Entwined Risks: Sovereign Default, Bank Failures and Economic Activity*

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Abstract

We propose a model that produces a two-way feedback loop connecting bank failure risk and sovereign default risk. Both risks are endogenous and their linkages have adverse macroeconomic effects. Sovereign stress weakens bank balance sheets and raises bank default probabilities, while banking fragility raises government-guarantee costs and sovereign spreads. This feedback loop increases the cost of capital to firms, thus reducing investment and output. Foreign investors exhibit preferred habitat, while limited liability can make risky sovereign debt attractive to domestic banks at the margin. The interaction of the two demand schedules determines the bond price and the allocation of public debt. This induces crowding-out of productive investment and amplifies the recession. Quantitative results calibrated to Spain match key fiscal moments in the data and show that rare sovereign stress events feature joint spikes in sovereign spreads and bank default, together with higher government-guarantee needs and larger bank holdings of sovereign debt. These episodes are driven in large part by shocks to bank fragility, and their effects are weakened by tighter capital requirements.

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1 Introduction

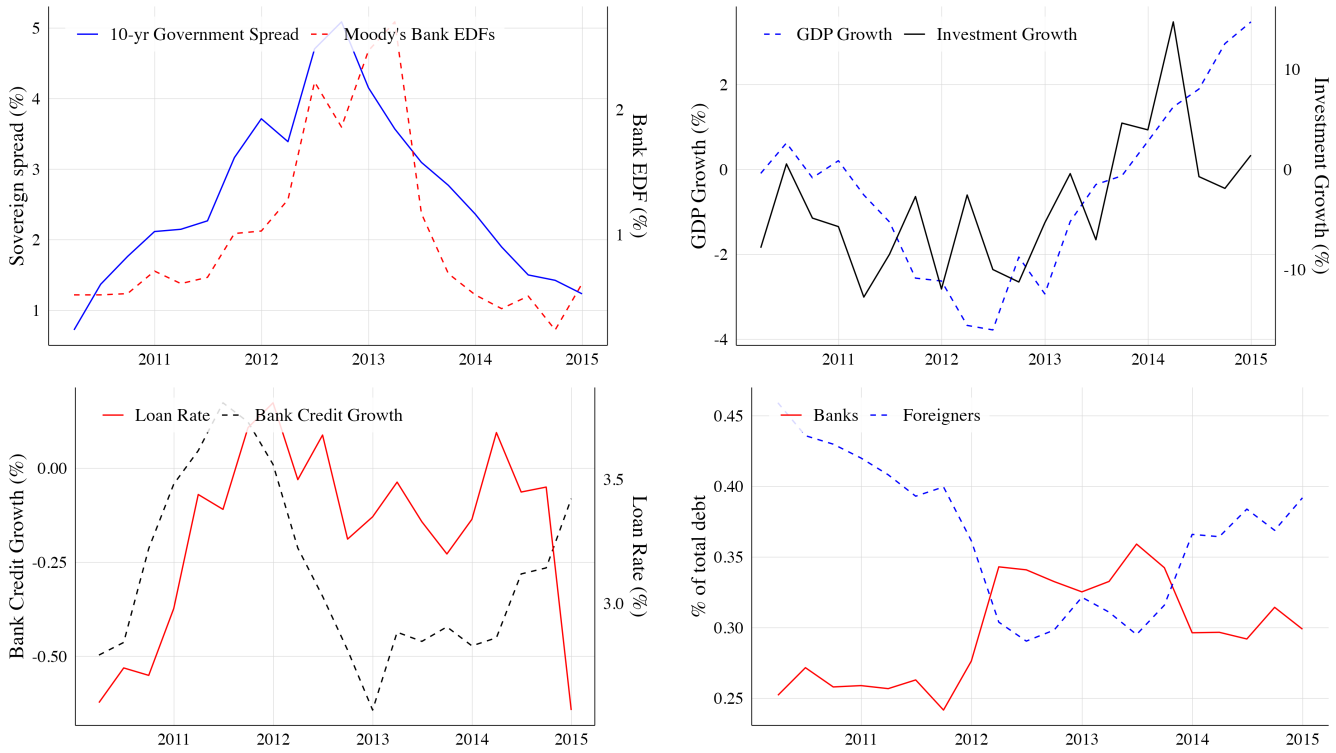
Historically, banking crises often predate or accompany sovereign defaults and are associated with severe economic downturns (see Reinhart & Rogoff 2011, Balteanu et al. 2021, Borensztein & Panizza 2009, Bocola 2016, Perez & Varraso 2018). The recent experience of the European debt crisis, the surge of sovereign debt globally fueled by the global financial crisis and the COVID crisis, and concerns for the fragility of banking systems have raised further awareness and interest in understanding this phenomenon.

The European debt crisis was characterized by rapid increases in sovereign and bank-default risk, a deep recession and a severe credit crunch. The two-way links by which sovereign and bank risk affect each other—the so-called sovereign-bank "doom loop" or "diabolic loop"—became dramatically evident in this episode (Brunnermeier et al. 2016). In one direction, bank bailouts significantly contributed to rising sovereign credit risk across Eurozone countries, as in the case of the 2008 Irish bailout (see Acharya et al. 2014, Hur et al. 2026). In the opposite direction, heightened sovereign risk in the GIIPS countries (i.e. Greece, Ireland, Italy, Portugal and Spain) caused losses on European banks' sovereign bond portfolios, raising concerns about their solvency (see Altavilla et al. 2017, Gennaioli et al. 2018, Arellano et al. 2025). The deep recession was characterized by large drops in investment (20%) and GDP (3%) in the EU as a whole between 2008 and 2013.

Consider the case of Spain as an example. Data for the 2010-2015 period plotted in Figure 1 illustrate clearly the feedback loop between sovereign and banking risks, deteriorating credit conditions, and sharp economic contraction during the European debt crisis. Panel (a) shows that the 10-year government bond spreads (red dashed line) and Moody's Expected Default Frequencies (EDFs) for banks (blue solid line) increased significantly, peaking around 2012, highlighting the close co-movement between sovereign and bank risks. Firm credit growth plummeted, reflecting tightened lending conditions, while loan rates spiked, further exacerbating financing constraints for firms (see Panel (c)). These developments in financial markets coincided with sharp decelerations in GDP growth and investment growth, as shown in Panel (b). Panel (d) shows that banks' sovereign holdings as a percentage of total government debt also increased markedly during the crisis, reinforcing the sovereign-bank nexus.

This paper studies the two-way feedback links between the risk of bank failures and sovereign risk and their macroeconomic implications, focusing on three closely related questions. First, what is the transmission mechanism by which bank fragility affects sovereign risk and sovereign stress feeds back into bank failures? Second, how does this mechanism alter sovereign pricing, banks' portfolio allocation, and

Figure 1: 2010-2012 Sovereign Debt Crisis - Spain. Panels, from left to right and top to bottom, show sovereign yields and bank EDFs, GDP and investment, firm credit and loan rates, and banks' sovereign holdings as a percentage of total government debt.



macroeconomic activity? Third, what role do bank capital requirements and banks' exposure to sovereign debt play in shaping these effects?

We answer these questions by examining the theoretical and quantitative implications of a dynamic general equilibrium model in which both bank failures and sovereign default are endogenous. We show that sovereign stress weakens banks through losses on their sovereign portfolios and raises the probability of bank failure. In the opposite direction, banking fragility raises expected government-guarantee costs and worsens the sovereign's financing conditions, lowering the price of public debt and increasing sovereign spreads. Both sides of this feedback loop raise firms' cost of capital and reduce the demand for capital and labor, generating sizable output costs. The amplification is stronger when public debt is high or banks hold more sovereign debt, and weaker when bank capital requirements are tighter.

The model combines a sovereign default environment in the spirit of Eaton & Gersovitz (1981) with a banking sector subject to limited liability and costly default. As in Gertler & Karadi (2011), households transition randomly between being consumer-workers and bankers. Banks raise deposits and banker equity to invest in productive capital and sovereign bonds, and they face idiosyncratic risk on capital returns as in Mendicino et al. (2020). Risk-neutral foreign investors also hold sovereign debt but have a preferred

habitat for a reference foreign share. Their inverse demand and domestic banks' portfolio demand jointly determine the sovereign bond price and the allocation of debt.

This structure delivers a tractable mechanism linking sovereign debt pricing, bank balance sheets, and macroeconomic outcomes. Higher sovereign risk lowers the return on banks' sovereign holdings and increases bank default probabilities. Higher bank fragility, in turn, raises bank funding costs and expected government-guarantee payouts. In bad states, limited liability also makes risky sovereign debt relatively attractive to banks, so they absorb a larger share of public debt. This endogenous bank absorption helps sustain sovereign funding, but it also crowds out productive investment, deepening the recession.

We calibrate the model to Spain. The model matches the fiscal moments well and captures the broad level of banking distress in the data, although it understates some financial-price moments. We then use the model to characterize sovereign stress events and to evaluate the fiscal and macroeconomic consequences of bank regulation.

Sovereign stress events are rare in the model, but they feature a sharp joint deterioration in sovereign borrowing and banking conditions. Across the crisis episodes generated by the baseline simulation, the sovereign spread rises from about 2.2 to roughly 3.5 percentage points and the bank default probability jumps from below one half of a percent to more than two percent, while government-guarantee payouts increase, the cost of capital of private firms rises, GDP falls by about five and a half percent, and investment collapses. At the same time, banks raise their share of total public debt from about 26 to more than 32 percent, which helps support sovereign financing but crowds out productive lending precisely when spreads peak. A decomposition of these episodes shows that shocks to bank fragility account for essentially all of the financial dynamics and for most of the real contraction, whereas TFP shocks alone generate a much milder response. Comparing all admissible simulation windows in the baseline and in a TFP-only economy confirms this: productivity shocks never produce spread increases as large as those observed in the crisis episodes and, for comparable spread increases, leave bank default risk essentially unchanged.

We then use the model to evaluate financial regulation. Raising the capital requirement from eight to ten percent lowers the unconditional bank default probability from 0.44 to 0.08 percent and the average sovereign spread from 2.41 to 1.55 percentage points, while raising investment, government spending, and GDP. It also dampens crises markedly: the GDP contraction falls from about 5.5 to 2.4 percent and the increase in the sovereign spread from 0.80 to 0.18 percentage points. The regulatory risk weight on sovereign debt instead involves a genuine trade-off. A higher weight raises the opportunity cost of sovereign holdings, so banks take less risk, hold less public debt, and are more resilient during crises. But lower domestic

absorption of public debt weakens the government's endogenous incentive to repay, raises the average spread, and reduces government-spending smoothing exactly when it is most valuable. Taken together, these results point to bank fragility as both a source and an amplifier of sovereign stress, and to bank capitalization rather than the regulatory treatment of sovereign exposures as the more reliable instrument for weakening the nexus.

Literature Review. This paper contributes to the literature on quantitative models of sovereign default initiated by Arellano (2008) and Aguiar & Gopinath (2006). Specifically, it contributes to the branch that studies the sovereign-bank nexus and the interplay between sovereign default, bank credit and output. In earlier work, Bocola (2016) analyzed how exogenous sovereign risk erodes the net worth of banks through losses on sovereign debt holdings, thereby constraining credit supply. Sosa-Padilla (2018), Mendoza & Yue (2012) and Perez & Varraso (2018) studied how endogenous sovereign defaults can trigger sharp contractions in working capital financing and output and the role that government support can play.

Recent studies by Arellano et al. (2025), Hur et al. (2026) and Thaler (2020) advanced this literature further. Hur et al. proposed a model in which exogenous shocks to bank equity affect sovereign risk and used it to study the role of government guarantees on bank capital. In their model, a sovereign default reduces the supply of working capital loans and thus increases their interest rate. Since banks are the only buyers of sovereign debt, their no-arbitrage condition links the price of debt to the working capital rate. Under repayment, higher debt issuance lowers the working capital rate and reduces the debt price. In Arellano et al., sovereign risk also harms the private sector by reducing working capital loans and increasing their rates but the transmission mechanism differs: Banks face a leverage constraint in which sovereign debt is fully pledgeable but private loans are not. This constraint yields a premium on the lending rate above the risk-free rate, and the constraint tightens as the value of sovereign bonds falls. Banks are again the sole holders of public debt. There are also general equilibrium effects operating via changes in goods and inputs prices. Firm heterogeneity matters because firms that are more financially dependent and that borrow from banks with larger public debt holdings are more affected. Thaler allows for intertemporal lending to finance capital accumulation by banks that also face a leverage constraint. Sovereign default lowers the banks' equity forcing them to shrink their balance sheet and cut private lending.

Our analysis differs from the existing literature in two key features that reflect the entwined risks of bank and sovereign defaults. First, in our model the probability of bank failure is endogenous and rises with sovereign risk. Second, endogenous banking fragility affects sovereign risk via changes in default

costs and default incentives as the sovereign internalizes the effects of its actions on the probability of bank failure and the transmission of banking fragility to households and firms. We also allow foreign investors to participate in the sovereign debt market but facing frictions in adjusting their bond holdings, so that bond prices respond to demand effects from both foreign investors and domestic banks. This framework produces feedback effects between sovereign risk and banking fragility that create a financial amplification mechanism with significant adverse effects on the real economy. In this respect, our paper introduces a new approach to model endogenous default costs via the entwined risks of bank and sovereign defaults, instead of mechanisms operating via working capital or corporate default risk studied in the literature (e.g., Sosa-Padilla 2018, Mendoza & Yue 2012, Arellano et al. 2025, Moretti 2023, Malluci 2021).

Our work is also related to theoretical studies that examine the foundations of the bank-to-sovereign nexus. This literature derives important findings from elegant frameworks of the "doom-loop" that often assume short time horizons and simplified production and investment formulations (e.g., Brunnermeier et al. 2016, Acharya et al. 2014, Cooper & Nikolov 2018, Fahri & Tirole 2018, Gennaioli et al. 2014). Our paper incorporates some of the key mechanisms from this theoretical research. For instance, as in Gennaioli et al., sovereign default embodies an endogenous cost because it causes a credit crunch via balance sheet effects on banks, and this cost is larger (and default incentives weaker) when banks have larger holdings of sovereign debt. We contribute by incorporating these mechanisms into a quantitative dynamic stochastic general equilibrium model with an infinite horizon and standard specifications of preferences and technology. The model captures the two-way sovereign-bank nexus and provides a new framework for evaluating the roles of financial regulation and fiscal policy in mitigating its adverse effects. In particular, by including both financial policy instruments (government guarantees on deposits, bank capital requirements, and flexible weights on bank holdings of sovereign debt) and fiscal policy instruments (income taxes and government expenditures), our model provides a platform for evaluating the role of financial regulation in public debt sustainability as well as the role of fiscal policy in supporting financial stability.

Finally, this paper also contributes to the literature studying capital requirements in quantitative macro-banking models (see e.g. Van Den Heuvel 2008, Mendicino et al. 2020, Begenau 2020, Corbae & D'Erasmo 2021, Elenev et al. 2021, Begenau & Landvoigt 2022, Mendicino et al. 2024). These models often focus on bank default risk abstracting from the interaction with sovereign risk. In contrast, we study the role of bank capital requirements in weakening the sovereign-bank nexus. Some of this literature does study the sovereign-bank nexus. Abad (2019) examines bank capital regulation in a model in which banking fragility and sovereign risk are linked. Bank insolvency is modeled in a manner similar to ours, driven by risk

shocks to the volatility of bank returns, but sovereign default is determined exogenously by a debt limit. Coimbra (2020) models sovereign default in the same way but in a setup in which bank default is driven by a value-at-risk constraint. Hence, a distinguishing feature of our approach relative to this literature is the endogenous choice of borrowing and default by both banks and the government. This contribution of our work is key to capture the two-way feedback loop between banking fragility and sovereign default and the role of capital requirements in mitigating the bank-sovereign nexus.

The remainder of the paper is structured as follows: Section 2 presents the model and Section 3 discusses the transmission mechanism. Section 4 discusses the calibration. Section 5 examines the model performance during periods of sovereign stress. Section 6 evaluates the effects of bank capital requirements and of the regulatory risk weight on sovereign debt. Section 7 concludes.

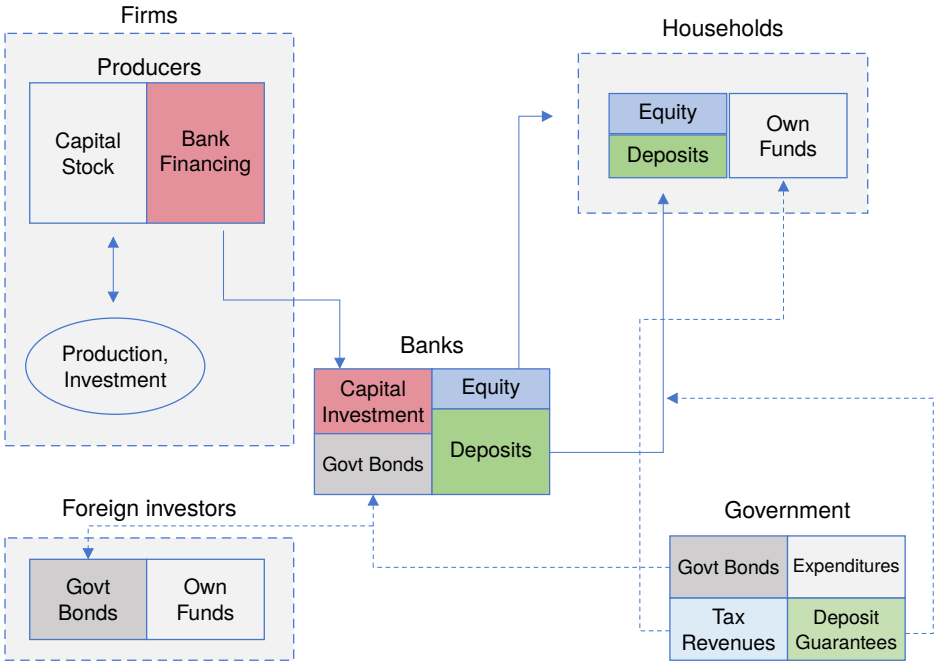
2 Model

We propose a framework that integrates a tractable dynamic model of financial intermediation (e.g., Mendicino et al. 2020, Gertler & Karadi 2011) into a model of strategic sovereign default in the vein of Eaton & Gersovitz (1981). The economy is populated by households, bankers, banks, final-goods producers, foreign investors, and a government. We characterize households using a formulation similar to that proposed by Gertler & Karadi (2011) to model banking within a tractable dynamic representative-agent setup. The representative household has a continuum of members divided into two groups, each of unit measure. One group are consumer-workers and the other are bankers.[1] Bankers exit ("die") randomly and are replaced by an equal mass of consumer-workers that become bankers. Consumer-workers consume, supply labor, and save using bank deposits. Bankers provide equity financing to banks, and those who exit transfer some of their wealth to new bankers and the rest to consumer-workers. Competitive banks use deposits and equity to invest in productive capital, which they own, and sovereign debt. They face a capital requirement constraint with potentially different weights on capital and debt. Final-goods producers rent capital from banks and hire labor from consumer-workers. Foreign investors can also buy sovereign bonds but facing frictions in adjusting their bond holdings. The government issues long-term debt, provides a partial guarantee on deposits, and defaults strategically. Figure 2 provides a visual representation of the agents in the model and their interactions.

This section describes first the optimization problems of the agents in the model in sequential form.

[1] Gertler and Karadi consolidated consumer-workers and bankers into a single group instead of separating them by assuming perfect insurance within the household. They noted, however, that this is is unlikely to alter the qualitative features of the model.

Figure 2: Model Sketch



Then it switches to a recursive formulation to characterize the recursive state space, the timeline of events within a period and the model's recursive Markov equilibrium.

2.1 Consumer-workers

Consumer-workers have the following expected lifetime utility function that depends on the streams of consumption, C_t, and labor, L_t:

$$\mathbb{E}\sum_{t=0}^{\infty}\beta^t\left\{C_t-\chi\frac{L_t^{1+\eta}}{1+\eta}\right\}. \tag{1}$$

Since utility is linear in C_t, consumer-workers are risk-neutral, and since it is also separable in C_t and L_t, there is no wealth effect on labor supply (i.e., the marginal rate of substitution between the two is independent of C_t). The parameter β is the consumer-workers subjective discount factor and η governs the Frisch elasticity of labor supply.

The consumer-worker chooses streams of C_t, L_t, and holdings of bank deposits to carry to the next period, d_{t+1}, to maximize the above utility function subject to this budget constraint:

$$(1-\tau)W_tL_t+\left[1-(1-\kappa)\Omega_t\right]d_t+\Pi_t=C_t+q_t^d d_{t+1} \tag{2}$$

For tractability, deposits are modeled as an asset akin to a discount bond bought at price q_t^d in the current period in exchange for a contracted repayment of d_{t+1} next period. The wage rate is W_t and wage income pays a labor tax at rate τ. Π_t are transfer payments received from retiring bankers, to be defined later. The government guarantees a fraction κ of losses on maturing deposits, d_t, from failing banks, with Ω_t denoting the loss per unit of d_t. Thus, the state-contingent recovery rate per unit of deposits is $1-(1-\kappa)\Omega_t$.

Consumer-workers take as given W_t, q_t^d, Π_t and Ω_t and they do not hold capital or sovereign debt directly. The first-order conditions of their optimization problem yield a labor supply condition standard from models without wealth effects that equates the marginal disutility of labor to the wage rate:

$$(1-\tau)W_t = \chi L_t^{\eta}.$$

Because of the linearity of the utility function, the Euler equation for deposits is:

$$q_t^d = \beta \mathbb{E}\left[1-(1-\kappa)\Omega_{t+1}\right].$$

This is the pricing condition of deposits. At equilibrium, the allocation of newly-issued deposits will be supply-determined and traded at this price. This pricing condition captures the effect of the risk of bank failures at t+1, which trigger deposit guarantee payments for a fraction $1-\kappa$ of the implied losses. Intuitively, it yields a premium in the deposit rate relative to the rate of time preference equal to the inverse of $\mathbb{E}\left[1-(1-\kappa)\Omega_{t+1}\right]$. Note the two roles that the losses incurred due to unguaranteed deposits have: realized Ω_t at date t has income effects by altering the actual proceeds from deposits maturing that period, losses Ω_{t+1} expected for t+1 induce a spread that affects the price and quantity of new deposits traded at date t.

Again because of linear preferences, the consumer-workers discount factor (which will be also the discount factor of bankers) is simply:

$$\Lambda_{t+1} \equiv \beta \frac{U_C(C_{t+1}, L_{t+1})}{U_C(C_t, L_t)} = \beta.$$

2.2 Final-goods producers

A representative final-goods producer operates this CES technology:

$$Y_t = e^{z_t} \left[\alpha {K_t}^{\epsilon} + (1-\alpha) {L_t}^{\epsilon} \right]^{\frac{1}{\epsilon}}, \tag{3}$$

At date t, the producer rents installed capital at the rental rate r_t^K from banks (who are the owners) and hires labor from consumer-workers. The parameter α is the capital-share parameter and ϵ determines the elasticity of substitution between capital and labor $(1/(1-\epsilon))$.

Taking W_t, r_t^K as given, the producer chooses demand for capital and labor so as to maximize profits

$$\Pi_t^f = Y_t - W_t L_t - r_t^k K_t.$$

Factor demand conditions are standard, equating marginal products to factor prices:

$$\frac{\partial Y_t}{\partial L_t} = W_t$$

$$\frac{\partial Y_t}{\partial K_t} = r_t^k$$

Note that, at equilibrium, date-t output, labor, and wages (and hence tax revenue) depend on the installed capital K_t that banks have available to rent, which is pre-determined as of t, while one of the banks' date-t choices is the accumulation of capital that determines K_{t+1} and thus affects production at t+1. Their capital investment I_t satisfies the standard law of motion, with δ as the depreciation rate:

$$K_{t+1} = I_t + (1-\delta) K_t. \tag{4}$$

2.3 Banking Sector

The banking sector is composed of the subset of households that are bankers and the continuum of competitive banks.

Bankers. As noted earlier, bankers have stochastic life spans and become consumer-workers when they die. An individual banker dies with probability $1-\theta$ each period. At the beginning of the period, a banker earns returns on its *individual* net worth n_{t-1} invested in the previous period at a rate equal to the gross

return on a diversified portfolio of bank equity claims $\rho_{b,t}$. If the banker survives, it starts the next period with $n_{t+1} = \rho_{b,t+1} n_t$, if it dies, it transfers to new bankers (of mass $1-\theta$) a fraction χ_b of its net worth (plus earnings), so the transfer is for $\chi(1-\theta)\rho_{b,t+1} n_t$, and the rest goes to consumer-workers. It follows, therefore, that aggregate net worth follows this law of motion:

$$N_{t+1} = [\theta + \chi_b(1-\theta)]\rho_{b,t+1} N_t.$$

Since, as we show later, the inherited balance sheet and current bank resolution determine N_t directly at equilibrium, the beginning-of-period net worth is determined within the period and hence is not a separate state variable.

In general, the objective of an individual banker is to maximize the expected present value of dividends, div_t discounted at the SDF of consumer-workers and adjusted for the probability of survival. Hence, the banker's optimization problem is:

$$V_{b,0} = \max_{[div_j, e_j]_{j=0}^{\infty}} \left\{ \mathbb{E}_0 \left[div_0 + \sum_{j=1}^{\infty} \theta^{j-1} \Lambda_{0,j} \left[(1-\theta)\rho_{b,j} e_{j-1} + \theta div_j \right] \right] \right\} \tag{5}$$

subject to

$$e_t + div_t = n_t$$

$$div_t \geq 0$$

where $\Lambda_{0,j} = \Pi[\Lambda_t]_{t=1}^{j}$. The first constraint is simply a balance sheet condition stating that net worth is allocated to dividends and to investing in bank equity e_t. The second condition requires dividens to be non-negative. Note that because of the risk-neutrality of preferences, $\Lambda_{0,j} = \beta^j$.

We show in the Appendix two key properties of the optimization problem (5). First, the banker's value function is homogeneous of degree one in net worth. Hence, we can write $V_{b,t} = \nu_{b,t} n_t$, where $\nu_{b,t}$ is the marginal value of a unit of the banker's net worth (which, as we explain below, is determined by the market return $\rho_{b,t}$ that is taken as given by the individual banker). Second, in a nondegenerate equilibrium with positive banking activity, setting $div_t = 0$ and $n_t = e_t$ is optimal. It is uniquely optimal when the value of investing one additional unit strictly exceeds its immediate dividend value.

The rationale of the second result can be illustrated using the first. In particular, we can combine $V_{b,t} = \nu_{b,t} n_t$ with the banker's balance-sheet constraint to express the date-t problem as the choice of a

"retention rate" $x_t \equiv e_t / n_t \in [0,1]$:

$$V_{b,t} = n_t \max_{x_t \in [0,1]} \left\{ \underbrace{(1 - x_t)}_{div_t / n_t} + x_t \, \mathbb{E}_t \left[\Lambda_{b,t+1} \rho_{b,t+1} \right] \right\}, \tag{6}$$

so that $\nu_{b,t} = \max \{1, \mathbb{E}_t [\Lambda_{b,t+1} \rho_{b,t+1}]\}$. The objective is linear in x_t over a compact set, and hence the solution is at a corner: the banker retains all its net worth whenever a retained unit is worth at least as much as a unit paid out as dividends, that is, whenever $\mathbb{E}_t [\Lambda_{b,t+1} \rho_{b,t+1}] \geq 1$. This inequality holds at equilibrium, since a binding capital requirement with $K_{t+1} > 0$ requires positive aggregate equity, otherwise all bankers would set $e_t = 0$. Full retention $x_t = 1$ is therefore optimal (uniquely so if the inequality is strict), and the marginal value of the banker's net worth is simply

$$\nu_{b,t} = \mathbb{E}_t \left[\Lambda_{b,t+1} \rho_{b,t+1} \right], \tag{7}$$

where $\Lambda_{b,t+1} \equiv \Lambda_{t+1} ((1 - \theta) + \theta \nu_{b,t+1})$. The primitive subjective discount factor remains Λ_{t+1}, which is just β. The additional term in $\Lambda_{b,t+1}$ converts next-period banker net worth into its retirement payoff or its continuation value upon survival. Thus, $\Lambda_{b,t+1}$ is an effective banker valuation kernel rather than a different subjective discount factor. Note that the term entering this kernel is the *marginal* value of net worth $\nu_{b,t+1}$, which by degree-one homogeneity is invariant to the scale of an individual banker's net worth. Hence e_t is the only date-t choice variable and the objective is exactly linear in it: the continuation value $\nu_{b,t+1}$ is already optimized, and equity holdings from $t+1$ onward follow the policy $e_{t+j} = n_{t+j}$.

The transfer to consumer-workers is

$$\Pi_t = \frac{(1 - \chi_b)(1 - \theta)}{\theta + \chi_b (1 - \theta)} N_t. \tag{8}$$

Banks. The banking system is composed of a continuum of banks, each operating across two consecutive dates only. This simplifies the analysis by keeping the intertemporal accumulation of financial net worth as a decision of the bankers. In the first period of operation, each bank raises equity from bankers and deposits from households to finance investments in building productive capital, k_{t+1}, and buying sovereign debt, b^b_{t+1}.[2] In the second period, the bank collects the payoffs of these investments and pays depositors, with all of these payments contingent on shocks to bank returns and the risks of sovereign and bank default, as we

[2]Equivalently, we could assume that banks purchase claims from final-goods producers. This yields the same outcome as banks renting installed capital to producers next period, which is the approach we followed.

explain next.

Banks are identical ex ante, but each bank experiences an i.i.d. idiosyncratic shock ω_{t+1} that alters the return on its capital holdings, producing ex post heterogeneity as in Merton (1974). The dispersion of these shocks across banks, σ_{t+1}, is stochastic and time-varying, and hence enters as an aggregate shock. We assume that σ follows an AR(1) process to be specified in the calibration section. Conditional on a realization of σ_{t+1}, the CDF and PDF from which the idiosyncratic shocks are drawn are denoted $F(\omega;\sigma_{t+1})$ and $f(\omega;\sigma_{t+1})$, respectively. Similarly, at the beginning of date t, the CDF of shocks to bank capital returns affecting banks operating in their second period is $F(\omega;\sigma_t)$.

For any arbitrary threshold $a_t > 0$ at which an individual bank could become insolvent at date t, we can define the truncated first moment and standard payoff function as

$$\begin{aligned} M_1(a_t;\sigma_t) &\equiv \int_0^a \omega \, dF(\omega;\sigma_t), \\ \Gamma(a;\sigma_t) &\equiv M_1(a;\sigma_t) + a\left[1 - F(a_t;\sigma_t)\right]. \end{aligned} \tag{9}$$

We assume a log-normal distribution for ω and hence:

$$F(a_t;\sigma_t) = \Phi\left(\frac{\log a + \sigma_t^2/2}{\sigma_t}\right), \qquad M_1(a_t;\sigma_t) = \Phi\left(\frac{\log a - \sigma_t^2/2}{\sigma_t}\right), \tag{10}$$

with both functions defined as zero for $a_t \leq 0$. The CDF $F(a_t;\sigma_t)$ corresponds to the bank's default probability and $M_1(a_t;\sigma_t)$ is the truncated first moment of its bank-specific return shock. Since we have a representative bank, at equilibrium $F(a_t;\sigma_t)$ is also the fraction of banks that default at date t.

The realized *market* return on capital is pinned down by the rental rate of capital as follows:

$$R^k_{t+1} = r^k_{t+1} + (1-\delta), \tag{11}$$

so that an individual bank's realized return on its capital holdings at t+1 is $\omega_{t+1}R^k_{t+1}$.

The realized gross return on its sovereign bonds is

$$R^b_{t+1} \equiv \frac{(1-\lambda)q_{t+1} + (c+\lambda)(1-\Delta_{t+1})}{q_t}, \tag{12}$$

where Δ_{t+1} is a binary variable that denotes the default decision of the government at t+1. It equals 0 if the government repays and 1 if it defaults. We assume that the government can default on the coupon and

maturing principal of its debt, $c + \lambda$, but the unmatured fraction continues to trade at a market-clearing price q_{t+1}.[3]

On the deposits side, deposits sold at t provide funding to the bank for the amount $q_t^d d_{t+1}$ in exchange for a pledge to repay d_{t+1} at t+1. Actual repayment, however, can be smaller if the bank becomes insolvent, in which case the government's gurantee for a fraction κ of the deposits implies an actual repayment of $[1 - (1 - \kappa)\Omega_{t+1}]d_{t+1}$.

In the first period of operation, a bank uses the equity (or net worth since $n_t = e_t$) received from bankers (priced at their marginal valuation or opportunity cost given by $\nu_{b,t}$) and the funds raised by selling deposits to invest in capital and sovereign debt. The bank chooses deposits and the portfolio of these investments so as to solve the following optimization problem:

$$\max_{k_{t+1}, b^b_{t+1}, d_{t+1}} \left\{ \mathbb{E}_t \left[\Lambda_{b,t+1} \max \left\{ \omega_{t+1} R^k_{t+1} k_{t+1} + [(1-\lambda) q_{t+1} + (c+\lambda)(1-\Delta_{t+1})] \, b^b_{t+1} - d_{t+1}, \, 0 \right\} \right] - \nu_{b,t} e_t \right\}, \tag{13}$$

s.t.

$$k_{t+1} + q_t b^b_{t+1} = q^d_t d_{t+1} + e_t, \tag{14}$$

$$e_t \geq \phi \left(k_{t+1} + \iota q_t b^b_{t+1} \right), \tag{15}$$

taking as given $R^k_{t+1}, e_t, \nu_{b,t}, q_{t+1}, q_t, q^d_t$. The objective function states that the bank maximizes expected discounted earnings net of deposit repayments (discounted at the banker's adjusted SDF) and of the cost of the equity provided by bankers. The innermost max operator captures limited liability: the bank defaults if its realized net worth is non-positive. The first constraint is the bank's balance sheet equation and the second constraint is the government's capital requirement stating that the bank's equity must be at least as large as a fraction ϕ of the value of its assets, with sovereign debt potentially weighing less as determined by the weight $\iota \leq 1$.

Using the property that $n_t = e_t$ and assuming that the capital requirement binds (which will be the case at equilibrium), the two constraints of the bank's problem yield expressions that determine k_{t+1} and d_{t+1}

[3] This is a partial-default convention: default does not write down the unmatured principal. This structure also resembles that of models with renegotiation in which some of the existing debt retains valued at an agreed haircut.

once the bank demand for sovereign bonds is known:

$$k_{t+1} = \frac{e_t}{\phi} - \iota q_t b^b_{t+1} \tag{16}$$

$$q^d_t d_{t+1} = (1-\phi)k_{t+1} + (1-\phi\iota)q_t b^b_{t+1}. \tag{17}$$

Ex post, a bank defaults if its realized net worth is negative, which as we show later hinges on the realization of ω_{t+1} being lower than a threshold $\overline{\omega}_{t+1}$. Section 3 characterizes this threshold and the associated default probability. For now, we use it to describe the bank's Euler equation governing its demand for bonds, which will play a central role in our analysis. This Euler equation can be expressed as follows:

$$q_t = \frac{e_t \left[\Lambda_{b,t+1}(1-F(\overline{\omega}_{t+1},\sigma_{t+1}))\left((1-\lambda)q_{t+1} + (c+\lambda)(1-\Delta_{t+1})\right)\right]}{\mathcal{D}_{q,t}}. \tag{18}$$

where

$$\mathcal{D}_{q,t} \equiv \frac{1-\iota}{q^d_t}\mathbb{E}_t\left[\Lambda_{b,t+1}(1-F(\overline{\omega}_{t+1},\sigma_{t+1}))\right] + \iota\mathbb{E}_t\left[\Lambda_{b,t+1}R^k_{t+1}\int_{\overline{\omega}_{t+1}}^{\infty}\omega_{t+1}dF(\omega_{t+1},\sigma_{t+1})\right].$$

This condition equates the marginal cost of buying sovereign debt at t with the expected marginal benefit of the returns it may yield at t+1. As noted in the numerator of the expression in the right-hand-side, these expected returns are affected by both the risk of sovereign default (via both Δ_{t+1} and q_{t+1} and the probability of bank failure (via $F(\overline{\omega}_{t+1},\sigma_{t+1})$). In the next Section, we discuss in more detail the intuition behind this condition and explain how it represents an inverse demand for sovereign debt from the bank.

2.4 Foreign investors

A continuum of deep-pockets, risk-neutral foreign investors participate in the domestic sovereign debt market. Without loss of generality, we focus on the representative foreign investor. Its purchases of sovereign bonds at date t are denoted B^f_{t+1}. Foreign investors discount future payoffs at rate β^*, the inverse of which can be interpreted as a constant world real interest rate that is also their opportunity cost. These investors also face frictions in purchasing bonds, in the form of transaction costs or preferred habitat features, as a result of which deviating from a target share of bond holdings $\bar{s}^f$ is costly (e.g., Greenwood & Vayanos (2014) and Vayanos & Vila (2021)). Otherwise, these investors solve the standard profit maximization problem of Eaton-Gersovitz models. The representative investor's first-order condition yields the

following expression:

$$q_t\left(1+\kappa^f\left(\frac{B^f_{t+1}}{B_{t+1}}-\bar{s}^f\right)\right)=\beta^*\mathbb{E}_t\left[(1-\lambda)q_{t+1}+(c+\lambda)(1-\Delta_{t+1})\right] \tag{19}$$

where $\kappa^f \geq 0$ is the slope of foreign inverse demand (or the elasticity with respect deviations of their bonds share relative to target). Using the definition of R^b_{t+1} and the assumption that $\beta^* = 1/R^*$, the above condition can be rewritten as:

$$\mathbb{E}_t\left[R^b_{t+1}\right]=R^*\left[1+\kappa^f\left(\frac{B^f_{t+1}}{B_{t+1}}-\bar{s}^f\right)\right]. \tag{20}$$

Without trading frictions ($\kappa^f = 0$), this condition reduces to the standard debt-pricing condition of Eaton-Gersovitz models. With trading frictions, however, neither domestic banks or foreign investors are the marginal price setter, and hence the above condition is not sufficient to determine q_t. Instead, the equilibrium bond price will be determined so as to clear the sovereign bond market, which requires aggregate demand for bonds to equal supply:

$$B_{t+1}=B^b_{t+1}+B^f_{t+1}. \tag{21}$$

2.5 Government

We adopt a formulation of the government's utility function similar to that in Arellano et al. (2025):

$$E_0\sum_{t=0}^{\infty}(\beta^G)^t\left\{\frac{G_t^{1-\gamma}}{1-\gamma}-\Delta_t\xi\right\}$$

The government has risk-averse preferences over public spending, with a coefficient of relative risk aversion γ, and discounts the future at a lower discount rate than households ($\beta^G < \beta$). Default carries the utility cost $\xi \geq 0$, but unlike in Arellano et al. this cost is a time-invariant parameter.[4] As explained before, default also differs in our model in that the government cannot issue new debt in the period it defaults and in that it cannot default on the unmatured debt.

If the government chooses to repay its outstanding debt at the beginning of the period ($\Delta_t = 0$), it faces

[4] In their model, ξ is stochastic with the intent of inducing movements in the bond pricing function for given debt and productivity, while in our model these movements result from changes in the aggregate risk shock of banks σ.

this budget constraint:

$$\tau W_t L_t + q_t \left(B_{t+1} - (1-\lambda)B_t\right) = (c+\lambda)B_t + G_t + \kappa D_t \Omega_t.$$

The government uses labor tax revenue and the resources generated by new debt issuance to pay for the coupon and maturing principal of its outstanding debt, its government expenditures and the cost of guarantees on the deposits of banks that fail at the beginning of the period, $\kappa D_t \Omega_t$. If instead it chooses to default ($\Delta_t = 1$), it faces this budget constraint:

$$\tau W_t L_t = G_t + \kappa D_t \Omega_t.$$

In this case, the labor tax revenue is used to pay for government expenditures and bank deposit guarantees. This constraint reflects the assumptions that the government cannot issue new debt in the period it defaults and that it defaults only on the coupon due and the maturing debt, not on the fraction of the debt that is not maturing. This unmatured debt continues to be traded by banks and foreign investors, with a supply of debt given simply by $B_{t+1} = (1-\lambda)B_t$.

Bank deposit guarantees It is important to show how the cost of deposit guarantees is known to the government once it formulates its default decision Δ_t (i.e., the government knows the value of $\kappa D_t \Omega_t$ under repayment v. default). This is important also because the default threshold of bank shocks that determines their default probability also helps determine the current-period's net worth of the banking system N_t.

The payments on deposit guarantees executed at the start of date t depends on the fraction of banks that default. Hence, to characterize the cost of these guarantees, we need to characterize first what determines if a bank defaults. As explained earlier, a bank defaults when it becomes insolvent. At date t, this happens for any $\omega_t \leq \overline{\omega}_t$ such that:

$$\overline{\omega}_t R_t^k k_t + \left[(1-\lambda)q_t + (c+\lambda)(1-\Delta_t)\right] b_t^b - d_t = 0.$$

The probability of default, the truncated mean and the standard return are therefore: $F(\overline{\omega}_t; \sigma_t)$, $M_1(\overline{\omega}_t; \sigma_t)$ and $\Gamma(\overline{\omega}_t; \sigma_t)$, respectively. Notice that $\overline{\omega}_t$ depends on the government's default decision Δ_t.

The average loss per unit of D_t is:

$$\Omega_t = \frac{1}{D_t}\int_0^{\overline{\omega}_t}\left\{D_t - \left[(1-\mu)\omega R_t^k K_t + \left[(1-\lambda)q_t + (c+\lambda)(1-\Delta_t)\right]B_t^b\right]\right\}dF(\omega;\sigma_t)$$

Using the condition defining $\overline{\omega}_t$, we obtain:

$$\Omega_t = \frac{\left[\overline{\omega}_t - \Gamma(\overline{\omega}_t,\sigma_t) + \mu M_1\left(\overline{\omega}_t,\sigma_t\right)\right]R_t^k K_t}{D_t}. \tag{22}$$

The cost of the deposit guarantees is then simply $\kappa D_t \Omega_t$.

Importantly, the term that explicitly includes the payoff on B_t^b vanishes from Ω_t because sovereign bonds are fully recovered in bank resolution (there is no additional haircut beyond sovereign default itself). Sovereign repayment and the future resale price of debt still affect resolution losses but implicitly through their effect on $\overline{\omega}_t$. It is also critical to note that Ω_t depends on whether the government defaulted or not at the start of date t, Δ_t, as well as on the outstanding debt B_t and the price of debt q_t (which itself will depend also on B_{t+1}). These variables affect the threshold $\overline{\omega}_t$, the average loss per unit of D_t, and the cost of the bank deposit guarantees to the government. This is how the government knows the values of $\kappa D_t \Omega_t$ to assign under repayment v. default in its budget constraints.

The threshold $\overline{\omega}_t$ also determines the net worth of the bankers and the equity of the banking system because it determines the bankers' return on their diversified portfolios of bank equity invested in the previous period (E_{t-1}). In particular, that rate of return is:

$$\begin{aligned}\rho_{b,t} &= \frac{R_t^k K_t}{E_{t-1}}\int_{\overline{\omega}_t}^{\infty}\left[\omega - \overline{\omega}_t\right]dF(\omega,\sigma_t)\\ &= \left[1-\Gamma\left(\overline{\omega}_t,\sigma_t\right)\right]R_t^k\frac{K_t}{E_{t-1}}.\end{aligned}$$

Aggregate investable net worth at the beginning of period t is obtained then using the law of motion $N_t = \left[\theta + \chi_b(1-\theta)\right]\rho_{b,t}E_{t-1}$ (using also the result that $N_{t-1} = E_{t-1}$):

$$\begin{aligned}N_t &= \left[\theta+\chi_b(1-\theta)\right]\int_{\overline{\omega}_t}^{\infty}\left[\omega R_t^k K_t + \left[(1-\lambda)q_t + (c+\lambda)(1-\Delta_t)\right]B_t^b - D_t\right]dF(\omega;\sigma_t)\\ &= \left[\theta+\chi_b(1-\theta)\right]\left[1-\Gamma\left(\overline{\omega}_t;\sigma_t\right)\right]R_t^k K_t.\end{aligned} \tag{23}$$

This result also has the implication that we do not need to treat N_t as a separate state variable. Its value is determined using the values of the state variables B_t, K_t, D_t, the prices q_t, R_t^k, and the default decision Δ_t

2.6 Markov Equilibrium

We study a recursive Markov equilibrium. The state space is organized as follows. There are two exogenous state variables, the two aggregate shocks (z, σ), and four endogenous state variables (B, B^b, D, K) that we group in the set S^e to simplify notation. Hence, the complete set of state variables for the current period is $S \equiv \{z, \sigma, S^e\}$. The values of the next-period's state variables are included in the set S', so that $S' \equiv \{z', \sigma', S^{e\prime}\}$ and $S^{e\prime} \equiv \{B', B^{b\prime}, D', K'\}$.

The timeline of events within a period is as follows:

1. At the beginning of the period, the state variables in S^e are known and the shocks (z, σ) are realized.
2. The labor market and the rental market of existing capital meet. This determines the wage rate, capital rental rate, labor and capital allocations, output and the revenue from labor taxes.[5]
3. The government decides whether to default on its outstanding debt B.
4. If the government repays ($\Delta = 0$):
   (a) The government chooses G and B'.
   (b) The payoffs on existing bank assets B^b and K are realized and the probability of bank default (or the fraction of banks that default) is determined, deposit guarantees on maturing deposits $\kappa D\Omega$ are paid, and the bankers' aggregate values of N, E, Π are determined.
   (c) Banks choose $D', K', B^{b\prime}$.
   (d) The markets for newly-issued deposits and sovereign debt meet and the corresponding prices are determined: q^d must satisfy the consumer-workers' deposit pricing condition, and q must clear the market of sovereign debt so that $B' = B^{f\prime} + B^{d\prime}$.
5. If the government defaults ($\Delta = 1$):
   (a) The government skips the payment $(c + \lambda)B$ to all bond holders and its unmatured debt continues to trade. G is set to satisfy the government budget constraint under default (i.e., labor tax revenues minus the cost of insured maturing deposits).

[5] It is possible to have factor markets meet first because K and z are known, firms rent existing capital from the bankers who own it, and we assume preferences that neutralize the wealth effect on labor supply.

(b) The payoffs on existing bank assets B^b and K are realized and the probability of bank default (or the fraction of banks that default) is determined, deposit guarantees on maturing deposits $\kappa D\Omega$ are paid, and the bankers' aggregate values of N, E, Π are determined.

(c) Banks choose $D', K', B^{b'}$.

(d) The markets for newly-issued deposits and sovereign debt meet and their prices are determined: q^d must satisfy the consumer-workers' deposit pricing condition, and q must clear the market of sovereign debt with the supply of debt set to $B' = (1-\lambda)B$ because the government cannot issue new debt in the period it defaults (i.e., $(1-\lambda)B = B^{f'} + B^{d'}$).

6. The period ends.

We construct the Markov equilibrium in two stages. First, we formulate the equilibrium of the private sector for given government actions. Since private agents are atomistic and take all prices and the actions of other agents as given, we can define a set of recursive functions that map the current state S into equilibrium prices and allocations. These include six pricing functions: $W(\mathrm{S}), r^k(\mathrm{S}), R^K(\mathrm{S}), q^d(\mathrm{S}), q(\mathrm{S}), \rho_b(\mathrm{S})$ and eight decision rules $L(\mathrm{S}), N(\mathrm{S}), \Pi(\mathrm{S}), \Omega(\mathrm{S}), D'(\mathrm{S}), B^{b'}(\mathrm{S}), B^{f'}(\mathrm{S}), K'(\mathrm{S})$. Private agents also take as given conjectures of the actions of the government $B'(\mathrm{S}), \Delta(\mathrm{S}), G(\mathrm{S})$ and of the law of motion of the endogenous states $\mathrm{S}^{\mathrm{e}\prime} = \zeta(\mathrm{S})$. The *private sector equilibrium* is defined by the set of all these recursive functions such that, given the conjectures about the government's actions and the law of motion $\zeta(\mathrm{S})$, consumer-workers, producers, bankers, and banks solve their optimization problems, the foreign bond demand condition holds, the market-clearing conditions of the markets for labor, sovereign debt, and bank deposits hold, and the aggregate resource constraint of the economy holds. In solving their problems, private agents formulate expectations (denoted by the expectations operator $\mathbb{E}$) as conditional expectations induced by the exogenous stochastic processes for (z, σ) and the law of motion $\zeta(\mathrm{S})$. At equilibrium, these expectations are rational because of the equilibrium condition requiring this law of motion to be consistent with the decision rules of the agents and the government.

The government is not an atomistic agent, and importantly for our analysis, it internalizes the effects of its actions on the private sector. To this end, the government uses the results of the private sector equilibrium to construct a mapping of how its actions affect private agents for each candidate choice of its actions (B', Δ) and their associated value of G under default or repayment. In particular, it constructs

the following mapping of the evolution of the aggregate state variables:

$$\widetilde{S}^{e\prime}(\mathrm{S};B',\Delta) \equiv \left\{B', \widetilde{B}^{b\prime}(\mathrm{S};B',\Delta), \widetilde{D}'(\mathrm{S};B',\Delta), \widetilde{K}'(\mathrm{S};B',\Delta)\right\}.$$

$\widetilde{B}^{b\prime}(\mathrm{S};B',\Delta), \widetilde{D}'(\mathrm{S};B',\Delta), \widetilde{K}'(\mathrm{S};B',\Delta)$ correspond to the decision rules of the private sector equilibrium solved under a given pair of values of (B',Δ). There are also associated functions of the same three arguments that return the losses on insured deposits, investable net worth of bankers, the deposit price, and the sovereign debt price of the private sector equilibrium: $\widetilde{\Omega}(\cdot), \widetilde{\mathcal{N}}(\cdot), \widetilde{\mathcal{Q}}^d(\cdot)$ and $\widetilde{\mathcal{Q}}(\cdot)$.[6] Since capital K is a predetermined state variable in the current period and factor demands are determined before the default and borrowing decisions, the government uses the same recursive functions for wages ($W(\mathrm{S})$), labor ($L(\mathrm{S})$), and the rental rate of capital ($r^K(\mathrm{S})$) as in the private equilibrium. The foreign holdings of bonds are implied by market clearing of the debt market as $\widetilde{B}^{b\prime}(\mathrm{S};B',\Delta) = B' - \widetilde{B}^{f\prime}(\mathrm{S};B',\Delta)$.

In the second stage of the Markov equilibrium construction, we use the above structure to formulate the recursive optimization problem of the government. At the beginning of the period, the government chooses whether to default or not by choosing the option that attains the highest value:

$$V(\mathrm{S}) = \max_{\Delta\in\{0,1\}} \{(1-\Delta)V^G(\mathrm{S}) + \Delta V^D(\mathrm{S})\}, \tag{24}$$

where V^G and V^D are the values under repayment and default.[7]

Repayment. If the government repays, it has access to the bond market and solves this problem:

$$V^G(\mathrm{S}) = \max_{G,B'} \left\{ \frac{G^{1-\gamma}}{1-\gamma} + \beta^G \mathbb{E}\left[V(\widetilde{S}^{e\prime}(\mathrm{S};B',0), z', \sigma')\right]\right\} \tag{25}$$

subject to

$$\tau W(\mathrm{S})L(\mathrm{S}) + \widetilde{\mathcal{Q}}(\mathrm{S};B',0)\left(B' - (1-\lambda)B\right) - (c+\lambda)B = G + \kappa D\widetilde{\Omega}(\mathrm{S};B',0). \tag{26}$$

[6] $\widetilde{\Omega}(\cdot)$ and $\widetilde{\mathcal{N}}(\cdot)$ are determined by the recursive representations of conditions (22) and (23). As we explained, N is not a state variable because its value is determined as the total return on the diversified portfolio of the bankers' equity investments from the previous period, which is determined using the state variables B, K, D, the equilibrium prices q, R^k, and the default decision Δ.

[7] In the numerical implementation, the repayment and default values are perturbed by i.i.d. Type-I extreme-value taste shocks, following the dynamic discrete-choice approach of Dvorkin et al. (2021). The resulting policy $\Delta(\mathrm{S}) \in [0,1]$ is interpreted computationally as a default probability. We omit these auxiliary shocks from the analytical notation.

In the continuation value $V(\widetilde{S^e}'(S; B', 0), z', \sigma')$, the government internalizes how its borrowing and repayment decisions affect the private sector by taking into account how they influence the evolution of all endogenous state variables, including those determined in the private sector equilibrium (new deposits and the bank's new investments in capital and sovereign debt). Since these are determinants of future prices and allocations, the government is implicitly internalizing the effect of its decisions on all the equilibrium variables. Note that because K is an element of S and factor allocations and output depend only on z and K, the government's current borrowing and default choices cannot affect them contemporaneously, but dynamically they do by altering capital accumulation and thus future factor allocations and prices.

Default. If the government defaults, its value function is

$$V^D(S) = \frac{G^{1-\gamma}}{1-\gamma} - \xi + \beta^G \mathbb{E}\left[V(\widetilde{S^e}'(S; (1-\lambda)B, 1), z', \sigma')\right] \tag{27}$$

with $G = \tau W(S)L(S) - \kappa D\widetilde{\Omega}(S; (1-\lambda)B, 1)$. Because the unmatured debt continues to trade when the government defaults, the continuation value and the per-unit cost of insured deposits in these expressions are evaluated at $B' = (1-\lambda)B$. The continuation value is given by $V(\cdot)$ because of the assumption that the government is precluded from issuing new debt only in the period in which it defaults (i.e., it can choose again in the following period whether to stay in default or issue new debt). In both this continuation value and in the cost of insured deposits, the government internalizes the effects of its default decision on the private sector equilibrium by evaluating the evolution of the endogenous states that correspond to the private sector equilibrium decision rules at the values $B' = (1-\lambda)B$, $\Delta = 1$. It is through these effects that the government takes into account the endogenous costs of default induced by the impacts of the default on banking fragility and economic activity. These costs have a contemporaneous component via the cost of deposit guarantees $\kappa D\widetilde{\Omega}(S; (1-\lambda)B, 1)$ and a dynamic component captured by the effects on future prices and allocations embedded in $\widetilde{S^e}'(S; (1-\lambda)B, 1)$

The model's *Markov equilibrium* can now be defined as the set of optimal decision rules of the government $B'(S), \Delta(S), G(S)$ that solve its optimization problem for given private-sector equilibrium decision rules solved for the same government decision rules and such that the law of motion $S^{e\prime} = \zeta(S)$ satisfies the consistency condition requiring the evolution of each element of $S^{e\prime}$ to be consistent with the private sector decision rules and the government decision rules. Specifically, given the government's optimal decision rules $(B'(S), \Delta(S))$, these conditions must hold: $D'(S) = \widetilde{D}'(S; B'(S), \Delta(S))$, $B^{b\prime}(S) = \widetilde{B^b}'(S; B'(S), \Delta(S))$

and $K'(S) = \widetilde{K}'(S; B'(S), \Delta(S))$. EGM:APPENDIX NEEDS UPDATING+COMPLETINGAppendix A.1 provides the formal definition of the Markov equilibrium and the full characterization of the recursive optimization problems of the private agents.

3 The Mechanism Driving the Entwined Risks in the Model

In this Section, we use some of the model's key optimality conditions in partial equilibrium to provide an economic intuition of how the risks of default of the sovereign and the banks interact and how they affect the real sector of the economy. We study the effects of sovereign risk on the banks' default threshold and default probability, and the conditions that determine the banks' holdings of sovereign debt and physical capital. To simplify notation, we use the optimality conditions in sequential form.

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Bank default threshold. Using the results from the previous Section, we can write the threshold of realizations of bank-specific returns at date t below which banks default in the current period as:

$$\overline{\omega}_t = \frac{D_t - \left[(1-\lambda)q_t + (c+\lambda)(1-\Delta_t)\right] B_t^b}{R_t^k K_t},$$

with the corresponding default probability $F(\overline{\omega}_t; \sigma_t)$. Clearly, for a given position of the banks in sovereign debt carried over from the previous period B_t^b (and the other state variables D_t, K_t), both the threshold and the bank default probability rise if the government defaults in date t and/or if the date-t price of the sovereign debt drops (which hinges on the date-t default decision and new debt issuance, and the risk of default in t+1). Hence, an observed default and/or the risk of a future sovereign default induce higher probability of bank default.[8].

Since the total return on the bankers' equity investments in banks is: $\rho_{b,t} E_t = \left[1 - \Gamma\left(\overline{\omega}_t, \sigma_t\right)\right] R_t^k K_t$, the higher bank default threshold induced by sovereign risk also reduces the return on the bankers' net worth. In turn, this reduces investable net worth, since $N_t = \left[\theta + \chi_b(1-\theta)\right] \rho_{b,t} E_{t-1}$.

The lower net worth causes adjustments in the banks' investments. Since the banks' capital requirement is binding, the banks have to choose their demand for sovereign debt B_{t+1}^b and their capital accumulation K_{t+1} so that the capital requirement holds at their given net worth. If the banks' demand for sovereign

[8]Larger deposit obligations, lower capital holdings and lower market returns on capital also raise the probability of bank default, but these are pre-determined at date t

bonds when sovereign risk rises enough to , as will be the case in our calibrated quantitative analysis, it follows then from the binding capital requirement that K_{t+1} falls.

Bank first-order condition for sovereign debt. Under the binding constraints (59)–(60),

$$\frac{\partial K_{t+1}}{\partial B^b_{t+1}} = -\iota q_t, \qquad \frac{\partial D_{t+1}}{\partial B^b_{t+1}} = \frac{(1-\iota)q_t}{q^d_t}.$$

Using limited liability, the first-order condition with respect to sovereign bond *face value* B^b_{t+1} is

$$0 = \mathbb{E}_t \Bigg[\Lambda_{b,t+1} \int_{\overline{\omega}_{t+1}}^{\infty} \Bigg\{ (1-\lambda) q_{t+1} + (c+\lambda)(1-\Delta_{t+1}) \\ -\iota q_t \omega_{t+1} R^k_{t+1} - \frac{(1-\iota)q_t}{q^d_t} \Bigg\} dF(\omega_{t+1}; \sigma_{t+1}) \Bigg]. \tag{28}$$

An additional unit of bond face value costs q_t. The capital requirement displaces ιq_t units of productive capital, while the remaining $(1-\iota)q_t$ is financed with deposits. Dividing (28) by the current price gives the equivalent return formulation

$$\mathbb{E}_t \left[\Lambda_{b,t+1} \int_{\overline{\omega}_{t+1}}^{\infty} \left(R^b_{t+1} - \iota \omega_{t+1} R^k_{t+1} - \frac{1-\iota}{q^d_t} \right) dF(\omega_{t+1}; \sigma_{t+1}) \right] = 0. \tag{29}$$

Bank-demand wedge for sovereign debt. All expectations and covariances below condition on information available at date t. Define the normalized survival-weighted banker valuation kernel

$$\mathcal{M}_{t+1} \equiv \frac{\Lambda_{b,t+1}[1 - F(\overline{\omega}_{t+1}; \sigma_{t+1})]}{\mathbb{E}_t \left[\Lambda_{b,t+1}[1 - F(\overline{\omega}_{t+1}; \sigma_{t+1})] \right]},$$

and the average capital return among surviving banks,

$$\mathcal{R}^k_{+,t+1} \equiv R^k_{t+1} \frac{\int_{\overline{\omega}_{t+1}}^{\infty} \omega_{t+1}\, dF(\omega_{t+1}; \sigma_{t+1})}{1 - F(\overline{\omega}_{t+1}; \sigma_{t+1})}.$$

Define the contractual yield spread on discount deposits as

$$s^d_t \equiv \frac{1}{q^d_t} - R^* = R^* \frac{(1-\kappa)\mathbb{E}_t[\Omega_{t+1}]}{1 - (1-\kappa)\mathbb{E}_t[\Omega_{t+1}]},$$

where the second equality follows from (41) under $\beta = \beta^* = 1/R^*$, as in the calibration. Using $\mathbb{E}_t[\mathcal{M}_{t+1}] = 1$, the bank first-order condition implies

$$\mathbb{E}_t[R^b_{t+1}] - R^* = (1-\iota)s^d_t + \iota\left(\mathbb{E}_t[\mathcal{R}^k_{+,t+1}] - R^*\right) - \operatorname{cov}_t\left(\mathcal{M}_{t+1}, R^b_{t+1}\right) + \iota \operatorname{cov}_t\left(\mathcal{M}_{t+1}, \mathcal{R}^k_{+,t+1}\right). \tag{30}$$

Preferred habitat makes the left side endogenous. Combining (30) with (20) gives

$$R^*\kappa^f\left(\frac{B^f_{t+1}}{B_{t+1}} - \bar{s}^f\right) = (1-\iota)s^d_t + \iota\left(\mathbb{E}_t[\mathcal{R}^k_{+,t+1}] - R^*\right) - \operatorname{cov}_t(\mathcal{M}_{t+1}, R^b_{t+1}) + \iota \operatorname{cov}_t(\mathcal{M}_{t+1}, \mathcal{R}^k_{+,t+1}). \tag{31}$$

This condition determines how the outstanding debt is split between domestic banks and foreign investors.

The first term on the right of (31) is the deposit-funding wedge. A higher expected uninsured loss lowers q^d_t and raises the contractual deposit yield. It is multiplied by $1-\iota$ because that fraction of an additional dollar spent on sovereign debt is deposit financed.

The second term is the regulatory opportunity cost. Increasing the market value of sovereign holdings by one unit crowds out ι units of productive capital. The relevant forgone return is $\mathcal{R}^k_{+,t+1}$ because limited-liability shareholders value payoffs only in survival states.

The covariance term combines two opposing risk components. Standard risk compensation arises because sovereign debt pays poorly when the marginal value of banker net worth is high. Risk shifting arises because bank survival and the sovereign return move together: bankers receive the upside in repayment states, while limited liability truncates their losses in states in which sovereign and bank outcomes are both poor. Stronger risk shifting lowers the return banks require to hold sovereign debt. The preferred-habitat slope translates the resulting bank-demand wedge into movements in foreign holdings and the equilibrium bond price.

Bank demand for sovereign debt. Substituting (12) into (29), define

$$\mathcal{D}_{q,t} \equiv \frac{1-\iota}{q^d_t}\mathbb{E}_t\left[\Lambda_{b,t+1}[1 - F(\overline{\omega}_{t+1}; \sigma_{t+1})]\right] + \iota\mathbb{E}_t\left[\Lambda_{b,t+1}R^k_{t+1}\int_{\overline{\omega}_{t+1}}^{\infty}\omega_{t+1}\, dF(\omega_{t+1}; \sigma_{t+1})\right].$$

Solving for q_t gives the condition that determines banks' sovereign bond holdings:

$$q_t = \frac{\mathbb{E}_t \left[\Lambda_{b,t+1}[1 - F(\overline{\omega}_{t+1}; \sigma_{t+1})] \left[(1-\lambda)q_{t+1} + (c+\lambda)(1-\Delta_{t+1})\right]\right]}{\mathcal{D}_{q,t}}. \tag{32}$$

Because B^b_{t+1} enters the survival term through (58), (32) is an inverse-demand relation for domestic banks. Together with preferred-habitat foreign demand and market clearing, it determines both the price and the allocation of sovereign debt. Bank funding costs, regulatory risk weights, and limited-liability risk shifting shape this relation.

Figure 3: Effects of the bank-risk state

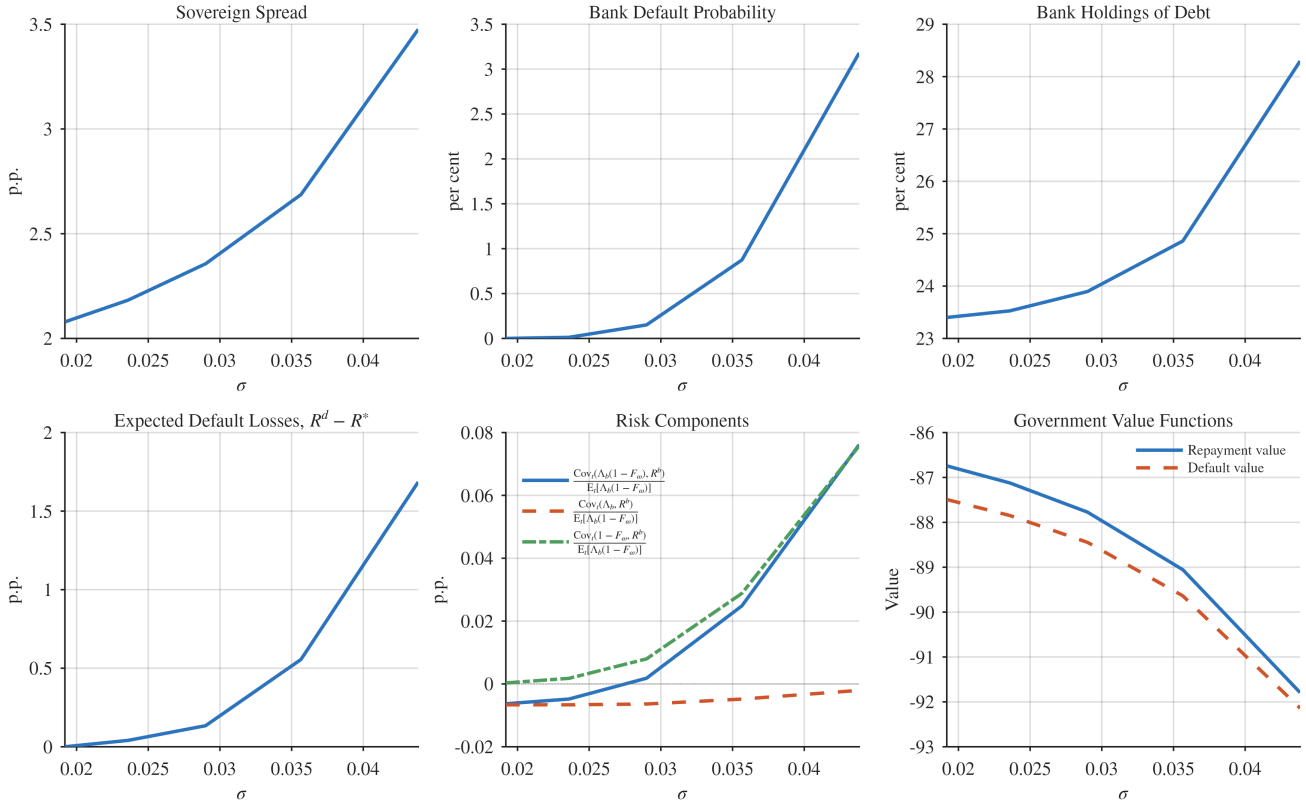


Figure 3 evaluates the equilibrium policy functions at different values of the bank-risk state σ, holding all other state variables at their ergodic means. A higher σ increases the dispersion of idiosyncratic capital returns without changing their mean and therefore places more banks below the default threshold. The bank default probability rises nonlinearly and becomes especially sensitive to σ when the banking sector is already fragile.

The deterioration in bank solvency lowers both the government's repayment and default values because bank failures reduce activity and raise guarantee payments under either choice. The repayment value

moves closer to the default value, however, making repayment less attractive at the margin. Sovereign spreads consequently rise from slightly above two percentage points to almost three and a half percentage points, feeding back into banks through the return on their sovereign holdings.

At the same time, banks increase their share of sovereign debt from about 23.5 to more than 28 percent. Expected bank-default losses and deposit funding costs work in the opposite direction, but the positive risk-shifting component strengthens sharply with σ and eventually dominates the negative risk-compensation component. Limited liability can therefore increase banks' willingness to hold risky sovereign debt even as their own funding becomes more expensive.

Figure 4: Impulse responses to a bank-risk shock

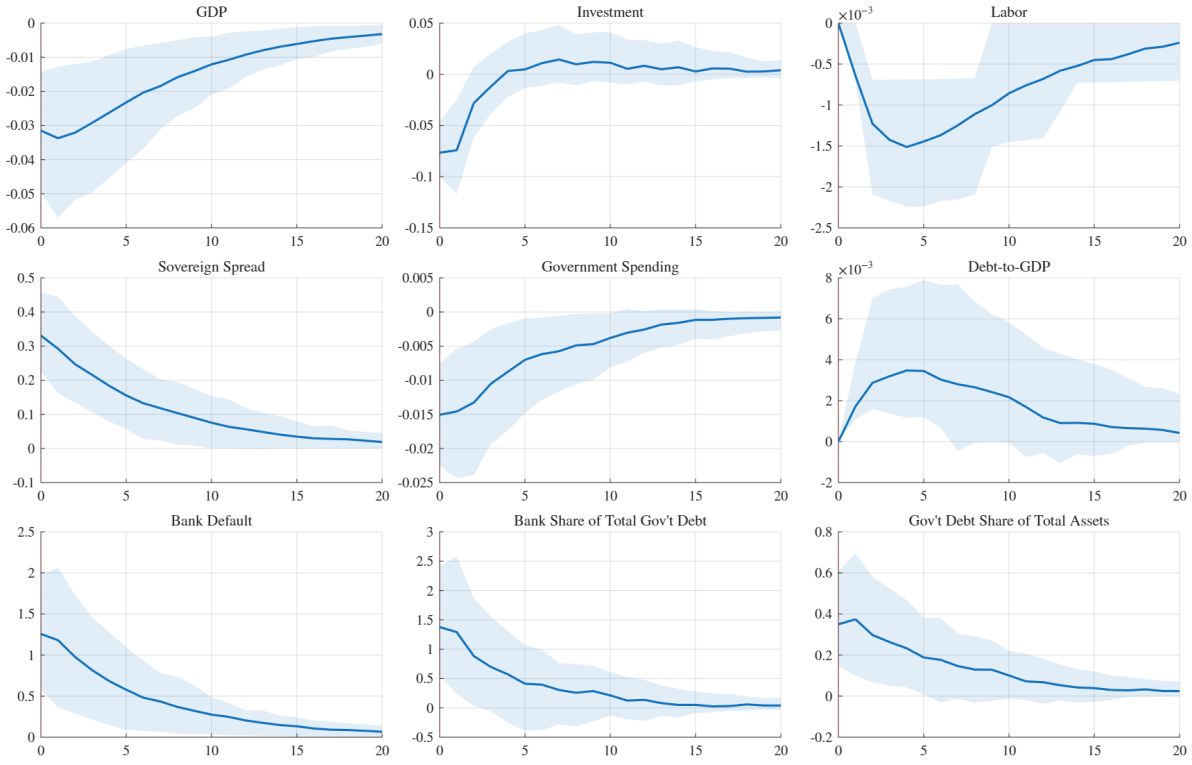


Figure 4 traces the response to a temporary increase in σ. The shock originates in the banking sector rather than in aggregate productivity, so the immediate rise in bank default is its direct effect. Bank failures reduce aggregate banker net worth and lending capacity, causing investment to contract sharply and GDP and labor to fall. These real effects persist as the bank-risk shock gradually dissipates.

Bank fragility then passes to the sovereign. Larger guarantee payments coincide with lower output and tax revenue. The government raises debt to smooth public spending, but spending still falls and the debt-to-GDP ratio increases. Weaker fiscal conditions and repayment incentives raise the sovereign spread

by about 30 basis points on impact.

Banks respond by increasing both their share of total government debt and the share of sovereign debt in their own assets. This absorption supports government financing, but it reallocates bank balance sheets away from productive capital and reinforces the decline in investment and GDP. Greater sovereign exposure also makes bank net worth more sensitive to sovereign spreads, completing the feedback from banks to the sovereign and back to banks. As σ returns to baseline, bank default, sovereign spreads, and bank portfolios gradually normalize, while the fiscal effects remain more persistent because debt is slow moving.

4 Calibration

We solve the model using value function iteration.[9] Then, we parameterize our model economy to try to capture some key features of the banking sector, the fiscal problems of the government, and the interaction between them. As is standard, we proceed in two steps by first setting the values for a number of externally calibrated or preset values, which we draw from the literature. With these in hand, we then parameterise another set of parameters by internally calibrating them with the objective of minimizing the distance between a collection of data and model moments. The model is calibrated quarterly using data for Spain during the 1999:Q1 - 2019:Q4 period. Results are reported in Tables 1 and 2.

Exogenous Processes. The economy is driven by log productivity z and the bank-risk state σ. The level of TFP entering production is e^z. The bank-risk state governs the cross-sectional dispersion of the idiosyncratic bank shock and therefore banking-sector fragility. We model the bank-risk state as an AR(1) in log volatility:

$$\log \sigma' = (1 - \rho_\omega) \log \bar{\sigma} + \rho_\omega \log \sigma + \epsilon^{\omega\prime}, \qquad \epsilon^{\omega\prime} \sim \mathcal{N}(0, \sigma_\omega^2). \tag{33}$$

The date-t bank-specific shock is drawn after σ is realized:

$$\omega \mid \sigma \sim \log \mathcal{N}\left(-\frac{\sigma^2}{2}, \sigma^2\right). \tag{34}$$

[9] See Online Appendix for details.

Thus the current resolution block uses dispersion σ, while a portfolio selected today integrates over σ' and $\omega' \mid \sigma'$. The idiosyncratic shock has conditional mean one and a cross-sectional dispersion that rises with the aggregate bank-risk state. Log productivity follows

$$z' = (1-\rho_z)\mu_z + \rho_z z + \epsilon^{z'}, \qquad \epsilon^{z'} \sim \mathcal{N}(0, \sigma_z^2), \tag{35}$$
$$\mu_z = -\frac{\sigma_z^2}{2(1-\rho_z^2)}.$$

The stationary variance of z is $\sigma_z^2/(1-\rho_z^2)$, so this choice of μ_z implies

$$\mathbb{E}[e^z] = 1.$$

Productivity in levels, rather than log productivity, therefore has unconditional mean one.[10]

Externally Calibrated Parameters

We set the TFP process persistence to $\rho_z = 0.92$ and the innovation standard deviation to $\sigma_z = 0.006$, values in line with estimated TFP processes for Spain. The quarterly depreciation rate δ is set to the typical value of 0.025, while the capital share in production α is set at 0.4. The deadweight losses from bankruptcy are set as in Mendicino et al. (2020) at 0.3. The government risk aversion γ is set at typical values for this parameter and as set in Arellano et al. (2025) at 2. For the Frisch elasticity of labor, we again rely on the common value in the literature and set it 0.75 implying an η of 1.33. The parameter governing the disutility of labor χ is essentially a scaling parameter, and we set it such that the steady-state labour supply is equal to $1/3$. The discount factor of households is set such that $1/\beta$ equals roughly the average risk-free rate which we take as the yield on German bunds over 2000-2019. We set the quarterly coupon to $c = 0.01$, so a risk-free government bond trades close to par. The bank capital requirement is $\phi = 0.08$, and the regulatory risk weight on sovereign debt is $\iota = 0.375$.

Internally Calibrated Parameters

For the remaining parameters, we set them to minimize the weighted sum of the squared distance between the simulated model moments and the corresponding data moments summarized in Table 2.

[10] In the Rouwenhorst approximation, let π_z denote the invariant distribution of the discrete transition matrix and let $\{z_i\}$ be the log-productivity grid. We set the level at node i to $a_i \equiv \exp(z_i)/\sum_j \pi_z(j)\exp(z_j)$, which imposes $\sum_i \pi_z(i)a_i = 1$ exactly on the finite grid.

Table 1: Model Parameters

Externally calibrated parameters					
Banks bankruptcy cost	μ	0.3	STD for TFP	σ_z	0.006
Depreciation rate of capital	δ	0.025	Frisch elasticity of labor	$1/\eta$	0.75
Government risk aversion	γ	2	Capital share in production	α	0.4
AR parameter TFP	ρ_z	0.92	Disutility of labor	χ	6.47579
Discount factor of consumers/foreigners	β/β^*	0.99/0.99	Capital requirement for banks	ϕ	0.08
Government debt risk weight	ι	0.375	Share of guaranteed deposits	κ	0.54
Government bond coupon	c	0.01			
Internally calibrated parameters					
Mean STD bank risk shock	$\bar{\sigma}$	0.029	CES exponent	ϵ	-0.142
Discount factor of government	β^G	0.969	Survival rate of bankers	θ	0.54
Labor income tax	τ	0.305	Transfer to new bankers	χ_b	0.95
Maturing debt	λ	0.045	STD bank risk innovation	σ_ω	0.1
Default cost	ξ	1.9	AR parameter bank risk	ρ_ω	0.875
Foreign debt-share reference	$\bar{s}^f$	0.744672	Foreign inverse-demand slope	κ^f	0.1

The internal calibration is organized around five blocks. First, $(\bar{\sigma}, \rho_\omega, \sigma_\omega)$ discipline the mean, persistence, and volatility of bank default risk. Second, (θ, χ_b) target the real bank equity return and bank price-to-book ratio. Third, $(\tau, \lambda, \beta^G, \xi)$ target government revenue, debt maturity, debt, and the sovereign spread. Fourth, $(\bar{s}^f, \kappa^f)$ target the mean and standard deviation of the domestic bank share of sovereign debt. Finally, the production parameter ϵ helps discipline the volatility of sovereign spreads.

Data targets and corresponding model values. Asset returns are annualized.

Table 2: Model Fit

Targets	**Definition**	**Data**	**Model**
Real Bank Equity Return	$(\rho - 1)$	5.13%	9.46%
Bank Price to Book Ratio	ν	1.57	1.08
Gov't Debt Maturity	$1/(4\lambda)$	6.47y	5.56y
Gov't Debt to GDP Ratio	$\frac{B}{GDP}$	53.72%	50.19%
Gov't Revenue to GDP Ratio	$\frac{\tau w L}{GDP}$	21.55%	21.67%
Gov't Debt Spread	$\frac{\lambda+c}{q} + (1-\lambda) - \frac{1}{\beta}$	1.03%	2.41%
Bank Default Prob.	$F(\bar{\omega})$	0.49%	0.44%
STD Gov't Debt Spread	$\text{SD}\left[\frac{\lambda+c}{q} + (1-\lambda) - \frac{1}{\beta}\right]$	1.17%	0.41%
STD Bank Default Prob.	$\text{SD}\left[F(\bar{\omega})\right]$	0.54%	0.69%
AC(1) Bank Default Prob.	$\text{AC}\left[F(\bar{\omega})\right]$	0.88	0.81
Mean Domestic Bank Share	$\frac{B^b}{B}$	25.53%	24.60%
STD Domestic Bank Share	$\text{SD}\left[\frac{B^b}{B}\right]$	5.59%	1.92%

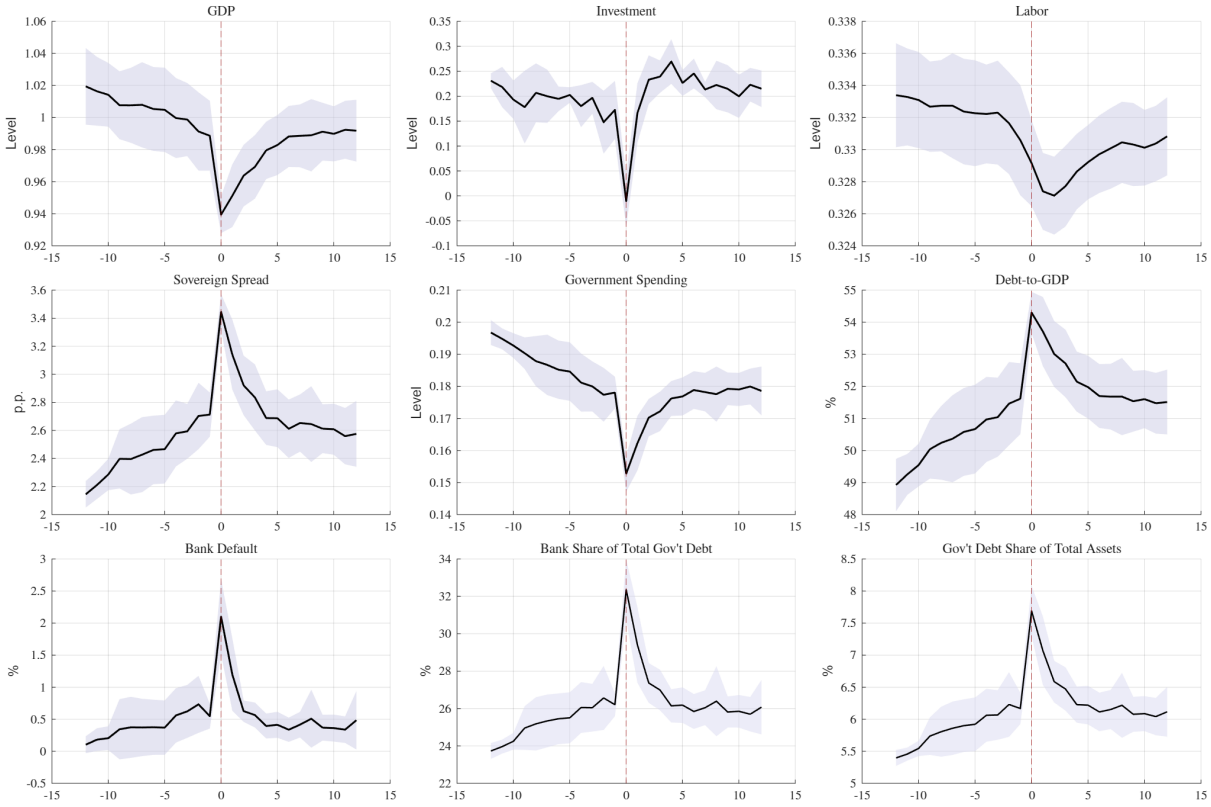
Overall, the model closely matches government revenue, the debt ratio, the mean bank default probability, and the mean domestic bank share. It produces somewhat shorter debt maturity, a higher mean but lower volatility of sovereign spreads, a lower price-to-book ratio, and a higher real bank equity return

than in the data. The preferred-habitat block matches the average domestic share closely but understates its volatility.

5 Sovereign Debt Crisis Dynamics

We now examine the dynamics of the economy around episodes of high sovereign risk. We define stress events as periods in which the sovereign spread rises more than one standard deviation above its unconditional mean, and we retain only complete 25-quarter windows, running from $t - 12$ to $t + 12$, in which the government never defaults. Such episodes are rare: our baseline simulation delivers twelve of them. Figure 5 plots the average path of the economy over the twelve quarters before and after the event date, marked by the vertical line, with shaded bands reporting the dispersion across events.

Figure 5: Sovereign debt crises



The financial variables move together at the event date. The sovereign spread rises from roughly 2.2 to about 3.5 percentage points, and the bank default probability jumps from below one half of a percent to more than two percent. At the same time, domestic banks absorb a substantially larger share of public debt: their share of total government debt rises from about 26 to more than 32 percent, and government

bonds rise from about 5.5 to nearly 8 percent of total bank assets. Sovereign stress and banking fragility are therefore not sequential in the model. They are two sides of the same episode, linked by the guarantee costs that bank failures impose on the budget and by the sovereign losses that a deteriorating bond price imposes on bank net worth.

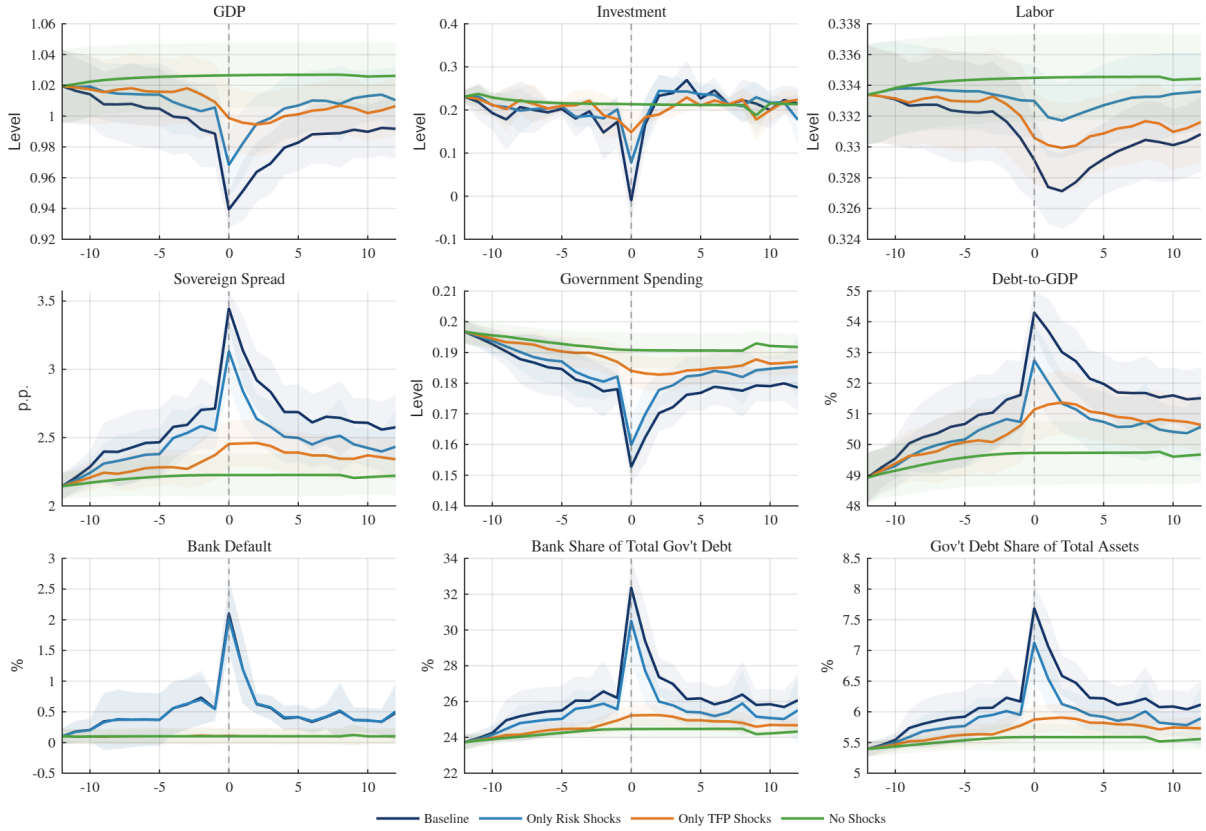
The fiscal and real responses are equally large. Government spending drops sharply at the event date even though the debt-to-GDP ratio jumps by close to three percentage points, so additional borrowing only partially smooths the fiscal shock. GDP falls by roughly five and a half percent relative to its pre-event level, labor contracts, and investment collapses to nearly zero at the trough. The amplification into the real economy is also persistent: investment and GDP remain well below their pre-event levels many quarters after sovereign spreads and bank default probabilities have begun to recede, because bank equity and public debt are slow-moving states.

The portfolio response is central to reading these paths. As sovereign stress intensifies, banks tilt toward government debt, which sustains demand for public bonds and keeps spreads lower than they would otherwise be. This absorption is not free. The reallocation of bank balance sheets toward sovereign debt crowds out productive lending precisely when the sovereign spread peaks, which is why the deepest fall in investment coincides with the largest bank exposure. The same mechanism that stabilizes sovereign financing in the short run therefore amplifies the recession by weakening capital accumulation, and it leaves bank net worth more sensitive to any further widening in spreads.

Figure 6 decomposes these episodes by feeding the same event windows through economies in which only one of the two shocks is active. The dark line is the baseline economy with both shocks, the light-blue line keeps only bank-risk shocks, the orange line keeps only TFP shocks, and the green line shuts down both. Bank-risk shocks account for essentially all of the financial dynamics. On their own they reproduce nearly the entire spike in the sovereign spread, almost all of the increase in the bank default probability, and most of the rise in both the bank share of government debt and the government-debt share of bank assets. TFP shocks alone generate a considerably smaller widening in the spread, a much smaller portfolio shift, and virtually no increase in bank default.

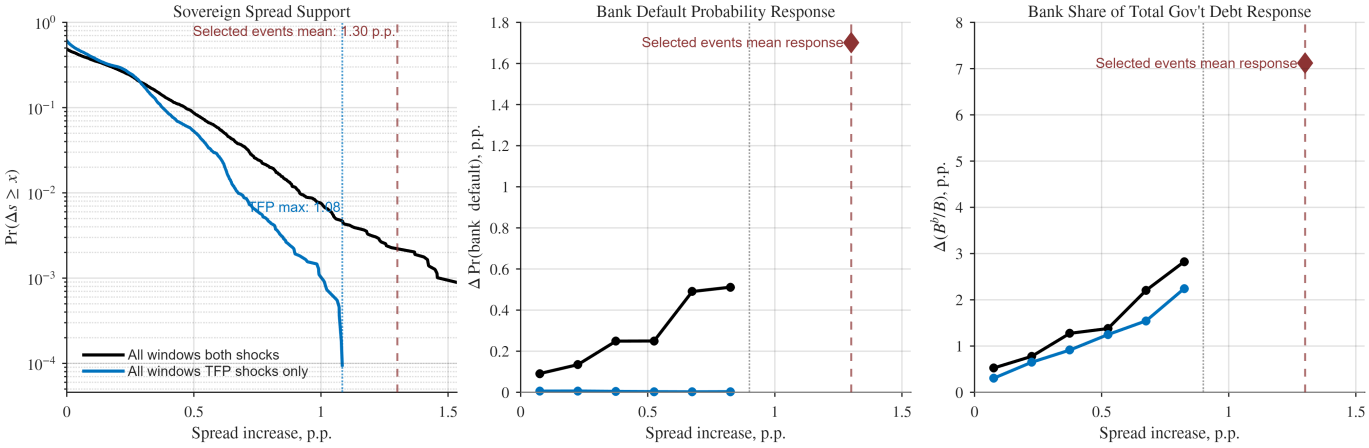
The real side is more balanced but points in the same direction. Bank-risk shocks account for a substantially larger part of the contraction in GDP, investment, and labor than TFP shocks, while the full baseline generates the deepest decline of all, so the two shocks interact rather than simply add up. The fiscal responses follow the same ordering: the fall in government spending and the increase in debt-to-GDP are far larger when bank risk moves than when only TFP moves. These crisis episodes are therefore not ordi-

Figure 6: Sovereign debt crises: decomposition by shocks



nary recessions that happen to coincide with elevated sovereign spreads. They arise because higher bank fragility raises expected guarantee costs, weakens the fiscal position and repayment incentives, and feeds back into sovereign risk.

Figure 7: Sovereign debt crises: baseline versus TFP shocks only



The event study conditions on the selected episodes, so we also compare the baseline economy with a TFP-only economy across all admissible windows. Figure 7 considers every complete 25-quarter window that contains no realized default and measures the associated spread increase as $\Delta s_t = s_t - s_{t-12}$. In the TFP-only economy the bank-risk state is held fixed at its steady-state value. The first panel plots the upper-tail probability $\Pr(\Delta s_t \geq x)$ for the two economies. TFP shocks do generate ordinary spread movements, but their upper tail thins out much faster: the largest increase produced by the TFP-only simulation is 1.08 percentage points, below the 1.30 percentage-point mean increase of the selected events. Productivity shocks alone therefore cannot reproduce the magnitude of the crises studied above.

The remaining two panels report banking responses conditional on the size of the spread increase, using common bins of width 0.15 percentage points and stopping at 0.90 percentage points, the largest value at which every displayed bin contains at least thirty observations from each economy. The bank-default response is the peak default probability over the first four quarters of the window relative to its average over the preceding twelve quarters, $\max_{h=0,\ldots,3} P^{\text{bank}}_{t+h} - \frac{1}{12}\sum_{h=-12}^{-1} P^{\text{bank}}_{t+h}$, and the bank-share response is defined analogously for $S^b_t = 100\, B^b_t / B_t$. The second panel delivers the sharpest distinction between the two economies: for comparable spread increases, bank default risk rises substantially in the baseline but is essentially flat when only TFP shocks operate. Spread increases of TFP origin simply do not carry the banking fragility that characterizes the selected events.

The third panel is more nuanced. The domestic bank share rises with the spread increase in both

economies, so TFP shocks do not generate a counterfactual sign for the portfolio response. The response is larger in the baseline, although the gap narrows toward the end of the common support, where it is roughly 2.95 against 2.49 percentage points. The defensible statement is therefore that TFP shocks alone generate too little amplification of bank sovereign holdings, rather than the wrong response. The red markers in the last two panels report the mean responses across the twelve selected events, 1.70 percentage points for bank default and 7.33 percentage points for the bank share at a mean spread increase of 1.30 percentage points. They lie outside the region of reliable common support and should be read as event-study reference values rather than as points on the conditional curves.

6 The Impact of Bank Regulation

The model contains two regulatory instruments, the capital requirement ϕ and the regulatory risk weight on sovereign debt ι, and both act directly on the mechanism of Section 3. The capital requirement limits leverage and therefore the scope for deposit-financed risk shifting. The risk weight determines how much bank equity a unit of sovereign debt absorbs: holding bank equity fixed, one additional unit of sovereign debt displaces ι units of productive capital, while the remaining $1 - \iota$ units are deposit financed. The baseline sets $\phi = 0.08$ and $\iota = 0.375$. We consider three counterfactual economies, each solved and simulated with the same shock sequences as the baseline: a tighter capital requirement, $\phi = 0.10$; a zero sovereign risk weight, $\iota = 0$; and a high sovereign risk weight, $\iota = 0.75$. Table 3 reports unconditional means.

Unconditional means from common-seed simulations. The sovereign spread is annualized and expressed in percentage points. GDP, investment, and government spending are levels. Ratios and probabilities marked with % are reported in percent.

Table 3: Regulatory Counterfactuals, Unconditional Means

Variable	Baseline	$\phi = 0.1$	$\iota = 0$	$\iota = 0.75$
GDP (level)	0.999	1.015	0.996	1.002
Investment (level)	0.204	0.207	0.204	0.205
Sovereign Spread (annual p.p.)	2.413	1.554	2.339	2.447
Government Spending (level)	0.191	0.197	0.191	0.192
Debt-to-GDP (%)	50.188	49.708	50.241	50.198
Bank Default Probability (%)	0.442	0.076	0.510	0.389
Bank Share of Total Gov't Debt (%)	24.597	24.523	25.498	23.847
Gov't Debt Share of Total Assets (%)	5.705	5.650	5.907	5.533

Raising the capital requirement to $\phi = 0.10$ reduces bank leverage and, with it, the incentive to shift risk onto the deposit guarantee. The quantitatively dominant effect is the collapse in bank default risk,

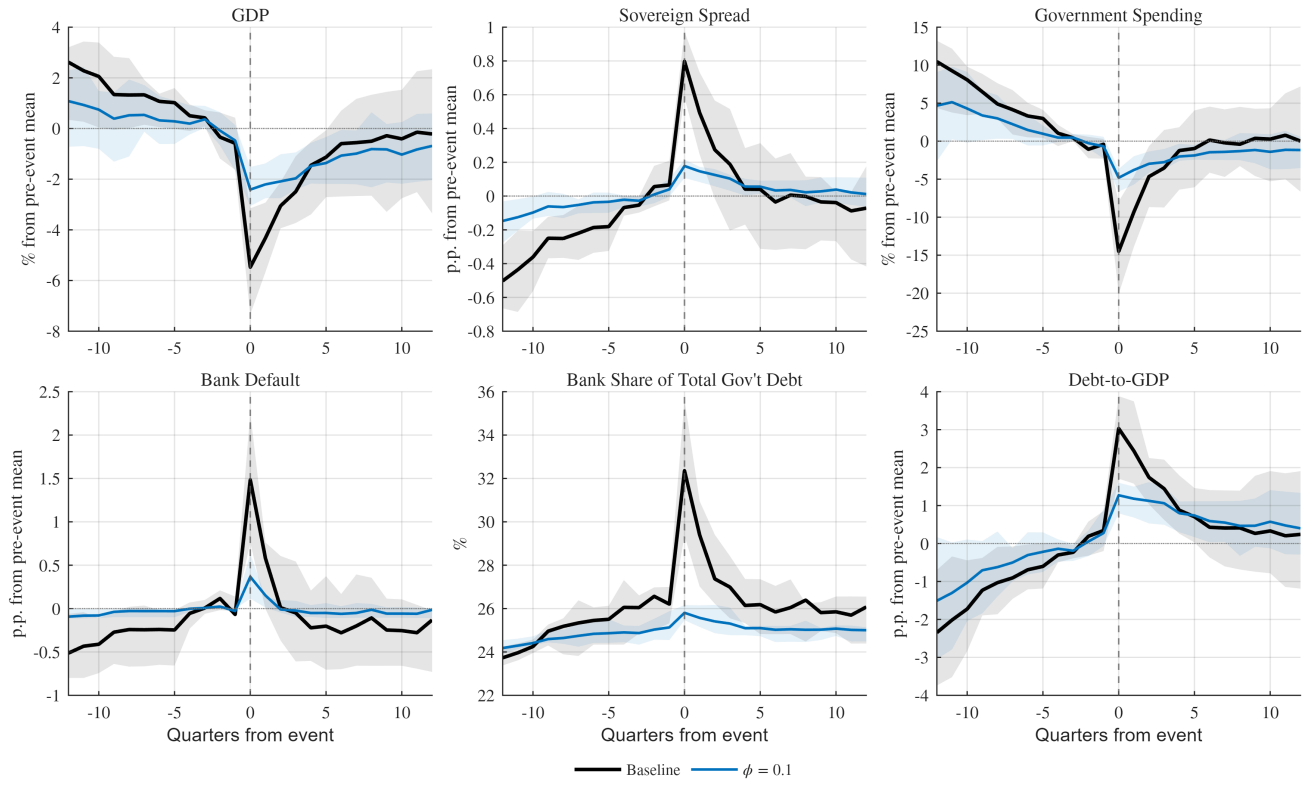
from 0.44 to 0.08 percent. Because expected guarantee costs fall with it, the bank-to-sovereign leg of the feedback loop weakens and the sovereign spread declines from 2.41 to 1.55 percentage points. A tighter requirement also restricts banks' risk-weighted balance-sheet capacity and can therefore limit productive lending, but in equilibrium the stabilization of the nexus dominates this direct intermediation cost: investment, government spending, and GDP are all higher than in the baseline, and the debt ratio is marginally lower.

Setting $\iota = 0$ makes government debt free in capital terms and eliminates direct portfolio crowding out, since additional sovereign holdings are then entirely deposit financed. Banks respond by taking more risk and absorbing more public debt: their share of total government debt rises to 25.5 percent, sovereign debt rises to 5.91 percent of bank assets, and the bank default probability increases to 0.51 percent. The fiscal side moves in the opposite direction. Because the government internalizes the effect of default on domestic banks but not on foreign creditors, greater domestic exposure raises the domestic cost of default, strengthens the repayment incentive, and modestly expands borrowing capacity. The sovereign spread is accordingly slightly lower, at 2.34 percentage points, and debt-to-GDP slightly higher. Investment is essentially unchanged, but greater bank fragility leaves GDP marginally below baseline.

A high risk weight, $\iota = 0.75$, reverses the portfolio force. Each unit of sovereign debt now displaces twice as much productive capital as in the baseline, which raises the opportunity cost of sovereign holdings and discourages deposit-financed risk shifting. Banks reduce their exposure on both measures and their default probability falls to 0.39 percent. Although crowding out per unit of debt is stronger, the fall in bank holdings limits the aggregate displacement of capital, so investment and GDP end up slightly above baseline. For the government, however, lower domestic exposure reduces the domestic cost of default, weakens the repayment incentive, and tightens financing conditions: the spread edges up to 2.45 percentage points while debt-to-GDP is essentially unchanged. The gains in bank stability and the deterioration in sovereign repayment incentives therefore pull in opposite directions.

Unconditional means understate what is at stake, because the nexus operates most forcefully in the tail. Figure 8 therefore repeats the event study of Section 5 under the baseline requirement, in black, and under $\phi = 0.10$, in blue. Both economies receive the same crisis shock sequences, and responses are measured relative to each economy's own pre-event mean, with the bank-share panel reported in levels. The tighter requirement dampens the crisis substantially. The GDP contraction falls from about 5.5 to 2.4 percent, and the increase in the bank default probability falls from 1.49 to 0.37 percentage points. Better-capitalized banks also make a far smaller crisis-driven shift into government debt, which limits both their sovereign

Figure 8: Sovereign debt crises: the role of capital requirements

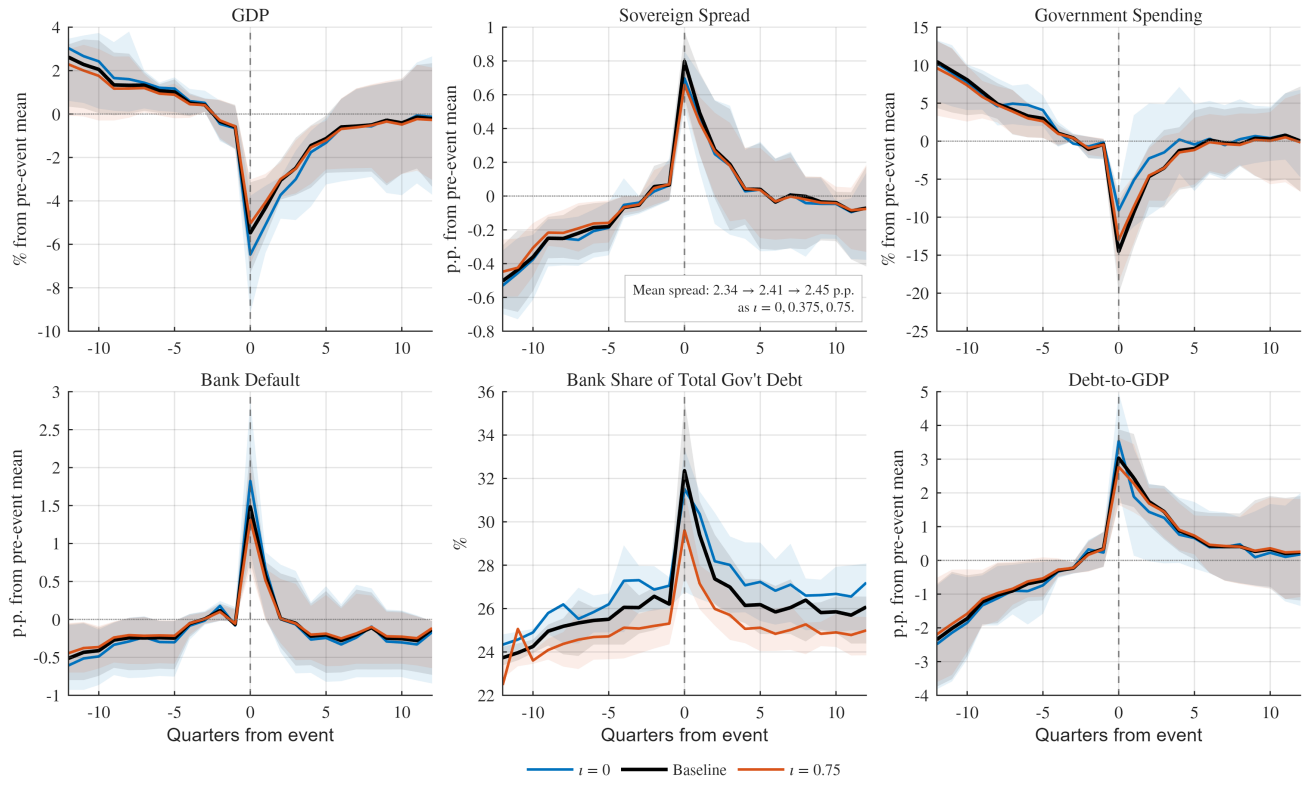


exposure and the crowding out of productive lending at the worst possible moment.

The weaker banking response mutes the feedback to the sovereign. The increase in the sovereign spread falls from about 0.80 to 0.18 percentage points, the contraction in government spending shrinks from roughly 14.5 to 4.8 percent, and the rise in debt-to-GDP is correspondingly smaller. Although a higher capital requirement directly restricts bank balance-sheet capacity, preserving bank equity and containing bank default dominates during these episodes. The conditional evidence therefore reinforces the unconditional results: stronger capital buffers weaken every major dimension of the sovereign-bank amplification mechanism at once.

Figure 9 performs the same exercise for the risk weight, with $\iota = 0$ in blue, the baseline $\iota = 0.375$ in black, and $\iota = 0.75$ in orange. The two opposing forces identified in the unconditional means are visible in the crisis paths. With a zero risk weight, banks enter the crisis with the largest sovereign holdings and the highest government-debt share of assets. Even though additional sovereign debt does not directly displace capital in that economy, the greater exposure and fragility produce the largest increase in bank defaults, about 1.83 percentage points, and the deepest GDP contraction, roughly 6.5 percent. Raising the risk weight to 0.75 lowers the increase in bank default to about 1.31 percentage points and the GDP contraction to about

Figure 9: Sovereign debt crises: the role of the sovereign risk weight



five percent. In these episodes, lower exposure and greater bank resilience dominate the stronger per-unit crowding out.

The fiscal panels show the other side of the trade-off. With $\iota = 0$, greater domestic bank exposure raises the domestic cost of default and supports borrowing during the crisis: debt-to-GDP rises by 3.54 percentage points and government spending falls by only 9.1 percent. With $\iota = 0.75$, debt-to-GDP rises by just 2.77 percentage points and government spending falls by about 13.0 percent, so the government smooths considerably less. The spread response illustrates the state dependence of these forces. Unconditionally, the mean spread rises from 2.34 to 2.45 percentage points as ι goes from zero to 0.75, consistent with lower domestic exposure weakening the endogenous repayment incentive. During the crisis, however, the increase in the spread is slightly smaller under the high risk weight, because reduced bank fragility and lower guarantee costs dampen the amplification of the shock. Since foreign investors are the marginal price setters, this average spread effect does not arise mechanically from weaker bank demand: it operates through the effect of debt ownership on the government's endogenous default and borrowing decisions.

Taken together, the two instruments are not interchangeable. A tighter capital requirement improves outcomes on essentially every margin here, both unconditionally and in the tail, because it attacks risk shifting without transferring the ownership of public debt abroad. A higher sovereign risk weight im-

proves bank and real-sector resilience during crises, but it does so by shrinking domestic absorption of public debt, which weakens the government's repayment incentive, raises the average spread, and reduces government-spending smoothing exactly when it is most valuable. These experiments reveal the policy trade-off clearly, but they do not by themselves establish that the welfare-optimal risk weight is interior. We leave that normative question to future work.

7 Conclusions

This paper studies the two-way feedback loop between sovereign default risk and bank failure risk in an environment in which both are endogenous. Sovereign stress weakens bank balance sheets through losses on sovereign portfolios and raises bank default probabilities. Banking fragility, in turn, raises expected government-guarantee costs and worsens sovereign financing conditions. Preferred-habitat foreign demand and domestic bank demand jointly determine sovereign prices and holdings. In bad states, limited liability can induce banks to absorb a larger share of public debt. This cushions sovereign financing in the short run, but it crowds out productive investment and amplifies the recession.

Quantitatively, the model calibrated to Spain matches the key fiscal moments well and captures the broad level of banking distress. Rare sovereign stress events feature joint spikes in sovereign spreads, bank spreads, and bank default, together with larger government-guarantee payouts and higher bank absorption of public debt, and the decomposition shows that shocks to bank fragility are a key driver of these episodes. Short-run experiments confirm that shocks originating in either banks or the sovereign produce persistent contractions, with stronger effects when sovereign debt or bank exposure is higher and weaker effects under tighter capital requirements. These findings highlight the importance of policies that strengthen bank balance sheets for weakening the sovereign-bank nexus and its macroeconomic costs.

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Appendices

A Model Derivations

This appendix defines the Markov equilibrium and derives the optimization problems and optimality conditions of the private agents. It then characterizes the government's problem, the bank-demand wedge, and the national accounts. Subsections A.1 and A.7 use the recursive formulation; all other subsections use the sequential formulation with time subscripts. The analytical equilibrium has a binary default decision, as in Section 2.6; the auxiliary taste shocks used in the numerical implementation are omitted.

A.1 Formal Definition of Equilibrium

The aggregate state is $\mathrm{S} = (z, \sigma, B, B^b, D, K)$, where (B, B^b, D, K) are inherited stocks. The exogenous shocks follow the processes specified in Section 4. Individual deposit holdings d and banker net worth n are individual states; they are distinct from the aggregate stocks. Aggregate investable net worth N is determined within the period from the inherited bank balance sheet and current resolution.

For every candidate government action (B', Δ), define the conditional private-sector transition

$$\begin{aligned} \widetilde{S}^{e\prime}(\mathrm{S}; B', \Delta) &= \left\{ B', \widetilde{B}^{b\prime}(\mathrm{S}; B', \Delta), \widetilde{D}'(\mathrm{S}; B', \Delta), \widetilde{K}'(\mathrm{S}; B', \Delta) \right\}, \\ \mathrm{S}' &= \left(z', \sigma', \widetilde{S}^{e\prime}(\mathrm{S}; B', \Delta) \right). \end{aligned} \tag{36}$$

As in the main text, tildes denote the private-sector responses used by the government when evaluating a candidate action. In particular, $\widetilde{\mathcal{Q}}$, $\widetilde{\mathcal{Q}}^d$, $\widetilde{\mathcal{N}}$, and $\widetilde{\Omega}$ denote the conditional bond price, deposit price, investable net worth, and deposit loss rate. The other conditional allocations and values are denoted analogously. The expectations operator $\mathbb{E}$ conditions on the current state and uses the exogenous shock processes and the relevant aggregate transition. When evaluating a candidate government action, that transition is (36).

Future functions inside expectations incorporate the government's equilibrium policies from the next period onward. A current candidate action changes the next aggregate balance sheet, but it does not commit future governments to that action. Each private agent takes the aggregate transition and all prices as given when varying its own choices.

Definition 1. *A Markov equilibrium in the positive-banking, full-retention regime described in the main text consists of government values and policies*

$$(V, V^G, V^D, B', \Delta, G),$$

private value functions $V_h(d, \mathrm{S})$ *and* $V_b(n, \mathrm{S})$*, the marginal value* $v_b(\mathrm{S})$*, individual optimal decision rules, aggregate allocations and prices*

$$(C, L, Y, N, E, \Pi, \Omega, \overline{\omega}, D', B^{b\prime}, B^{f\prime}, K', I, NX)(\mathrm{S}),$$
$$(W, r^k, R^k, q^d, q)(\mathrm{S}), \qquad \rho_b(\mathrm{S}', \mathrm{S}),$$

their conditional private-sector counterparts, and a law of motion $\zeta(\mathrm{S})$ *for the endogenous aggregate states, such that:*

1. *Private optimality. For each feasible current state and candidate government action, consumer-workers, producers, bankers, and banks solve the problems below, taking the aggregate transition and prices as given. Foreign investors satisfy the preferred-habitat demand condition. Private continuation values use the equilibrium functions at the next state. Values are finite, and intertemporal choices satisfy the transversality conditions stated below.*

2. *Resolution, aggregation, and feasibility. Inherited bank claims are resolved according to* (44)*–*(48)*. The equity market clears with* $E = N$*, the capital requirement binds in the regime under study, and the labor, installed-capital, deposit, and sovereign-debt markets clear. The government budget and aggregate resource constraints hold. These conditions and private optimality are imposed jointly for every candidate action used in the government's problem.*

3. *Government optimality. The functions* $(V, V^G, V^D, B', \Delta, G)$ *solve* (68)*–*(70)*, using the conditional private-sector responses. Default implies* $B' = (1 - \lambda)B$*, so only the unmatured debt remains in circulation and there is no net issuance in that period.*

4. *Correct conjectures and state transitions. The government's conjectured responses coincide with the private-sector equilibrium for every feasible candidate action, including actions not selected in equilibrium. Substitu-*

tion of the optimal government policies reproduces all equilibrium values, allocations, and prices. In particular,

$$
\begin{aligned}
(B^{b\prime}, D', K')(\mathrm{S}) &= (\widetilde{B}^{b\prime}, \widetilde{D}', \widetilde{K}')(\mathrm{S}; B'(\mathrm{S}), \Delta(\mathrm{S})), \\
(q, q^d, N, \Omega)(\mathrm{S}) &= (\widetilde{\mathcal{Q}}, \widetilde{\mathcal{Q}}^d, \widetilde{\mathcal{N}}, \widetilde{\Omega})(\mathrm{S}; B'(\mathrm{S}), \Delta(\mathrm{S})), \\
\zeta(\mathrm{S}) &= \left\{ B'(\mathrm{S}), B^{b\prime}(\mathrm{S}), D'(\mathrm{S}), K'(\mathrm{S}) \right\}.
\end{aligned}
$$

Thus $\mathrm{S}' = (z', \sigma', \zeta(\mathrm{S}))$*, and private expectations are the rational expectations induced by the exogenous shock processes and* ζ*.*

The sequential problems below characterize private optimality along the dated prices and allocations generated by these recursive functions. To construct a conditional response at $(\mathrm{S}; B', \Delta)$, evaluate the sequential optimality and market-clearing conditions at the candidate action, using the implied current prices and allocations and the transition in (36). Current factor prices and labor remain unchanged because production uses inherited K. Future prices, policies, and private values are generated by the equilibrium functions at the implied S'. Thus the sequential and recursive formulations describe the same private-sector decisions and payoffs.

A.2 Consumer-workers and Final-goods Producers

Consumer-workers. Given initial deposits d_0, an individual consumer-worker chooses consumption, labor, and saving sequences to solve

$$
\max_{\{C_t, L_t, d_{t+1}\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ C_t - \chi \frac{L_t^{1+\eta}}{1+\eta} \right\}, \tag{37}
$$

subject, at every date and history, to

$$
C_t + q_t^d d_{t+1} = (1-\tau) W_t L_t + [1 - (1-\kappa)\Omega_t] d_t + \Pi_t, \qquad C_t, L_t, d_{t+1} \geq 0. \tag{38}
$$

Choices at date t depend only on information available at that date. The consumer-worker takes the stochastic sequences of wages, deposit prices, recovery rates, and transfers as given. In the equilibrium with positive consumption considered in the main text, the marginal utility of wealth is one. An additional unit of deposits inherited at t therefore has marginal value $1 - (1-\kappa)\Omega_t$. The labor and saving conditions

are

$$(1-\tau)W_t = \chi L_t^{\eta}, \tag{39}$$

$$q_t^d \geq \beta \mathbb{E}_t[1-(1-\kappa)\Omega_{t+1}],$$

$$d_{t+1}\left(q_t^d - \beta \mathbb{E}_t[1-(1-\kappa)\Omega_{t+1}]\right) = 0. \tag{40}$$

Here $\mathbb{E}_t$ conditions on date-t information. With positive deposit issuance, market clearing gives

$$q_t^d = \beta \mathbb{E}_t[1-(1-\kappa)\Omega_{t+1}]. \tag{41}$$

At this price the consumer-worker is indifferent at the margin over deposit holdings, and their aggregate quantity equals banks' issuance D_{t+1}. Admissible optimal saving plans satisfy

$$\lim_{T\to\infty} \beta^T \mathbb{E}_0\left[[1-(1-\kappa)\Omega_T]d_T\right] = 0.$$

The realized gross return on deposits issued at t is $[1-(1-\kappa)\Omega_{t+1}]/q_t^d$, and

$$\mathbb{E}_t\left[\frac{1-(1-\kappa)\Omega_{t+1}}{q_t^d}\right] = \frac{1}{\beta}.$$

Thus the government reimburses the fraction κ of deposit losses, while consumer-workers bear the fraction $1-\kappa$. Expected uninsured losses lower the issue price; current realized losses enter the budget through inherited deposits.

Final-goods producers. At each date t, a competitive producer chooses capital and labor demand to solve

$$\max_{K_t, L_t \geq 0}\left\{e^{z_t}[\alpha K_t^{\epsilon} + (1-\alpha)L_t^{\epsilon}]^{1/\epsilon} - r_t^k K_t - W_t L_t\right\}.$$

In this static problem, K_t and L_t denote factor demands. Market clearing equates capital demand to the inherited stock and labor demand to consumer-workers' labor supply. At positive factor inputs, the first-

order conditions are

$$r_t^k = e^{z_t}\alpha K_t^{\epsilon-1}[\alpha K_t^\epsilon + (1-\alpha)L_t^\epsilon]^{1/\epsilon-1}, \tag{42}$$

$$W_t = e^{z_t}(1-\alpha)L_t^{\epsilon-1}[\alpha K_t^\epsilon + (1-\alpha)L_t^\epsilon]^{1/\epsilon-1}. \tag{43}$$

Constant returns imply zero profits, $Y_t = W_t L_t + r_t^k K_t$. Together with (39), these equations determine current labor, output, factor prices, and tax revenue from (z_t, K_t). The gross market return on installed capital is $R_t^k = r_t^k + 1 - \delta$. Banks' current investment instead determines K_{t+1}, with $I_t = K_{t+1} - (1-\delta)K_t$.

A.3 Bank Resolution and Aggregate Net Worth

The date-t payoff per unit of inherited sovereign face value is $(1-\lambda)q_t + (c+\lambda)(1-\Delta_t)$. Under default, the coupon and maturing principal are not paid, but the remaining principal retains its market value. A bank becomes insolvent when its capital and sovereign payoffs do not cover maturing deposits. For a symmetric inherited bank portfolio with $K_t > 0$, the threshold is

$$\overline{\omega}_t = \frac{D_t - [(1-\lambda)q_t + (c+\lambda)(1-\Delta_t)]\, B_t^b}{R_t^k K_t}. \tag{44}$$

For a threshold $a_t > 0$, the mean-one lognormal distribution implies

$$F(a_t;\sigma_t) = \Phi\left(\frac{\log a_t + \sigma_t^2/2}{\sigma_t}\right), \qquad M_1(a_t;\sigma_t) = \int_0^{a_t} \omega\, dF(\omega;\sigma_t) = \Phi\left(\frac{\log a_t - \sigma_t^2/2}{\sigma_t}\right),$$
$$\Gamma(a_t;\sigma_t) = M_1(a_t;\sigma_t) + a_t[1 - F(a_t;\sigma_t)]. \tag{45}$$

For $a_t \leq 0$, set $F(a_t;\sigma_t) = M_1(a_t;\sigma_t) = 0$ and retain the definition of Γ, so $\Gamma(a_t;\sigma_t) = a_t$. A nonpositive threshold therefore means that no bank defaults. Integrals below are over the support $\omega > 0$, including when a threshold is negative.

The total equity payoff from inherited banks is divided between investable net worth and transfers to consumer-workers. Limited liability gives

$$\begin{aligned} N_t + \Pi_t &= \int_0^\infty \max\left\{\omega R_t^k K_t + [(1-\lambda)q_t + (c+\lambda)(1-\Delta_t)]\, B_t^b - D_t, 0\right\} dF(\omega;\sigma_t) \\ &= [1 - \Gamma(\overline{\omega}_t;\sigma_t)]R_t^k K_t. \end{aligned} \tag{46}$$

In a failed bank, depositors recover the sovereign payoff in full and the fraction $1-\mu$ of the capital payoff. Hence the total deposit shortfall before government guarantees is

$$\begin{aligned} D_t\Omega_t &= \int_0^{\max\{\overline{\omega}_t,0\}} \left\{ D_t - \left[(1-\lambda)q_t + (c+\lambda)(1-\Delta_t)\right] B_t^b - (1-\mu)\omega R_t^k K_t \right\} dF(\omega;\sigma_t) \\ &= \left[\overline{\omega}_t F(\overline{\omega}_t;\sigma_t) - (1-\mu)M_1(\overline{\omega}_t;\sigma_t)\right] R_t^k K_t \\ &= \left[\overline{\omega}_t - \Gamma(\overline{\omega}_t;\sigma_t) + \mu M_1(\overline{\omega}_t;\sigma_t)\right] R_t^k K_t. \end{aligned} \tag{47}$$

If $D_t = 0$, set $\Omega_t = 0$; guarantee payments and deposit losses are then zero. The government pays $\kappa D_t\Omega_t$, and households receive $[1-(1-\kappa)\Omega_t]D_t$ in total. Sovereign payoffs affect losses through the threshold even though they disappear as a separate term in the last expression.

The fraction $\theta + \chi_b(1-\theta)$ of the equity payoff is available to surviving and entering bankers; the remaining fraction $(1-\chi_b)(1-\theta)$ goes to consumer-workers. Hence

$$\begin{aligned} N_t &= [\theta + \chi_b(1-\theta)][1-\Gamma(\overline{\omega}_t;\sigma_t)]R_t^k K_t, \\ \Pi_t &= \frac{(1-\chi_b)(1-\theta)}{\theta + \chi_b(1-\theta)} N_t. \end{aligned} \tag{48}$$

These expressions recover current investable net worth and retirement transfers from the inherited balance sheet and current equilibrium prices. No separate lagged equity stock is needed for this calculation. When the government evaluates a candidate (B_{t+1}, Δ_t), the same expressions use that default decision and its associated bond price q_t. Resolution, net worth, and current financial prices must therefore be determined jointly.

A.4 Bankers: Sequential Problem and Homogeneity

An active banker at date t has net worth n_t and chooses dividend and equity sequences to solve the date-t version of (5):

$$V_{b,t} = \max_{\{div_{t+j}, e_{t+j}\}_{j=0}^{\infty}} \mathbb{E}_t \left[div_t + \sum_{j=1}^{\infty} \beta^j \theta^{j-1} \left\{ (1-\theta)\rho_{b,t+j} e_{t+j-1} + \theta div_{t+j} \right\} \right]. \tag{49}$$

At every date along the banker's survival history, the constraints are

$$\begin{aligned} e_{t+j} + div_{t+j} &= n_{t+j}, & e_{t+j}, div_{t+j} &\geq 0, \\ n_{t+j+1} &= \rho_{b,t+j+1} e_{t+j}, & j &= 0, 1, \ldots. \end{aligned} \tag{50}$$

The banker takes the stochastic sequence of diversified equity returns as given, and each choice depends only on information available at its date. The retirement payoff is the total wealth transferred upon retirement, as in the primitive objective; the split between entrants and consumer-workers affects aggregation through χ_b.

Multiplying initial wealth and every feasible dividend and equity choice by the same positive constant multiplies every payoff in (49) by that constant. The maximized value is therefore homogeneous of degree one in initial net worth:

$$V_{b,t} = \nu_{b,t} n_t. \tag{51}$$

The coefficient $\nu_{b,t}$ is the marginal value of date-t banker wealth and is independent of an individual banker's scale. Finite expected payoffs and the transversality condition

$$\lim_{T \to \infty} (\beta\theta)^T \mathbb{E}_t[\nu_{b,t+T} n_{t+T}] = 0$$

rule out a residual terminal value along the survival history.

After optimizing the later choices in the sequence, one unit retained at t yields $\rho_{b,t+1}$ units of wealth at $t+1$. This wealth pays out upon retirement with probability $1-\theta$ and has marginal value $\nu_{b,t+1}$ upon survival with probability θ. Its expected marginal value is therefore $\mathbb{E}_t[\Lambda_{b,t+1}\rho_{b,t+1}]$, where

$$\Lambda_{b,t+1} \equiv \beta[(1-\theta) + \theta\nu_{b,t+1}]. \tag{52}$$

For $n_t > 0$, writing $x_t = e_t/n_t$ gives the retention condition

$$\begin{aligned} \nu_{b,t} &= \max_{0 \leq x_t \leq 1} \{1 - x_t + x_t \mathbb{E}_t[\Lambda_{b,t+1}\rho_{b,t+1}]\} \\ &= \max\{1, \mathbb{E}_t[\Lambda_{b,t+1}\rho_{b,t+1}]\}. \end{aligned} \tag{53}$$

If the expectation is below one, every banker pays out all its wealth. This is incompatible with positive capital investment and a positive capital requirement. In the positive-banking equilibrium, the expectation is therefore at least one, and full retention is optimal. It is uniquely optimal if the inequality is strict; at equality we select full retention, as in the main text. Consequently,

$$e_t = n_t, \qquad div_t = 0, \qquad E_t = N_t, \qquad \nu_{b,t} = \mathbb{E}_t[\Lambda_{b,t+1}\rho_{b,t+1}]. \tag{54}$$

The primitive discount factor remains β. The extra term in $\Lambda_{b,t+1}$ values next-period wealth at its retirement payoff or its marginal value in the remaining optimal dividend sequence.

A.5 Banks: Portfolio Choice and the Return on Equity

Portfolio problem. A bank formed at date t operates at t and $t+1$. Throughout this appendix, we restrict attention to the binding capital-requirement regime described in the main text. Given equity $e_t > 0$, the bank chooses nonnegative $(k_{t+1}, b^b_{t+1}, d_{t+1})$ to solve

$$\max_{k_{t+1},b^b_{t+1},d_{t+1}\geq 0} \Bigg\{ \mathbb{E}_t \Bigg[\Lambda_{b,t+1} \int_0^\infty \max \Big\{ \omega_{t+1} R^k_{t+1} k_{t+1} + \left[(1-\lambda)q_{t+1} + (c+\lambda)(1-\Delta_{t+1})\right] b^b_{t+1} - d_{t+1}, 0 \Big\} dF(\omega_{t+1};\sigma_{t+1}) \Bigg] - \nu_{b,t} e_t \Bigg\}, \tag{55}$$

subject to

$$k_{t+1} + q_t b^b_{t+1} = q^d_t d_{t+1} + e_t, \tag{56}$$

$$e_t = \phi[k_{t+1} + \iota q_t b^b_{t+1}]. \tag{57}$$

The bank takes current funding prices, the equity valuation, and the joint distribution of future prices and government decisions as given. Its idiosyncratic shock is integrated out separately from aggregate uncertainty. The bank distributes its payoff at $t+1$ and then ceases to operate; the bankers value this payoff using $\Lambda_{b,t+1}$. The bank receives no direct equity payoff from deposit guarantees.

For $k_{t+1} > 0$, its next-period insolvency threshold is

$$\overline{\omega}_{t+1} = \frac{d_{t+1} - \left[(1-\lambda)q_{t+1} + (c+\lambda)(1-\Delta_{t+1})\right] b^b_{t+1}}{R^k_{t+1} k_{t+1}}. \tag{58}$$

At the symmetric equilibrium portfolio, this is the date-$t+1$ version of (44), because the portfolio chosen at t becomes the inherited portfolio at $t+1$. An individual portfolio deviation changes the bank's own threshold but leaves aggregate recovery rates and prices unchanged.

Reduction to bond choice. Aggregate equity $E_t = N_t$ and the two binding constraints imply

$$K_{t+1} = \frac{E_t}{\phi} - \iota q_t B^b_{t+1}, \tag{59}$$

$$q^d_t D_{t+1} = (1-\phi)K_{t+1} + (1-\phi\iota)q_t B^b_{t+1} = \frac{1-\phi}{\phi}E_t + (1-\iota)q_t B^b_{t+1}. \tag{60}$$

For an individual bank the same equations hold with lowercase quantities and fixed e_t. Substituting these expressions into (55) reduces the bank's problem to the choice of bond holdings, over the set for which the implied capital and deposit quantities are nonnegative. When varying bond face value,

$$\frac{\partial k_{t+1}}{\partial b^b_{t+1}} = -\iota q_t, \qquad \frac{\partial d_{t+1}}{\partial b^b_{t+1}} = \frac{(1-\iota)q_t}{q^d_t}.$$

Substituting these derivatives into the marginal equity payoff gives the first-order condition for an interior portfolio:

$$0 = \mathbb{E}_t\left[\Lambda_{b,t+1}\int_{\overline{\omega}_{t+1}}^{\infty}\left\{(1-\lambda)q_{t+1} + (c+\lambda)(1-\Delta_{t+1}) - \iota q_t \omega_{t+1} R^k_{t+1} - \frac{(1-\iota)q_t}{q^d_t}\right\} dF(\omega_{t+1};\sigma_{t+1})\right]. \tag{61}$$

The boundary term vanishes because equity pays zero at the insolvency threshold. Using the denominator from the main text,

$$\mathcal{D}_{q,t} \equiv \frac{1-\iota}{q^d_t}\mathbb{E}_t[\Lambda_{b,t+1}(1-F(\overline{\omega}_{t+1};\sigma_{t+1}))] + \iota\mathbb{E}_t\left[\Lambda_{b,t+1}R^k_{t+1}\int_{\overline{\omega}_{t+1}}^{\infty}\omega_{t+1}\,dF(\omega_{t+1};\sigma_{t+1})\right].$$

Rearranging gives the sequential version of the inverse-demand equation (32):

$$q_t = \frac{\mathbb{E}_t[\Lambda_{b,t+1}(1-F(\overline{\omega}_{t+1};\sigma_{t+1}))\{(1-\lambda)q_{t+1} + (c+\lambda)(1-\Delta_{t+1})\}]}{\mathcal{D}_{q,t}}. \tag{62}$$

All displacement and deposit-funding terms carry the current bond price because the derivative is with respect to face value. The inverse-demand equation is the interior optimality condition for the reduced problem with a binding capital requirement; the equilibrium portfolio must attain the maximum in (55).

Diversified equity return and aggregation. The payoff and constraints are homogeneous of degree one in $(k_{t+1}, b^b_{t+1}, d_{t+1}, e_t)$. Optimal portfolio ratios can therefore be chosen independently of individual bank scale. Under the symmetric portfolio selection, diversification eliminates idiosyncratic risk and the market return on equity is

$$\begin{aligned}\rho_{b,t+1} &= \frac{1}{E_t}\int_0^\infty \max\left\{\omega_{t+1}R^k_{t+1}K_{t+1} + \left[(1-\lambda)q_{t+1} + (c+\lambda)(1-\Delta_{t+1})\right]B^b_{t+1} - D_{t+1}, 0\right\} dF(\omega_{t+1};\sigma_{t+1}) \\ &= \left[1-\Gamma(\overline{\omega}_{t+1};\sigma_{t+1})\right]R^k_{t+1}\frac{K_{t+1}}{E_t}. \end{aligned} \tag{63}$$

The return is independent of the scale of an individual banker's investment. At the optimal bank portfolio, (54) implies that the bank's net present value is $e_t\{\mathbb{E}_t[\Lambda_{b,t+1}\rho_{b,t+1}] - \nu_{b,t}\} = 0$. The equity payoff is allocated next period according to

$$\begin{aligned} N_{t+1} &= [\theta + \chi_b(1-\theta)]\rho_{b,t+1}N_t, \\ \Pi_{t+1} &= (1-\chi_b)(1-\theta)\rho_{b,t+1}N_t. \end{aligned} \tag{64}$$

This law follows from the portfolio inherited at $t+1$ and (48); it is consistent with computing net worth directly from the balance sheet at each date.

A.6 Foreign Investors

The preferred-habitat schedule in the main text can be represented by a risk-neutral investor's date-t portfolio problem with a quadratic carrying cost. For positive aggregate debt supply B_{t+1}, taking q_t, B_{t+1}, and the distribution of future sovereign payoffs as given, the investor solves

$$\begin{aligned}\max_{b^f_{t+1}\geq 0}\Big\{&\beta^*\mathbb{E}_t\left[(1-\lambda)q_{t+1} + (c+\lambda)(1-\Delta_{t+1})\right]b^f_{t+1} \\ &- q_t b^f_{t+1} - \frac{\kappa^f q_t}{2B_{t+1}}(b^f_{t+1} - \bar{s}^f B_{t+1})^2\Big\}. \end{aligned} \tag{65}$$

The term $(1-\lambda)q_{t+1}$ is the resale value of unmatured debt at $t+1$. Risk neutrality and the absence of a funding constraint allow the investor's sequence of portfolio decisions to be characterized by this problem at each date. At positive foreign holdings, the first-order condition is

$$q_t\left[1+\kappa^f\left(\frac{B^f_{t+1}}{B_{t+1}}-\bar{s}^f\right)\right]=\beta^*\mathbb{E}_t\left[(1-\lambda)q_{t+1}+(c+\lambda)(1-\Delta_{t+1})\right]. \tag{66}$$

At zero foreign holdings, the left-hand side is at least the right-hand side. For $\kappa^f > 0$, the objective is strictly concave; with $\kappa^f = 0$, positive finite holdings require the standard risk-neutral pricing equality. The share formulation presumes $B_{t+1} > 0$; at zero supply, both investor groups hold zero and no share ratio is evaluated. The carrying cost is a representation of foreign demand and is borne outside the domestic economy, so it is not an additional domestic use of goods.

Setting $R^* = 1/\beta^*$ and using the sovereign return defined in (12) recovers

$$\mathbb{E}_t[R^b_{t+1}] = R^*\left[1+\kappa^f\left(\frac{B^f_{t+1}}{B_{t+1}}-\bar{s}^f\right)\right].$$

The foreign-demand condition, bank optimality, and market clearing are part of the joint private-sector equilibrium; they do not form a separate block independent of bank funding, resolution, and capital accumulation.

A.7 Government Optimization and Market Clearing

For a candidate action, the government budget determines spending as

$$\begin{aligned} G = {} & \tau W(\mathrm{S})L(\mathrm{S}) + \widetilde{\mathcal{Q}}(\mathrm{S};B',\Delta)[B'-(1-\lambda)B] \\ & -(c+\lambda)(1-\Delta)B - \kappa D\widetilde{\Omega}(\mathrm{S};B',\Delta). \end{aligned} \tag{67}$$

Under repayment, the government chooses spending and next-period debt to solve

$$V^G(\mathrm{S}) = \max_{G,B'}\left\{\frac{G^{1-\gamma}}{1-\gamma}+\beta^G\mathbb{E}\left[V\left(z',\sigma',\widetilde{S}^{e\prime}(\mathrm{S};B',0)\right)\right]\right\}, \tag{68}$$

subject to (67) with $\Delta = 0$, positive spending, a feasible conditional private equilibrium, and a next state within the state space. Under default,

$$V^D(\mathrm{S}) = \frac{G^{1-\gamma}}{1-\gamma} - \xi + \beta^G \mathbb{E}\left[V\left(z', \sigma', \widetilde{S}^{e\prime}(\mathrm{S}; (1-\lambda)B, 1)\right)\right], \tag{69}$$

$$V(\mathrm{S}) = \max\{V^G(\mathrm{S}), V^D(\mathrm{S})\}. \tag{70}$$

When $\gamma = 1$, period utility is $\log G$. An infeasible branch is assigned value $-\infty$. A maximizing branch determines $\Delta(\mathrm{S})$; ties may be resolved by any fixed measurable rule. Under repayment, $(G(\mathrm{S}), B'(\mathrm{S}))$ attains the maximum in (68). Under default, $B'(\mathrm{S}) = (1-\lambda)B$ and

$$G(\mathrm{S}) = \tau W(\mathrm{S}) L(\mathrm{S}) - \kappa D \widetilde{\Omega}(\mathrm{S}; (1-\lambda)B, 1).$$

The continuation is V in both branches because the restriction on new issuance lasts only for the current default period. When comparing actions, the government internalizes their effects on current bond prices, bank losses, guarantee payments, investable net worth, and the entire endogenous next-state vector in (36).

The labor market clears when consumer-workers' labor supply equals producers' labor demand, and producers rent the inherited capital stock K. With the unit-mass normalization for the representative private agents, deposit, equity, and sovereign-debt market clearing requires

$$\begin{aligned} d'(D, \mathrm{S}) &= D'(\mathrm{S}), & E(\mathrm{S}) &= N(\mathrm{S}), \\ B'(\mathrm{S}) &= B^{b\prime}(\mathrm{S}) + B^{f\prime}(\mathrm{S}), & B^f &= B - B^b. \end{aligned} \tag{71}$$

The capital, bond, and deposit quantities chosen by the representative bank coincide with their aggregate counterparts under symmetry. Aggregate consumption satisfies

$$C(\mathrm{S}) = (1-\tau)W(\mathrm{S})L(\mathrm{S}) + [1 - (1-\kappa)\Omega(\mathrm{S})]D + \Pi(\mathrm{S}) - q^d(\mathrm{S})D'(\mathrm{S}).$$

Finally, domestic goods-market clearing is

$$Y(\mathrm{S}) - \mu M_1(\overline{\omega}(\mathrm{S});\sigma)R^k(\mathrm{S})K = C(\mathrm{S}) + G(\mathrm{S}) + I(\mathrm{S}) + NX(\mathrm{S}), \tag{72}$$

$$NX(\mathrm{S}) \equiv [(1-\lambda)q(\mathrm{S}) + (c+\lambda)(1-\Delta(\mathrm{S}))]\,(B - B^b) - q(\mathrm{S})[B'(\mathrm{S}) - B^{b\prime}(\mathrm{S})]. \tag{73}$$

The same conditions hold at every feasible candidate action with conditional current quantities. Under default, debt-market clearing still applies to the surviving stock $(1-\lambda)B$. The resource constraint follows from the sectoral budgets and resolution accounting, as derived below.

A.8 Bank-Demand Wedge for Government Bonds

Consider the interior bank and foreign portfolios for which (61) and (66) hold as equalities. All expectations and covariances in this subsection condition on information available at date t. Dividing the bank's face-value condition by q_t and using (12) gives

$$0 = \mathbb{E}_t\left[\Lambda_{b,t+1}\int_{\overline{\omega}_{t+1}}^{\infty}\left\{R^b_{t+1} - \iota\omega_{t+1}R^k_{t+1} - \frac{1-\iota}{q^d_t}\right\}dF(\omega_{t+1};\sigma_{t+1})\right].$$

In sequential notation, the normalized survival-weighted banker valuation kernel and the mean capital return among surviving banks are

$$\mathcal{M}_{t+1} \equiv \frac{\Lambda_{b,t+1}[1-F(\overline{\omega}_{t+1};\sigma_{t+1})]}{\mathbb{E}_t[\Lambda_{b,t+1}(1-F(\overline{\omega}_{t+1};\sigma_{t+1}))]}, \tag{74}$$

$$\mathcal{R}^k_{+,t+1} \equiv R^k_{t+1}\frac{1-M_1(\overline{\omega}_{t+1};\sigma_{t+1})}{1-F(\overline{\omega}_{t+1};\sigma_{t+1})}. \tag{75}$$

For positive survival probability, $\mathbb{E}_t[\mathcal{M}_{t+1}] = 1$, and the bank condition becomes

$$\mathbb{E}_t[\mathcal{M}_{t+1}R^b_{t+1}] = \frac{1-\iota}{q^d_t} + \iota\mathbb{E}_t[\mathcal{M}_{t+1}\mathcal{R}^k_{+,t+1}]. \tag{76}$$

Expanding each expectation of a product and subtracting R^* yields

$$\mathbb{E}_t[R^b_{t+1}] - R^* = (1-\iota)s^d_t + \iota(\mathbb{E}_t[\mathcal{R}^k_{+,t+1}] - R^*) - \mathrm{cov}_t(\mathcal{M}_{t+1}, R^b_{t+1}) + \iota\,\mathrm{cov}_t(\mathcal{M}_{t+1}, \mathcal{R}^k_{+,t+1}), \qquad s^d_t \equiv \frac{1}{q^d_t} - R^*. \tag{77}$$

Substituting foreign demand gives the equilibrium wedge

$$R^*\kappa^f\left(\frac{B^f_{t+1}}{B_{t+1}}-\bar{s}^f\right)=(1-\iota)s^d_t+\iota(\mathbb{E}_t[\mathcal{R}^k_{+,t+1}]-R^*)$$
$$-\operatorname{cov}_t(\mathcal{M}_{t+1},R^b_{t+1})+\iota\operatorname{cov}_t(\mathcal{M}_{t+1},\mathcal{R}^k_{+,t+1}). \tag{78}$$

The deposit-pricing equation also implies

$$s^d_t=\left(\frac{1}{\beta}-R^*\right)+\frac{(1-\kappa)\mathbb{E}_t[\Omega_{t+1}]}{q^d_t}. \tag{79}$$

If $\beta^*=\beta$, the first term is zero and the contractual deposit spread consists entirely of compensation for expected uninsured losses. This distinction keeps the wedge valid when domestic and foreign discount factors differ. The remaining terms reflect the capital displaced by bond holdings and the covariance of asset payoffs with the survival-weighted value of banker wealth. These identities characterize the interior portfolios in the binding capital-requirement regime.

A.9 National Accounts

Foreign sovereign holdings satisfy $B^f_t=B_t-B^b_t$. All date-t stocks (B_t,B^b_t,D_t,K_t) are inherited; choices made at t determine the stocks dated $t+1$. The household and government budgets are

$$(1-\tau)W_tL_t+[1-(1-\kappa)\Omega_t]D_t+\Pi_t=C_t+q^d_tD_{t+1}, \tag{80}$$
$$\tau W_tL_t+q_t[B_{t+1}-(1-\lambda)B_t]-(c+\lambda)(1-\Delta_t)B_t=G_t+\kappa\Omega_tD_t. \tag{81}$$

Adding the budgets cancels taxes and deposit guarantees:

$$W_tL_t+q_tB_{t+1}-q^d_tD_{t+1}-[(1-\lambda)q_t+(c+\lambda)(1-\Delta_t)]B_t+(1-\Omega_t)D_t+\Pi_t=C_t+G_t. \tag{82}$$

The new bank balance sheet and the split of the inherited equity payoff satisfy

$$K_{t+1}+q_tB^b_{t+1}=q^d_tD_{t+1}+N_t,$$
$$N_t+\Pi_t=[1-\Gamma(\overline{\omega}_t;\sigma_t)]R^k_tK_t. \tag{83}$$

Substitution into (82), together with bond-market clearing, gives

$$W_t L_t + N_t + \Pi_t + (1 - \Omega_t) D_t - [(1-\lambda) q_t + (c+\lambda)(1-\Delta_t)] B_t^b = C_t + G_t + K_{t+1} + NX_t, \quad (84)$$

where

$$NX_t \equiv [(1-\lambda) q_t + (c+\lambda)(1-\Delta_t)] B_t^f - q_t B_{t+1}^f. \quad (85)$$

The external transfer can equivalently be written as

$$NX_t = (c+\lambda)(1-\Delta_t) B_t^f - q_t [B_{t+1}^f - (1-\lambda) B_t^f].$$

It includes coupon and principal payments to foreign investors and the resources received from their net purchases. Resales of unmatured bonds enter through those net purchases. Thus foreign holdings dated $t+1$ are holdings of the full outstanding stock, including surviving debt.

For a surviving bank, the equity payoff plus repayment to depositors is its full asset payoff. For a failed bank, equity pays zero and depositors recover the sovereign payoff and the fraction $1-\mu$ of the capital payoff before government guarantees. Adding the total equity payoff in (46) to deposit recovery from (47), and using the unit mean of ω, gives

$$\begin{aligned} N_t + \Pi_t + (1 - \Omega_t) D_t = {} & R_t^k K_t + [(1-\lambda) q_t + (c+\lambda)(1-\Delta_t)] B_t^b \\ & - \mu M_1(\overline{\omega}_t; \sigma_t) R_t^k K_t. \end{aligned} \quad (86)$$

Sovereign assets are not subject to the additional resolution haircut. Substituting this identity into (84) yields

$$W_t L_t + R_t^k K_t - \mu M_1(\overline{\omega}_t; \sigma_t) R_t^k K_t = C_t + G_t + K_{t+1} + NX_t.$$

Finally, use $R_t^k = r_t^k + 1 - \delta$, zero producer profits $Y_t = W_t L_t + r_t^k K_t$, and $I_t = K_{t+1} - (1-\delta) K_t$ to obtain

$$Y_t - \mu M_1(\overline{\omega}_t; \sigma_t) R_t^k K_t = C_t + G_t + I_t + NX_t, \quad (87)$$

$$GDP_t \equiv Y_t - \mu M_1(\overline{\omega}_t; \sigma_t) R_t^k K_t. \quad (88)$$

Deposit guarantees, domestic sovereign payments, and transfers from retiring bankers redistribute domestic resources and cancel in aggregation. Bank resolution destroys real resources through the term proportional to μ. The fixed sovereign-default cost ξ is a utility cost and is not an additional use of goods. The accounting identities hold under both repayment and default, with default imposing $B_{t+1} = (1 - \lambda)B_t$.

B Computational Appendix

C Data sources