Default and Development*

Lei Li
Stony Brook University

Gabriel Mihalache
The Ohio State University

December 2024

Abstract

We develop a quantitative theory of the long-run frequency of sovereign default, in which the government's willingness to risk crises reflects the sectoral composition of the economy. Development and structural transformation alter the trade-offs faced by the government, with the implication that default is largely a lower income country phenomenon, as in the data. Default impacts adversely the balance sheets of financial intermediaries, who then offer unfavorable rates on working capital loans to producers. The resulting contraction in activity is asymmetric across sectors, based on their financing requirements, and tax revenues fall. Governments find it unappealing to risk default if the economy is more vulnerable to financial distress, due to a larger share of value added from manufacturing and services, even for the same Debt to GDP ratio. This mechanism supports the notion of countries eventually "graduating" from sovereign default crises.

Keywords: sovereign default, structural transformation, discretionary policy
JEL classification: E44, H6, O11

*We thank Alexis Anagnostopoulos, Yan Bai, Eva Cárceles-Poveda, Juan Carlos Conesa, Chang Liu, Immo Schott, and César Sosa-Padilla for insightful comments and suggestions. We are grateful to the Institute for Advanced Computational Science at Stony Brook University and to the Ohio Supercomputer Center for access to the Seawulf and Pitzer clusters, respectively. Corresponding author: mihalache@gmail.com

This paper lays out a theory of the incidence of sovereign default throughout countries' development process. It concerns the question of why sovereign default seems, almost exclusively, a phenomenon specific to lower income countries. This is an issue of first-order importance, given recent estimates of large and highly persistent social costs of sovereign default (Hébert and Schreger 2017; Farah-Yacoub, Luckner, and Reinhart 2024). We point to sectoral composition as a determinant of default risk and argue that structural transformation is an avenue for "graduating" from default risk. Our paper provides a quantitative-theoretic analysis of this conjecture and discusses suggestive empirical support for our mechanism, in an application to the Philippines.

Standard sovereign default theory and its quantitative analysis, e.g., Eaton and Gersovitz (1981), Aguiar and Gopinath (2006), and Arellano (2008), have little to say about the long-run determinants of the average frequency of default. Whenever models allow for trend growth, as in Aguiar et al. (2016), the usual homogeneity properties of values and policies apply and behavior is a function of Debt to GDP and stationary shocks alone, rather than the absolute levels of either debt or income. This irrelevance of the level of development is in stark contrast with the data. Figure A.4 in the Appendix compares "Advanced" and "Emerging" economies over time, by relying on the International Monetary Fund's classification. Panel A.4a shows that the Debt to GDP ratio is broadly comparable across countries, advanced and emerging alike. In contrast, Panel A.4b plots the share of countries in each group with debt in a state of default.[1] Default is rare for advanced economies but common for emerging and low-income countries.

While prior work emphasized, for example, the broader role of institutions (Acemoglu, Johnson, and Robinson 2005), political economy factors (Azzimonti and Mitra 2023a), or the currency denomination of the debt, "original sin" (Eichengreen, Hausmann, and Panizza 2007; Engel and Park 2022), we focus on the sectoral composition of the economy and its impact on private and public demand for financing. In our model, manufacturing relies more heavily on financial services than agriculture and thus it is more sensitive

1. We code a country as being in default if there is *any* government debt in default, using the BoC–BoE Sovereign Default Database of Beers, Ndukwe, and Charron (2023). We then confirm the robustness of this stylized fact to narrower definitions of default, using the episodes identified in the updated Asonuma and Trebesch (2016) dataset.

to the detrimental consequences of government default on the balance sheet of financial intermediaries, as explored by Gennaioli, Martin, and Rossi (2014), Sosa-Padilla (2018), and Arellano, Bai, and Bocola (2024) among others. As the economy develops and agriculture shrinks as a share of total employment (Herrendorf, Rogerson, and Valentinyi 2014), the real and financial disruptions induced by public default worsen, which in turn incentivizes prudent fiscal policy and lowers the frequency of default episodes.

Table A.3 in the Appendix compiles suggestive, associative evidence for our mechanism. It reports conditional panel logit estimates from a model of the incidence of default, coded using the Beers, Ndukwe, and Charron (2023) data, as a function of the country's share of employment in agriculture, from Hamilton and Vries (2023). Our results are associative or correlational, rather than causal, because we do not attempt to identify exogenous variation in sectoral composition, and therefore we cannot rule out that, for example, the share of agriculture and the default propensity co-move due to a third, latent factor. This limitation notwithstanding, we check the robustness of our baseline specification to the inclusion of Debt to GDP, a natural predictor of default, as well as country and year fixed effects. Each additional 1% decrease in the share of the labor force in agriculture is associated with roughly a 0.17% decrease in the likelihood that the country finds itself in default in any one year.

Our analysis builds on the framework of Arellano, Bai, and Bocola (2024), for the interaction between private financial conditions and sovereign default, augmented with standard structural transformation production, as in Herrendorf, Rogerson, and Valentinyi (2013, 2014). We study a closed economy in which agriculture and manufacturing[2] firms employ workers subject to a working capital requirement: a fraction of the wage bill must be financed ahead of time, using working capital loans, and the required fraction is greater for manufacturing. Financial intermediaries extend these working capital loans to producers, hold long-term government debt, and fund their activities using deposits made by households, under a net worth constraint. We follow Gertler and Karadi (2011) and Arellano, Bai, and Bocola (2024) and assume that households periodically send out bankers

2. For tractability, we do not model explicitly a third services sector and instead treat manufacturing as a catch-all term for all activities other than agriculture. Considering a three sector extension would enhance the model's quantitative scope, but it would not alter our main message.

to operate the financial intermediaries, endowed with a certain amount of net worth which could prove insufficient in the case of financial distress. We study a discretionary fiscal policy problem for the government. Its choice to default impacts negatively the intermediaries' balance sheets, and triggers tight financial conditions and a recession, with varying severity across sectors, worse in manufacturing. Finally, as the economy develops, with larger productivity increases in agriculture than in other sectors, the share of manufacturing in value added increases and therefore financial distress leads to deeper aggregate recessions and lower tax revenue for the government. In turn, this disincentivizes fiscal policies that increase the risk of default. Overall, more developed economies exhibit both lower shares of agriculture in total value added and a lower frequency of government default, even though they do not differ from poorer economies in any other dimension, e.g., the nature or severity of political economy distortions (Azzimonti and Mitra 2023b).

1 Model

Our model features two productive sectors, agriculture and manufacturing, the output of which comes together into a composite numéraire good, a public sector fiscal authority, a representative household, and a financial intermediation sector. We describe each agent's problem in turn and characterize private sector outcomes and the resulting equilibrium. We study an infinite horizon, discrete time setting, $t \in \{0, 1, \dots\}$. The fiscal policy and financial frictions in production blocks of our model follow Arellano, Bai, and Bocola (2024), while the multisectoral, structural transformation features are loosely based on the reference treatment of Herrendorf, Rogerson, and Valentinyi (2014).

1.1 Households

Each period, a "large family" representative household sends out workers and bankers, to supply labor to production firms and to operate financial intermediaries, respectively. The household saves via risk-free deposits with financial intermediaries, who, in turn, extend working capital loans to production firms and trade defaultable government bonds.

The household owns all financial and non-financial firms in the economy and therefore receives all profits as income, at the end of each period.

The household's budget constraint, expressed in numéraire, is given by

$$C_t + q_t^s s_t + N_t = w_t \ell_t + s_{t-1} + F_t + \Pi_{a,t} + \Pi_{m,t}, \tag{1}$$

where C_t is the level of consumption, s_t are the risk-free deposits made at discount bond price q_t^s, and N_t are the resources with which the household endows its bankers. The right-hand-side of the constraint is given by the sources of funds: wage income $w_t \ell_t$, the previous period's risk-free deposit s_{t-1}, the profits of financial intermediaries F_t, and the profits of production firms, $\Pi_{a,t}$ and $\Pi_{m,t}$, in agriculture and manufacturing, respectively.

The household endows its bankers with N_t, at the start of the period, given by

$$N_t = \overline{n} + (1 - D_t)(1 - \lambda) q_t B_t, \tag{2}$$

consisting of an exogenous, minimal amount $\overline{n}$, and the market value of unmatured government bonds, inherited from the previous period's bankers' investments, assuming that the government does not default this period. If the government does default, the market value of the outstanding public debt is nil and N_t reduces to $\overline{n}$ alone. Government default is encoded in the dummy variable $D_t \in \{0, 1\}$. We lay out the problems of financial intermediaries and that of the government shortly.

We assume that household preferences are given by $\mathbb{E}_t \sum_{\iota=0}^{\infty} \beta^{\iota} \left(C_{t+\iota} - \frac{1}{1+\sigma} \ell_{t+\iota}^{1+\sigma} \right)$, quasi-linear in consumption, with a constant elasticity of labor supply, following Arellano, Bai, and Bocola (2024). This functional form greatly enhances tractability and allows us to economize on costly state variables in our global solution method.

1.2 Financial Intermediaries

Competitive bankers choose how much risk-free deposits to accept from households s_t, how many units of government bonds to hold into next period B_{t+1}, and how much working capital loans to extend to production firms b_t. Their objective is to maximize the expected present value of next period's intermediation profits, given by $\beta \mathbb{E}_t F_{t+1}$, with

$$F_{t+1} = (1 - D_{t+1})(\kappa + (1 - \lambda)q_{t+1})B_{t+1} + (1 + r_t^w)b_t - s_t, \tag{3}$$

where κB_{t+1} is the debt service payment scheduled by the B_{t+1} bond units, $q_{t+1}(1 - \lambda)B_{t+1}$ is the market value of unmatured bonds,[3] and r_t^w is the rate at which working capital loans b_t are extended. s_t are the risk-free deposits owed to the household.

Financial intermediaries operate subject to a budget constraint

$$q_t B_{t+1} + b_t \leq q_t^s s_t + N_t \tag{4}$$

and a leverage constraint

$$q_t^s s_t \leq q_t B_{t+1} + \phi b_t. \tag{5}$$

When the budget constraint holds with equality, which it will in equilibrium, the two constraints can be consolidated into a single one, which limits the intermediaries' ability to extend working capital loans by a multiple of their net worth,

$$b_t \leq \frac{1}{1 - \phi} N_t. \tag{6}$$

The parameter $\phi \in [0, 1)$ captures the pledgeability of working capital loans in the intermediaries' leverage constraint.

In sum, bankers maximize $\beta \mathbb{E}_t F_{t+1}$ subject to (3) and (6), and the ex post, realized payoff F_{t+1} will be received by the representative household at the start of next period, once this period's banker retires.[4] For future use, we denote the Lagrange multiplier on (6) by $\zeta_t \geq 0$, as it plays a central role for the financial conditions faced by producers.

3. The government issues long-term bonds. We employ the standard modeling strategy of assuming that each period a constant share λ of outstanding bonds matures. This approach economizes on state variables and a single parameter λ controls the entire maturity profile of the debt (Hatchondo and Martinez 2009).

4. We follow Arellano, Bai, and Bocola (2024) and assume that bankers operate for one period only before retiring and being replaced. See Gertler and Karadi (2011) for a case with longer-lived bankers.

1.3 Sectoral Production

The production decisions made by competitive firms in either manufacturing or agriculture are analogous, and therefore, for expositional purposes, we lay out the generic problem of a firm in sector $i \in \{a, m\}$. The representative producer in sector i takes all prices as given and decides how much labor to employ $\ell_{i,t}$, in order to maximize its profit, given by

$$\max_{\ell_{i,t}} (1-\tau) p_{i,t} y_{i,t} - w_t \ell_{i,t} - (1 + r_t^w) b_{i,t} \tag{7}$$

subject to a decreasing returns to scale production function

$$y_{i,t} = A_{i,t} \ell_{i,t}^{\alpha}, \tag{8}$$

given exogenous stochastic productivity $A_{i,t}$. The firm faces a working capital requirement, in that a share θ_i of the wage bill must be borrowed in advance of production: the firm must borrow $b_{i,t} = \theta_i w_t \ell_{i,t}$ at a given market rate r_t^w. The government collects revenue taxes, at a flat rate τ, symmetrically across sectors.

1.4 Final Good Producers

Final goods are produced by a perfectly competitive representative firm, relying on agriculture and manufacturing goods as inputs. Given prices $p_{a,t}$ and $p_{m,t}$ for agriculture and manufacturing goods, respectively, the final good producer maximizes its profit by choosing the input mix, $y_{a,t}$ and $y_{m,t}$,

$$\max_{y_{a,t}, y_{m,t}} P_t Y_t - p_{a,t} \left(y_{a,t} - \overline{y}_a \right) - p_{m,t} y_{m,t}, \tag{9}$$

given technology summarized by the production function

$$Y_t = \left((1-\omega) \left(y_{a,t} - \overline{y}_a \right)^{\frac{\eta-1}{\eta}} + \omega y_{m,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}, \tag{10}$$

where $\overline{y}_a$ is the subsistence agricultural input level, as standard in structural transformation models. The associated price index of the final good, normalized to unity, is given by

$$P_t = \left((1-\omega)^{\eta} \, p_{a,t}^{1-\eta} + \omega^{\eta} p_{m,t}^{1-\eta} \right)^{\frac{1}{1-\eta}} = 1. \tag{11}$$

Note that, because of the presence of a subsistence level of agriculture input in the quantity index Y_t but not in the price index P_t, the relation between intermediates, final goods, and Gross Domestic Product is given by

$$p_{a,t} y_{a,t} + p_{m,t} y_{m,t} = \text{GDP}_t = Y_t + p_{a,t} \overline{y}_a, \tag{12}$$

where the term $p_{a,t}\overline{y}_a$ is akin to a time-varying endowment, as discussed by Herrendorf, Rogerson, and Valentinyi (2014, p. 883).[5]

1.5 The Government

The government is relatively impatient compared to the private sector, discounting using a factor $\beta_g \leq \beta$. Its objective is given by $\mathbb{E}_t \sum_{\iota=0}^{\infty} \beta_g^{\iota} \left(\frac{1}{1-\sigma_g} G_{t+\iota}^{1-\sigma_g} - D_{t+\iota} \nu_{t+\iota} \right)$, which it maximizes under discretion, by choosing whether to default this period D_t, how much debt to have outstanding next period B_{t+1}, and how much public spending to undertake G_t. The policymaker's choices satisfy the following budget constraint,

$$(1-D_t)\kappa B_t + G_t = [B_{t+1} - (1-D_t)(1-\lambda)B_t] q_t + \tau \sum_{i \in \{a,m\}} p_{i,t} y_{i,t}, \tag{13}$$

where the two terms on the left-hand-side represent the uses of funds, debt service payments κB_t and public spending G_t, respectively, while the right-hand-side lists sources of funds, the proceeds from net bond issuance and the collected revenue tax.

If the government chooses default today, setting $D_t = 1$, all outstanding debt is

5. Without endowing the final goods producer with $p_{a,t}\overline{y}_a$, as we did implicitly in equation (9), it would not break even and instead generate losses. This endowment-like term is typically allocated to households in structural transformation papers, as they generally assume that households consume directly the outputs of various sectors. We find it useful to introduce a final good instead, for households to consume, as it streamlines the exposition of public debt and financial frictions in our model.

repudiated and the government experiences a direct utility cost given by a random variable ν_t. Moreover, the government foresees the consequences of its default on the tax revenue it collects. Finally, note that unlike many sovereign default models, we assume that default is not accompanied by financial market exclusion: the government can issue new bond units even in the period of default itself.

1.6 Private Sector Outcomes

It is instructive to characterize private sector outcomes for arbitrary current and future government policies. These private responses will constitute additional constraints on the government's discretionary policy problem, to be studied shortly. The full system of sixteen equations in as many unknowns, which jointly determine private sector variables, is relegated to Appendix B. Instead, here we highlight several features of the environment, for arbitrary public policies.

Asset prices and financial conditions. Using the first-order conditions of the household and those of the financial intermediaries, we find that the rate on deposits is pinned down by the discount factor of the household, $q_t^s = \beta$, and that sovereign bond prices can be expressed recursively, using current and expected default policies, as

$$q_t = \beta \mathbb{E}_t (1 - D_{t+1})(\kappa + (1 - \lambda) q_{t+1}). \tag{14}$$

The rate on working capital loans r_t^w satisfies the condition

$$\beta(1 + r_t^w) = 1 + (1 - \phi)\zeta_t, \tag{15}$$

where ζ_t is the Lagrange multiplier on the leverage constraint (6). If demand for working capital loans is low enough compared to the financial intermediaries' net worth, the constraint is slack and the rate on working capital matches the risk-free rate on deposits, as induced by the households' discounting, β. Instead, if net worth is scarce and thus $\zeta_t > 0$, the working capital rate must increase, reflecting the limited pledgeability of these loans.

Production and the sectoral composition. By consolidating all agents' budget constraints we recover the economy-wide resource constraint $Y_t = C_t + G_t$, as expected for our closed economy without capital investment.

Given wages and goods' prices, the relative demand for agriculture and manufacturing

$$\frac{p_{a,t}}{p_{m,t}} = \frac{1-\omega}{\omega}\left(\frac{y_{a,t}-\overline{y}_a}{y_{m,t}}\right)^{-\frac{1}{\eta}} \tag{16}$$

matches supply in each sector

$$y_{i,t} = A_{i,t}\left(\frac{(1-\tau)\alpha p_{i,t}A_{i,t}}{w_t(1+\theta_i r^w_t)}\right)^{\frac{\alpha}{1-\alpha}} \tag{17}$$

so that the labor market clears

$$\ell_t^{1+\frac{\sigma}{1-\alpha}} = \left(\frac{(1-\tau)\alpha}{\chi}\right)^{\frac{1}{1-\alpha}}\sum_{i\in\{a,m\}}\left(\frac{p_{i,t}A_{i,t}}{1+\theta_i r^w_t}\right)^{\frac{1}{1-\alpha}}. \tag{18}$$

The resulting wage bills induce the total demand for working capital loans across both sectors, b_t, as

$$b_t = \sum_{i\in\{a,m\}}\theta_i w_t \ell_{i,t} \leq \frac{N_t}{1-\phi}. \tag{19}$$

1.7 Recursive Formulation of the Government's Problem

We study public borrowing and default policies under discretion. To this end, we turn to a recursive formulation amenable to the study of Markov Perfect equilibria. The state variables are given by the productivity shocks in agriculture and manufacturing, A_a and A_m, respectively, and the utility cost of default ν, collected in $S = \langle A_a, A_m, \nu\rangle$, together with the outstanding stock of public debt B.

At the start of each period, the government chooses whether to default or not,

$$V(S,B) = \max_{D\in\{0,1\}}\left\{(1-D)W(S,B) + D\left[W(S,0)-\nu\right]\right\} \tag{20}$$

with $D(S,B)=1$ encoding the choice to default in state $\langle S,B\rangle$. If it does so, the government experiences the utility cost ν and repudiates all outstanding debt, B resets to zero.

Turning to the government's bond issuance behavior, its policy function $B'(S, B)$ is the solution to the problem

$$W(S, B) = \max_{G,B'} \left\{ \frac{G^{1-\sigma_g}}{1-\sigma_g} + \beta_g \mathbb{E}_{S'|S} V(S', B') \right\} \tag{21}$$

$$\text{subject to} \quad \kappa B + G \leq [B' - (1-\lambda)B] q(S, B') + T(S, B, B'), \tag{22}$$

where $T(S, B, B')$ is the tax revenue from the private sector's outcomes associated with state $\langle S, B \rangle$ and public borrowing B'. The bond price schedule is consistent with financial intermediaries' bond demand,

$$q(S, B') = \beta \mathbb{E}_{\nu', S'|S} (1 - D(S', \nu', B')) \left[\kappa + (1-\lambda) q(S', B''(S', B')) \right]. \tag{23}$$

The yield-to-maturity of the bond is given by $\frac{\kappa}{q(S,B')} - \lambda$ and we report the spread relative to the risk-free deposit rate given by $\frac{1}{\beta} - 1$. Appendix C defines the recursive Markov Perfect Equilibrium for our model.

2 Quantitative Analysis

We calibrate our model, at a yearly frequency, using data from the Philippines, over the last three decades. We pick the Philippines due to data availability and a clear pattern of structural transformation within our sample. Table A.4 in the Appendix documents the trend in the share of agriculture in employment, the share of credit going to agriculture, together with the average level of government spreads. We calibrate all parameters and shock processes to 1990s data, when the agricultural share was highest, then induce structural transformation in the model by changing one key parameter alone, as to replicate the sectoral composition of the Philippines in the 2000s. We then evaluate the model's predictions over sovereign spreads and other untargeted moments in the later part of the sample.

2.1 Shock Processes

Our model features three shocks: the productivity in manufacturing A_m, the productivity in agriculture A_a, and the shock to the value of default ν. To emphasize that our argument relies critically on structural transformation and not trend growth in general, we study an environment with stationary shocks. To this end, we normalize $A_m = 1$ at all times and assume that A_a and ν are stationary, uncorrelated AR(1) processes,

$$A_a' = (1-\rho_a)\overline{A}_a + \rho_a A_a + \varepsilon_a', \tag{24}$$

$$\nu' = (1-\rho_\nu)\overline{\nu} + \rho_\nu \nu + \varepsilon_\nu', \tag{25}$$

which we discretize with standard quadrature methods. Introducing volatility in A_m is feasible but burdensome computationally. While doing so would allow a better fit of the cyclical features of sector shares, this dimension of the data is not key to our argument and therefore we abstract from the A_m shock in our quantitative analysis.

2.2 Parameter Values and Computation

We fix several model parameters to either values that are standard in the literature or directly, one-to-one, to the relevant data moments. Then, we set all remaining parameters in order to fit jointly key moments in the Philippines 1990s data.

The top panel of Table 1 collects values for those parameters which we set externally. These include household preferences, the production technology, and fiscal policy, which we discuss in turn. We set the household's discount factor β so as to induce a risk-free real rate of 4%, a common target in the sovereign default literature. We use a value of σ consistent with a Frisch elasticity of labor supply of 0.75, the conservative value used by Arellano, Bai, and Bocola (2024). The government's coefficient of relative risk-aversion is 2, as standard in the literature. The tax rate τ matches the average tax revenue to GDP of roughly 20%. Lacking data on the maturity profile of government debt in the Philippines in the 1990s, we choose a value of λ corresponding to a 5 years Macaulay duration of debt, broadly in line with the evidence from emerging markets, including Bai, Kim, and

Mihalache (2017). We then assign the debt service parameter κ to normalize the risk-free price for the sovereign bond to unity. Finally, the production parameters include: return to scale for labor α, set to the conventional 0.67 value, the parameters of the CES aggregator for final goods, η and ω, set to standard structural transformation values, the average level of productivity in agriculture $\overline{A}_a$ which we pick to normalize mean GDP, and the working capital requirement for agriculture θ_a. Based on the linear nature of the (6) constraint and the expressions for equilibrium demand for working capital, further normalizations are needed. Given our value of $\overline{n}/(1-\phi)$ in the joint moment matching exercise, we set θ_a to zero, assuming no working capital requirement in agriculture. In comparison, in the data only about 6% of all credit goes to the agricultural sector, as reported by Table A.4 in the Appendix.

The set of parameters set jointly, to match target moments in the data, are collected in bottom panel of Table 1. All parameters impact most moments to varying degrees, yet some parameters are much more influential for certain moments. In this spirit, we list parameters aligned with the moment that is most impacted by their value. A first group of parameters includes the government's discount factor β_g, the utility cost of default process, $\overline{\nu}$, ρ_ν, and the standard deviation of the innovation. These are based on moments of sovereign spreads, the Debt to GDP ratio, and the share of public spending in GDP. The lower bound on net worth $\frac{\overline{n}}{1-\phi}$ is most influential for the correlation of spread with GDP, as it controls the real resource costs of default through the working capital channel.[6] The working capital requirement for manufacturing θ_m, in turn, is a key determinant of the volatility of spreads, since it shapes output losses due to default risk across different shock levels. The parameters of the agricultural productivity process and the subsistence level of agriculture are used to match moments of the cyclical component of GDP and the share of labor employed in agriculture, respectively.

Absent data on financing and leverage at the sector level, our strategy is to set working capital requirements as captured by the θ_a and θ_m parameters indirectly, by targeting spread volatility and cyclical properties. The UN's FAO reports the share of credit allocated to

6. Note that, just as in Arellano, Bai, and Bocola (2024), $\overline{n}$ and ϕ cannot be disentangled, as they impact allocations through the ratio $\overline{n}/(1-\phi)$ alone. We can always normalize ϕ and recalibrate $\overline{n}$ appropriately, noting that the absolute level of the ζ_t Lagrange multipliers in equation (15) would change as well.

agriculture, going back only to the late 1990s. It trends downward, from values around 8% in the early 2000s, to as low as 3% more recently, with a spike to over 12% during the Great Recession. This is broadly consistent with our choice of $\theta_a = 0$. For manufacturing, we find $\theta_m = 1$ fits the spread moments best, a value lower than the 1.27 figure reported by Arellano, Bai, and Bocola (2024) in their study of Italian firms during the European debt crisis.

We compute our model using a global solution method based on discrete choice techniques, as introduced to sovereign default models by Dvorkin et al. (2021).[7] It calls for augmenting the sovereign's problem with low variance Extreme Value Type I (Gumbel) shocks, which slightly perturb the choice of borrowing B' and decouple the tight destabilizing loop between long-term bond prices and borrowing decisions, a standard source of numerical instability, as discussed by, e.g., Chatterjee and Eyigungor (2012). Appendix D provides further details on the computation.

2.3 Examining the Mechanism

Figure 1 illustrates the consequences of sovereign borrowing for financial conditions and its disparate impact across the sectors of the economy. These effects are central to our mechanism. We fix shocks to their means and the initial debt B to a level marked by the solid vertical line in each panel. We vary the government's debt level for next period B' on the horizontal axis, to plot financial conditions in the top three panels and real quantities in the bottom three panels.

Panel 1a shows the price received by the sovereign for its long-term bond. It falls monotonically in B', reflecting the increased risk of default in the following periods. The associated reduction in the market value of outstanding bonds is transmitted to the net worth of financial intermediaries, in Panel 1b. As default next period becomes near certain and sovereign bonds lose all value, the net worth converges to the minimal level $\overline{n}$. As a consequence of lower net worth, the financial constraint (6) tightens and the rate on working capital loans must increase, as captured by Panel 1c.

7. Further examples of these and related methods applied to default models include Mihalache (2020), Chatterjee et al. (2023), and Arellano, Bai, and Mihalache (2023), among others.

The impact of tight financial conditions on output levels is plotted in Panel 1d, expressed as percent deviation from their corresponding levels at $B' = 0$, a benchmark where government default risk is at its lowest. Manufacturing output is most sensitive to working capital rates and its activity level contracts monotonically. Agriculture expands, as it does not require working capital loans and it can now absorb some of the labor released by manufacturing, while overall aggregate output Y falls. Total employment shrinks, in Panel 1e, reflecting lower wages from depressed labor demand in manufacturing. The reduction in activity due to higher default risk induces lower tax revenues, in Panel 1f. The loss of tax revenue constitutes a real resource cost of default to the sovereign, which, together with the utility cost ν, incentivizes repayment in our model.

In sum, high enough government borrowing raises the risk of default and leads to tight financial conditions for firms, which in turn lower their demand for labor and induce a recession, with sectors most reliant on financing cutting output the most.

The discussion so far might lead one to incorrectly infer that more public debt can only worsen private outcomes. This is not the case. While "too much" debt does imply higher default risk and therefore depressed market value of debt and lower net worth, another channel is also present. If government debt is "too low," net worth is again low and possibly insufficient to meet working capital demand, even though the government's bonds are risk-free. That is, in this model, public debt has a liquidity provision role. We illustrate this in Figure 2, where we plot equilibrium GDP against the start-of-period debt level B. We express it as percent deviation from the level associated with loose financial conditions, where GDP is maximized. We fix shocks to their means, vary current debt B on the horizontal axis, and consider equilibrium B' choices in every state. We distinguish three cases: first, when debt is low, activity is depressed because intermediaries are financially constrained due to low net worth from insufficient liquidity. Second, when enough public debt is outstanding, but not too much, financial conditions are loose and all demand for working capital is met at the lowest rate possible, $r^w = \frac{1}{\beta} - 1$. Finally, as debt increases further, default quickly becomes likely and the value of net worth collapses. Note that, in terms of private sector activity, having no outstanding public debt is equally harmful to having a large debt stock that will surely go into default next period.

In equilibrium, the government avoids this socially-undesirable range of insufficient debt endogenously, and increases its issuance quickly to stimulate output and tax revenue. Only in the short-run aftermath of a default will debt be generally "too low," as the sovereign takes several periods to issue sufficient debt, due to its spending smoothing motive, governed by the σ_g parameter. This low output after default channel is another, less obvious cost of default in our model.[8]

2.4 Structural Transformation

We turn finally to our main result, that structural transformation leads to lower default risk and spreads. To illustrate this idea, we start with our baseline parameter values and alter only the mean level of productivity in agriculture, in order to match the share of employment in agriculture in the Philippines in the 2000s. We find that this requires roughly a doubling of $\overline{A}_a$, from 0.9 to about 1.8. As illustrated in Table 2, this leads to a reduction in the share of the labor force employed in agriculture from about 47% to slightly under 39%, as in the data. The associated fall in mean spread is 0.3%, from 3.3% to 3.0%, the same with the untargeted change in the data, from 3.2% to 2.9%. Note that these are comparisons across ergodic distribution means rather than transition paths. This is because we focus on longer-term trends in mean spreads and because transition dynamics are fast in our model with only public debt B as the sole endogenous state variable.

The change in the sectoral composition of the economy raises the endogenous cost of default and enables the government to support more debt issuance in equilibrium. Average Debt to GDP goes up by about 7% when $\overline{A}_a$ doubles, in line with the observation, at least in more recent data, that public debt is higher in more developed economies.

Figure 3 documents the monotonic nature of the relationship between the sectoral composition of the economy and sovereign default risk. On the horizontal axis we vary mean productivity in agriculture $\overline{A}_a$, from the 0.9 value in the baseline to the 1.8 value needed to match average sectoral composition in the 2000s. The left vertical axis corresponds to the

8. By issuing more debt faster in the aftermath of defaults, the government would support production and increase tax revenue, leading to additional public spending which it values, but this would come at the cost of higher debt service in the future. In practice, in our quantitative results, it takes 4+ periods to debt levels to return to typical levels following a default.

share of employment in agriculture, while the right vertical axis is used for the average spread level, the dashed line in the figure. Spreads are initially somewhat flat but then respond more strongly to the expansion of employment in finance-reliant manufacturing. Together with the global secular trend away from agricultural employment and into manufacturing and services, this monotonic pattern suggests that the frequency of crises is set to decline asymptotically, as countries "graduate" from default. Our model suggests that "serial defaulters" might be a dying breed.

3 Conclusion

We have found that the sectoral composition of the economy can impose, by itself, a certain degree of fiscal discipline and lower sovereign default frequency. Sovereign debt crises lead to domestic financial disruptions which impact sectors asymmetrically. As emerging markets adopt new, frontier technologies and productivity growth in agriculture is faster than in other sectors, the costs of debt crises increase in lockstep. Whether textbook patterns of development are the eventual destiny of all countries is far from a foregone conclusion, though (Ferreira, Monge-Naranjo, and Mello Pereira 2019).

We have set our argument in a closed economy framework, where we can more sharply isolate the two-way interactions between private sector financial conditions and the sovereign's policies. We conjecture that our mechanism would still be operational in a model where some of the government's debt is held abroad, by foreigners. As Broner, Martin, and Ventura (2010) argue, the domestic private sector has a comparative advantage in holding their own sovereign's bonds, since the government understands that an indiscriminate default would be costlier when more of the debt is held domestically.

The distinction between agriculture and manufacturing is not the only relevant dimension of sectoral heterogeneity. Whether employment and capital are concentrated in tradable versus nontradable goods sectors can also significantly impact default and the speed of the subsequent recovery (Arellano, Bai, and Mihalache 2018). Similarly, the natural resources extraction sector is plausibly a key driver in several historic episodes, as discussed by Esquivel (2024) in his study of giant oil field discoveries. Finally, our results here point to promising avenues for research concerning a broader role for nonhomothetic growth in the study of discretionary fiscal policy, debt crises, and financial distress. See, for example, Rojas and Saffie (2022) for a recent treatment of nonhomotheticity, in a tradable versus nontradable setting, in relation to sudden stop crises. We hope to address such questions in future work.

References

Acemoglu, Daron, Simon Johnson, and James A Robinson. 2005. "Institutions as a fundamental cause of long-run growth." *Handbook of economic growth* 1:385–472.

Aguiar, Mark, Satyajit Chatterjee, Harold Cole, and Zachary Stangebye. 2016. "Quantitative models of sovereign debt crises." In *Handbook of macroeconomics,* 2:1697–1755. Elsevier.

Aguiar, Mark, and Gita Gopinath. 2006. "Defaultable debt, interest rates and the current account." *Journal of International Economics* 69 (1): 64–83.

Arellano, Cristina. 2008. "Default risk and income fluctuations in emerging economies." *American economic review* 98 (3): 690–712.

Arellano, Cristina, Yan Bai, and Luigi Bocola. 2024. "Sovereign default risk and firm heterogeneity." *Journal of the European Economic Association* 0 (0): –.

Arellano, Cristina, Yan Bai, and Gabriel Mihalache. 2018. "Default risk, sectoral reallocation, and persistent recessions." *Journal of International Economics* 112:182–199.

———. 2023. "Deadly Debt Crises: COVID-19 in Emerging Markets." *The Review of Economic Studies* 91, no. 3 (May): 1243–1290.

Asonuma, Tamon, and Christoph Trebesch. 2016. "Sovereign debt restructurings: preemptive or post-default." *Journal of the European Economic Association* 14 (1): 175–214.

Azzimonti, Marina, and Nirvana Mitra. 2023a. "Political constraints and sovereign default." *Journal of International Money and Finance* 137:102895.

Azzimonti, Marina, and Nirvana Mitra. 2023b. *Sovereign Default and Tax-smoothing in the Shadow of Corruption and Institutional Weakness.* Technical report. National Bureau of Economic Research.

Bai, Yan, Seon Tae Kim, and Gabriel Mihalache. 2017. "The payment schedule of sovereign debt." *Economics Letters* 161 (December): 19–23.

Beers, David, Obiageri Ndukwe, and Alex Charron. 2023. *BoC–BoE Sovereign Default Database: Methodology and Assumptions.* Technical report. Bank of Canada.

Broner, Fernando, Alberto Martin, and Jaume Ventura. 2010. "Sovereign risk and secondary markets." *American Economic Review* 100 (4): 1523–1555.

Chatterjee, Satyajit, Dean Corbae, Kyle Dempsey, and José-Víctor Ríos-Rull. 2023. "A quantitative theory of the credit score." *Econometrica* 91 (5): 1803–1840.

Chatterjee, Satyajit, and Burcu Eyigungor. 2012. "Maturity, indebtedness, and default risk." *American Economic Review* 102 (6): 2674–99.

Dvorkin, Maximiliano, Juan M Sánchez, Horacio Sapriza, and Emircan Yurdagul. 2021. "Sovereign debt restructurings." *American Economic Journal: Macroeconomics* 13 (2): 26–77.

Eaton, Jonathan, and Mark Gersovitz. 1981. "Debt with potential repudiation: Theoretical and empirical analysis." *The Review of Economic Studies* 48 (2): 289–309.

Eichengreen, Barry, Ricardo Hausmann, and Ugo Panizza. 2007. "Currency mismatches, debt intolerance, and the original sin: Why they are not the same and why it matters." In *Capital controls and capital flows in emerging economies: Policies, practices, and consequences,* 121–170. University of Chicago Press.

Engel, Charles, and JungJae Park. 2022. "Debauchery and original sin: The currency composition of sovereign debt." *Journal of the European Economic Association* 20 (3): 1095–1144.

Esquivel, Carlos. 2024. *The sovereign default risk of giant oil discoveries.* Technical report. Working Paper.

Farah-Yacoub, Juan P, Clemens M Graf von Luckner, and Carmen M Reinhart. 2024. *The social costs of sovereign default.* Technical report. National Bureau of Economic Research.

Ferreira, Pedro Cavalcanti, Alexander Monge-Naranjo, and Luciene Torres de Mello Pereira. 2019. "From Malthus to Malthus." In *2019 Meeting Papers.* 1552. Society for Economic Dynamics.

Gennaioli, Nicola, Alberto Martin, and Stefano Rossi. 2014. "Sovereign default, domestic banks, and financial institutions." *The Journal of Finance* 69 (2): 819–866.

Gertler, Mark, and Peter Karadi. 2011. "A model of unconventional monetary policy." *Journal of monetary Economics* 58 (1): 17–34.

Hamilton, Calumn, and Gaaitzen J de Vries. 2023. *The Structural Transformation of Transition Economies.* University of Groningen, Groningen Growth / Development Centre.

Hatchondo, Juan Carlos, and Leonardo Martinez. 2009. "Long-duration bonds and sovereign defaults." *Journal of international Economics* 79 (1): 117–125.

Hébert, Benjamin, and Jesse Schreger. 2017. "The costs of sovereign default: Evidence from argentina." *American Economic Review* 107 (10): 3119–3145.

Herrendorf, Berthold, Richard Rogerson, and Akos Valentinyi. 2013. "Two perspectives on preferences and structural transformation." *American Economic Review* 103 (7): 2752–2789.

———. 2014. "Growth and structural transformation." In *Handbook of economic growth,* 2:855–941. Elsevier.

Mihalache, Gabriel. 2020. "Sovereign default resolution through maturity extension." *Journal of International Economics* 125c (July): 103326.

Powell, Michael JD. 1970. "A hybrid method for nonlinear equations." *Numerical methods for nonlinear algebraic equations,* 87–161.

Rojas, Eugenio, and Felipe Saffie. 2022. "Non-homothetic sudden stops." *Journal of International Economics* 139:103680.

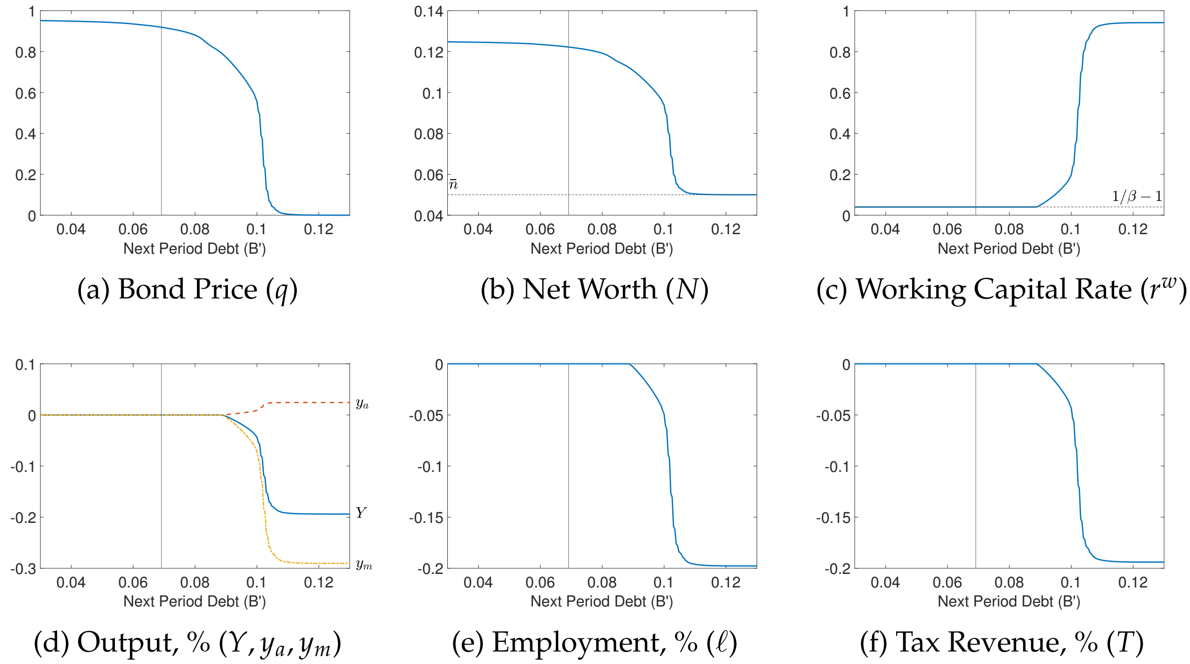
Sosa-Padilla, Cesar. 2018. “Sovereign defaults and banking crises.” *Journal of Monetary Economics* 99:88–105.

	Value	Description	Target or Source		
Household					
β	0.96	Household discounting	4% risk-free rate		
σ^{-1}	0.75	Frisch labor supply elasticity	Arellano, Bai, and Bocola (2024)		
Government					
σ_g	2.00	Government CRRA	Standard value		
τ	0.20	Tax rate	Share of tax revenue in GDP		
λ	0.20	Public debt maturity	5 years Macaulay duration		
κ	0.24	Debt service payment	Normalization		
Production					
α	0.67	Decreasing returns to labor	Standard value		
$\overline{A}_a$	0.90	Mean productivity, agriculture	Normalization, mean GDP		
η	0.85	CES elasticity of substitution	Herrendorf, Rogerson, and Valentinyi (2013)		
ω	0.65	CES share, agriculture	Normalization		
θ_a	0.00	Working capital, agriculture	Normalization		
	Value	**Description**	**Target**	**Data**	**Model**
Debt and default					
β_g	0.85	Government discounting	Mean spread	3.22	3.28
$\overline{\nu}$	1.87	Utility default cost	Debt to GDP	0.59	0.30
ρ_ν	0.85	Autocorrelation cost	Autocorellation spread	0.64	0.61
Std ε'_ν	0.14	Innovation, cost	Std G / Std GDP	1.90	1.85
Working capital					
$\frac{\overline{n}}{1-\phi}$	0.05	N lower bound	Corr GDP & spread	-0.46	-0.43
θ_m	1.00	Working capital, manufacturing	Std spread	1.24	1.05
Production					
ρ_a	0.93	Autocorrelation productivity	Autocorrelation GDP	0.46	0.46
Std ε'_a	0.013	Innovation, agriculture	Std GDP	2.00	2.30
$\overline{y}_a$	0.10	Subsistence level, agriculture	Share of labor in agriculture	0.47	0.47

Table 1: Parameter Values

	1990s		2000s		Δ	
	Data	Model	Data	Model	Data	Model
Mean Productivity in Agriculture ($\overline{A}_a$)		0.9		1.8		0.9
Agriculture Share of Employment (%)	46.7	47.0	39.0	39.4	-7.7	-7.6
Mean Government Spread (%)	3.2	3.3	2.9	3.0	-0.3	-0.3

Table 2: Structural Transformation and Spreads, Data and Model



(a) Bond Price (q)

(b) Net Worth (N)

(c) Working Capital Rate (r^w)

(d) Output, % (Y, y_a, y_m)

(e) Employment, % (ℓ)

(f) Tax Revenue, % (T)

Figure 1: Sovereign Borrowing and Private Outcomes

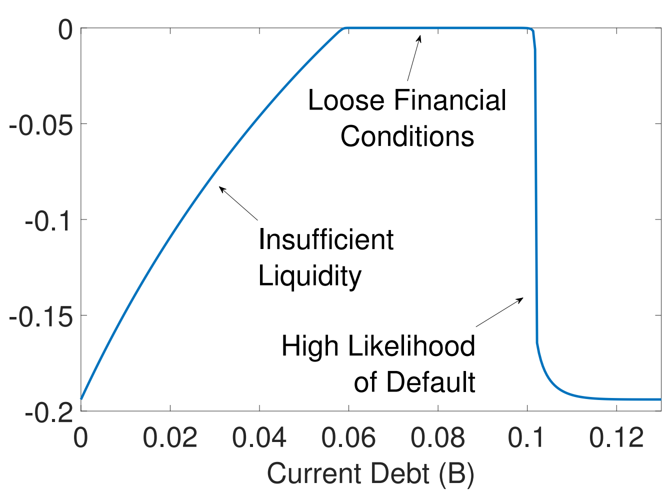


Figure 2: GDP as a Function of Debt

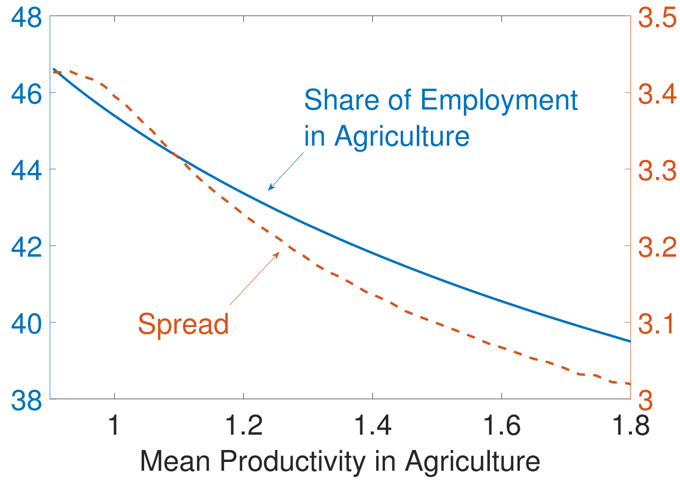


Figure 3: Structural Transformation and Default

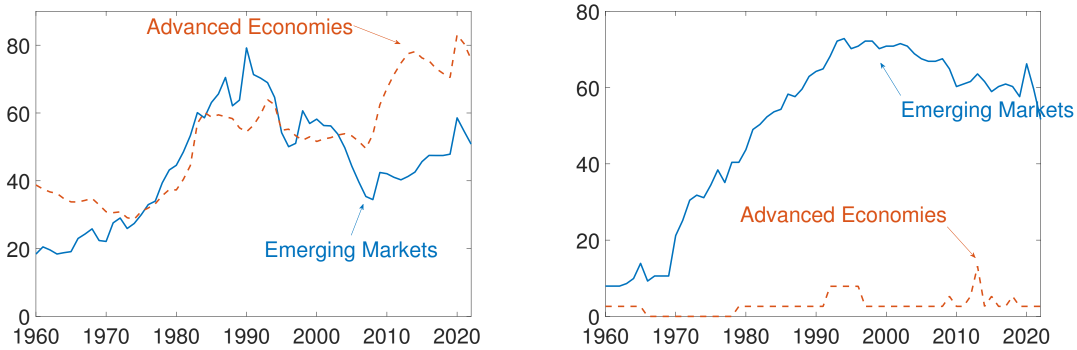
Appendix

A Additional Tables and Figures

Figure A.4a plots the Debt to GDP ratios over time, for Emerging Markets and Advanced Economies. The right panel compares these economies' likelihood of default over time. In sum, Advanced Economies issue about the same or slightly more debt than Emerging Markets, but are far less likely to declare default.

Table A.3 reports conditional panel logit estimation coefficients for a model of default status, as measured by the BoC-BoE dataset on defaults, as a function of the employment share of agriculture, the Debt to GDP ratio, and country- and time-fixed effects.

Table A.4 documents structural transformation patterns in Philippines data, across decades, from the 1990s to the 2010s, in terms of the share of labor employed in agriculture, the share of credit allocated to agricultural firms, and the spread on government debt.



(a) Debt to GDP by Group

(b) Share of Group in Default

Figure A.4: Default and Development

Default	(1)	(2)	(3)
Employment Share of Agriculture	0.185	0.174	0.171
	(0.020)	(0.026)	(0.045)
Debt to GDP		0.019	0.016
		(0.009)	(0.012)
Country FE	×	×	×
Year FE			×
N	812	584	584

Table A.3: The Share of Agriculture in Employment and Default Propensity

NOTE: Conditional panel logit estimates. The dependent variable is a dummy encoding whether the country's government (panel unit) had any debt in default in a particular year, from Beers, Ndukwe, and Charron (2023). The main explanatory variable is the share of employment in agriculture, from Hamilton and Vries (2023). Debt to GDP is from IMF WEO. OIM standard errors in parentheses.

The Philippines	1990s	2000s	2010s
Agriculture Share of Employment (%)	46.7	39.0	32.0
Agriculture Share of Credit (%)	n.a.	7.3	5.0
Government Spread (%)	3.2	2.9	1.4

Table A.4: Structural Transformation and Spreads in the Data

B Private Sector Outcomes

Given shocks (A_a, A_m, ν), current and future government policies (G, D, B), as well as break-even sovereign bond prices q from equation (23), private outcomes are given by sectoral prices p_a and p_m, sectoral output levels y_a and y_m, labor demand in each sector ℓ_a and ℓ_m, demand for working capital loans by each sector b_a and b_m, labor supply ℓ, total final output Y, private consumption C, wages w, the working capital loan rate r^w, the supply of working capital b, the supply of deposits s, and the discount bond price for deposits q^s. This results in a total of sixteen variables which are jointly, statically determined by the following system of equations, where we suppress sequential notation for convenience.

$$\ell_i = \left((1-\tau)\alpha \frac{p_i A_i}{(1+\theta_i r^w)w}\right)^{\frac{1}{1-\alpha}}, \quad i \in \{a, m\} \tag{Labor Demand}$$

$$w = \chi \ell^{\sigma} \tag{labor Supply}$$

$$\ell = \sum_{i \in \{a,m\}} \ell_i \tag{Labor Market Clearing}$$

$$y_i = A_i \ell_i^{\alpha}, \quad i \in \{a, m\} \tag{Sectoral Production}$$

$$Y = \left((1-\omega)\left(y_a - \overline{y}_a\right)^{\frac{\eta-1}{\eta}} + \omega y_m^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} \tag{Final Output}$$

$$p_a = (1-\omega)\left((1-\omega)\left(y_a - \overline{y}_a\right)^{\frac{\eta-1}{\eta}} + \omega y_m^{\frac{\eta-1}{\eta}}\right)^{\frac{1}{\eta-1}} \left(y_a - \overline{y}_a\right)^{-\frac{1}{\eta}} \tag{Price of Agriculture}$$

$$p_m = \omega\left((1-\omega)\left(y_a - \overline{y}_a\right)^{\frac{\eta-1}{\eta}} + \omega y_m^{\frac{\eta-1}{\eta}}\right)^{\frac{1}{\eta-1}} y_m^{-\frac{1}{\eta}} \tag{Price of Manufacturing}$$

$$b_i = \theta_i w \ell_i, \quad i \in \{a, m\} \qquad \text{(Working Capital Demand)}$$

$$\underbrace{\left(\frac{N}{1-\phi} - b\right)}_{\geq 0} \underbrace{\left(1 + r^w - \frac{1}{\beta}\right)}_{\geq 0} = 0 \text{ with c.s.} \qquad \text{(Working Capital Supply)}$$

$$b = \sum_{i \in \{a,m\}} b_i \qquad \text{(Working Capital Market Clearing)}$$

$$q^s = \beta \qquad \text{(Deposit Demand)}$$

$$N + q^s s = qB' + b \qquad \text{(Deposit Supply)}$$

$$Y = C + G \qquad \text{(Resource Constraint)}$$

and net worth is given by $N = \overline{n} + (1 - D)(1 - \lambda)qB$, from equation (2).

C Definition of Equilibrium

A recursive Markov Perfect Equilibrium consists of

- government value functions $V(S, B)$ and $W(S, B)$,
- government policy functions $D(S, B)$, $B'(S, B)$, and $G(S, B)$,
- the bond price schedule $q(S, B')$,
- the tax revenue function $T(S, B, B')$,
- private sector outcomes, as functions of $\langle S, B, B' \rangle$,
  - prices p_a and p_m, and quantities y_a, y_m, and Y,
  - labor supply ℓ and demand ℓ_a, ℓ_m,
  - working capital demand b_a, b_m and supply b,
  - wages w and the working capital rate r^w,
  - risk-free deposits s with associated discount bond price q^s,
  - and private consumption C,

such that

- given the bond price schedule q and the tax revenue function T, the government policy functions D, B', and G solve problems (20) and (21) and achieve value levels V and W,
- given government's default and borrowing policies, D and B', the bond price schedule satisfies the bond demand of financial intermediaries (23),
- given government policies, private sector outcomes satisfy the system of equation in Appendix B, for every state $\langle S, B \rangle$ and arbitrary B',
- given private sector outcomes, the tax revenue function is given by

$$T(S, B, B') = \tau \sum_{i \in \{a,m\}} p_i(S, B, B') y_i(S, B, B').$$

D Computation

We solve the recursive formulation of our default model, from Section 1.7, using discrete choice methods, as introduced by Dvorkin et al. (2021). This requires that both B and B' be restricted to lie on the grid.

We iterate to convergence, jointly, over the q and V functions, using equations (20), (21), and (23), using a "one loop" algorithm. With taste shocks, we define

$$H(S,B,B') = (1-\beta_g)\frac{G(S,B,B')^{1-\sigma_g}}{1-\sigma_g} + \beta_g \mathbb{E}_{S'|S} V(S',B') + \epsilon_{B'}, \tag{26}$$

where the $\epsilon_{B'}$ shocks, one for each possible value of B', are distributed Extreme Value Type I (Gumbel), with location parameter given by the Euler-Mascheroni constant multiplied by minus γ, and scale parameter γ. We set $\gamma = 5 \times 10^{-3}$, the smallest value needed for robust convergence across alternative parameter values in our calibration.

Now, (21) becomes

$$W(S,B) = \gamma \log \sum_{B'} \exp \frac{H(S,B,B')}{\gamma} \tag{27}$$

and the associated choice probabilities are given by

$$\Pr(B' = h|S,B) = \frac{\exp \frac{H(S,B,h)}{\gamma}}{\sum_f \exp \frac{H(S,B,f)}{\gamma}}. \tag{28}$$

In order to solve the government's problem, we need a candidate for the T tax revenue function, which summarizes the private sector's responses to sovereign borrowing and default. Each iteration, we solve for T for all possible combinations of S, B, and B' using the system of equations in Appendix B. There are two cases, based on which of the two inequalities in the complementarity slackness condition for the supply of working capital binds. First, we guess that financial conditions are loose, with

$$\underbrace{\left(\frac{N}{1-\phi} - b\right)}_{>0} \underbrace{\left(1 + r^w - \frac{1}{\beta}\right)}_{=0} = 0, \tag{29}$$

and solve a reduced system of seven equations in seven unknowns using Powell's hybrid method (Powell 1970). We then check that indeed net worth is sufficient, i.e., the strict inequality on the left. If this is the case, we can construct the tax revenue T in this combination of states and government policies. If, instead, net worth is insufficient given the demand for working capital loans at the r^w rate implied by β, we solve a system of eight equations in eight unknowns for the case given by

$$\underbrace{\left(\frac{N}{1-\phi} - b\right)}_{=0} \underbrace{\left(1 + r^w - \frac{1}{\beta}\right)}_{>0} = 0, \tag{30}$$

that is, we also need to solve for r^w, together with the other unknowns, before we can construct T.

Whenever we are unable to solve the systems of equations, because, for example, we are considering an extreme combination of shocks, states, and policy choices, we assign this particular B' a very large negative value, effectively disallowing the sovereign from picking it. We confirm that this is not binding for the final, converged solution.