbol{s}})$, the price of deposits is $q^d(\tilde{\boldsymbol{s}}) = q^b(\tilde{\boldsymbol{s}})$ and the law of motion for the threshold productivity and aggregate level of domestic debt solve* (13)-(14)*. For states in which the economy is closed ($e = c$) the threshold productivity and the price of public debt solve* (13)-(14).

Finally, combining the budget constraints (2), (4) and (10) with (12)-(14), one can obtain expressions for aggregate consumption workers and bankers

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

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

Some observations can be made out of equations (15) and (16). First, the level of output $A\mathbb{E}\left[z|z > \underline{z}\right]$ depends on the cutoff elasticity $\underline{z}$ 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.

Given the characterization of the dynamics of aggregate variables in the domestic economy I can define the government's problem. Since the government is unable to commit to future policy rules, it chooses its policy rules at any given period taking as given the policy rules that represent future governments' decisions, and a Markov perfect equilibrium is characterized by a fixed point in these policy rules. At this fixed point, the government does not have the incentive to deviate from other government's policy rules, thereby making these rules time-consistent.

Denote $\underline{z}'\left(s, e; B', \iota\right)$ and $B^{d'}\left(s, e; B', \iota\right)$ 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. Given its time inconsistency problem the government optimally chooses current period repayment and debt issuance to maximize the weighted average utility of workers and bankers given that foreign investors and domestic agents expect future government policies to be $\{\mathcal{B}'(\mathbf{s}), \mathcal{I}(\mathbf{s})\}$.

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

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

subject to

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

The value of repaying in the closed economy is given by

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

subject to

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

Finally, the value of defaulting on debt (both in the closed or open) economy is given by

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

These last equations follow from the fact that the value of defaulting is equivalent to the value of repaying zero domestic debt since there are no reputational consequences of defaulting in the closed economy.

Note that the facts that workers are identical and bankers share consumption risk within their household facilitates aggregation of the objective function of the government. I also assume that the government faces a pricing curve of public debt for any potential level of external public debt $q^b(s, B^{x\prime})$ and chooses optimally in what point of the curve to issue debt.[14] Additionally, the recursive formulation of the government problem highlights the reputational consequences of a sovereign default. A default on the open economy triggers a reversion to the closed economy. On the other hand, a default on the closed economy does not entail any reputational costs. Having defined the government problem I define a Markov perfect equilibrium.

Definition **1.** *A Markov perfect 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 $\{\mathcal{B}'(\boldsymbol{s}), \mathcal{I}(\boldsymbol{s})\} = \{B'(\boldsymbol{s}), \iota(\boldsymbol{s})\}$.

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. A description of the numerical solution algorithm is provided in Appendix B.

3. Public Liquidity, Sovereign Defaults and Repayment Incentives

This section describes how the government can affect the allocation of resources in the domestic economy by issuing public debt, and how this ability interacts with the government's incentives to repay debt.

3.1. *Public Debt as a Provision of Public Liquidity*

One of the roles of public debt in this economy is to provide liquidity to the domestic financial system. By liquidity I refer to the availability of instruments that can be used to transfer wealth across periods (Woodford (1990), Holmström and Tirole (1998)). These papers argue that there is room for an active management of public liquidity through the issuance of government

[14] This assumption is shared in models based on Eaton and Gersovitz (1981). The presence of a pricing schedule from which the government can choose is consistent with a sequential borrowing game in which the government announces how many bonds to issue and then each lender offers the government a price at which they are willing to buy the bonds the government is issuing.

securities whenever there are financial frictions in the private sector that prevents it from satisfying its demand for liquidity with privately issued securities. In those situations the provision of public liquidity leads to a more efficient functioning of the productive sector.

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 (risky) rate of 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 improves the allocation of inputs and increases output. Why does output increase when low-productivity banks are dropping from production? Because the labor that was employed by these banks is now employed by banks with higher productivities. And how are high-productivity banks able to employ more labor? Due to a reduction in wages through a general equilibrium effect which occurs given that now the aggregate demand for labor is lower since less banks are producing.

Given the efficient screening effect associated to an increase in the return on public debt, the government can induce a more efficient allocation of labor by increasing its debt issuance so that its return (and the return of deposits) increase in equilibrium. However, there is a limit on how much liquidity the government can or wants to provide. When the economy is open, there is a return at which foreign investors are willing to buy public debt. After this return is reached, all additional debt is bought by foreign investors with a perfectly elastic demand, and public debt no longer provides liquidity domestically. When the economy is closed, the limits on the liquidity provision come from the presence of a 'Laffer curve' of debt by which after certain threshold an additional unit of promised debt decreases its price to a point in which raised resources are lower.

The role of public debt as a security that provides liquidity to the domestic economy hinges on the need for credit among domestic agents and the presence of financial frictions (i.e. the borrowing constraint) on the banking sector. If financial frictions within the banking system were removed, which would correspond to the particular case of $\kappa = \infty$, then changes in the return of public debt would not affect real allocations. Particularly, in the case of a distribution of idiosyncratic productivities with bounded support, the equilibrium allocations in the frictionless case would correspond to only the bank with the highest productivity investing in his technology and all the other banks lending to this banks and/or investing in public debt. In this context, changes in the return on public debt may affect the return on the different investments but will not affect the real allocation of labor.

3.2. *Public Liquidity and Sovereign Default*

The effects of a default on the governments ability to issue debt and provide liquidity depend on whether the government defaults when the economy is open or closed. While the economy is closed the government can decide to issue debt and default optimally without facing further exclusion from any market nor reputational losses. Its optimal repayment decision trades-off redistribution concerns. Repaying public debt held by bankers requires taxing workers and this may be undesirable for high enough levels of debt given that it may lead to highly unequal levels of consumption between workers and bankers. This results in a maximum level of domestic debt that the government can credibly issue in the closed economy and a limit on the government's ability to provide liquidity.

When the economy is open, a sovereign default triggers a temporary exclusion from external financial markets and reversion to the closed economy. Therefore, the punishment of this reversion allows the government to issue higher levels of public debt and enhances its ability to provide liquidity. The consequence of a higher ability of the government to provide liquidity is a larger level of output while the economy is open, relative to when it is closed, following a default. This is because banks with low-productivity technologies, that used to invest in public debt, now choose to invest in their technologies given that the stock of government debt is endogenously scarcer, which in turn lowers average labor productivity.

The negative effect of a open-economy default on output is enhanced by a negative balance-sheet effect on bankers. A sovereign default has a negative impact on the net worth of those banks that were exposed to public debt. Some of the banks that received this negative shock obtain a high productivity draw for the following period. With a lower net worth, those banks can raise less resources in the interbank market (compared to what they could have obtained in the case of government repayment) and reduce the levels of investment in their productive technology, thereby reducing aggregate labor demand. A lower aggregate demand for labor lowers wages (given the inelastic labor supply) and this has an impact on the optimal portfolio choices of individual banks. The banks that used to be indifferent between investing in their own productive technology and investing in public debt (or lending to other banks) now prefer the former option as the costs of this investment are lower. This reduces the threshold productivity level above which banks prefer to invest in their productive technology and lowers the average productivity of the aggregate economy, generating an output cost. The output cost is due to a composition effect of how labor is allocated to banks with differing productivities.

One implication of the model is that the reduction in output following a default is due to a misallocation of labor. After a default more bankers with lower productivities engage in production. This leads to higher cross-sectional dispersion of productivities and returns on banking activities.

4. Supporting Empirical Evidence

In this section I provide empirical evidence in support of two key model predictions. The first prediction is that banks with less attractive investment opportunities tend to purchase more public debt. This is a key prediction that is inherent to the concept of public debt as liquidity provision. The second prediction is regarding the dynamics of banking-related variables during an episode of default.

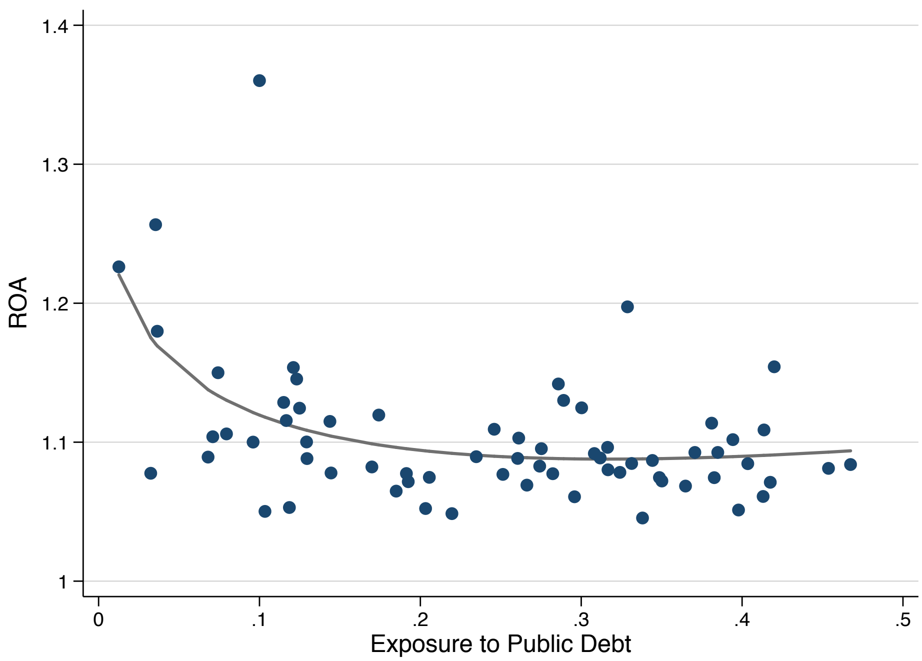
I collected micro-data on individual banks' balance sheets in Argentina for the period 1999-2010 at an annual frequency. The data comes from the Central Bank of Argentina that requires all banks to report their balance sheet information. The full dataset contains data balance sheets from 115 financial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

To test the first prediction I constructed 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 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. Hence, we should expect those banks that are more exposed to public debt to have lower returns on average. Figure 3 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

[15]I average the data across time since the model's prediction relates to expected returns rather than realized returns.

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. In Appendix C I show that this negative relationship is still present when we control for the observed volatility of banks' return on assets, ruling out the possibility of higher returns only reflecting higher risk. In that Appendix I also 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.

FIGURE 3. Banks' Performance and Holdings of Public Debt

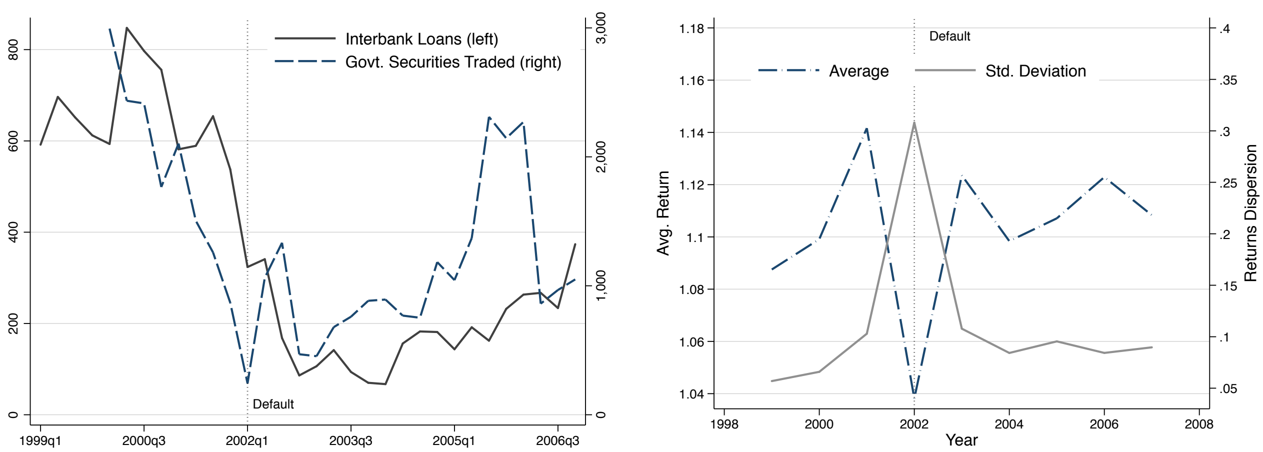


Notes: The horizontal axis contains the average exposure to public debt over years. The vertical axis contains the average annual gross return on financial assets over years. Each dot correspond to an individual bank. The solid line corresponds to the fractional-polynomial of best fit. See Appendix C for details on the construction of these variables.

I then focus on the dynamics of banking-related variables around episodes of default. According to our 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 Figure 4a, interbank loans dropped significantly after the default and so did the volume traded of government securities in secondary markets. Additionally, according to the model, in response to lower risk-adjusted rates of interbank lending, more banks invest in their projects with lower productivities, leading to a decrease in the average return of their investments as well as an increase in their cross-sectional dispersion. These dynamics were also observed during the Argentinean default of December 2001. As shown in Figure 4b, realized average bank returns dropped significantly immediately after the default. Additionally, the cross-sectional dispersion of realized returns increased following the default. More dispersed returns are consistent with higher degrees of misallocation after a default.[16] Finally, as shown Figure C.1 in Appendix C, the dynamics of the interbank rate are in line with those predicted by the model.

Figure 4. Bank Dynamics Around a Default Episode

(A) Interbank Lending & Govt Securities Trading (B) Average Returns & Returns Dispersion



Notes: Panel (A) shows the evolution of total interbank loans (left axis) and the evolution of the volume of government securities traded in the Buenos Aires stock exchange. Both variables are 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 C for details on the construction of these variables.

The evidence on more dispersed bank returns 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 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.

[16]Higher dispersion in returns is indicative of higher dispersion of marginal returns of capital, which is a symptom of misallocation.

5. Quantitative Analysis of the Model

This section performs a quantitative analysis of the model by calibrating it to the Argentinean economy for the period 1994-2012. I consider the Argentinean economy to be an interesting case for study for two reasons. First, the period of analysis includes one of the largest sovereign defaults on 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 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.[17] Second, throughout the period of analysis the economy exhibited significant levels of external public debt and domestic public debt held in the banking system (23% and 9% of annual GDP on average, respectively), which makes it an appropriate candidate for testing this theory.

5.1. *Calibration*

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

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

Additionally, I assume that idiosyncratic productivity shocks z are distributed Pareto with shape parameter λ (i.e. $G(z) = 1 - z^{-\lambda}$) 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 preferences-specific parameters (α, β, γ), bank-related parameters $(\sigma, \kappa, \lambda, \mu_a, \rho_a, \sigma_a)$ and government-related parameters (R, ϕ). 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 $R = 1.01$, 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 et al. (2011). I set the value of the discount factor to $\beta = 0.9$ which is in the range of

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

discount factors considered in quantitative models of sovereign default.[18] Low discount factors are needed to generate defaults on equilibrium.

Table 1. Calibrated Parameters

Parameter		Value	Comments/Targets
Selected Directly			
Risk aversion coefficient	γ	2.00	Standard value
Risk free interest rate	R	1.01	Standard value
Reentry probability	ϕ	0.06	Dias and Richmond (2008)
Discount factor	β	0.90	Quantitative default models
Banks LC constraint	κ	7.50	Banking data
Shape of idiosyncratic prod. dist.	λ	3.50	Gopinath and Neiman (2014)
Average growth rate	μ_a	1.01	GDP data
Calibrated			
Growth rate autocorrelation	ρ_a	0.50	GDP data
Std. deviation of growth shocks	σ_a	0.02	GDP data
Bankers survival probability	σ	0.79	Banking & GDP data
Utility weight of workers	α	0.92	Banking & GDP data

The value of the shape of the distribution of idiosyncratic productivity shocks is disciplined with estimates of the dispersion of Argentinean firms' productivity during the 2002 crisis from Gopinath and Neiman (2014). I set $\lambda = 3.5$, which generates a standard deviation of productivities of banks that is in line with the cross-sectional dispersion of productivities estimated in their paper. This parameter determines the strength of the output cost of default: a default disrupts the role of the financial sector in reallocating resources and resource reallocation is more important when productivities are dispersed. I carry out a sensitivity analysis of the main results to this and other key parameters in the model in Appendix D.2.

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 to match the average leverage ratio of total net worth to total assets in the banking system of 12% during the sample period.

[18]For example, the calibrated value of (quarterly) β is 0.88 in Mendoza and Yue (2012) and 0.8 in Aguiar and Gopinath (2006). Arellano (2008) uses a higher calibrated value for β of 0.953.

The remaining two parameters (α, σ) are jointly calibrated to match two moments of the Argentinean economy. These two moments are: *i.* the average stock of public debt held by banks while the economy is open, and *ii.* the share of value added that corresponds to workers compensations. The first data moment is computed using aggregate bank balance-sheet data. I consider the periods of 1994-2001 and 2006-2012 as periods in which Argentina had access to external credit markets.[19] The second data moment is measured as the ratio of compensation to workers to the sum of compensation to workers and profits. I exclude payments to capital since this factor is not included in the model. The calibrated values of these parameters are $\sigma = 0.79$ and $\alpha = 0.92$. All data moments are correctly matched by their model counterparts, as reported in Table D1 in Appendix D.1.

5.2. *Business Cycle Properties of the Model*

This section assesses the model's quantitative performance by comparing moments from the data with moments from the model's ergodic set. 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. In order to make moments comparable, the moments from the model simulated data where computed for those states in which the government has access to external financial markets. More specifically, I compute 1,000 simulations each of 1,000 periods, compute statistics dropping the first 100 observations and keeping those states in which the economy is open. I then report average statistics over the 1,000 simulations.

Table 2 compares the model moments with their data counterparts for those moments that were not targeted in the calibration.[20] The model can generate significant levels of external debt sustained in equilibrium (81% of quarterly GDP).[21] This suggests that the presence of an endogenous internal cost of default, together with the loss of access to external debt markets for

[19]During 2002-2005 Argentina was in default with external creditors and excluded from international markets. In June 2005 the Argentinean government reached an agreement with most creditors by which it restructured its defaulted debt. This agreement allowed the country to exit the default status as reflected by the change in its credit ratings. During the following years Argentina only occasionally issued some external debt.

[20]All return and interest rate statistics are expressed on a quarterly basis, and debt is expressed as a percentage of quarterly GDP.

[21]The equilibrium levels of external public debt are comparable to, and in some cases higher than, those obtained in previous quantitative models of endogenous default, calibrated for the Argentinean economy. For example, Arellano (2008) generates levels of external debt of the order of 6% of quarterly GDP and the average level of debt in the model in Aguiar and Gopinath (2006) is 27% of GDP. Mendoza and Yue (2012) report an average level of external debt-to-annual GDP ratio of 23% and Chatterjee and Eyigungor (2012) use a model of long-term debt that generates levels of external debt of the order of 70% of quarterly GDP.

a random number of periods, are able to generate commitment for the government to credibly sustain high levels of external debt. However, the external debt levels generated by the model are still below those observed in the data (93% of quarterly GDP), which in turn suggest the presence of an additional unmodeled degree of government commitment to repay debt.

TABLE 2. Business Cycle Statistics

Statistic	Data	Baseline Model
First moments		
External public debt (% of GDP)	93.0%	81.3%
Interest rate spread	1.7%	0.5%
Bank return on assets	3.1%	4.4%
Standard Deviation		
Consumption ($\sigma(c)/\sigma(y)$)	1.01	1.03
Trade balance	1.9%	1.3%
Public debt	7.7%	1.0%
Interest rate spread	1.5%	2.8%
Correlations		
Output - Consumption	93.1%	90.7%
Output - Trade balance	-27.1%	-22.2%
Output - Interest rate spread	-40.9%	-24.9%
Public debt - Interest rate spread	11.7%	-16.4%
Cross-sectional moments		
Bank returns dispersion	8.6%	22.5%
Correlation Returns dispersion - Output	-77.2%	-42.6%

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. Moments from the model correspond to average statistics of moments from 1,000 simulations. Each simulation includes 1,000 periods and restricts attention to those states in which the economy is open. The variables trade balance, external and total public debt are measured in % of quarterly GDP. Bank returns and the interest rate spread correspond to quarterly returns. The first moment is the average for all variables except spreads, for which the median is reported. 'Bank returns dispersion' corresponds to the average cross-sectional standard deviation of banks' quarterly returns on assets. 'Correlation Returns dispersion - Output' corresponds to the time series correlation between output and the cross-sectional standard deviation of quarterly returns on assets.

The model underestimates the median levels of sovereign spreads. The median quarterly bond spread in the model's simulations is 0.5%, which is below the median spread of 1.7% basis points observed in the data. This should not come as a surprise since the model isolates from risk premium in debt prices (by assuming risk-neutral foreign investors), which account for a significant fraction of sovereign spreads (see, for example, Aguiar et al. (2016)). The model is also in line with measures of banks performance, which were not a target of the calibration. The average return on assets for banks is 4.4% in the model which is comparable to the 3.1% in the data.

The model reproduces the volatility of the trade balance but underestimates the volatility of public debt and overestimates that of interest rate spreads.[22] The model correctly predicts the high co-movement between aggregate consumption and output. Additionally, the model correctly predicts the relative volatility of consumption with respect to output. In the model consumption is as volatile as output given the presence of shocks to the growth rate of productivity and an endogenous interest rate on debt. The model also yields a negative correlation between trade balance and output, which is a key feature of emerging markets business cycles.

The model is also consistent with a negative co-movement between interest rate spreads and output, and near zero correlation between public debt and interest rate spreads. The counter-cyclicality of interest rate spreads can be understood with the relative attractiveness of default in low productivity states, where agents have lower income and high marginal utility from consuming. The second result is more related to the fact that the total stock of public debt includes external debt and domestic debt which may have different implications for sovereign risk and this attenuates any co-movement between the total stock of public debt and interest rate spreads.

Finally, I also assess the model's ability to reproduce certain cross-sectional moments. The model overestimates the average cross-sectional standard deviation of bank returns, a moment that was not targeted by the calibration strategy. However, the model correctly predicts counter-cyclical dispersion of returns. The correlation of the cross-sectional standard deviation of returns and output is -78% in the data and -43% in the model. The counter-cyclicality of return dispersion in the model has to do with the fact that the endogenous component of

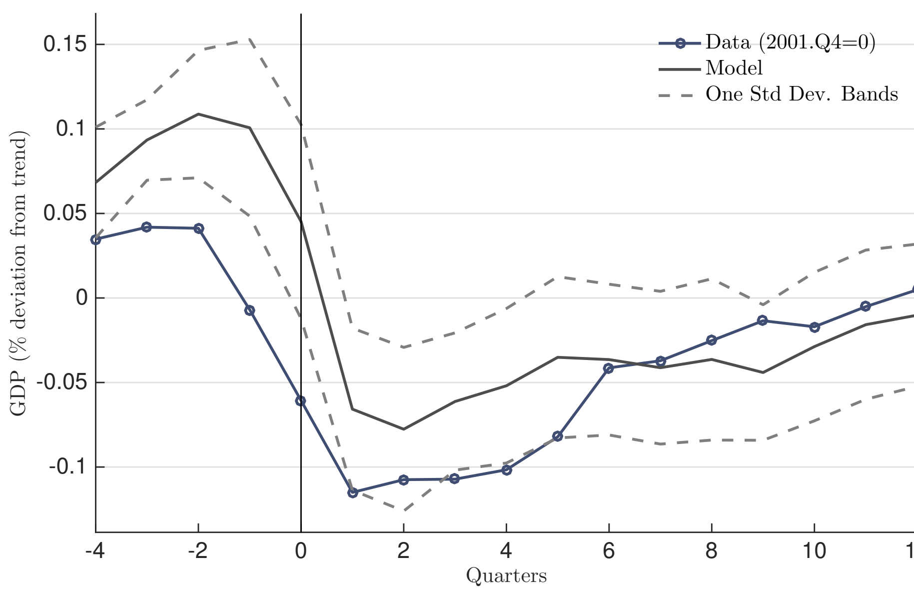
[22]The high levels of spread volatility are due to excessively high spreads in periods before defaults. If these outlier observations in the model are not considered, the volatility of spreads is actually lower than that in the data.

variations in output is due to misallocation of resources across banks, which manifests in higher dispersion of returns.

5.3. *Output Dynamics Around Default Episodes*

This section studies the dynamics of output in the model around sovereign default episodes and compares it to the data. The dynamics of output in the model are given by the average path of output around the episodes of default identified in the simulations. Figure 5 plots the model's output dynamics compared to the Argentinean output around the default episode of 2001.Q4. Both series are shown as percentage deviations from trend output.[23] One-standard-deviation bands for the model's average are included. The date of default is set to zero and the window goes from 4 quarters before the default episode to 12 quarters after.

FIGURE 5. Output Dynamics Around Default Episodes



Notes: Model data is obtained from identifying 200 default episodes in simulations and computing the average behavior of output around those episodes.

The model's output dynamics are similar to the evolution of output during the 2001 default. The overall behavior of output under the simulated default episode replicates the evolution of output in Argentina both in terms of the magnitude of the fall and the recovery dynamics. In the model, the peak-to-trough fall of output is 18%, close to the 16% observed fall in output during the 2001 default. Additionally, the post-default output recovery in the model is consistent with the Argentinean experience. In both cases output starts recovering in the same year of the

[23] Trend output was obtained by applying an HP filter to both the observed and simulated series of output.

default and three years later roughly recovers its trend level but is still below its pre default levels. The model also accounts for the fall in output prior to the 2001 default. The fall in output in the model during a default event has two components. One is the exogenous drop in aggregate productivity that triggers the default. The second component is the endogenous output cost that comes from the internal costs of default. Both components lead to a lower productivity.

I assess the relevance of the endogenous component of output dynamics during a default by quantifying the drop in output that is only due to the decision of default. To do this I compute an impulse-response type of exercise in which the 'impulse' is the decision to default and the response is the dynamics of output. More specifically, I first identify 200 states in the simulations in which default is optimal. For each of these states I compute the dynamics of output under default in the absence of aggregate shocks[24] and compare them to the output dynamics that would result if the government repaid also in the absence of aggregate shocks. I compute the percent difference of output under both decisions to repay and default and average them over all episodes.

The blue line in Figure 6a shows the average effect of a default on output for the baseline calibration. A default triggers a drop in output as strong as 8.6% that then recovers gradually and 5 years later is 1.5% below what it would be in the absence of a default. This implies that of the 18% peak-to-trough fall in output in the model around default episodes, roughly half of it is explained by the internal costs (which leaves the other half explained by the fall in exogenous aggregate productivity that triggered the default). In other words, the sovereign default triggers an amplification effect on the contraction of economic activity of approximately 100%. Over the three years following a default, output is on average 5% below what it would be in the absence of 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.

[24]The default impulse is unexpected in the sense that the policies from the competitive equilibrium are such that the government is expected to repay in those states. The dynamics of output following a default depend on the realization of an aggregate shock which determines when the economy re-enters external financial markets. I smooth the impact of this shock by simulating for each simulated default episode 1000 different paths of output after default and report the average.

5.4. *The Importance of Liquidity, Exclusion and Reputation*

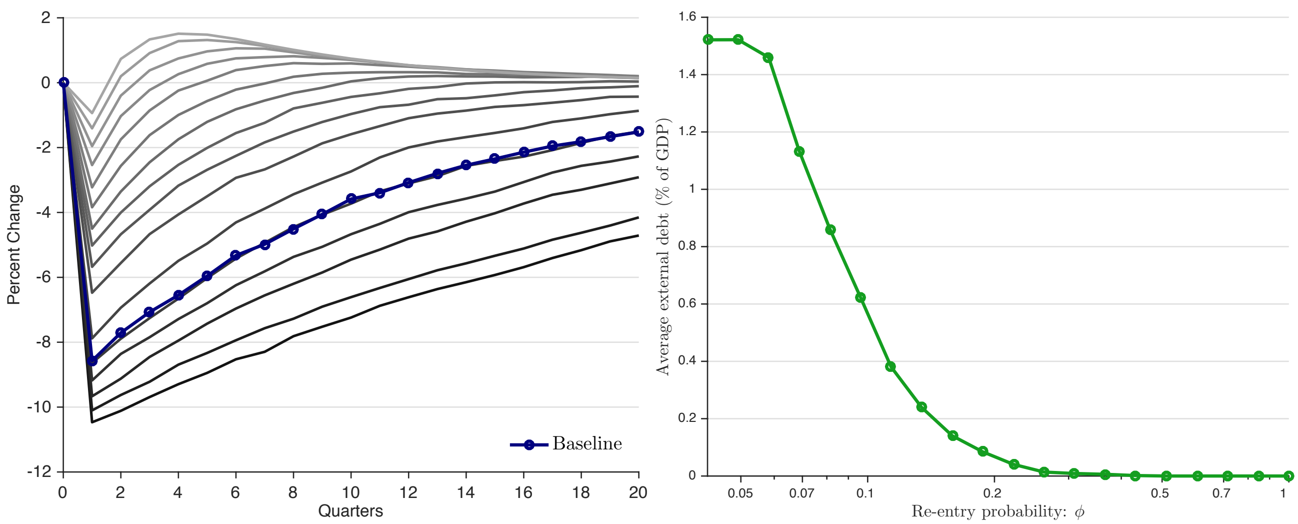
In the model a sovereign default when the economy is open triggers a temporary exclusion from external financial markets and a reversion to the closed economy. This reversion can generate commitment for the government insofar the ability of the government to provide liquidity after a default is undermined during the period in which the economy is closed. How much commitment can this reversion to the closed economy generate will depend on the length of the period of exclusion. In this section I use the calibrated model to quantify the importance of the exclusion and loss of reputation after a default in generating the government to repay debt.

I solve and simulate multiple economies that differ in the probability of re-entering external financial markets following a default on the open economy. I leave all the other parameters of the economy in their values of the baseline calibration and vary the parameter ϕ within the range $[0.04, 1]$, which map to periods of exclusion of average length between 1 and 24 quarters. First, I assess the role of the length of exclusion from external financial markets in determining the dynamics of output after a default. For this I do the same impulse-response exercise described above in which I compare the difference of the dynamics of output under the decision to repay and default for multiple economies.

Results, shown in Figure 6a, indicate that the length of exclusion from financial markets plays an important role in determining the depth and persistence of the output cost of default. For example, in an economy with an average period of exclusion of 1 year (which corresponds to $\phi = 0.25$) the peak-to-trough drop in output due to default is 1% and output recovers after 2 quarters, whereas in an economy with an average period of exclusion of 6 years (which corresponds to $\phi = 0.04$) the peak-to-trough drop in output due to default exceeds 10% and reaches its half-life after 5 years. The reason for why the length of exclusion affects output dynamics is through its effect on the ability of government to provide liquidity domestically. When the length of exclusion is short, the government's credibility to repay debt is similar when the economy is open and closed, since continuation values are similar. Hence, its endogenous ability to provide liquidity in the closed and open economy is similar which implies that the drop in output following a default in the open economy is small. On the other hand, when the length of exclusion is long, the government's credibility to repay debt in the open economy is higher than in the closed precisely because a default in the open economy would lead to a protracted period during which the economy is closed. This in turn undermines the ability

Figure 6. The Role of the Length of Exclusion

(A) Output Cost of Default (B) Average External Debt



Notes: Each line in panel (A) shows the average percent difference of the evolution of output under a default and its evolution under a repayment decision. I identify 200 states in the simulations in which the government decides to default when the economy is open. Then the evolution of output is computed in the absence of aggregate shocks and compared with the evolution of output if the government decided to repay instead of default. Each line corresponds to economies with different values of ϕ that range between 0.03 and 0.25. Lighter tones of gray correspond to economies with shorter periods of exclusion (higher values of ϕ). The blue line with circles corresponds to the baseline calibrated economy. Panel (B) shows the average level of external public debt in the simulations of various economies that differ in their level of ϕ (shown in the x-axis).

of the government to provide liquidity following a default on an open economy, resulting in a deeper and more persistent drop in output.

The fact that the model endogenously delivers a depressed level of output while the economy is in external financial autarky provides a microfoundation to a commonly adopted assumption in quantitative default models by which the economy suffers an output cost of default for as long as they are excluded from financial markets. Here, the depressed level of output is due to the loss of reputation that the government suffers which undermines its ability to provide liquidity to the domestic economy.

Second, I analyze the effects of the length of period of exclusion on the average levels of external debt that the government sustains in equilibrium. In the baseline calibration domestic agents are more impatient than foreign investors and the government has incentives to issue external as much external debt as it can credibly commit to repay (in most states) to frontload consumption for workers. Therefore, equilibrium levels of external debt reflect the degree of commitment that the government has through the presence of the endogenous costs of default. Figure 6b shows the average simulated ratio of external debt to GDP for different economies that only differ in the probability of re-entry to external markets ϕ. Consistent with the previous result, the length of exclusion from financial markets also plays an important role in determining the government's ability to credibly sustain external debt in equilibrium. For example, in an economy with an average period of exclusion of 1 year the average levels of external debt are less than 5% of quarterly GDP, whereas in an economy with an average period of exclusion of 6 years the average level of external debt is around 150% of quarterly GDP.

From this analysis I can conclude that the loss of access to external markets, when accompanied by a loss of reputation for the government, is important in determining both the dynamics of output and the ability of the government to sustain external debt in equilibrium. The government's ability to provide liquidity domestically is undermined while it has low reputation and is excluded from external financial markets, and this undermined ability to provide liquidity enhances the output costs of default and provides the government with additional sources of commitment.

6. Policy Analysis

This section studies the effects two policies that are targeted at addressing the government's lack of commitment problem. I consider policies designed to increase the banks' exposure to public debt. In practice, various countries have regulation in place by which banks are persuaded or required to hold public debt in their balance-sheets.

These type of policies can have a positive effect on welfare given the presence of a positive externality generated by banks' holdings of public debt. When individual bankers solve their portfolio problem, they do not take into account the fact that by investing in public debt they enhance the government's commitment to repay its debt by increasing the cost of default. This in turn allows the government to credibly issue higher levels of external debt in equilibrium and households to benefit from higher consumption front-loading.

I analyze the case of two policies: the implementation of a subsidy on banks' purchases of public debt, and a minimum requirement of public debt holdings in banks. I find that the former is more effective in allowing for higher levels of external debt and is also welfare enhancing. The reason is that the subsidy, in addition to enhancing aggregate exposure of banks to public debt, induces a positive selection of banks into production. The subsidy induces banks with low productivities to hold public debt instead of investing in their technologies, and thus crowds-out low productivity banks from production. On the other hand, a minimum requirement induces a negative effect on the allocation of labor, by forcing high-productivity banks to use resources to buy public debt, that would otherwise be invested in high-productivity technologies.

In contemporaneous work, Chari et al. (2018) study the optimal dynamic pattern of financial repression in the context of a closed economy in which the government can engage in discriminatory default and public debt is useful to smooth the cost of distortionary taxation. Here, I stress how the presence of banks with heterogeneous investment opportunities can give rise to different results for different policies that target a higher exposure of banks to public debt.

6.1. *Subsidy on Public Debt*

I consider the implementation of a subsidy on bank purchases of public debt. This policy is characterized by the parameter τ_b which is a proportional subsidy that banks face when acquiring sovereign debt. I describe the banker's problem and characterize the competitive equilibrium in the economy with a subsidy in Appendix E. The presence of the subsidy distorts the portfolio decision of the marginal bank, by making public debt a more attractive investment. In particular, the cutoff productivity above which bankers decide to invest in their productive technology now satisfies the following condition

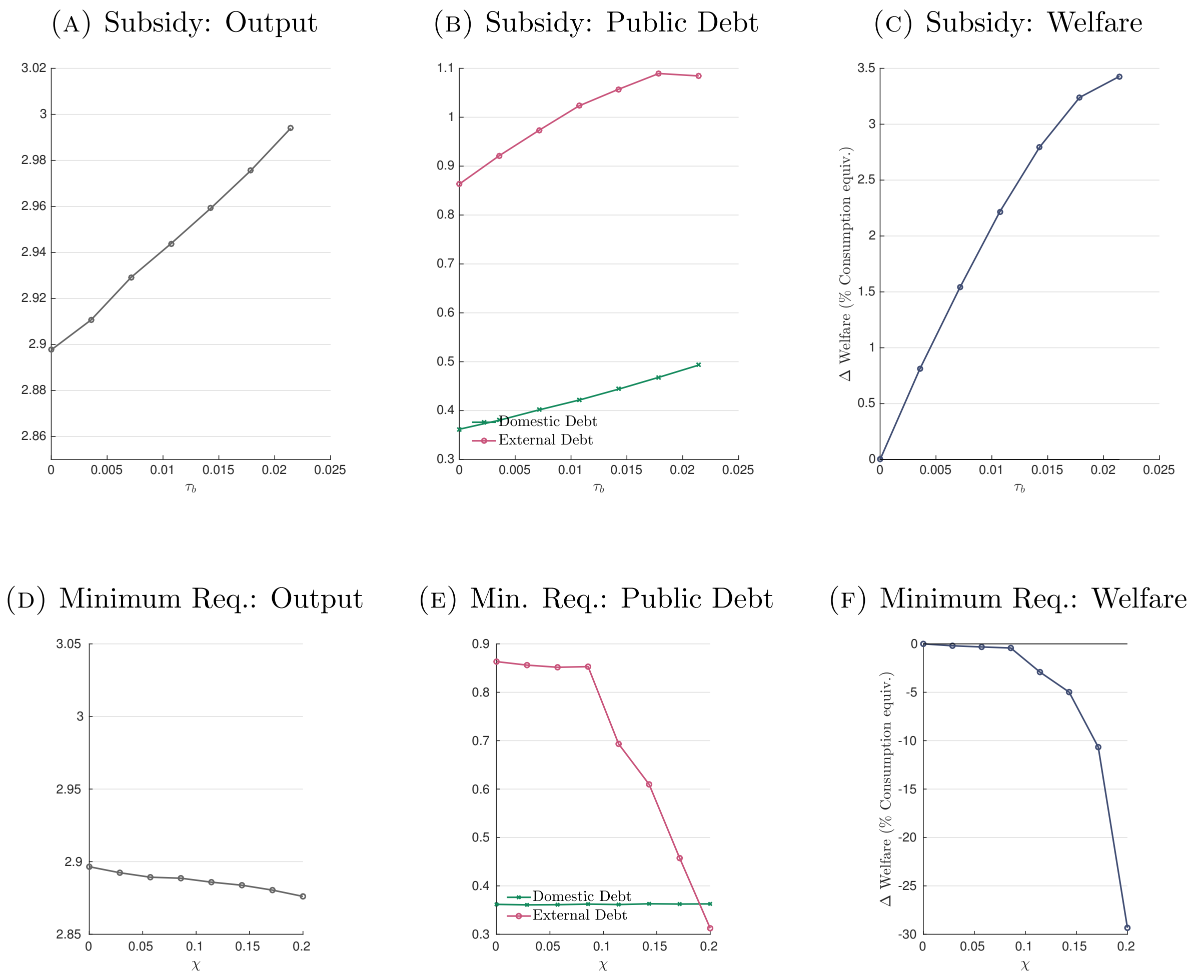
$$\mathbb{E}\left[\Omega(\tilde{\mathbf{s}}')A'\right]\frac{\underline{z}'(\tilde{\mathbf{s}})}{w(\tilde{\mathbf{s}})} = \mathbb{E}\left[\Omega(\tilde{\mathbf{s}}')\frac{\iota(\tilde{\mathbf{s}}')}{q^b(\tilde{\mathbf{s}})(1-\tau_b)}\right].$$

A subsidy to public debt induces the marginal bank to invest in 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.

The presence of the subsidy also enhances the aggregate exposure to public debt. By making public debt cheaper, a higher share of banks invest in public debt and the aggregate banks' exposure to public debt increases (see Figure 7b). This has a positive effect on government's commitment, by increasing the cost of default. This in turn allows the government to credibly issue more external debt (see Figure 7b).

I then compute the welfare effects of implementing the policy. I define the welfare benefit (or cost) of implementing a policy of subsidy τ_b, denoted $\delta^{\tau_b}(\mathbf{s})$ as the unconditional average across all states of the percent change in the lifetime consumption stream required by both workers and bankers in the economy without a subsidy in a given state to be as well off as living in an

FIGURE 7. Policy Analysis: Subsidy and Minimum Requirement on 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 ratio of external and domestic public debt to quarterly GDP in economies with different values of subsidies to banks' holdings of public debt, τ_b. Panel (C) shows the welfare change (measured in % of consumption) of introducing a subsidy to banks' holdings of public debt, τ_b. Panel (D) shows the average level of output in economies with different values of minimum requirements of public debt, χ. Panel (E) shows the average ratio of external and domestic public debt to quarterly GDP in economies with different values of minimum requirements of public debt, χ. Panel (F) shows the welfare change (measured in % of consumption) of introducing a minimum requirement ξ of public debt in banks.

economy with a subsidy τ_b. Since $\delta^{\tau_b}(\mathbf{s})$ is state-dependent I then compute its average over the states of the ergodic set of the baseline economy.[25] Figure 7c shows the results. For values of

[25]Formally, $\delta^{\tau_b} = \sum_{\mathbf{s}} p(\mathbf{s})\delta^{\tau_b}(\mathbf{s})$ where $\delta^{\tau}(\mathbf{s})$ solves

$$\mathbb{E}\left[\sum_{t=0}^{\infty} \beta^t \left(\alpha u\left(C_t^w(1+\delta^{\tau_b}(\mathbf{s}))+(1-\alpha)u\left(C_t^b(1+\delta^{\tau_b}(\mathbf{s})\right)\right)\right|\mathbf{s}\right] = W^{\tau_b}\left(A_{-1}, g, \underline{z}, B^d, B^x\right)$$

τ_b that range from 0 to 2.5% the policy is welfare enhancing. This is due to the fact that not only does the policy allow for higher levels of external public debt, thereby allowing workers to frontload consumption, but it also increases the level of output by inducing a better allocation of resources.

One concern regarding our policy analysis is the role of a low discount factor driving the main results. With low values of the discount factor the value of issuing higher levels of external debt and front-loading consumption is high. In Appendix E I re-compute our policy analysis using an alternative parametrization with a higher value of the discount factor of $\beta = 0.96$. Main results remain unchanged under this alternative parametrization. In particular, the policy yields the similar effects on the level of external debt and output, with the main difference being that the consumption equivalent gains of the policy are smaller, given that consumption front-loading is less valuable.

6.2. *Minimum Requirement on Public Debt Holdings*

I 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 22

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

The formal derivations of the solution to the banks' problem, as well as the equations that characterize the competitive equilibrium be found 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. As a result, the aggregate level of output falls as labor is allocated into technologies with lower productivities on average. Figure 7d shows the average level of output in economies with different values of χ.

I then analyze the effect of the minimum requirement on the aggregate exposure of banks to public debt. On the one hand, the presence of the minimum requirement increases the

where $W^{\tau_b}\left(A_{-1}, g, \underline{z}, B^d, B^x\right)$ denotes the value function in the economy with policy τ_b.

exposure to public debt of banks with high-productivity. On the other hand, as argued above, the minimum requirement induces some low-productivity banks to invest in their technology, which in turn reduces the aggregate exposure to public debt of low-productivity banks. In fact, for our baseline calibration, this second effect offsets the direct effect of the policy, and the average aggregate bank exposure of public debt remains roughly unchanged for different values of χ (see Figure 7e). This in turn impedes the government to gain commitment and increase the levels of external debt.

The welfare effects of the implementation of a minimum requirement policy χ are shown in Figure 7f. This policy is welfare reducing for all considered values of χ. The reason is that the policy induces a worse allocation of labor in the economy and fails to increase the aggregate exposure of banks to public debt (since the increase in the exposure of productive banks is offset by a reduction in the exposure of banks with lower productivities). In Appendix E I show that these results remain unchanged when I use an alternative parametrization with a higher value of the discount factor.

7. 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. In the model economy the role of public debt is dual. First, it is a security that allows to perform inter-temporal trade when the holders of this security are foreign investors. Second, it provides liquidity to the domestic financial system given the presence of financial frictions in the domestic economy.

Banks that do not have good investment opportunities invest in public debt to transfer their wealth across time. After a default the government looses reputation and with it, its 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. I provide evidence from Argentina using individual banks data that is supportive of the model's main mechanism. When quantifying the model to match the Argentinean economy I find that a default can generate a deep and persistent fall in output. Additionally, the presence of an endogenous cost of default is important in aligning the government's incentives to repay, as the model can account for observed levels of external public debt.

Finally, I make the point that implementing a subsidy to public debt purchases from banks can be a desirable policy as it enhances government's commitment by increasing default risk, while at the same time inducing a good selection of banks that invest in their projects and generate output. One feature of the theoretical framework is that the presence of foreign investors puts a halt in how much liquidity the government can provide internally. This may give room for capital controls to enhance the government's ability provide liquidity. I leave for future research the study of optimal capital in the context of this economy.

References

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

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

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

Angeletos, G.-M., F. Collard, H. Dellas, and B. Diba (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, 690–712.

Arellano, C., Y. Bai, and L. Bocola (2017): "Sovereign Default Risk and Firm Heterogeneity," Manuscript.

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

Balke, N. (2018): "The Employment Costs of Sovereign Default," Manuscript.

Basu, S. (2009): "Sovereign Debt and Domestic Economic Fragility," Manuscript.

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

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

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

Bianchi, J., J. C. Hatchondo, and L. Martinez (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, 879–926.

Bocola, L. and A. Dovis (2016): "Self-Fulfilling Debt Crises: A Quantitative Analysis," Manuscript.

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

Broner, F., A. Martín, and J. Ventura (2010): "Sovereign Risk and Secondary Markets," *American Economic Review*, 100, 1523–1555.

Bulow, J. and K. Rogoff (1989): "Sovereign Debt: Is to Forgive to Forget?" *The American Economic Review*, 79, 43–50.

Chari, V. V., A. Dovis, and P. J. Kehoe (2018): "On the Optimality of Financial Repression," Manuscript.

Chari, V. V. and P. J. Kehoe (1993): "Sustainable Plans and Debt," *Journal of Economic Theory*, 61, 230–261.

Chatterjee, S. and B. Eyigungor (2012): "Maturity, Indebtedness, and Default Risk," *The American Economic Review*, 102, 2674–2699.

D'Erasmo, P. (2011): "Government Reputation and Debt Repayment in Emerging Economies," Manuscript, University of Maryland, College Park.

D'Erasmo, P. and E. Mendoza (2017): "Optimal Domestic (and External) Sovereign Default," Manuscript.

D'Erasmo, P. and E. G. Mendoza (2016): "Distributional incentives in an equilibrium model of domestic sovereign default," *Journal of the European Economic Association*, 14, 7–44.

Dias, D. A. and C. Richmond (2008): "Duration of Capital Market Exclusion: Stylized Facts and Determining Factors," Manuscript.

Du, W. and J. Schreger (2018): "Sovereign Risk, Currency Risk, and Corporate Balance Sheets," Manuscript.

Eaton, J. and M. Gersovitz (1981): "Debt with Potential Repudiation: Theoretical and Empirical Analysis," *The Review of Economic Studies*, 48, 289–309.

Gelos, R. G., R. Sahay, and G. Sandleris (2011): "Sovereign Borrowing by Developing Countries: What Determines Market Access?" *Journal of International Economics*, 83, 243–254.

Gennaioli, N., A. Martín, and S. Rossi (2014): "Sovereign Default, Domestic Banks, and Financial Institutions," *The Journal of Finance*, 69, 819–866.

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

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

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

Gopinath, G. and B. Neiman (2014): "Trade Adjustment and Productivity in Large Crises," *The American Economic Review*, 104, 793–831.

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

Hatchondo, J. C., L. Martinez, and C. Sosa-Padilla (2016): "Debt dilution and sovereign default risk," *Journal of Political Economy*, 124, 1383–1422.

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

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

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

Kalemli-Ozcan, ., C. Reinhart, and K. Rogoff (2016): "Sovereign Debt and Financial Crises: Theory and Historical Evidence," *Journal of the European Economic Association*, 14, 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 J. Moore (1997): "Credit Cycles," *Journal of Political Economy*, 105, 211–248.

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

Mallucci, E. (2017): "Domestic Debt and Sovereign Defaults," Manuscript.

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

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

Na, S., S. Schmitt-Grohé, M. Uribe, and V. Yue (2018): "The twin ds: Optimal default and devaluation," *American Economic Review*, 108, 1773–1819.

Ottonello, P. and D. J. Perez (2018): "The Currency Composition of Sovereign Debt," Manuscript.

Passadore, J. and Y. Xu (2018): "Illiquidity in Sovereign Debt Markets," Manuscript.

Reinhart, C. M. and K. S. Rogoff (2011): "From Financial Crash to Debt Crisis," *The American Economic Review*, 101, 1676–1706.

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

Sosa Padilla, C. (2018): "Sovereign Defaults and Banking Crises," Forthcoming at *Journal of Monetary Economics*.

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

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

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

Appendix A. Omitted Proofs and Results (For Online Publication)

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 (abusing notation) $\tilde{\mathbf{s}}' = (\mathbf{s'}, \mathcal{B}'(\mathbf{s}), \mathcal{I}(\mathbf{s})))$ 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/her idiosyncratic productivity, a banker faces the following recursive problem

$$v(n, z; \tilde{\mathbf{s}}) = \max_{l' \geq 0, b^{d'} \geq 0, d'} (1-\sigma)n + \mathbb{E}\big[\Lambda(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')v(n', z'; \tilde{\mathbf{s}}')|\tilde{\mathbf{s}}\big] \tag{22}$$

subject to:

$$\sigma n = w(\tilde{\mathbf{s}})l' + q^b(\tilde{\mathbf{s}})b^{d'} + q^d(\tilde{\mathbf{s}})d', \tag{23}$$

$$n' = A'zl' + \iota(\tilde{\mathbf{s}}')(b^{d'} + d'), \tag{24}$$

$$q^d(\tilde{\mathbf{s}})d' \geq -\kappa\sigma n. \tag{25}$$

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 2. *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 worker's and banker's 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 worker's consumption is consistent with its budget constraint (2)
(3) Given prices, bank allocations and value functions solve the recursive banker's problem (22)

(4) The labor market and the interbank deposit market clear

$$\int l'(z,n,\tilde{\boldsymbol{s}})\mathrm{d}\mathcal{G}(n,z;\tilde{\boldsymbol{s}}) = 1 \tag{26}$$

$$\int d'(z,n,\tilde{\boldsymbol{s}})\mathrm{d}\mathcal{G}(n,z;\tilde{\boldsymbol{s}}) = 0 \tag{27}$$

(5) The public debt market clears

for $e = o$:
$$\int b^{d'}(z,n,\tilde{\boldsymbol{s}})\mathrm{d}\mathcal{G}(n,z;\tilde{\boldsymbol{s}}) \leq B' \tag{28}$$

$$q^b(s,B') \geq \frac{\mathbb{E}\left[\iota(\boldsymbol{s}')|\tilde{\boldsymbol{s}}\right]}{R} \tag{29}$$

$$\left(\int b^{d'}(z,n,\tilde{\mathbf{s}})\mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}}) - B'\right)\left(q^b(s,B') - \frac{\mathbb{E}\left[\iota(\boldsymbol{s}')|\tilde{\mathbf{s}}\right]}{R}\right) = 0 \tag{30}$$

for $o = c$:
$$\int b^{d'}(z,n,\tilde{\boldsymbol{s}})\mathrm{d}\mathcal{G}(n,z;\tilde{\boldsymbol{s}}) = B' \tag{31}$$

(6) The joint distribution of net-worth and productivity evolves according to

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

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*

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

- 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*

Proof of Proposition 1

I 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 (23) to substitute away d' I can re-write the recursive problem of the banks as

$$\nu(z;\tilde{\mathbf{s}})n = \max_{l'\geq 0, b^{d'}\geq 0} (1-\sigma)n + \mathbb{E}\big[\Lambda(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\nu(z';\tilde{\mathbf{s}}')n'|\tilde{\mathbf{s}}\big] \tag{32}$$

subject to:

$$n' = \left(R^l(z;\tilde{\mathbf{s}},\tilde{\mathbf{s}}') - R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right) w(\tilde{\mathbf{s}})l' + \left(R^b(\tilde{\mathbf{s}},\tilde{\mathbf{s}}') - R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right) q^b(\tilde{\mathbf{s}})b^{d'} + R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\sigma n$$

$$(1+\kappa)\sigma n \geq w(\tilde{\mathbf{s}})l' + q^b(\tilde{\mathbf{s}})b^{d'}$$

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 $R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}') \equiv \frac{\mathcal{I}(\mathbf{s}')}{q^d(\tilde{\mathbf{s}})}$. This problem is linear in $l', b^{d'}$ and its solution involves corners.

If $q^b(\tilde{\mathbf{s}}) = q^d(\tilde{\mathbf{s}})$, the expected risk-adjusted return on deposits and public debt are the same and, given the constant returns to scale technology, the solution to the portfolio problem 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 $z \leq \underline{z}'(\tilde{\mathbf{s}})$: $\quad w(\tilde{\mathbf{s}})l' = 0 \quad q^d(\tilde{\mathbf{s}})d' = x \in [0,\sigma n] \quad q^b(\tilde{\mathbf{s}})b^{d'} = \sigma n - x$

Now I verify our conjecture of linearity. Substituting the solution to the problem in (32) the level of net worth scales away and I 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.

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 I obtain equation (12).

Now I show that for states in which the economy is open ($e = o$) and the price of debt is $q^b(\tilde{\mathbf{s}}) < \overline{q}(\tilde{\mathbf{s}})$, the price of deposits is $q^d(\tilde{\mathbf{s}}) = q^b(\tilde{\mathbf{s}})$. First note that market clearing in the interbank market implies that $q^d(\tilde{\mathbf{s}}) \leq q^b(\tilde{\mathbf{s}})$, 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.

Now suppose that $q^b(\tilde{\mathbf{s}}) < \overline{q}(\tilde{\mathbf{s}})$. Under this condition I show that $q^d(\tilde{\mathbf{s}}) = q^b(\tilde{\mathbf{s}})$, or equivalently $\mathbb{E}\left[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')R^d(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\right] = \mathbb{E}\left[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')R^b(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')\right]$. I show this 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 no bank would buy public debt and there is a cutoff $\overline{z}$ such that banks with $z < \overline{z}$ lend to other banks and banks with $z < \overline{z}$ borrow and invest everything in their production. Market clearing in the deposits market implies

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

which implies $\underline{z}' = G^{-1}\left(\frac{\kappa}{1+\kappa}\right)$. Using the indifference condition for $\underline{z}'$ and the expression for wages, the risk-adjusted return of interbank deposits would be

$$
\mathbb{E}\left[\Omega(\tilde{\mathbf{s}}, \tilde{\mathbf{s}}')A'\right] \frac{G^{-1}\left(\frac{\kappa}{\kappa+1}\right)}{\sigma N(\tilde{\mathbf{s}})},
$$

which is lower than the risk-adjusted return from investing in public debt, which is a contradiction.

Now I 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

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

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

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

which is true given our original assumption.

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 $B' = B^{d\prime}$.

Appendix B. Numerical Solution (For Online Publication)

De-trending of the Banker and Government Problem

First I derive the de-trended recursive banker's problem and then the government problem. The state variables for the banks problem are given by $(n, z; A_{-1}, g, \underline{z}, B^d, B^x)$.[26] The banker's problem is given by

$$v(n_0, z_0; A_{-1}, g_0, \underline{z}_0, B_0^d, B_0^x) = \max_{\{n_t, l_t, b_t^d, d_t\}_{s=1}^{\infty}} \mathbb{E}_0 \sum_{t=1}^{\infty} (1-\sigma)\Lambda_{0,t} n_t \tag{33}$$

subject to

$$n_t = \prod_{s=0}^{t} R_s^d n_0 + \sum_{s=1}^{t} \prod_{u=s}^{t-1} R_u^d \left[\left(R_s^l - R_s^d\right) w_{s-1} l_s + \left(R_s^b - R_s^d\right) q_{s-1}^b b_s^d \right] \tag{34}$$

$$q_t^b b_{t+1} \geq \kappa \sigma n_t \tag{35}$$

$$b_{t+1}^d \geq 0 \tag{36}$$

Equation (34) is obtained by iterating over the definition of net worth. Now I 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. Conjecture the 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

$$\Lambda(\hat{\mathbf{s}}, \hat{\mathbf{s}}') = \Lambda(\mathbf{s}, \mathbf{s}') \exp(g)^{-\gamma} \tag{37}$$

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

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

$$
\begin{aligned}
v(\hat{n}, z; \hat{\mathbf{s}}) &= (A_{-1}\mu_g)^{-1} v(n, z; \mathbf{s}) \\
&= (A_{-1}\mu_g)^{-1} \max_{l' \geq 0, b^{d'} \geq 0, d' \geq -\kappa n/q^d} (1-\sigma)n + \mathbb{E}\big[\Lambda(\mathbf{s}, \mathbf{s}')\left(\sigma v(n', z'; \mathbf{s}')\right)|\mathbf{s}\big] \\
&= \max_{l' \geq 0, \hat{b}^{d'} \geq 0, \hat{d}' \geq -\kappa \hat{n}/q^d} (1-\sigma)\hat{n} + \mathbb{E}\big[\Lambda(\mathbf{s}, \mathbf{s}') \exp(g) \left(\sigma v(\hat{n}', z'; \hat{\mathbf{s}}')\right)|\mathbf{s}\big] \\
&= \max_{l' \geq 0, \hat{b}^{d'} \geq 0, \hat{d}' \geq -\kappa \hat{n}/q^d} (1-\sigma)\hat{n} + \mathbb{E}\big[\Lambda(\hat{\mathbf{s}}, \hat{\mathbf{s}}') \exp(g)^{1-\gamma} \left(\sigma v(\hat{n}', z'; \hat{\mathbf{s}}')\right)|\mathbf{s}\big] \qquad (38)
\end{aligned}
$$

where in the third equality I use the definition of $\hat{n}'$ and the homogeneity of degree one of the value function, and in the third equality I use equation (37).

Now I 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 I can write the recursive problem of the government as

$$W^o(g, \underline{z}, \hat{B}^d, \hat{B}^x) = \max_{\iota \in \{0,1\}} \iota W^{or}(g, \underline{z}, \hat{B}^d, \hat{B}^x) + (1-\iota) W^{od}(g, \underline{z}), \qquad (39)$$

$$W^c(g, \underline{z}, \hat{B}^d) = \max_{\iota \in \{0,1\}} \iota W^{cr}(g, \underline{z}, \hat{B}^d) + (1-\iota) W^{cd}(g, \underline{z}). \qquad (40)$$

The value of repaying in the open economy is

$$W^{or}(g, \underline{z}, \hat{B}^d, \hat{B}^x) = \max_{\hat{B}'} \alpha u(\hat{C}^w) + (1-\alpha) u(\hat{C}^b) + \beta \exp(g)^{1-\gamma} \mathbb{E}\left[W^o(g', \underline{z}', \hat{B}^{d'}, \hat{B}^{x'})|\hat{s}\right] \qquad (41)$$

subject to

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

The value of repaying in the closed economy is

$$
\begin{aligned}
W^{cr}(g, \underline{z}, \hat{B}^d) = \max_{\hat{B}^{d'}} & \alpha u(\hat{C}^w) + (1-\alpha) u(\hat{C}^b) \qquad (42) \\
& + \beta \mathbb{E}\left[\phi W^o(g', \underline{z}', \hat{B}^{d'}, 0) + (1-\phi) W^c(g', \underline{z}', \hat{B}^{d'})\right]
\end{aligned}
$$

where

$$\hat{C}^w = \sigma \frac{\exp(g)}{\mu_g} \mathbb{E}\left[z|z > \underline{z}\right] - (1-\sigma)\hat{B}^d$$

$$\hat{C}^b = (1-\sigma) \frac{\exp(g)}{\mu_g} \mathbb{E}\left[z|z > \underline{z}\right] + (1-\sigma)\hat{B}^d$$

$$\underline{z}' = \underline{z}'\left(\hat{s}, c; \hat{B}^{d'}, 1\right)$$

Finally, the value of defaulting on debt (both in the closed or open) economy is given by

$$W^{od}(g, \underline{z}) = W^{cd}(g, \underline{z}) = W^{cr}(g, \underline{z}, 0). \tag{43}$$

Numerical Algorithm

Denote $\hat{x} = \frac{x}{A_{-1}\mu_g}$ the de-trended version of variable x. Let $\hat{\mathbf{s}} = (\hat{s}, e)$ denote the de-trended aggregate state, where $\hat{s} = \left(g, \underline{z}, \hat{B}^d, \hat{B}^x\right)$. First I 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

$$\underline{z}'(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota) = \left[(\kappa+1)\sigma \hat{N} \frac{\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}') \frac{\mathcal{I}(\hat{\mathbf{s}}')}{q^b(\hat{\mathbf{s}}, \hat{B}^{x'})}\right]}{\mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}')\exp(g')\right]}\right]^{\frac{1}{1+\lambda}} \tag{44}$$

$$q^b(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota)\hat{B}^{d'}(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota) = \sigma \hat{N}\left((1-\underline{z}^{-\lambda})(1+\kappa) - \kappa\right) \tag{45}$$

$$\hat{N}(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota) = \left(\frac{\exp(g)}{\mu_g} \frac{\lambda \underline{z}}{\lambda - 1} + \iota \hat{B}^d\right) \tag{46}$$

$$\nu(\hat{\mathbf{s}}; \hat{B}^{x'}, \iota) = (1-\sigma) + \sigma \mathbb{E}\left[\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}') \frac{\mathcal{I}(\hat{\mathbf{s}}')}{q^b(\hat{\mathbf{s}}, \hat{B}^{x'})}\left[1 + \frac{(\kappa+1)}{\lambda - 1}\underline{z}'(\hat{\mathbf{s}})^{-\lambda}\right]\right] \tag{47}$$

where

$$\Omega(\hat{\mathbf{s}}, \hat{\mathbf{s}}') = \beta \exp(g)^{1-\gamma}\left(\frac{\hat{\mathcal{C}}^b(\hat{\mathbf{s}}')}{\hat{\mathcal{C}}^b(\hat{\mathbf{s}})}\right)^{-\gamma} \nu(\hat{\mathbf{s}}'). \tag{48}$$

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

$$\underline{z}'(\hat{\mathbf{s}};\hat{B}^{b'},\iota)^{-(1+\lambda)}(\kappa+1)\frac{\mathbb{E}\left[\Omega(\hat{\mathbf{s}},\hat{\mathbf{s}}')\mathcal{I}(\hat{\mathbf{s}}')\right]}{\mathbb{E}\left[\Omega(\hat{\mathbf{s}},\hat{\mathbf{s}}')\exp(g)'\right]} = \frac{\left(\left(1-\underline{z}'(\hat{\mathbf{s}};\hat{B}^{b'},\iota)^{-\lambda}\right)(1+\kappa)-\kappa\right)}{B^{b'}}. \tag{49}$$

Note that I have used the functional forms used in the calibration to substitute for $u(\cdot), G(\cdot)$ and I 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 (47) 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 $\mathcal{E}_1^c(\mathbf{s}, B^{d'}, \iota)$ and $\mathcal{E}_2^c(\mathbf{s}, B^{d'}, \iota)$ for all $(\mathbf{s}, B^{d'}, \iota) \in \mathcal{S} \times G_{\hat{B}^d} \times \{0,1\}$, 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 (44)-(49). 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 $q^d(\mathbf{s}) = q^b(\mathbf{s})$).

(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 I use piecewise linear interpolation.

(6) If $\sup_{\mathbf{s},B^{x\prime},\iota}\left\|\mathcal{E}_1^o(\mathbf{s}, B^{x\prime}, \iota) - \mathbb{E}\left[\Omega(\hat{\mathbf{s}},\hat{\mathbf{s}}')\frac{\mathcal{I}(\hat{\mathbf{s}}')}{q^b(\hat{\mathbf{s}},\hat{B}^{x\prime})}\right]\right\| < \epsilon$, $\sup_{\mathbf{s},B^{x\prime},\iota}\left\|\mathcal{E}_2^o(\mathbf{s}, B^{x\prime}, \iota) - \mathbb{E}\left[\Omega(\hat{\mathbf{s}},\hat{\mathbf{s}}')\exp(g')\right]\right\| < \epsilon$, $\sup_{\mathbf{s},B^{d'},\iota}\left\|\mathcal{E}_1^c(\mathbf{s}, B^{d'}, \iota) - \mathbb{E}\left[\Omega(\hat{\mathbf{s}},\hat{\mathbf{s}}')\mathcal{I}(\hat{\mathbf{s}}')\right]\right\| < \epsilon$, $\sup_{\mathbf{s},B^{d'},\iota}\left\|\mathcal{E}_2^c(\mathbf{s}, B^{d'}, \iota) - \mathbb{E}\left[\Omega(\hat{\mathbf{s}},\hat{\mathbf{s}}')\exp(g')\right]\right\| < \epsilon$ 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. I solve the Markov Perfect Equilibrium by solving a fixed point between the expected government policies and the optimal one-period deviation policies that solve government problem (39)-(42) in its de-trended recursive representation.

The algorithm to solve for the Markov Perfect equilibrium follows these steps:

(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 (39) - (43). 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.

Appendix C. Empirical Analysis

The micro-data on individual banks' balance sheet data comes from the Central Bank of Argentina. I 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.

I focus on measures of banks' performance and exposure to public debt. All variables are measured at book value. I consider two measures of banks' performance: return on assets and return on equity. I compute return on assets as the ratio of annual financial income to financial assets. I include in financial income the concept of 'other income' since most of the losses associated to the sovereign default were assigned to this book concept. Return on equity is reported in the balance-sheet information and is measured as the ratio of annual profits to book value of equity. I also consider two measures of banks' exposure to public debt. The first and preferred measure is the ratio of loans to the non-financial public sector to total assets (I 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 (I refer to this measure as PD Exposure 2). While the second measure includes securities, it is overestimated since it also includes private securities given that the available data consolidates public and private securities together. However, I still consider this measure as an imperfect measure of exposure to public debt as the public securities represent more than two thirds of the total securities traded domestically.

I provide robustness analysis regarding the relationship between measures of banks' performance and exposure to public debt. I estimate a set of regressions of measures of banks' performance on measures of exposure to public debt. I consider the two measures of exposure to public debt previously described, and consider as measures of banks' performance the return on assets and return on equity. I 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. The preferred specification is the former since average bank performance over time better measures expected bank returns which is the performance metric that this theory predicts should be related to exposure to public debt.

Results are shown in Table C1. 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.

Table C1. Regressions Banks' Performance and Exposure to Public Debt

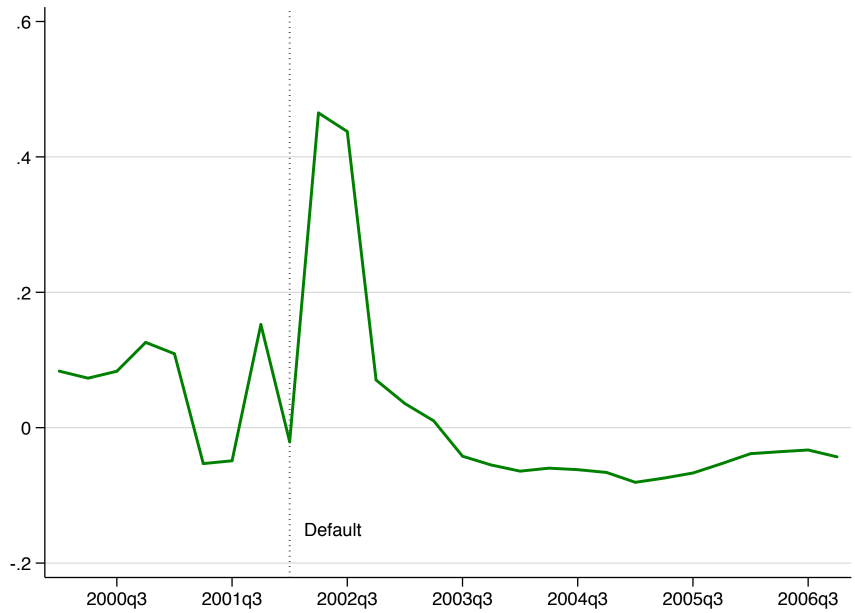
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RoA	RoA	RoA	RoA	RoA	RoA	RoE	RoE
PD Exposure 1	-0.142**		-0.063		-0.072		-0.411**	
	(0.056)		(0.039)		(0.056)		(0.171)	
PD Exposure 2		-0.111**		-0.077***		-0.052*		-0.047
		(0.046)		(0.028)		(0.029)		(0.080)
N	81	80	81	80	500	499	496	495
Specification	Baseline	Baseline	Cont: σ_{RoA}	Cont: σ_{RoA}	Panel	Panel	Panel	Panel
Year FE	No	No	No	No	Yes	Yes	Yes	Yes

Notes: The dependent variable is the return on financial assets in columns (1)-(6) and the return on equity 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. Columns (3)-(4) also include the standard deviation (across time) of return on assets as an additional control. Columns (1)-(4) use cross sectional data by averaging individual bank's variables over time. Columns (5)-(8) use bank-year panel data. The estimation method used in all columns is OLS. "Year FE" are year dummy variables. Robust standard errors are in parentheses. $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

Columns 5 and 6 estimate the baseline regression but using panel data instead of averaging variables across time for every bank. These specifications include year fixed effects. When using panel data the relationship is still negative but looses significance for one specification. Finally, the last two columns estimate the same specification as in columns 5 and 6 using returns on equity as dependent variable. In these cases, the estimated relationship between banks returns on equity and exposure to public debt is negative in both cases (when we measure exposure as the first or second measure), and statistically significant in the first case.

Finally, Figure C.1 shows the behavior of the interbank rate during the December 2001 default. After spiking in the first two quarters after the default[27], the interbank rate stabilized at a lower level than the average pre-default level. A lower interbank rate after a default episode is a prediction of the model.

Figure C.1. Interbank Rate Around a Default Episode



Notes: This figure shows the annual real rate of interbank loans. This is computed as the nominal rate in local currency minus expected inflation. To compute expected inflation we use average expected inflation from survey data after 2004 (when these data becomes available) and use realized inflation until then.

[27]The immediate spike in the interest rate could be attributed to counter-party credit risk in the midst of the banking crisis.

Appendix D. Quantitative Analysis (For Online Publication)

D.1. *Model Fit*

Table D1. Calibrated Parameters

Statistic	Data	Model
Domestic public debt (% of GDP)	35.0%	36.2%
Share of compensation to workers	71.3%	71.4%
Output growth		
Standard deviation	2.1%	2.4%
Autocorrelation	43.8%	53.6%

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. Moments from the model correspond to average statistics of moments from 1,000 simulations. Each simulation includes 1,000 periods and restricts attention to those states in which the economy is open. The first two statistics corresponds to averages. Domestic public debt corresponds to banks' exposure to public debt, and is expressed in % of quarterly GDP. The share of compensation to workers in the data corresponds to ratio of value added generated by workers to the sum of value added generated by workers and profits. In the model it corresponds to ratio of payments to workers to total output.

D.2. *Sensitivity Analysis*

This section analyzes the sensitivity of the main results to key parameters in the model. In particular, I 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), and the weight of workers on the government preferences (parameter α). Results are reported in Table D2. 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. I consider two alternative values, $\beta = 0.88$, which is lower than the baseline value and $\beta = 0.97$ higher than the baseline value and in line with quantitative business cycle models. I find that the levels of external debt are smaller in the economy with a higher discount factor since the

TABLE D2. Sensitivity Analysis

Parametrization	Value	External Public Debt	Domestic Public Debt	Output Level	Output Cost of Default
Baseline Model	-	81.3%	36.2%	0.0%	-7.3%
Discount Factor	Higher $\beta = 0.97$	49.1%	36.3%	0.0%	-6.3%
	Lower $\beta = 0.88$	77.7%	36.1%	-0.0%	-7.3%
Leverage Constraint	Tighter $\kappa = 5.00$	48.0%	36.3%	-9.5%	-7.1%
	Looser $\kappa = 8.00$	68.8%	36.2%	1.6%	-7.6%
Prod. Dispersion	Lower $\lambda = 3.70$	30.9%	28.6%	-7.9%	-5.0%
	Higher $\lambda = 3.20$	128.6%	47.2%	15.3%	-11.0%
Bankers Cons. Rate	Higher $\sigma = 0.78$	36.9%	31.7%	-1.2%	-6.4%
	Lower $\sigma = 0.80$	69.2%	45.7%	2.4%	-6.7%
Workers Weight	Higher $\alpha = 0.93$	46.0%	36.3%	0.0%	-7.5%
	Lower $\alpha = 0.90$	35.6%	36.2%	-0.0%	-4.0%

Notes: Moments from the model correspond to average statistics of moments from 1,000 simulations. Each simulation includes 1,000 periods and restricts attention to those states in which the economy is open. All moments are averages. 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.

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 not significantly different from 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. 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 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 9.5% lower than in the baseline economy. 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.

Rows 6 and 7 show the sensitivity to the dispersion of idiosyncratic productivity, by analyzing economies with $\lambda = 3.2$ and $\lambda = 3.7$. A higher dispersion of productivities ($\lambda = 3.2$) 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 has large effects on the average productivity and hence on output. This implies a sovereign default has a larger effect on output (11% on impact, compared to 7.3% in the baseline economy) and thus on the government's commitment. Consequently, the average level of external public debt is 129% of quarterly GDP, significantly higher than in the baseline economy. An opposite picture emerges in the economy with less dispersed productivities.

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. Furthermore, the government's ability to credibly issue external public debt is non-monotone on the stock of domestic public debt. This is because very low levels of domestic debt makes default more attractive since the output costs of default are lower, and very high levels of domestic debt makes default attractive to redistribute resources from bankers to workers.

Finally, the last two rows 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.

Appendix E. Policy Analysis (For Online Publication)

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

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

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

subject to:

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

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

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

subject to:

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

$$(1+\kappa)\sigma n \geq w(\tilde{\mathbf{s}})l' + q^b(\tilde{\mathbf{s}})(1-\tau_b)b^{d'},$$

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 $q^d(\tilde{\mathbf{s}}) = q^b(\tilde{\mathbf{s}})(1-\tau_b)$ is given by

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

Substituting the solution into the objective function, I 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 I characterize the competitive equilibrium. The labor market clearing condition is given by

$$w(\tilde{\mathbf{s}}) = (\kappa+1)\sigma\left(\left[A\mathbb{E}[z|z>\underline{z}] + \iota(\tilde{\mathbf{s}})B^d\right]\right)\left[1 - G\left(\underline{z}'(\tilde{\mathbf{s}})\right)\right] \tag{50}$$

The total demand for public debt is determined residually

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

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 $B' = B^{d'}$.

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

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

subject to:

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

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

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

subject to:

$$n' = \left(R^l(z;\tilde{\mathbf{s}},\tilde{\mathbf{s}}') - R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right) w(\tilde{\mathbf{s}})l' + \left(R^b(\tilde{\mathbf{s}},\tilde{\mathbf{s}}') - R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')\right) q^b(\tilde{\mathbf{s}})b^{d'} + R^d(\tilde{\mathbf{s}},\tilde{\mathbf{s}}')q^d(\tilde{\mathbf{s}})\sigma n,$$

$$(1+\kappa)\sigma n \geq w(\tilde{\mathbf{s}})l' + q^b(\tilde{\mathbf{s}})b^{d'},$$

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

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 $q^d(\tilde{\mathbf{s}}) = q^b(\tilde{\mathbf{s}})$ is given by

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

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

Substituting the solution into the objective function, I 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 I characterize the competitive equilibrium. The labor market clearing condition is given by

$$w(\tilde{\mathbf{s}}) = (\kappa-\chi+1)\sigma\left(\left[A\mathbb{E}[z|z>\underline{z}] + \iota(\tilde{\mathbf{s}})B^d\right]\right)\left[1 - G\left(\underline{z}'(\tilde{\mathbf{s}})\right)\right] \tag{51}$$

To characterize market clearing in the public debt market I 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.

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

$$q^b(\tilde{\mathbf{s}})B^{b'}(\tilde{\mathbf{s}}) = \underbrace{\int_{z<\underline{z}}\sigma n \mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}}) - \int_{z>\underline{z}}\kappa\sigma n \mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}})}_{\text{Demand from low } z \text{ bankers}} + \underbrace{\int_{z>\underline{z}}\chi\sigma n \mathrm{d}\mathcal{G}(n,z;\tilde{\mathbf{s}})}_{\text{Demand from high } z \text{ bankers}}$$

$$= \sigma\left(\left[A_t\mathbb{E}[z|z>\underline{z}] + \iota_t B^d_t\right]\right)\left(G(\underline{z}'(\tilde{\mathbf{s}}))(1+\kappa-\chi) - \kappa + \chi\right).$$

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 $B' = B^{d'}$.

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

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

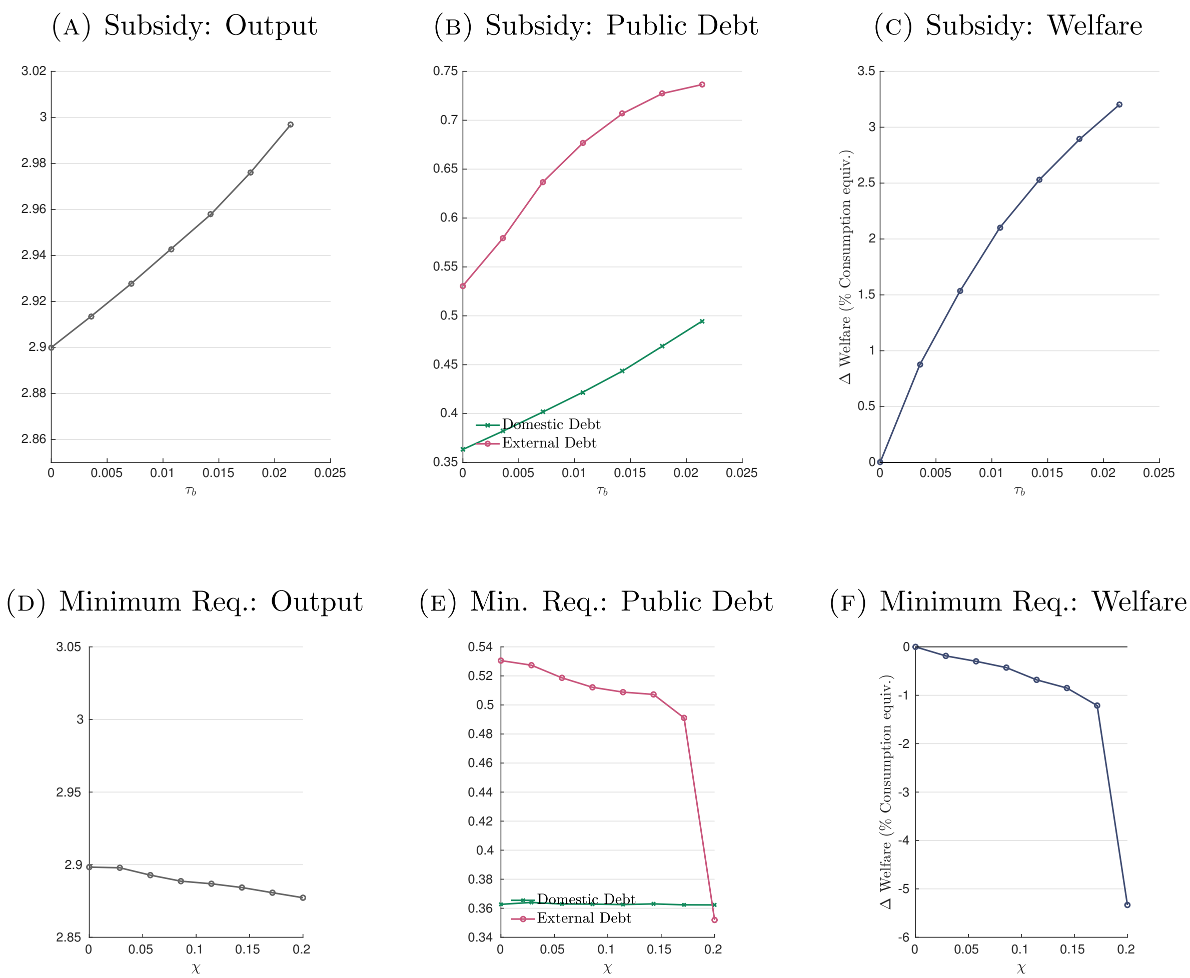
In those states in which the economy is open this equation determines the equilibrium stock of domestic public debt, for a given return of public debt. In those states in which the economy is closed, it determines the equilibrium price of debt given that $B' = B^{d'}$. Finally, the cutoff productivity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

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

E.3. *Sensitivity Analysis*

Figure E.1, panels (A) - (C), show the effects of imposing the subsidy on banks' holdings of public debt on output, public debt and welfare for a calibrated economy with a discount factor of $\beta = 0.96$ and all remaining parameters at the values of the baseline calibration. Panels (D) - (F) show the effects of imposing a minimum requirement on banks' holdings of public debt on the same variables.

FIGURE E.1. Subsidy and Minimum Requirement on Public Debt with High β



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 ratio of external and domestic public debt to quarterly GDP in economies with different values of subsidies to banks' holdings of public debt, τ_b. Panel (C) shows the welfare change (measured in % of consumption) of introducing a subsidy to banks' holdings of public debt, τ_b. Panel (D) shows the average level of output in economies with different values of minimum requirements of public debt, χ. Panel (E) shows the average ratio of external and domestic public debt to quarterly GDP in economies with different values of minimum requirements of public debt, χ. Panel (F) shows the welfare change (measured in % of consumption) of introducing a minimum requirement ξ of public debt in banks. For each economy I use the baseline parameterization with the exception of the discount factor which is set to $\beta = 0.96$.