Sovereign Defaults and Banking Crises

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Abstract

Episodes of sovereign default feature three key empirical regularities in connection with the banking systems of the countries where they occur: (i) sovereign defaults and banking crises tend to happen together, (ii) commercial banks have substantial holdings of government debt, and (iii) sovereign defaults result in major contractions in bank credit and production. This paper provides a rationale for these phenomena by extending the traditional sovereign default framework to incorporate bankers who lend to both the government and the corporate sector. When these bankers are highly exposed to government debt, a default triggers a banking crisis, which leads to a corporate credit collapse and subsequently to an output decline. When calibrated to the 2001-02 Argentine default episode, the model is able to produce default in equilibrium at observed frequencies, and when defaults occur credit contracts sharply, generating output drops of 7 percentage points, on average. Moreover, the model matches several moments of the data on macroeconomic aggregates, sovereign borrowing, and fiscal policy. The framework presented can also be useful for studying the optimality of fractional defaults.

Keywords: Sovereign Default, Banking Crisis, Credit Crunch, Endogenous Cost of Default, Bank Exposure to Sovereign Debt.

JEL: F34, E62

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1. Introduction

Sovereign defaults and banking crises have been recurrent events in emerging economies. Recent default episodes in emerging economies (e.g., Russia 1998, Argentina 2001-02) have shown that whenever the sovereign decides to default on its debt there is an adverse impact on the domestic economy, largely through disruptions of the domestic financial systems. Why does this happen? Both in the Argentine and Russian cases (and also in others discussed below), the banking sectors were highly exposed to government debt. In this way a government default directly decreased the value of the banking sector's assets. This forced banks to reduce credit to the domestic economy (a *credit crunch*), which in turn generated a decline in economic activity.

The recent debt crisis in Europe also highlights the relationship between defaults, banking crises, and economic activity. In early 2012, most of the concerns around Greece's possible default (or unfavorable restructuring) were related to the level of exposure that banks in Greece and other European countries had to Greek debt. The concerns were not only about losing what had been invested in Greek bonds, but also, and mostly, over how this shock to banks' assets would impact their lending ability and ultimately the economic activity as a whole.[1]

This leads to the realization that sovereign default episodes can no longer be understood as events in which the defaulter suffers mainly from international financial exclusion and trade punishments. The motivation above, the empirical evidence reviewed later on, and the policy discussions (e.g., IMF, 2002, Lane, 2012) all suggest shifting the attention to domestic financial sectors and how they channel the adverse effects of a default through the rest of the economy.

The main contribution of this paper is in the quantification of the impact that a sovereign default has on the domestic banks balance sheets, their lending ability and economy-wide activity. To do so, we build on the work of Brutti (2011), Sandleris (2016), and Gennaioli et al. (2014) to apply a theory of the transmission mechanism of sovereign defaults to a quantitative setup. We endogenize the output cost of defaults in the following way: a sovereign default

[1]Another related and current policy debate concerns the necessary improvements to regulatory policy for European banks and the ways in which they value their holdings of sovereign debt. Different proposals have been put forward aimed at lowering the fragility of the banking sector and its exposure to sovereign risk, like the implementation of Eurobonds (see. Favero and Missale, 2012), or the creation of European Safe Bonds (see Brunnermeier et al., 2011), among others. These proposals highlight how important it is for policy-making to have a better understanding of the dynamic relation between sovereign borrowing, bank fragility, and economic activity, and to have reliable quantifications of the impact of different government policies. Our paper provides builds on theory of the dynamics to provide a quantification of the impact.

triggers a credit crunch, and this credit crunch generates output declines. Ours is the first quantitative paper to endogenize the output cost of default as a function of the repudiated debt. This makes our framework a natural starting point to study the optimality of fractional defaults.

Based on three key empirical regularities, namely that (i) defaults and banking crises tend to happen together, (ii) banks are highly exposed to government debt, and (iii) crisis episodes are costly in terms of credit and output, we build a theoretical framework that links defaults, banking sector performance, and economic activity. This paper rationalizes these phenomena extending a traditional sovereign default framework (in the spirit of Eaton and Gersovitz, 1981) to include bankers who lend to both the government and the corporate sector. When these bankers are highly exposed to government debt, a default triggers a banking crisis which leads to a corporate credit collapse and consequently to an output decline.

These dynamics that characterize a default and a banking crisis are obtained as the optimal response of a benevolent planner: faced with a level of spending that needs to be financed, and having only two instruments at hand (debt and taxes), the planner may find it optimal to default on its debt even at the expense of decreased output and consumption. The planner balances the costs and benefits of a default: the benefit is the lower taxation needed to finance spending, and the cost is the reduced credit availability and the subsequently decreased output. Quantitative analysis of a version of the model calibrated to the 2001-02 Argentine default yields the following main findings: (1) default on equilibrium, (2) v-shaped behavior of output and credit around crisis episodes, (3) mean output decline in default episodes of approximately 7 percentage points, and (4) the overall quantitative performance of the model is in line with the business cycle regularities observed in Argentina and other emerging economies.

Layout. The remainder of this section reviews the related literature and the empirical evidence motivating the paper. Section 2 introduces the economic problem of banks with holdings of defaultable government debt. Section 3 describes the rest of the model economy and defines the equilibrium. Section 4 presents details of the calibration and the numerical solution. Section 5 has the main results, and Section 6 presents robustness exercises. Section 7 concludes. All tables and graphs are at the end of the manuscript.

1.1. Related literature

This paper belongs to the quantitative literature on sovereign debt and default, following the contributions of Eaton and Gersovitz (1981) and Arellano (2008). In particular, a related work is by Mendoza and Yue (2012) who are the first to endogenize the cost of default: a sovereign default forces the private sector to use less efficient resources. We propose an alternative and complementary source for output costs: a disruption in domestic lending triggered by non-performing sovereign bonds in domestic banks' balance sheets.

In recent years there has been a surge in studies looking at the feedback loop between sovereign risk and bank risk. Acharya et al. (2014) model a stylized economy where bank bailouts (financed via a combination of increased taxation and increased debt issuance) can solve an underinvestment problem in the financial sector, but exacerbate another underinvestment problem in the non-financial sector. Higher debt needed to finance bailouts dilutes the value of previously issued debt, increases sovereign risk and creates a feedback loop between bank risk and sovereign risk because banks hold government debt in their portfolios. On the policy side, Brunnermeier et al. (2011) argue for the creation of European Safe Bonds as a way to break this feedback loop. The idea relies on pooling (buying debt from all the European countries) and tranching (securitization of those bonds into two tranches: a small and safe senior tranche, and a larger and riskier junior tranche). Regulatory reform will in turn induce banks to hold the senior tranche breaking the link between sovereign risk and bank risk.

Other researchers have recently (and independently) noticed the link between sovereign risk and bank fragility, and have studied how it affects borrowing policies and default incentives. Gennaioli et al. (2014) construct a stylized model of domestic and external sovereign debt in which domestic debt weakens the balance sheets of banks. This potential damage to the banking sector represents in itself a signaling device that attracts more and cheaper foreign lending. Balloch (2016) studies an economy where domestic banks demand government debt for its colateralizability properties (above and beyond its financial return). Domestic bank holdings serve as an imperfect commitment device, and help the sovereign to raise funds from abroad at lower rates.[2] Our analysis relates to these papers in that it also identifies the damage that

[2]Another related study is Brutti (2011) who presents a sovereign debt model in which public debt is a source of liquidity and a default generates a liquidity crisis.

financial institutions suffer during defaults. We identify the reduced credit as the endogenous mechanism generating output costs of defaults and also analyze the benefit side: how distortionary taxation can be reduced when defaults occur. Additionally, our dynamic stochastic general equilibrium model allows us to quantify the importance of the "balance-sheet channel" while also being able to account for various empirical regularities in emerging economies. [3]

Recent work has also study the effects of banks' exposure and default risk on the domestic economy. Broner et al. (2014) provide a model with creditor discrimination and financial frictions, where an increase in sovereign risk incentivizes domestic holdings of sovereign debt (due to discrimination in favor of domestic creditors), crowds-out private investment and generates an output decline. Bocola (2016) studies the macroeconomic implications of increased sovereign risk in a model where banks are exposed to government debt. His framework takes default risk as given and shows how the anticipation of a default can be recessionary on its own. Perez (2015) who also studies the output costs of default when domestic banks hold government debt. Public debt serves two roles in his framework: it facilitates international borrowing, and it provides liquidity to domestic banks. We relate to these studies in analyzing the balance-sheet effects of a sovereign default in a quantitative model where default decisions are endogenous.

Finally, this paper also relates to recent research on optimal fiscal policy in the presence of sovereign risk. Pouzo and Presno (2016) study the optimal taxation problem of a planner in a closed economy with defaultable debt. Our main differences with Pouzo and Presno (2016) are two: firstly, they rely on an exogenous cost of default, whereas we propose an endogenous structure; and secondly, they assume commitment to a certain tax schedule but not to a repayment policy, whereas we assume no commitment on the part of the government. Kirchner and van Wijnbergen (2016) study the effectiveness of debt-financed fiscal stimulus when government debt is held by leveraged-constrained domestic banks. Higher government deficits tighten banks' leverage constraint and create a crowding-out effect on private investment (which may offset the initial stimulus). We also analyze the dynamic relationship between government policy and bank holdings of sovereign debt, but our focus is on the default incentives and output costs rather than on the stabilizing effects of government stimuli.

[3] Our analysis is also consistent with Sandleris (2016), who finds that the main costs of default come through the effects on the agents' balance sheets and expectations.

1.2. Empirical evidence

In this sub-section we review the three main empirical regularities that motivate this study.

Defaults and banking crises tend to happen together. A recent empirical study on banking crises and sovereign defaults is the one by Balteanu et al. (2011). Using the dates of sovereign debt crises provided by Standard & Poor's and the systemic banking crises identified in Laeven and Valencia (2008), they build a sample with 121 sovereign defaults and 131 banking crises for 117 emerging and developing countries from 1975 to 2007. Among these, they identify 36 "twin crises" (defaults and banking crises): in 19 of them a sovereign default preceded the banking crisis and in 17 the reverse was true. [4]

Banks are highly exposed to sovereign debt. Kumhof and Tanner (2005) define the "exposure ratio" of a given country as the financial institutions' net credit to the government divided by the financial institutions' net total assets. Using IMF data for the period 1998-2002 they report an average exposure ratio of 22% for all countries, 24% for developing economies, and 16% for advanced economies. Interestingly, for countries that actually defaulted this ratio was even higher (e.g., Argentina: 33%, Russia: 39%). A more recent empirical study by Gennaioli et al. (2016) reports an average exposure ratio of 9.3% when using granular data from Bankscope (which includes banks from both advanced and developing countries). When they focus only on defaulting countries, they find an exposure ratio of roughly 15%. [5]

Crisis episodes are characterized by decreased output and credit. It has been documented that output falls sharply in the event of a sovereign default. The estimates vary across the empirical literature, but all show that the output costs of defaults are sizable (e.g., Reinhart and Rogoff, 2009 report an 8% cumulative output decline in the three-year run-up to a domestic and external default crisis). [6] Additionally, output exhibits a v-shaped behavior around defaults.

These crises are also characterized by decreased credit to the private sector. Data from the Financial Structure Dataset (Beck et al., 2010) indicate that private credit (as a percentage of GDP) falls on average 8% in the default year and remains low for the subsequent periods.

[4]Previous empirical studies have found similar results, e.g. Borensztein and Panizza (2009) and Reinhart and Rogoff (2009), among many others.

[5]Broner et al. (2014) also document the increase in exposure experienced in European countries since 2007.

[6]Sturzenegger (2004) finds that a defaulting country that also suffers a banking crisis would typically experience output 4.5% below trend five years after the event.

2. Modeling bankers

The quantitative impact of sovereign defaults and banking crises depends on the specifics of the transmission mechanism. This mechanism, in turn, depends on the modeling of the financial sector, and so we devote this section to the bankers' problem describing the market for loanable funds and discussing the main assumptions. The rest of the model economy, which is standard in the quantitative literature of sovereign debt, is presented in the next section.

2.1. Preliminaries

Bankers are assumed to be risk-neutral agents. In each period, they participate in two different credit markets: the loan market (between private non-financial firms and bankers) and the sovereign bond market (between the domestic government and bankers). The working assumption is that they participate in these markets sequentially. [7]

The bankers lend to both firms and government from a pool of funds available to them during each period. These bankers start the period with the following resources: A, $s(k)$ and b. A represents an exogenous endowment, which the bankers receive each period. [8] $s(k)$ is the return on a storage technology: the previous period the banker put k into this technology, and today the return is $s(k)$. b represents the level of sovereign debt owned by the bankers at the beginning of the period (which was optimally chosen in the previous period). Hereinafter $d \in \{0, 1\}$ will stand for the default policy, with $d = 1$ (0) meaning default (repayment).

Sequence of events for the bankers. Firstly, the banker receives the endowment, A, has access to the stored funds from the previous period, $s(k)$, and gets government debt repayment, $b(1-d)$. Secondly, with those funds in hand, the banker extends intraperiod loans to firms, l^s. Finally, at the end of the period, the banker collects the proceeds from the loans, $l^s(1+r)$, and then solves a portfolio problem: chooses how much to lend to the government, $(1-d)qb'$, and how much to store, k', with the remainder being left for consumption, x.

[7] The assumption of sequential banking is no different from the day-market/night-market assumption commonly used in the money-search literature (e.g., Lagos and Wright, 2005).

[8] There are a number of ways to interpret this endowment, A. See subsection 2.4 for a detailed discussion.

2.2. Bankers problem

From the above timing we have that lending to the firms is limited by the funds obtained at the beginning of the period: $\mathcal{F} \equiv A + s(k) + b(1-d)$. This is captured in the following lending constraint: $l^s \leq \mathcal{F}$. The problem of the bankers can be written in recursive form as:

$$\begin{aligned} W(b,k,z) &= \max_{\{x,l^s,b',k'\}} \left\{ x + \delta\, \mathbb{E}W(b',k',z') \right\} && (1)\\ s.t.\ x &= \mathcal{F} + l^s r - k' - (1-d)qb' && (2)\\ l^s &\leq \mathcal{F} && (3)\\ \mathcal{F} &\equiv A + s(k) + b(1-d) && (4) \end{aligned}$$

where $W(\cdot)$ is the banker's value function, $\mathbb{E}$ is the expectation operator, b' represents government bonds demand, q is the price per sovereign bond, r is the interest rate on the private loans, x is the end-of-period consumption of the banker (akin to dividends), δ stands for the discount factor, and z is the aggregate productivity. We can rewrite (1) - (4) as follows:

$$\begin{aligned} W(b,k;z) = \max_{\{l^s,b',k',\mu\}} \Big\{ & A + s(k) + b(1-d) + l^s r - k' - (1-d)qb' \\ & + \delta\, \mathbb{E}W(b',k';z') + \mu[A + s(k) + b(1-d) - l^s] \Big\}. \end{aligned}$$

Assuming differentiability of $W(\cdot)$, the first-order conditions are:

$$\begin{aligned} l^s &: \quad r - \mu = 0 && (5)\\ k' &: \quad -1 + \delta\mathbb{E}\left\{W_{k'}\right\} = 0 && (6)\\ b' &: \quad -(1-d)q + \delta\mathbb{E}\left\{W_{b'}\right\} = 0 && (7)\\ \mu &: \quad A + s(k) + b(1-d) - l^s \geq 0 \ \ \&\ \mu[A + s(k) + b(1-d) - l^s] = 0 && (8) \end{aligned}$$

Combining equations (5), (6), and the envelope condition with respect to k, we obtain:

$$1 = s_k(k')\delta\mathbb{E}\left\{(1+r')\right\}, \tag{9}$$

which defines the optimal choice of k'. Combining equation (7) with the envelope condition with respect to b we obtain:

$$q = \begin{cases} \delta\,\mathbb{E}\{(1-d')(1+r')\} & \text{if } d = 0 \\ 0 & \text{if } d = 1 \end{cases} \tag{10}$$

This expression shows that in the case of a default in the next period, ($d' = 1$) the lender loses not only its original investment in sovereign bonds but also the future gains that those bonds would have created had they been repaid. These gains are captured by r'.

Equation (10) is the condition pinning down the price of debt subject to default risk in this model. It is similar to the one typically found in models of sovereign default with risk-neutral foreign lenders, where δ is replaced by the (inverse of the) world's risk-free rate, which represents the lenders' opportunity cost of funds.

The loan supply function (l^s) is given by:

$$l^s = \begin{cases} A + s(k) + (1-d)b & \text{if } r \geq 0 \\ 0 & \text{if } r < 0 \end{cases} \tag{11}$$

2.3. Loan market characterization

A central aim of this model is to highlight how a sovereign default generates a credit crunch, which translates into an increase in borrowing costs for the corporate sector (firms) and a subsequent economic slowdown. This mechanism puts the financial sector in the spotlight and Figure 1 shows how the private credit market reacts to a sovereign default. The supply for loans was just derived above, the demand for loans comes from the problem of firms (detailed in the next section) and responds to standard working capital needs.

Given that the intraperiod working capital loan is always risk-free (because firms are assumed to never default on the loans), the bankers will supply inelastically the maximum amount that they can. This inelastic supply curve is affected by a default: when the government defaults, bankers' holdings of government debt become non-performing and thus cannot be used in the private credit market. This is graphed as a shift to left of the l^s curve in Figure 1. This ends up in firms facing higher borrowing costs ($r^*_{d=1} > r^*_{d=0}$) and getting lower private credit in equilibrium. The planner (whose problem is defined in section 3.4) takes into account how a default will disrupt this market.

2.4. Discussion of the main assumptions

Absence of deposits. The main simplifying assumption in the modeling of bankers is having no deposits dynamic. Instead, we assume that they receive a constant flow every period: this allows us to fix ideas and focus on the asset side of the bankers' balance sheet and how it responds to a sovereign default. Incorporating deposits can make the effects of a default even larger: (i) following the logic of Gertler and Kiyotaki (2010) (also used in Balloch, 2016), modeling deposits we could have bankers as leveraged-constrained agents and so receiving a negative wealth shock (like a sovereign default) will force them to decrease their liabilities (deposits), which will in turn constrain even further the supply of loanable funds and make the effect of a default even stronger; and (ii) anticipating the possibility of a sovereign default and fearing that bankers will not be able to fully repay deposits, households may engage in a run on the bankers, and thus put more contractionary pressure on the supply of loanable funds.

Both these effects go in the same direction and so our results can be understood as a lower bound for the effects of sovereign defaults on the domestic supply of credit. Hence, we see the absence of deposits as a sensible modeling assumption given that: (i) it renders the problem more tractable and the dimensionality of the state space smaller, and (ii) it is conservative on the quantitative impact of our mechanism.

Constant A. Even when abstracting from deposits may be convenient for computational purposes, assuming a constant A may be unnecessarily simplistic from a calibration point of view. In section 6.2 we relax this assumption and instead model the endowment A as a function of the general state of the economy (i.e. as a function of aggregate productivity). This modification allows for procyclical flows to banks (a feature of the data) and makes defaults even tougher on the domestic economy: when times are bad (low productivity), a default shrinks the supply of domestic credit even more. [9]

No foreign lenders. Another simplifying assumption is that the private sector can only borrow from domestic lenders. Allowing the private sector to borrow also from abroad will decrease the relevance of the domestic credit market for domestic production and potentially weaken the channel highlighted in the model. However, as long as a fraction of the domestic firms need to

[9]All the main results are robust to this modification, as shown in section 6.2.

borrow from domestic sources (probably because not every firm in the economy is capable of tapping international markets), the mechanism proposed in the model will still play a central role in our understanding of the dynamics of macroeconomic aggregates and the incentives to default on sovereign debt. Moreover, this assumption has robust empirical support as the vast majority of corporate credit in emerging economies comes from domestic bank lending. [10]

3. (Rest of the) Model economy

Time is discrete and goes on forever. There are four players in this economy: households, firms, bankers (whose problem was already outlined in Section 2), and the government. In this framework, the households do not have any inter-temporal choice, so they make only two decisions: how much to consume and how much to work. The production in the economy is conducted by standard neoclassical firms that face only a working capital constraint: they have to pay a fraction of their wage bill up-front which creates a need for external financing.

The bankers lend to both firms and government, and also have access to a storage technology. Finally, the government is a benevolent one (i.e., it maximizes the households' utility). It faces a stream of spending that must be financed and it has three instruments for this purpose: labor income taxation, borrowing, and default. We assume the government has no commitment technology, and this means that in each period it can default on its debt. This default decision is taken at the beginning of the period and it influences all other economic decisions. Accordingly, the following subsections examine how the economy works under both default and no-default, and ultimately how the sovereign optimally chooses its tax, debt, and default policies.

3.1. Timing of events

If the government starts period t in good credit standing (i.e., not excluded from the credit market), the timing of events is as follows (where *primed* variables represent next-period values):

- Period t starts and the government makes the default decision: $d \in \{0, 1\}$

    1. if default is chosen ($d = 1$) then:

[10] According to IMF (2015) domestic bank lending represented 78% to 84% of all corporate debt in emerging economies in the period 2003–2014, while foreign bank lending was responsible for only 6% to 8%.

(a) the government gets excluded and the credit market consists of only the (intraperiod) private loan market: firms borrow to meet the working capital constraint and bankers lend (l^s) up to the sum of their endowment and stored funds ($A + s(k)$).

(b) firms hire labor, produce and then distribute profits (Π^F) and repay principal plus interest of the loan ($l^s(1 + r)$).

(c) bankers choose how much to store for next period (k').

(d) labor and goods markets clear, and taxation (τ) and consumption take place.

(e) at the end of period-t a re-access *coin* is tossed: with probability ϕ the government will re-access in the next period with a 'fresh start' (i.e., with $b' = 0$), and with probability $1 - \phi$ the government will remain excluded in the next period.

2. if repayment is chosen ($d = 0$) then:

(a) the credit market now consists of two markets: the one for working capital loans and the one for government bonds. The bankers serve first the working capital market (l^s) up to the sum of their endowment, stored funds and the repaid government debt ($A + s(k) + b$).

(b) firms hire labor, produce and then distribute profits (Π^F) and repay principal plus interest of the loan ($l^s(1 + r)$).

(c) bankers decide on sovereign lending (qb') and storage (k').

(d) labor and goods markets clear, and taxation and consumption take place.

- Period t+1 arrives

3.2. Decision problems

Here we describe the decision problems of households and firms, and also state the government budget constraint.

Households' problem. The only decisions of the households are the labor supply and consumption levels. Therefore, the problem faced by the households can be expressed as:

$$\max_{\{c_t, n_t\}_0^\infty} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t, n_t) \tag{12}$$

$$\text{s.t. } c_t = (1 - \tau_t) w_t n_t + \Pi_t^F, \tag{13}$$

where $U(c,n)$ is the period utility function, c_t stands for consumption, n_t denotes labor supply, w_t is the wage rate, τ_t is the labor-income tax rate, and Π_t^F represents the firms' profits. Solving the problem we obtain:

$$-\frac{U_n}{U_c} = (1-\tau_t)w_t, \tag{14}$$

which is the usual intra-temporal optimality condition equating the marginal rate of substitution between leisure and consumption to the after-tax wage rate. Therefore, the optimality conditions from the households' problem are equations (13) and (14).

Firms' problem. The firms demand labor to produce the consumption good. They face a working capital constraint that requires them to pay up-front a certain fraction of the wage bill, which they do with intra-period loans from bankers. Hence, the problem is:

$$\max_{\{N_t, l_t^d\}} \Pi_t^F = z_t F(N_t) - w_t N_t + l_t^d - (1+r_t)l_t^d \tag{15}$$

$$\text{s.t. } \gamma w_t N_t \leq l_t^d \tag{16}$$

where z is aggregate productivity, $F(N)$ is the production function, l_t^d is the demand for working capital loans, r_t is the interest rate charged for these loans, and γ is the fraction of the wage bill that must be paid up-front.

Equation (16) is the working capital constraint. This equation will always hold with equality because firms do not need loans for anything else but paying $\gamma w_t N_t$; thus any borrowing over and above $\gamma w_t N_t$ would be sub-optimal. Taking this into account we obtain the following first-order condition:

$$z_t F_N(N_t) = (1+\gamma r_t)w_t, \tag{17}$$

which equates the marginal product of labor to the marginal cost of hiring labor once the financing cost is factored in. Therefore, the optimality conditions from the firms' problem are represented by equation (17) and equation (16), evaluated with equality.

Government Budget Constraint. The government has access to labor income taxation and (in case it is not excluded from credit markets) debt issuance in order to finance a stream of public spending and (in case it has not defaulted) debt obligations. Its flow budget constraint is:

$$g + (1 - d_t)B_t = \tau_t w_t n_t + (1 - d_t)B_{t+1} q_t \tag{18}$$

where B_t stands for debt (with positive values meaning higher indebtedness), g is an exogenous level of public spending, and $\tau_t w_t n_t$ is the labor-income tax revenue.

3.3. Competitive Equilibrium given Government Policies

Definition 1. *A Competitive Equilibrium given Government Policies is a sequence of allocations $\{c_t, x_t, n_t, N_t, l_t^d, l_t^s, k_{t+1}, b_{t+1}\}_{t=0}^{\infty}$ and prices $\{r_t, w_t, \Pi_t^F\}_{t=0}^{\infty}$, such that given sovereign bond prices $\{q_t\}_{t=0}^{\infty}$, government policies $\{\tau_t, d_t, B_{t+1}\}_{t=0}^{\infty}$, shocks $\{g, z_t\}_{t=0}^{\infty}$, and initial values k_0, b_0, the following holds:*

1. $\{c_t, n_t\}_{t=0}^{\infty}$ *solve the households' problem in (12) - (13).*
2. $\{N_t, l_t^d\}_{t=0}^{\infty}$ *solve the firms' problem in (15) - (16).*
3. $\{x_t, l_t^s, k_{t+1}, b_{t+1}\}_{t=0}^{\infty}$ *solve the bankers' problem in (1) - (3).*
4. *Markets clear:* $n_t = N_t$, $b_t = B_t$, $l_t^d = l_t^s$; *and*
   the aggregate resources constraint holds: $c_t + x_t + k_{t+1} + g = z_t F(n_t) + A + s(k_t)$.

3.4. Determination of Government Policies

We focus on Markov-perfect equilibria in which government policies are functions of payoff-relevant state variables: the level of public debt, the level of storage held by bankers and aggregate productivity. The benevolent planner wants to maximize the welfare of the households. To do so it has three policy tools: taxation, debt, and default. But it is subject to two constraints: (1) the allocations that emerge from the government policies should represent a competitive equilibrium, and (2) the government budget constraint must hold.

The government's optimization problem can be written recursively as:

$$V(b, k, z) = \max_{d \in \{0,1\}} \left\{ (1 - d)V^{nd}(b, k, z) + d\, V^d(k, z) \right\} \tag{19}$$

where V^{nd} (V^d) is the value of repaying (defaulting). The value of no-default is:

$$V^{nd}(b, k, z) = \max_{\{c,x,n,k',b'\}} \{U(c, n) + \beta\, \mathbb{E}V(b', k', z')\} \tag{20}$$

subject to:

$$
\begin{aligned}
g + b &= \tau w n + b' q && \text{(gov't b.c.)} \\
c + x + g + k' &= zF(n) + A + s(k) && \text{(resources const.)}
\end{aligned}
$$

$$
\left.
\begin{aligned}
x &= (A + s(k) + b)(1+r) - k' - qb' \\
q &= \delta\, \mathbb{E}\left\{(1-d')(1+r')\right\} \\
1 &= s_k(k')\delta \mathbb{E}\left\{1+r'\right\} \\
r &= \tfrac{znF_n}{A+s(k)+b} - \tfrac{1}{\gamma} \\
-\tfrac{U_n}{U_c} &= (1-\tau)w \\
w &= \tfrac{zF_n}{(1+\gamma r)}
\end{aligned}
\right\} \quad \text{(comp. eq. conditions)}
$$

The value of default is:

$$
V^d(k,z) = \max_{\{c,x,n,k'\}} \left\{ U(c,n) + \beta\, \mathbb{E}\left[\phi V(0,k',z') + (1-\phi)V^d(k',z')\right]\right\} \tag{21}
$$

subject to:

$$
\begin{aligned}
g &= \tau w n && \text{(gov't b.c.)} \\
c + x + g + k' &= zF(n) + A + s(k) && \text{(resources const.)}
\end{aligned}
$$

$$
\left.
\begin{aligned}
x &= (A + s(k))(1+r) - k' \\
1 &= s_k(k')\delta \mathbb{E}\left\{1+r'\right\} \\
r &= \tfrac{znF_n}{A+s(k)} - \tfrac{1}{\gamma} \\
-\tfrac{U_n}{U_c} &= (1-\tau)w \\
w &= \tfrac{zF_n}{(1+\gamma r)}
\end{aligned}
\right\} \quad \text{(comp. eq. conditions)}
$$

3.4.1. Recursive Competitive Equilibrium

Definition 2. *The Markov-perfect Equilibrium for this economy is (i) a borrowing rule $b'(b,k,z)$, and a default rule $d(b,k,z)$ with associated value functions $\{V(b,k,z), V^{nd}(b,k,z), V^d(k,z)\}$, consumption, labor and storage rules $\{c(b,k,z), x(b,k,z), n(b,k,z), k'(b,k,z)\}$, and taxation rule $\tau(b,k,z)$, and (ii) an equilibrium pricing function for the sovereign bond $q(b',k,z)$, such that:*

1. *Given the price $q(b',k,z)$, the borrowing and default rules solve the sovereign's maximization problem in (19) – (21).*
2. *Given the price $q(b',k,z)$ and the borrowing and default rules, the consumption, labor and storage plans $\{c(b,k,z), x(b,k,z), n(b,k,z), k'(b,k,z)\}$ are consistent with competitive equilibrium.*

3. *Given the price $q(b', k, z)$ and the borrowing and default rules, the taxation rule $\tau(b, k, z)$ satisfies the government budget constraint.*

4. *The equilibrium price function satisfies equation (10)*

4. Numerical Solution

We solve the model using value function iteration with a discrete state space. [11] We solve for the equilibrium of the finite-horizon version of our economy, and we increase the number of periods of the finite-horizon economy until value functions and bond prices for the first and second periods of this economy are sufficiently close. We then use the first-period equilibrium objects as the infinite-horizon-economy equilibrium objects.

4.1. Functional Forms and Stochastic Processes

The period utility function of the households is:

$$U(c, n) = \frac{\left(c - \frac{n^{\omega}}{\omega}\right)^{1-\sigma_c}}{1 - \sigma_c} \tag{22}$$

where σ_c controls the degree of risk aversion and ω governs the wage elasticity of the labor supply. These preferences (called GHH after Greenwood et al., 1988) have frequently been used in the Small Open Economy - Real Business Cycle literature (e.g. Mendoza, 1991). This functional form turns off the wealth effect on labor supply and thus helps in avoiding the potentially undesirable effect of having a counter-factual increase of output in default periods.[12]

The bankers' storage technology is:

$$s(k) = k^{\alpha_k}. \tag{23}$$

The production function available to the firms is:

$$F(N) = N^{\alpha}. \tag{24}$$

[11]The algorithm computes and iterates on two value functions: V^{nd} and V^{d}. Convergence in the equilibrium price function q is also assured.

[12]Using GHH preferences, the marginal rate of substitution between consumption and labor does not depend on consumption, and thus the labor supply is not affected by wealth effects. For a study of how important GHH preferences are in generating output drops in the Sudden Stops literature, see Chakraborty (2009).

The only source of exogenous uncertainty in this economy is z_t, total factor productivity (TFP). The logarithm of TFP follows an AR(1) process:

$$\log(z_t) = \rho \log(z_{t-1}) + \varepsilon_t \tag{25}$$

where ε_t is an *i.i.d.* $N(0, \sigma_\varepsilon^2)$.

4.2. Calibration

The model is calibrated to an annual frequency using data for Argentina from the period 1980-2005. Table 1 contains the parameter values.

The parameters *above the line* are either set to independently match moments from the data or are parameters that take common values in the literature. The labor share in output (α) and the risk aversion parameter for the households (σ_c) are set to 0.7 and 2 respectively, which are standard values in the quantitative macroeconomics literature. The working capital requirement parameter (γ) is taken directly from the Argentine data. In the model γ is equal to the ratio of private credit to wage payments and the data show that for Argentina this ratio was 52%. [13] We use TFP estimates from the ARKLEMS team in order to estimate ρ and σ_ε.

The discount factor for the bankers (δ) takes a usual value in RBC models with an annual frequency, 0.96. It is important to realize that the exact value of δ is crucial not in itself but in how it compares with the households discount factor (discussed below). The parameter on the bankers' storage technology (α_k) is set to 0.97 which provides curvature useful to avoid indeterminacy in the choice of k'. [14]

There are two more *above the line* parameters to discuss: the curvature of labor disutility (ω) and the probability of financial redemption (ϕ). The value of ω is typically chosen to match empirical evidence of the Frisch wage elasticity, $1/(\omega - 1)$. The estimates for this elasticity vary considerably: Greenwood et al. (1988) cite estimates from previous studies ranging from 0.3 to 2.2, while González and Sala (2015) find estimates ranging from -13.1 to 12.8 for Mercosur

[13] We measure this ratio for the period 1993-2007 using data for Private Credit from IMF's International Financial Statistics, and data for Total Wage-Earners' Remuneration from INDEC (Argentina's Census and Statistics Office). The latter time series is not available prior to 1993.

[14] Accumulating k in this model is akin to hoarding cash (in a similar but nominal model). Hence, $\alpha_k < 1$ implies a negative net real rate of return on k, a common occurrence for cash equivalent instruments in emerging economies.

countries. Here we take $\omega = 2.5$ as the benchmark scenario, implying a Frisch wage elasticity of 0.67, a value in the middle range of the estimates.

The probability of financial redemption is governed by the parameter ϕ. The evidence presented by Gelos et al. (2011) is that emerging economies remain excluded for an average of 4 years after a default. This finding applies only to external defaults. It can be argued that governments have additional mechanisms (regulatory measures, moral suasion, etc.) for placing their debt in domestic markets, making domestic exclusion shorter than external exclusion. Therefore, the benchmark calibration will be $\phi = 0.5$, which, given the annual frequency of the calibration, implies a mean exclusion of 2 years.

The parameters *below the line* $\{\beta, A, g\}$ are simultaneously determined in order to match a set of meaningful moments of the data. The value of the exogenous spending level (g) is set to 0.0934 to match the ratio of General Government Expenditures to GDP for Argentina in the period 1991-2001 of 11.4% (from the World Bank's World Development Indicators, WDI).

The remaining parameters are set so that the model matches the default frequency and the exposure ratio observed in Argentina. According to Reinhart and Rogoff (2009), Argentina has defaulted on its domestic debt 5 times since its independence in 1816, implying a default probability of 2.5%, which is our calibration target. As discussed above, the banking sector of virtually every emerging economy is highly exposed to government debt. The average *exposure ratio* (as defined in Section 1.2) in Argentina was 26.5% for the period 1991-2001.

5. Results

First, we show the ability of the benchmark calibration of the model to account for salient features of business cycle dynamics in Argentina. Secondly, we study the dynamics of output around sovereign default episodes. Thirdly, we discuss the behavior of credit around defaults and the properties of the endogenous costs of defaults generated by our model. Fourthly, we analyze the benefit side of defaults, a reduction in distortionary taxation. Fifthly, we examine the dynamics in the sovereign debt market.

5.1. Business cycle moments

Table 2 reports business cycle statistics of interest from both the Argentine data and our model simulations. For the latter we report moments from pre-default samples. [15] We simulate the model for a sufficiently large number of periods, allowing us to extract 1,000 samples of 11 consecutive years before and 4 consecutive years after a default. [16]

Overall, the benchmark calibration of the model is able to account for several salient facts of the Argentine economy, as well as to approximate reasonably well the targeted moments. As in the data, in simulations of the model consumption and output are positively and highly correlated, and the consumption volatility is higher than the output volatility. [17] The model also approximates well the dynamics of employment: it is both procyclical and less volatile than output. As found in the data, the model features a negative correlation between employment and sovereign spreads. [18] None of these moments were targeted by the calibration process, but they are all, nonetheless, reproduced in the model.

The model generates an output drop at default that is endogenous. Data from the WDI indicate that in the 2001-02 Argentine default episode, real GDP per capita fell 13.7 percentage points (measured as peak-to-trough using the de-trended series). The benchmark calibration delivers a median decrease of 7.2 percentage points. The sovereign default triggers a credit crunch in the model and this in turn generates an output collapse. This collapse is due to reduced access to the labor input, which is the only variable input in the economy. The inability of the economy to resort to a substitute input generates a sharp output decline. It is important to keep in mind that the average output drop was not among the targeted moments in the calibration strategy, which is why the mechanism presented in the paper is able to account for 53% of the observed output drop.

[15]The exceptions are the default rate (which we compute using all simulation periods) and the credit and output drop surrounding a default (computed for a window of 11 years before and 4 years after a default).

[16] We focus our quantitative analysis on the 2001-02 Argentine default. To do this, we choose a time window that is restricted to 11 years pre-default and 4 years post-default (i.e., 1991-2006 in the data), in order to be consistent with previous studies that report statistics for no-default periods and also to be consistent with Reinhart and Rogoff (2011), who identify Argentina as falling into domestic default both in 1990 and 2007, in addition to the previously mentioned 2001-02 episode.

[17]These facts also characterize many other emerging economies, as documented by Neumeyer and Perri (2005), Uribe and Yue (2006) and Fernández-Villaverde et al. (2011), among others.

[18]The data for the correlation between employment and sovereign spreads are from Neumeyer and Perri (2005), while all the other employment data in Table 2 come from Li (2011).

The credit drop that drives the endogenous cost of default is the main mechanism of the model. The benchmark calibration is able to produce a mean credit drop of 8 percentage points, which accounts for 20% of the actual credit drop observed in the 2001-02 Argentine default (measured as peak-to-trough using the de-trended series).[19]

Given that the model features debt holders who are domestic, the correct debt-to-output ratio to look at in the data is Domestic Debt to GDP. To do so we take the ratio of Total Debt to Output from Reinhart and Rogoff (2010) and extract only its domestic debt part by using the share of Domestic Debt to Total Debt from Reinhart and Rogoff (2011):

$$\underbrace{\frac{TD}{Y}}_{\text{from Reinhart and Rogoff (2010)}} \times \underbrace{\frac{DD}{TD}}_{\text{from Reinhart and Rogoff (2011)}} = \underbrace{\frac{DD}{Y}}_{\text{relevant debt ratio}} .$$

This exercise gives a mean Domestic Debt to GDP ratio of 11.3% for the period 1991-2001. As shown in Table 2, the benchmark calibration of the model features a debt-to-output ratio of 11.5%, which is in line with its data counterpart.

The average level of storage chosen by the bankers is also in line with empirical evidence. The benchmark calibration features an storage-to-assets ratio of 14.4% while the data counterpart is 11.3%. [20]

The level, cyclicality, and volatility of sovereign spreads were also not among the targeted moments, and they are closely reproduced by the model. The same is true for the correlation between the tax-rate and output: as in the data, the model exhibits a negative correlation.[21] This result has been dubbed "optimal procyclical fiscal policy" for emerging economies, in the sense that the fiscal policy (in this case the tax rate) amplifies the cycle. Why is the tax rate "procyclical" in our model? Because when output is high, it is cheaper to borrow and postpone taxation, whereas when output is low, the reverse is true. Thus, we expect periods of high output to be associated with lower tax rates and vice versa. Moreover, when the government defaults it is left with only taxation in order to finance spending, which leads to even more

[19]Both the real GDP per capita and the Private Credit per capita series are taken from WDI, and their respective trends are computed using annual data from 1991 to 2006.

[20]Bank's assets in the model are loans, storage and debt. The data for the mean storage-to-asset ratio in Table 2 come from the Financial Structure Dataset (Beck et al., 2010), the WDI and the Argentine Central Bank, and it corresponds to bank holdings of money (and money-like instruments) as a fraction of total assets.

[21]The data for $\rho(\tau, y)$ in Table 2 come from Talvi and Végh (2005).

fiscal procyclicality. [22]

5.2. Output dynamics around defaults

One contribution of this paper is to provide a framework able to deliver endogenous output declines in default periods. Figure 2 shows the behavior of output around defaults: the model does feature a decline in output (and consequently in consumption) in the default period. The size of the output drop accounts for 53% of the observed output drop in the data. [23]

The model also produces a v-shape behavior of output around defaults. Argentina's output dynamics before and after the default event mostly lie within the 99% confidence bands of the model simulations. As in Mendoza and Yue (2012), the v-shaped recovery of output after a default event is driven by two forces: TFP and re-access to credit. TFP is mean-reverting and thus very likely to recover after defaults. Also, when the sovereign regains access to credit markets, then the output recovery is even faster. [24]

5.3. Endogenous costs of defaults: credit contractions

Why does a default generate such a sharp output decline? This paper gives a *credit crunch* explanation: given that bankers hold government debt as part of their assets, when a default comes a considerable fraction of those assets losses value; thus, the bankers' lending ability decreases and as a consequence credit to the private sector contracts. Given that the productive sector is in need of external financing, a credit crunch translates into an output decline.

Figure 3 presents the behavior of the Private Credit simulated series around defaults. [25] It shows that credit to the private sector falls in the default period and continues falling in the subsequent periods. The magnitude of the credit drop accounts for 20% of the observed credit drop in the data; in other words, credit plays a more important role in the model economy than in the data.

[22] This result is by no means new in the literature and it is in fact a consequence of more general capital market imperfections. See Cuadra et al. (2010) and Riascos and Végh (2003).

[23] Figure 2 is constructed from the model simulations as follows: first, we identify the simulation periods when defaults happen; secondly, we construct a time series of 11 years before and 4 years after each default and compute deviations from trend; thirdly, we compute relevant quantiles and construct a series for the median output deviations from trend around defaults; fourthly, we plot deviations from trend generated by the model and those observed in the data for the $t-3$ to $t+3$ time window, with t denoting the default year.

[24] See the Online Appendix for an analysis of the effects of market re-access on output and credit recovery.

[25] Figure 3 is constructed in the same way as Figure 2. See footnote 23.

5.3.1. Two properties of the output cost of defaults

Here we analyze two properties of the output costs of default: that they are increasing in the level of TFP and that they are increasing also in the *size* of the default (i.e. the level of outstanding debt that is repudiated).

Using the numerical solution of the model we are able to compute the effect of defaults on output. The left panel of Figure 4 shows the percent decline of output as a function of TFP. [26] As the figure shows, the cost increases with the level of TFP. This property (referred to in the literature as "asymmetric cost of defaults") is shared by other papers with endogenous cost-of-default structures (e.g. Mendoza and Yue, 2012) and has been shown to be critical to match the counter-cyclicality of sovereign spreads: in good times (high TFP) defaulting is too costly, investors understand this and assign a low probability to observing a default event, this translates into low spreads; on the contrary, during bad times (low TFP) defaulting is less costly (and therefore a more attractive policy choice), defaults are more likely and spreads are consequently higher. [27]

A second property of the cost of defaults is that they are an increasing function of the level of debt. This has a clear intuition: the more debt a government repudiates, the higher the cost of repudiation. Our framework is to our knowledge the first quantitative model that endogenously delivers this behavior (which is supported by the data, see Arellano et al., 2013). The right panel of Figure 4 shows how the output cost of defaults increases with the level of outstanding debt.[28] This happens because sovereign debt plays a "liquidity" role in our economy: the more debt is repaid, the more funds can be lent in the private credit market, and the lower is the equilibrium interest rate paid by firms. As explained above, a credit crunch translates into an output decline, and the larger is the stock of repudiated debt, the larger the credit crunch. [29]

[26] The shaded area in the left panel of Figure 4 represents the "default region," which are the levels of TFP shock at which the country decides to default when facing the mean debt-to-output level and the mean bank storage observed in the simulations.

[27] Chatterjee and Eyigungor (2012) provide a detail discussion about the asymmetric nature of default costs. They use an ad hoc cost-of-default function (in an endowment-economy model) and their calibration implies the same asymmetry that our model delivers endogenously.

[28] The shaded area in the right panel of Figure 4 represents the "default region," which (in this case) are debt-to-output levels for which the country decides to default when facing the mean TFP and the mean bank storage levels.

[29] The liquidity role of government debt has been highlighted by Bolton and Jeanne (2011), Brutti (2011) and Sandleris (2016).

5.4. Benefit of defaults: reduced taxation

As argued in the introduction, the optimal default decision comes from balancing costs and benefits of defaults. The costs of default were discussed above: output declines due to a credit contraction. The benefits on the other hand come from reduced taxation. Figure 5 shows the behavior of the labor income tax rate around defaults: we plot the equilibrium tax rate and also the "counterfactual" tax rate that would have been necessary to levy if instead of defaulting the government had repaid its debt.

The reduced taxation is precisely the difference between the counterfactual tax rate and the equilibrium tax rate: this difference is of roughly 20 percentage points on average. This tax decline represents a benefit of defaulting because households dislike increases in distortionary taxes. In other words, a default allows the government to *afford* a tax cut.

This subsection and the previous one show that the planner finds a strategic default to be the optimal *crisis resolution mechanism*: due to worsening economic conditions, the sovereign finds it optimal to default on its obligations (and assume the associated costs) instead of increasing the tax revenues required for repayment. [30]

5.5. Sovereign bonds market

As discussed above, the model performs quite well with respect to the sovereign bond market dynamics: it produces defaults in bad times and therefore countercyclical spreads. Figure 6 shows the equilibrium default region (in the left panel) and the combinations of spreads and indebtedness levels from which the sovereign can choose (in the right panel). With respect to the left panel, the white area represents the repayment area: it is increasing with the level of productivity and decreasing with the level of indebtedness. The right panel presents the spreads schedule that the government faces. As expected, the spreads that the government can choose from increase with the level of indebtedness and decrease with the level of productivity.

The model also features a positive correlation between spreads and the debt-to-output ratio, as seen in the data. From Figure 6 we can see that default incentives increase with the debt ratio, hence bond prices are decreasing with the debt ratio (which results in the positive correlation

[30] Adam and Grill (2017) study optimal sovereign defaults in a Ramsey setup with full commitment. They find that Ramsey optimal policies occasionally involve defaults, even when those defaults imply large costs.

between spreads and debt ratios). [31]

Next we turn to the behavior of spreads in the run-up to a default. Figure 7 shows that the spreads generated by the model mimic the behavior of the Argentine spreads, in that they are relatively flat until the year previous to a default, when they spike. The spreads dynamics in the run-up to a default, as seen in the data, are well within the 99% confidence bands of the model simulations.

6. Robustness

In this section we study the robustness of our results to two modifications. First, we show that the main results are robust to a calibration featuring a lower exposure ratio. Secondly, we study a model with stochastic bankers' endowment and also show that the main results are robust to this extension. The online appendix contains a thorough parameter sensitivity analysis and also provides a brief discussion about the quantitative relevance of some of our simplifying assumptions.

6.1. Calibration to a lower exposure ratio

In a recent paper, Gennaioli et al. (2016) report an average exposure ratio of 9.3% when using the entire Bankscope dataset (covering both advanced and developing countries). When they focus only on defaulting countries, they find an exposure ratio that is roughly 15%. In this subsection we re-calibrate our model to feature a lower exposure ratio close to this magnitude and refer to this version as the "low-exposure" economy. [32]

Table 3 shows selected moments of the data, the benchmark economy and the low-exposure economy. We can see that the dynamics of the sovereign debt market remain mostly unchanged. At a virtually identical default frequency (which was a targeted moment), the low-exposure economy has a mean debt-to-output ratio of 6.39% (which represents 55% of the ratio obtained in the benchmark economy and 56% of the observed ratio). The lenders understand that,

[31] While it is true that higher debt makes the cost of default higher (see Section 5.3.1), it is also true that higher debt makes the benefit of defaulting higher: the counterfactual tax break that households enjoy during defaults is larger with larger debt stocks. Hence, what matters for the correlation between spreads and debt is the net effect on default incentives.

[32] The parameter values for the low-exposure calibration are the same as the benchmark calibration with the exception of the households' discount factor (β, which now is 0.99) and the level of bankers' endowment (A, which now takes the value of 0.2095).

with a higher A (i.e. a higher bankers' endowment), debt is less important for the functioning of private credit markets and therefore the planner has a higher temptation to default on it, therefore they reduce sovereign lending. They equilibrium spread is almost identical across the two simulated economies, but more volatile for the low-exposure calibration. [33]

As the theory predicts, an economy with a lower exposure ratio has a lower debt-to-output ratio, should experience a smaller credit crunch and consequently exhibit milder output drops at defaults. Along these lines, we see from Table 3 that the low-exposure calibration can explain only 44% of the output decline at defaults (5.95% versus the observed 13.67%).

The main difference between this low-exposure economy and the benchmark economy is quantitative: the lower exposure ratio implies (in line with the theory) that the credit and output drops are smaller. However, the main mechanisms are still present qualitatively and in some dimensions even quantitatively.

6.2. Stochastic bankers' endowment

A simplifying assumption used so far was to model banker's endowment as a constant. However, there is enough evidence showing that bank funding does move with cycle, and this may have interesting implications for our study. In particular, movements in A can change the quantitative effect of defaults and alter the default incentives: for example, a high level of A makes debt repayment less important for the credit supply (i.e. lower output cost of default) and therefore increases the temptation to default.

To quantify the effect that movements in A may have we extend the benchmark model and introduce the following functional form for banker's endowment, following Mallucci (2015):

$$A_t = a_0 + a_1 z_t. \tag{26}$$

In this subsection we re-calibrate our model and refer to this version as the "stochastic–A" economy. [34] The last column in Table 3 has the results for this version of the model. The

[33] Other non-targeted business cycle moments (not reported in Table 3), like relative volatilities and correlations with output, are also in line with the data.

[34] We calibrate parameters $\{a_0, a_1\}$ to match the mean (26.5%) and the standard deviation (2%) of the exposure ratio. The calibrated values are $a_0 = 0.16$, and $a_1 = 0.045$. The stochastic–A version approximates well these two moments, featuring a mean exposure of 26.9% and a standard deviation of 2.4% (not reported in Table 3). All other parameters remain unchanged.

behavior of the sovereign debt market is very similar to the one in the benchmark calibration: spreads are large and volatile, and the mean debt level is also in line with the data. Both the credit and the output drops are somewhat magnified, and so in that dimension the stochastic-A economy is closer to the Argentine evidence explaining 55% of the output decline and 25% of the credit crunch. Overall, the quantitative predictions of the model remain robust to this extension.

7. Conclusions

The prevalence of defaults and banking crises is a defining feature of emerging economies. Three facts are noteworthy about these episodes: (i) defaults and banking crises tend to happen together, (ii) the banking sector is highly exposed to government debt, and (iii) crisis episodes involve decreased output and credit.

In this paper, we have provided a rationale for these phenomena. Bankers who are exposed to government debt suffer from a sovereign default that reduces the value of their assets (i.e., a banking crisis). This forces the bankers to decrease the credit they supply to the productive private sector. This *credit crunch* translates into reduced and more costly financing for the productive sector, which generates an endogenous output decline.

The benchmark calibration of the model produces a close fit with the Argentine business cycle moments. When calibrated to target the observed default frequency and exposure ratio, the model generates sovereign spreads that compare well with the data, in terms of both levels and volatility. Furthermore, the model features a v-shaped behavior for both credit and output around defaults, which is consistent with the data. The mechanism proposed in the paper is able to account for 53% of the observed GDP drop and 20% of the observed credit drop around default periods.

This paper quantifies the impact of a sovereign default on the domestic banks' balance sheets, their lending ability and economy-wide activity. Its chief methodological contribution is that it presents an endogenous default cost that works through a general-equilibrium effect of the government's default decision on the economy's working-capital interest rate. Additionally, ours is the first quantitative paper to endogenize the output cost of default as a function of repudiated debt. This makes our framework a natural starting point for further research on the optimality of fractional defaults.

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Tables

Table 1: Benchmark Calibration.

Concept	Symbol	Value
Curvature of labor disutility	ω	2.5
Labor share in output	α	0.70
Household risk aversion	σ_c	2
Banker's discount factor	δ	0.96
Storage technology curvature	α_k	0.97
Probability of financial redemption	ϕ	0.50
Working capital requirement	γ	0.52
TFP auto-correlation coefficient	ρ	0.7631
Std. dev. of TFP innovations	σ_ε	2.62%
Government Spending	g	0.0934
Household's discount factor	β	0.80
Banker's endowment	A	0.20

Table 2: Simulated Moments and Data.

Moment	Data	Model
$\sigma(c)/\sigma(y)$	1.59	1.55
$\sigma(n)/\sigma(y)$	0.57	0.74
$corr(c, y)$	0.72	0.99
$corr(n, y)$	0.52	0.98
$corr(\tau, y)$	-0.69	-0.75
$corr(R_s, y)$	-0.62	-0.51
$corr(R_s, n)$	-0.58	-0.53
$corr(R_s, b/y)$	0.64	0.59
$E(R_s)$ (in %)	7.44	7.39
$\sigma(R_s)$ (in %)	2.51	2.76
$E(b/y)$ (in %)	11.32	11.54
E(bank storage /assets) (in %)	11.26	14.37
Average output drop (in %)	13.67	7.16
Average credit drop (in %)	40.11	8.00
Default rate (in %)	2.5	2.6
$E(g/y)$ (in %)	11.4	11.5
E(exposure ratio) (in %)	26.5	26.8

Note: The mean and the standard deviation of a variable x are denoted by $E(x)$ and $\sigma(x)$, respectively. All variables are logged (except those that are ratios) and then de-trended using the Hodrick-Prescott filter, with a smoothing parameter of 6.25, as suggested by Ravn and Uhlig (2002). We report deviations from the trend. R_s stands for bond spread. The data for sovereign spreads are taken from J.P. Morgan's EMBI, which represents the difference in yields between an Argentine bond and a US bond of similar maturity. The spreads obtained in the simulations are computed as the difference between the interest rate paid by the government and that paid by the private sector. Results are robust to using an ad hoc constant risk-free rate.

Table 3: Selected Moments: Data, Benchmark Economy and Alternative Economies.

Moment	Data	Benchmark Economy	Low–Exposure Economy	Stochastic–A Economy
$E(R_s)$ (in %)	7.44	7.39	7.31	8.05
$\sigma(R_s)$ (in %)	2.51	2.76	4.24	2.75
$E(b/y)$(in %)	11.32	11.54	6.39	11.74
Average output drop (in %)	13.67	7.16	5.95	7.59
Average credit drop (in %)	40.11	8.00	5.48	10.10
Default rate (in %)	2.5	2.6	2.5	3.2
Gov't Spending/ output (in %)	11.4	11.5	11.6	11.5
Mean Exposure Ratio (in %)	26.5	26.8	16.3	26.9

Note: The mean and the standard deviation of a variable x are denoted by $E(x)$ and $\sigma(x)$, respectively. All variables are logged (except those that are ratios) and then de-trended using the Hodrick-Prescott filter, with a smoothing parameter of 6.25, as suggested by Ravn and Uhlig (2002). We report deviations from the trend. R_s stands for bond spread. The data for sovereign spreads are taken from J.P. Morgan's EMBI, which represents the difference in yields between an Argentine bond and a US bond of similar maturity. The spreads obtained in the simulations are computed as the difference between the interest rate paid by the government and that paid by the private sector. Results are robust to using an ad hoc constant risk-free rate.

Figures

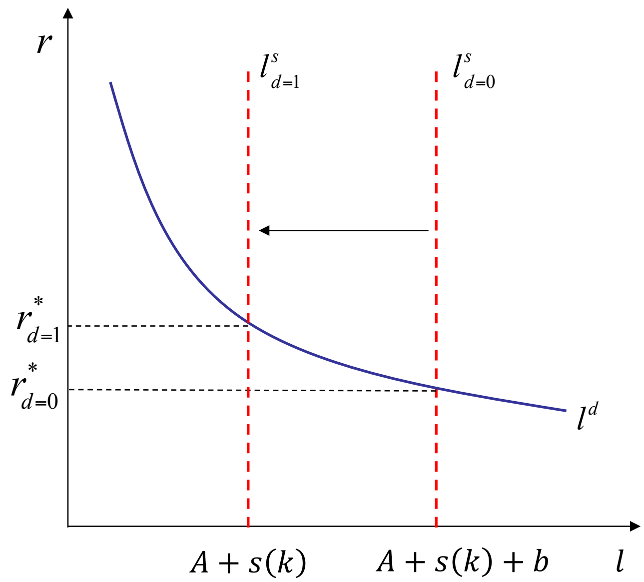

Figure 1: Loan Market in Period t.

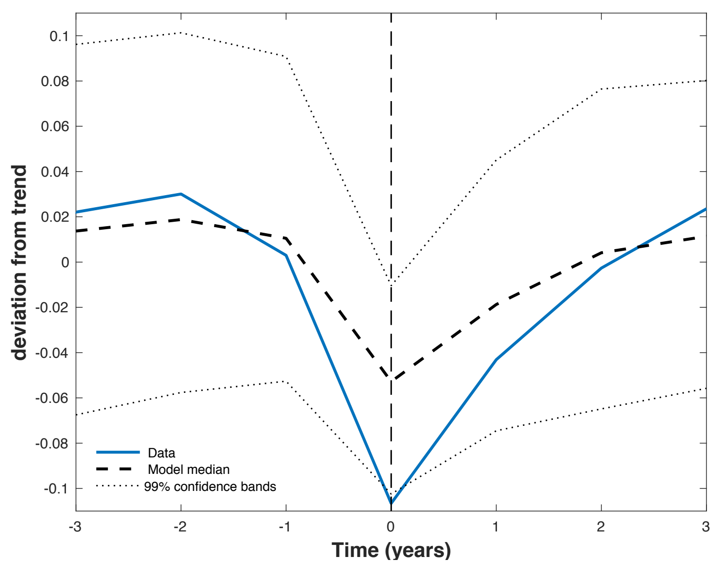

Figure 2: Output around Defaults.

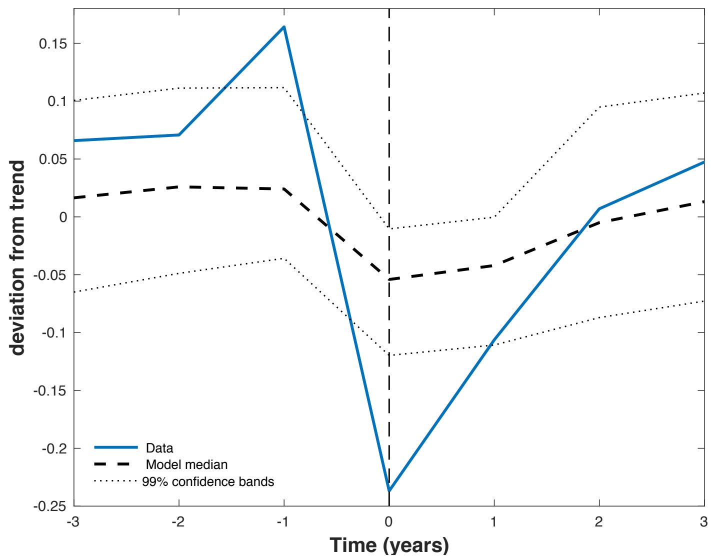

Figure 3: Private Credit around Defaults.

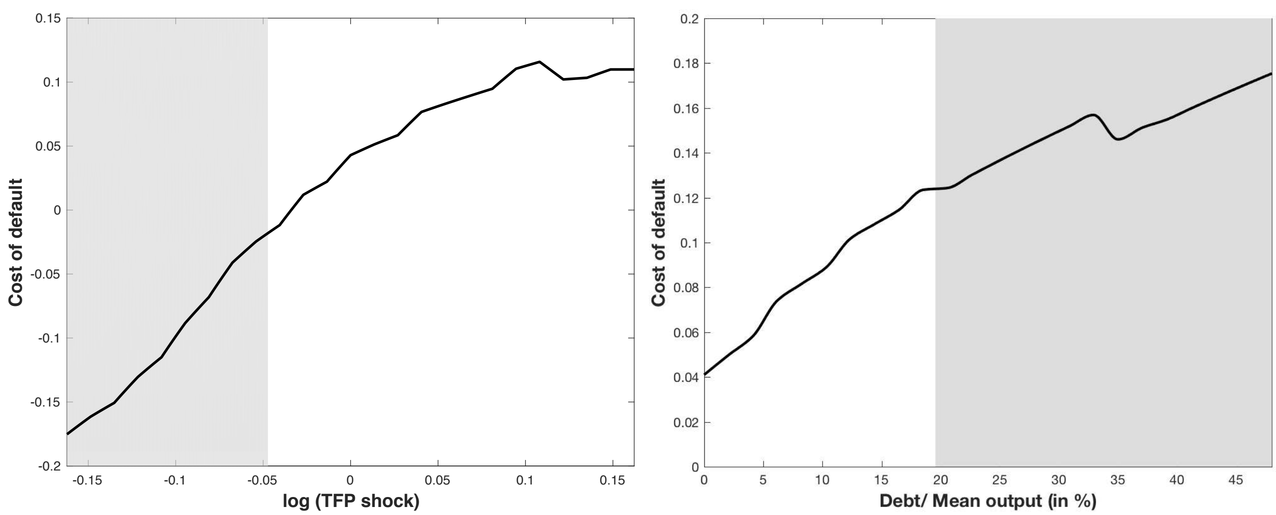

Figure 4: Cost of default. The left (right) panel shows the cost of default as a function of TFP (debt-to-output ratio). The figure is constructed for the mean bank storage and mean debt-to-output (TFP) levels observed in the simulations. The solid line represents the percent output cost of a default, $1 - y_{d=1}/y_{d=0}$. The shaded area is the "default region": productivity (debt-to-output) levels for which default is optimal given that the banks storage and the debt-to-output (TFP) are at their mean levels.

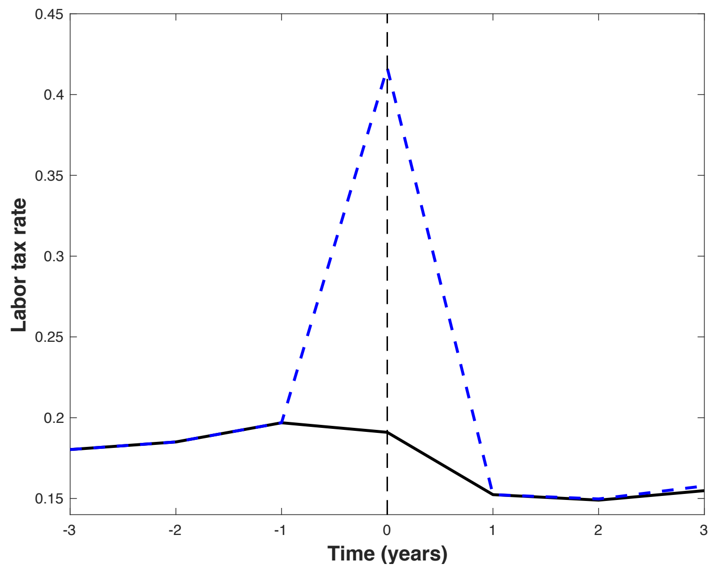

Figure 5: Labor-Income Tax Rate around Defaults. The solid line is for the equilibrium tax rate and the dashed line is for the counterfactual repayment tax rate.

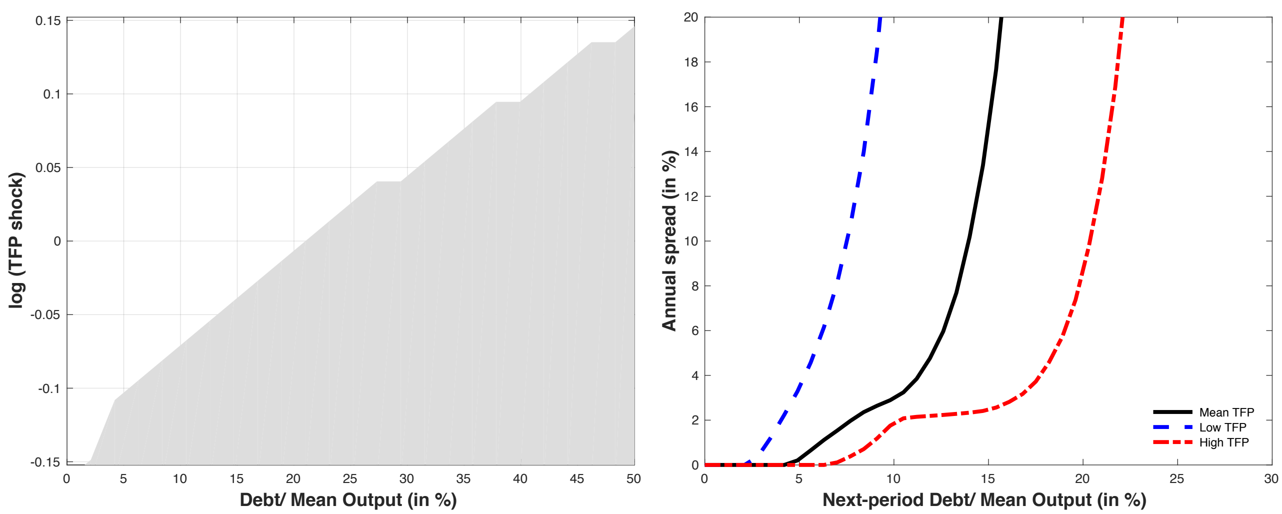

Figure 6: Default Region and Spreads-Borrowing Menu. The left panel shows the default region, where the shaded area represents combinations of debt levels and TFP realizations for which default is optimal. The right panel corresponds to the combinations of spreads and borrowing that the government can choose from. The solid line is for the average TFP level, the dashed line is for a TFP realization 1 standard deviation below mean, and the dashed-dotted line is for a TFP realization 1 standard deviation above the mean. Both panels assume the bank's storage is at the mean level observed in the simulations.

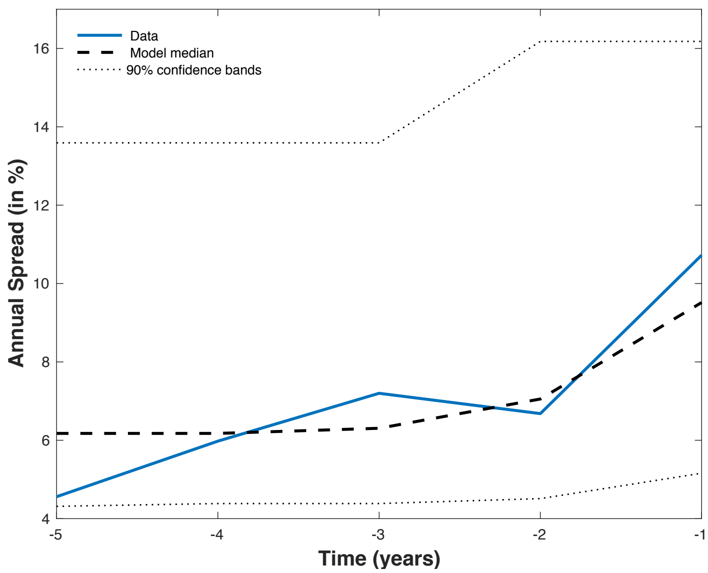

Figure 7: Spreads in the Run-up to a Default.

Online Appendix for "Sovereign Defaults and Banking Crises"

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This Online Appendix presents the details of a number of analyses and robustness tests that are referred to in the main paper. Section A presents a sensitivity analysis to assess the robustness of the main quantitative results in the main paper. Section B discusses some simplifying assumptions and how relaxing them may affect the main results.

A. Sensitivity Analysis

In this section we vary the value of some key parameters in order to get an insight on how each of them affect the dynamics. Note that parameter values are changed one at a time (i.e. keeping the values of all other parameters unchanged). Table 1 summarizes the findings of this exercise. [1]

A.1. Tightness of the working capital constraint

Let us first consider how the model behaves with different values of γ. This parameter governs the tightness of the working capital constraint, $\gamma \in (0, 1]$. A high (low) value of γ means that firms need to pay up-front a higher (lower) proportion of their wage bill; this means that private credit in the form of working capital loans is more (less) important for production.

Panel B of Table 1 shows that the model performs as expected: for lower values of γ (cases in which private credit is not so important for production), default is not very costly. Consequently, the government is tempted to default too often. Creditors, understanding this, reduce lending in the government bonds market. Along those lines, we see that for values of $\gamma \leq .30$ the mean debt ratio is zero and the observed default rate is also zero. On the other hand, high values of γ make defaults very costly. This raises the observed debt ratios and lowers the observed

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[1] While columns 1 to 5 have self-explanatory headings, columns 6 and 7 warrant a minor clarification: they report output drops and credit drops around defaults (measured as peak-to-through using the de-trended series), respectively.

default rates. In these less frequent (i.e., rarer than the benchmark) defaults, the costs in terms of output and credit drops are considerable larger than in the benchmark calibration (precisely because higher exposure ratios bring higher output and credit drops during defaults). These dynamics imply a non-monotonic behavior of the default rate as we increase the value of γ. This leads to (for example) having two scenarios with a zero default rate and with zero spreads that are very different: on the one hand, low enough values of γ, for which there is no lending (default temptation is too high), and on the other hand, sufficiently large values of γ, for which there are large debt and exposure ratios (default costs are too large).

A.2. Financial exclusion after defaults

Next, lets consider how the model economy reacts to changes in the re-entry probability (ϕ). Panel C of Table 1 has the results for the sensitivity analysis regarding parameter ϕ.

When the government can re-access credit markets immediately after a default ($\phi = 1$), the overall costs of a default (exclusion from credit markets being among them) are reduced. A lower default cost renders repudiation more attractive, so we see that for $\phi = 1$ default is more frequent. Consequently, the government has to pay higher spreads. If, on the other hand, we lower ϕ (making re-access to credit markets less frequent), then the exclusion cost of default is larger, default is chosen less frequently, and the government can obtain better debt prices (i.e., it can pay lower spreads).

Figure 1 shows how a credit crunch looks in the model. The benchmark calibration of the model features a collapse in the private sector credit (i.e., working capital loans to firms, in the model). In the two panels of Figure 1 we can see the workings of a credit crunch: as firms are in need of external financing, when loanable funds shrink, output shrinks along with them.

We can also see the effect of exclusion from financial markets: if the government remains excluded, the private credit reduces (and remains low) and the output decline becomes more protracted. On the other hand, an immediate re-access to the credit market implies a rapid recovery in both credit and output. [2]

[2] As in Mendoza and Yue (2012), the v-shaped recovery of output after a default event is driven by two forces: TFP and re-access to credit. TFP is mean-reverting and thus very likely to recover after defaults. Also, when the sovereign regains access to credit markets, then the output recovery is even faster.

A.3. Relative weights in the social welfare function

The model in the main article makes the (common) assumption that the planner only cares about the households utility. However, we can study the dynamics of the model under different social welfare functions. In particular, we could study the default incentives and the transmission mechanism from defaults to banking crises when the planner cares about a weighted average of all residents utilities: households and bankers.

Formally, the planner's optimization problem can now be written recursively as:

$$\mathcal{V}(b,k,z) = \max_{d\in\{0,1\}} \left\{(1-d)\mathcal{V}^{nd} + d\mathcal{V}^{d}\right\} \tag{1}$$

where $\mathcal{V}^{nd}$ ($\mathcal{V}^{d}$) is the value of repaying (defaulting). Given that there are two types of residents (households and bankers), the overall objective function of the planner is a convex combination of the value functions of the two types of residents. Then:

$$\mathcal{V}^{i}(b,z) = \theta V^{i}(b,k,z) + (1-\theta)W^{i}(b,k,z),$$

where $i = \{nd, d\}$ and $\theta \in [0,1]$ is the weight assigned to the households' *happiness* in the planner's objective function. The parameter θ gives the model a certain flexibility. Letting θ be equal to one we obtain the benchmark calibration studied in the main article. Moving θ to zero implies that the planner will only care about bankers.

Therefore, the value of no-default is:

$$\mathcal{V}^{nd}(b,k,z) = \max_{\{c,x,n,k',b'\}} \left\{\theta V^{nd}(b,k,z) + (1-\theta)W^{nd}(b,k,z)\right\} \tag{2}$$

subject to:

$$\begin{aligned}
V^{nd}(b,k,z) &= U(c,n) + \beta\mathbb{E}V^{nd}(b',k',z') && \text{(hh's value function)}\\
W^{nd}(b,k,z) &= x + \delta\mathbb{E}W^{nd}(b',k',z') && \text{(banker's value function)}\\
g + b &= \tau w n + b'q && \text{(gov't b.c.)}\\
c + x + g + k' &= zF(n) + A + s(k) && \text{(resources const.)}
\end{aligned}$$

$$\left.\begin{aligned} x &= (A + s(k) + b)(1+r) - k' - qb' \\ q &= \delta\, \mathbb{E}\left\{(1-d')(1+r')\right\} \\ 1 &= s_k(k')\delta \mathbb{E}\left\{1+r'\right\} \\ r &= \tfrac{znF_n}{A+s(k)+b} - \tfrac{1}{\gamma} \\ -\tfrac{U_n}{U_c} &= (1-\tau)w \\ w &= \tfrac{zF_n}{(1+\gamma r)} \end{aligned}\right\} \quad \text{(comp. eq. conditions)}$$

The value of default is:

$$\mathcal{V}^d(k,z) = \max_{\{c,x,n,k'\}} \left\{\theta V^d(k,z) + (1-\theta) W^d(k,z)\right\} \tag{3}$$

subject to:

$$\begin{aligned} V^d(k,z) &= U(c,n) + \beta\, \mathbb{E}\left\{\phi V(0,k',z') + (1-\phi)V^d(k',z')\right\} && \text{(hh's value function)} \\ W^d(k,z) &= x + \delta\, \mathbb{E}\left\{\phi W(0,k',z') + (1-\phi)W^d(k',z')\right\} && \text{(banker's value function)} \\ g &= \tau w n && \text{(gov't b.c.)} \\ c + x + g + k' &= zF(n) + A + s(k) && \text{(resources const.)} \end{aligned}$$

$$\left.\begin{aligned} x &= (A + s(k))(1+r) - k' \\ 1 &= s_k(k')\delta \mathbb{E}\left\{1+r'\right\} \\ r &= \tfrac{znF_n}{A+s(k)} - \tfrac{1}{\gamma} \\ -\tfrac{U_n}{U_c} &= (1-\tau)w \\ w &= \tfrac{zF_n}{(1+\gamma r)} \end{aligned}\right\} \quad \text{(comp. eq. conditions)}$$

Panel D of Table 1 presents the results for using different values in the relative weights of the planner's objective function (i.e., different values for the parameter θ). We can see that response of the default rate is non-monotonic. For high values of θ (i.e., high relative weight to the households' utility) the default frequency is lower: the planner values the households utility more, these agents have concave utility functions and therefore dislike profoundly swings in consumption and leisure, and increases in distortionary taxes, hence it is in the planner's best interest to keep crisis events relatively infrequent. As the parameter θ increases, the planner assigns less and less weight to the households utility and so crises are more frequent and spreads are higher. The case of $\theta = 0$ where the planner only cares about the welfare of the bankers is an extreme one: since the bankers receive the entire hit of the defaults it is now optimal to never default.

B. Discussion of additional simplifying assumptions

The model described in the main article involved a series of simplifying assumptions that were made in order to isolate the effect that a sovereign default has on the banking and productive sectors of the economy. In this subsection we discuss ways to relax two of these assumptions and the implications of doing so. [3]

Constant government spending. In order to simplify the optimal fiscal policy planning, we have assumed a constant level of government expenditures, g. While this is a useful first approximation, relaxing this assumption could improve the model's quantitative performance. A commonly used alternative is to render g valuable by including it in the agents' preferences. In this case, g becomes an extra fiscal policy instrument: the planner understands that a higher g implies either higher taxation or higher indebtedness, but also takes into account the agents' preferences for g. Then, when the country defaults and consumption declines, the planner will find it optimal to decrease g as well in order to satisfy the intra-temporal optimality condition relating private and public consumption. Thus, if we were to "endogenize" g in this way, the model would be able to account for the observed pro-cyclicality of government spending (see Cuadra et al., 2010).

Another alternative is to follow the tradition of Lucas and Stokey (1983) and have g follow an exogenously given stochastic process. Extending in this way the model presented in the main article, "good times" and "bad times" will now be indexed by the realizations of both the TFP process and the "expenditure" shock. We consider that, while enriching the environment, this second alternative does not add any new insights to our understanding of the dynamics of sovereign debt, bank lending, and defaults. [4]

Total defaults. The model economy in the main article is based on the assumption that sovereigns can either repay in full or default in full. This is an assumption shared by most of the papers in the quantitative literature on sovereign debt and default. In models à la Eaton and Gersovitz (1981), this assumption is easily justified by making the cost of the default independent of its

[3] The main article already has a discussion of other (main) simplifying assumptions.

[4] The computational challenge of adding an "expenditure" shock, as in Lucas and Stokey (1983) (or Aiyagari et al., 2002), boils down to adding an extra exogenous state variable, which increases the state space but keeps the algorithm and solution method otherwise unchanged.

size: if a country is to suffer the costs of defaulting, it had better obtain all the possible gains thereof, which implies a full repudiation. In our environment, the cost of a default (i.e., the output decline) is not independent but actually a function of the amount of debt repudiated. The very nature of the model renders it a suitable laboratory for studying the extent to which sovereigns would like to conduct partial defaults, and also for analyzing the dynamics of such defaults.

Recent work by Arellano et al. (2013) has incorporated the option for sovereigns in models of this type to partially default on their debts. One advantage of our framework over Arellano et al. (2013)'s is that in our environment incentives to default on fractions of the debt arise endogenously rather than by assuming an ad hoc "cost-of-default" function that depends on the amount of defaulted debt. Studying the reasons why countries may partially default on their debts is nonetheless beyond the scope of this study.

References for Online Appendix

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Tables and Figures for Online Appendix

Table 1: Sensitivity Analysis.

	Moments (in %)					
	Default rate	$E\{b/y\}$	$E\{R_s\}$	Exposure	$y\downarrow$	Credit $\downarrow$
Panel A.						
Data	2.5	11.32	7.44	26.5	13.67	40.11
Benchmark calibration	2.6	11.54	7.39	26.8	7.16	8.00
Panel B. Working capital constraint (benchmark: $\gamma = .52$)						
$\gamma = 0.3$	0	0	0	0	n.a.	n.a.
$\gamma = 0.45$	19.24	2.11	45.30	6.48	3.77	4.08
$\gamma = 0.65$	0.31	43.74	3.91	56.89	15.50	24.83
$\gamma = 1$	0	50.13	0	61.10	n.a.	n.a.
Panel C. Reentry Probability (benchmark: $\phi = .5$)						
$\phi = 0.10$	1.22	26.40	5.84	45.56	7.52	8.73
$\phi = 0.25$	2.39	17.17	7.36	35.42	7.27	9.46
$\phi = 0.75$	4.04	12.81	8.93	29.67	9.05	14.09
$\phi = 1$	7.97	15.90	14.80	36.05	11.88	25.71
Panel D. HH weight in social welfare function (benchmark: $\theta = 1$)						
$\theta = 0$	0	21.57	0	30.55	n.a.	n.a.
$\theta = 0.25$	8.28	17.23	13.06	36.03	8.49	18.42
$\theta = 0.50$	3.75	11.01	7.30	25.66	7.49	9.43
$\theta = 0.75$	3.12	10.24	6.80	24.17	7.03	8.38

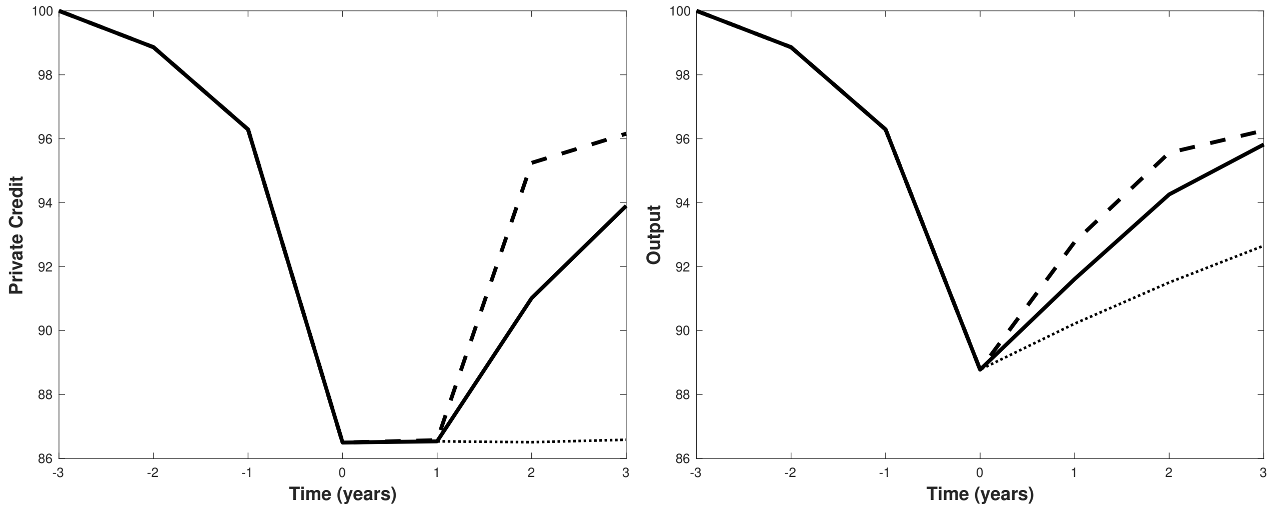

Figure 1: Private Credit, Output, and Financial Exclusion. The left panel corresponds to Private Credit. The right panel corresponds to Output. Both series are normalized so that $T - 3 = 100$. The solid line (—) is for the model average, the dashed line ($---$) is for the case of immediate re-access, and the dotted line ($\cdots\cdot$) is for the no re-access case.