The Aggregate-Demand Doom Loop: Precautionary Motives and the Welfare Costs of Sovereign Risk*

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Abstract

I examine the role of households' precautionary savings motive in amplifying and propagating movements in sovereign spreads. I study this mechanism in a model where the government of a small open economy borrows from foreigners but the debt is then partially held by heterogeneous domestic savers. In a calibration to Spain in the 2000s, I find that default risk accounts for about half of the output contraction. More generally, sovereign risk exacerbates volatility in consumption over time and across agents, creating large and unequal welfare costs even if default does not materialize.

JEL Classification E21, F34, H63

Keywords Sovereign risk, default, aggregate demand, precautionary motives, heterogeneous agents

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Introduction

Sovereign debt crises coincide with pronounced output contractions. With sovereign debt levels sharply increasing around the world after the Covid-19 crisis, there is renewed interest in quantifying the welfare consequences of sovereign risk. I take the Eurozone crisis as an example, when spreads increased steeply for many European countries such as Spain. Spain did not ultimately default on its debts, yet output fell by about 10% of its 2008 peak, unemployment doubled, and private consumption contracted by up to 15% of the pre-crisis maximum. The resulting increase in the aggregate saving rate was not unique to the Spanish experience. I document that increases in sovereign spreads are associated with declines in output accompanied by larger declines in consumption in a panel of EU countries during the crisis.

In this paper I develop a model of sovereign debt that rationalizes these large output and consumption contractions in response to sovereign risk. The mechanism relies on the interaction between default risk and the precautionary savings motive of households. When economic conditions worsen and sovereign default becomes more likely, households find it optimal to cut consumption in favor of higher savings, which leads to low aggregate spending. As wages are downwardly rigid, a recession follows. The model then generates a vicious cycle of high spreads and demand shortages causing further increases in debt and spreads. This 'aggregate-demand doom loop' amplifies recessions when sovereign risk emerges. Even if default does not materialize, its possibility endogenously exacerbates the volatility of consumption and output, resulting in large welfare costs of sovereign risk. I calibrate the model to Spain to quantify this amplification mechanism.

The model illustrates how prolonged periods of heightened sovereign risk carry costs in terms of output and employment through the feedback loop between spreads and demand. A lesson for policy is that swift resolution mechanisms that avoid uncertainty about debt sustainability and delays could enable significant welfare gains.

The contribution of this paper relative to the literature is to incorporate domestic demand conditions to the analysis of sovereign debt sustainability. Most studies assume either households that are effectively in financial autarky or one-sector models in which all output can be exported, rendering aggregate demand either exogenous or irrelevant. As a result, they cannot account for the role of households' savings decisions in the unfolding of a crisis. In contrast, by explicitly taking households and the government as separate actors, I describe how their interactions can create events in which aggregate spending reacts to the anticipation of the government's actions differently than if those decisions were made in a coordinated way.

In the canonical model, output and spreads are correlated solely because recessions increase default incentives: given debt prices, the presence of sovereign risk does not affect the economy unless a default actually happens (with the exception of some recent work highlighting bank lending and investment, see below). I find that the aggregate-demand doom loop generates large welfare costs of sovereign risk even if default is not ultimately triggered.

I consider a small open economy in which heterogeneous households, subject to uninsurable idiosyncratic income risk, decide both their savings and their exposure to government debt. This Bewley setup results in a wealth distribution which interacts with the government's decision to repay its debts. Rigidities in nominal wage setting combined with a currency peg (the model's representation of the Euro) create an aggregate-demand externality that transmits insufficient spending into increases in unemployment and contractions in output (Schmitt-Grohé and Uribe, 2016). Finally, when the government defaults, it bears a cost in terms of lost TFP and exclusion from capital markets, as is common in the literature. In addition to this effect, as in equilibrium some of the debt is held domestically, defaults redistribute wealth.

These costs of default, which affect the government's repayment strategy, are anticipated by households and induce them to increase their savings during crises. For households, the TFP costs of defaults faced by the government act as volatility in future income, which boosts their precautionary motive. On the other hand, the type of redistribution induced by defaults tends to be progressive: it creates capital losses for holders of debt (who tend to be richer) and lowers tax burdens for everyone. In other words, defaults transfer from agents with low to high marginal propensity to consume (MPC). However, during a crisis, when default is only a potential event in the future, such redistribution is only expected. This reverses the identity of low and high MPC agents, as unconstrained savers react equally to present and future transfers, while constrained agents only react to current income. Section 3 provides more insight into these forces, which underpin the quantitative analysis, by studying two highly stylized models.

To quantify the welfare costs of sovereign risk, I calibrate the model to Spain in the 2000s. In addition to standard moments in the sovereign debt literature, I target the private wealth-to-GDP ratio as well as the Gini index for wealth and the share of sovereign debt held domestically. This ensures that the distributional effects captured by the model are disciplined by the Spanish micro-data. I then simulate the model to obtain episodes which resemble the Spanish crisis. I find that the presence of sovereign risk worsens the recession, doubling the output contraction relative to a model in which sovereign risk is absent. Moreover, the presence of sovereign risk amplifies the unconditional volatility of aggregate consumption. This extra volatility is costly for the economy: a move from the ergodic mean of the benchmark model to that of a world in which defaults are impossible is worth about 4.2% of permanent consumption to the average household. The same number grows to almost 10% at the height of a crisis. These simple comparisons overstate the gains by not including a transition period and by shifting individual agents wealth levels. I also compute the welfare gains of removing default risk, including the transition and keeping agents at their current levels of wealth, and find that the episodes of crisis are extremely costly. At the beginning of a crisis, the average household would give about 3.4% of permanent consumption to ban defaults.

While the main argument of this paper would go through in a representative-agent version of the model, many of the effects of default which underpin the amplification channel are redistributive in nature. This makes inequality quantitatively important, both because of the differential impact of default risk on different agents and because the differential responses of those agents shape the aggregate response. I find that welfare costs during crises are highly unequal and regressive as wealth dampens the impact of ths crisis. The bottom 10% of the distribution experiences a drop in its certainty-equivalent consumption that is on average twice as a large as that experienced by the top 10% during a simulated crisis period. Furthermore, the reaction of the consumption of the median household (an approximation of what the representative-agent version of the model would capture) is about 20% weaker than that of aggregate consumption in those same episodes, implying that heterogeneity contributes to about a fifth of the direct aggregate-demand impulse.

Finally, the model ties the presence of sovereign risk to a high volatility of consumption relative to income. Standard models of sovereign debt share this feature on the surface: the real interest rate is countercyclical, which makes consumption procyclical. However, these models refer to the government's borrowing rate, which is not necessarily the one faced by households. Moreover, in the case of the Spanish crisis, the private sector was accumulating assets at the same time as the government debt was growing, which already puts into question the identification between national and government borrowing implicitly at the heart of standard models. In addition, during this period households were managing an aggregate net worth position of about 100% of GDP (see Figure 2). While private borrowing rates do tend to correlate with the rate on government securities, this is typically not true of saving rates (see Arnold and de Vries-van Ewijk, 2014; Martínez Pagés, 2017, and Figure 20 in the Appendix). The claim that only borrowing rates (in extremis, only the government borrowing rate) matter is therefore problematic.

Discussion of the Literature This paper relates to several strands of literature. I build on canonical models of sovereign debt (Eaton and Gersovitz, 1981; Aguiar and Gopinath, 2006; Arellano, 2008) by considering a benevolent government borrowing without commitment from international creditors. Recent papers have emphasized internal costs of sovereign default. Mendoza and Yue (2012) argue that domestic firms lose access to some imported inputs after a default, which reduces aggregate productivity. From these papers I take the shape and size of default costs, which are exogenous in my model.

Others such as Gennaioli, Martin and Rossi (2014), Pérez (2018), and Mallucci (2015) argue that the presence of domestic debt creates default costs through the disruption of financial intermediation. In these papers, households save and provide deposits to the financial sector. However, these one-sector models satisfy the law of one price and effectively abstract from the aggregate demand effects I emphasize.

I also build on models in which nominal rigidities in wage setting combined with an exchange rate peg create an aggregate demand externality (Schmitt-Grohé and Uribe, 2016, and a large literature). Anzoategui (2020) and Bianchi, Ottonello and Presno (2019) combine wage rigidities and default risk to consider policy tradeoffs when austerity depresses aggregate demand but endogenously decreases the probability of a debt crisis. They ask whether nominal rigidities can overturn the result in Cuadra, Sánchez and Sapriza (2010) that lack of commitment and sovereign default risk induces governments to follow procyclical fiscal policies. These papers abstract from the precautionary effects that are at the core of my argument by assuming that domestic households are unable to save.

Philippon and Roldán (2018) study the optimal sovereign deleveraging plan in a related but stylized setting. They find that the direct contractionary impact of austerity negates the gains from deleveraging in the crisis and argue for a gradual plan. Corsetti et al. (2013) also present the possibility of expansionary austerity in a context with equilibrium multiplicity. Romei (2015) considers the distributional impact of different speeds of fiscal consolidation in the absence of aggregate demand effects.

In a similar line to mine, Arellano, Bai and Mihalache (2020) consider a New Keynesian small open economy model with an aggregate demand externality where the government chooses its fiscal and default policy. They focus on the case when the Central Bank follows a Taylor rule, the currency floats freely and the economy undergoes a real devaluation at the time of default. These differences in assumptions affect their conclusions in interesting and complementary ways to the ones presented here.

Some studies, like Bocola (2016), Arellano, Bai and Bocola (2017), Arellano, Bai and Mihalache (2018), or Balke (2017), explicitly consider anticipation effects in investment from sovereign risk, endogenizing the correlation of interest rates for government borrowing and investment or working capital loans assumed by Neumeyer and Perri (2005). In these papers, when the probability of default increases, banks attach a higher value to safe assets, driving up borrowing costs for firms. Investment drops which depresses growth in a complementary way to the one emphasized here. Because it works through the supply side of the economy, this mechanism cannot by itself account for the savings pattern of households in the crisis. Moreover, this mechanism requires that banks be unable to raise equity, which is correct in the short run but less likely as time passes. I take the opposite stand that the financial sector acts as a veil for the nonfinancial private sector. This also highlights inequality within the private sector as a driver of the output response to sovereign risk.

Part of how sovereign risk affects demand is because of redistribution. In this sense, I relate to models such as Eggertsson and Krugman (2012), Auclert (2017), or Korinek and Simsek (2016), where shocks contract demand because they redistribute from high-MPC to low-MPC agents. This paper features this idea prominently, except that the timing of transfers reverses the identities of low- and high-MPC agents.

This paper also relates to studies in which sovereign debt policy responds to distributional concerns, as has been emphasized since Woodford (1990). While distributional concerns are featured in its objective function, the government in my model does not issue debt to help domestic agents, who can save in the international risk-free bond, with their self-insurance (as in Aiyagari and McGrattan, 1998; Shin, 2006). D'Erasmo and Mendoza (2016) build a heterogeneous-agents model of sovereign default and find that levels of debt like those of present day Spain suggest a government with a bias towards favoring its creditors. Ferriere (2016), Ferrière and Navarro (2018), and Deng (2021) argue for a positive link between progressive taxation on the one hand and incentives to repay sovereign debt and fiscal multipliers on the other. Guembel and Sussman (2009), Andreasen, Sandleris and van der Ghote (2011), and Dovis, Golosov and Shourideh (2016) study political economy considerations in sovereign debt policy.

Finally, the setup with heterogeneous households allows for a clean separation of the debts and assets of the government and the private sector. In canonical models of sovereign debt, allowing households access to risk-free borrowing and saving unravels the equilibrium. The reason is simple: if the government has access to lump-sum taxes and the representative household can commit to repay loans, then the government can use its tax policy to effectively have the household borrow on its behalf at the risk-free rate. This has naturally led researchers to study models in which the private sector's financial choices are constrained. An alternative is to constrain the tax instruments at the government's disposal. In my model, even though the government can collect lump-sum taxes and agents can save, it cannot make those taxes agent-specific. This provides a natural constraint on the government's ability to sidestep its lack of commitment.

Layout The remainder of the paper is organized as follows. Section 2 presents some motivating evidence and Section 3 builds intuition by analyzing two simple models. Section 4 describes the quantitative model while Section 5 defines the equilibrium and clarifies the inner workings of the model. Section 6 discusses the calibration and Section 7 summarizes results from the model solution. Section 8 focuses on crises and presents the main results. Finally, Section 9 concludes.

2. Motivating Evidence

Figure 1 plots total GDP and households' consumption for Spain in the 2000s. To show each series in as raw a form as possible, I plot them relative to the value at the start of 2008. Output and consumption strongly contract during the crisis years. Moreover, consumption contracts more than output as the crisis unfolds. Comparing the trough of the crisis to early 2011 to isolate the effect of sovereign risk as much as possible, the output and consumption contractions are of the order of 5% and 9%.

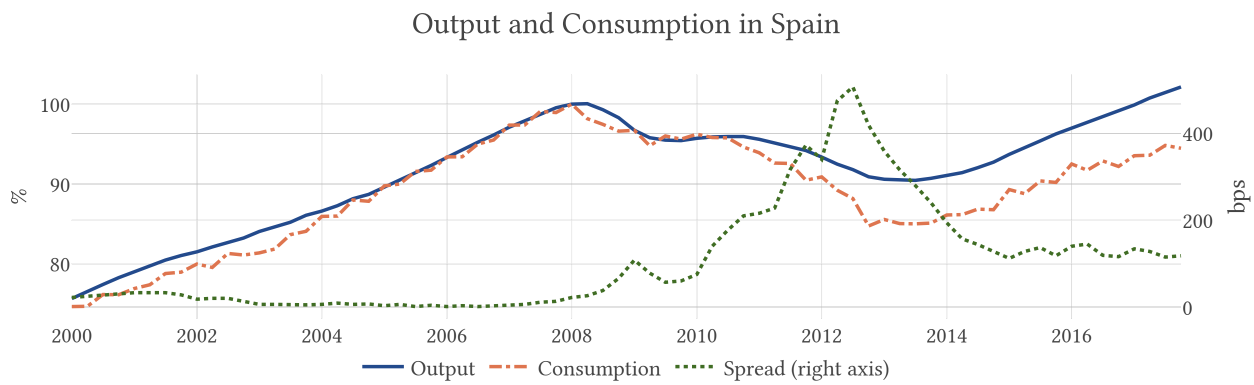

Figure 1: Spanish Output and Consumption in the 2000s

The case of Spain in the Eurozone crisis is of particular interest, as a default did not actually happen even though full repayment by the government was uncertain during the period: Figure 1 reveals that a 10-year Spanish government bond paid a significant interest rate spread over a comparable German Bund, peaking at about 500 basis points in late 2012. Figure 18 shows that the share of firms reporting insufficient demand as the main factor limiting their production increased significantly during the crisis in what looks like two phases, consistent with the private deleveraging followed by sudden stop interpretation of Martin and Philippon (2017). The two phases are also noticeable as two separate instances of output contraction in Figure 1.

Moreover, as Figure 2 reveals, while the private-deleveraging phase of the crisis coincides with a levelling off of liabilities and a large drop in assets (possibly related to the housing bust), during the sovereign-risk phase Spanish households increased their net worth mainly by accumulating more assets. While these are only aggregate, descriptive data, the pattern is consistent with a

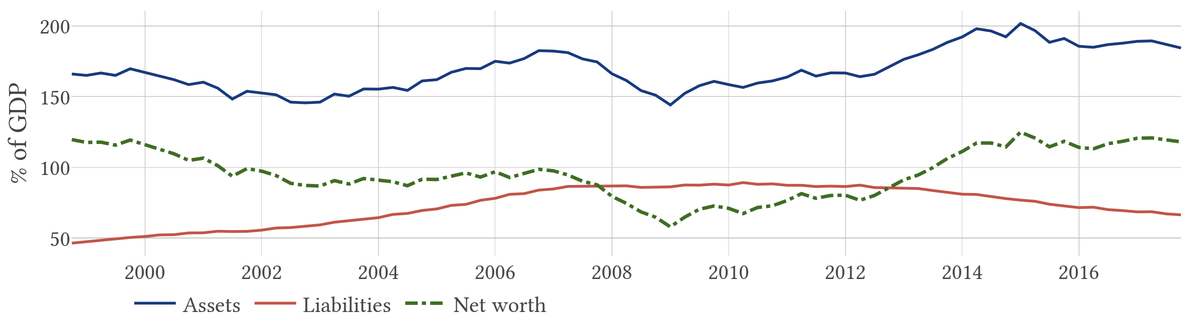

Figure 2: Net Worth of Spanish Households

Source: Eurostat

larger propensity to save during the second phase of crisis, when sovereign risk is present.

Finally, the patterns emphasized for Spain in Figure 1 are not a particular feature of the Spanish experience. Using quarterly data for 11 European countries between 2010 and 2013, I consider equations of the type

$$Q_{jt} = \beta Spread_{jt} + \gamma X_{jt} + \mu_j + \delta_t + \epsilon_{jt} \tag{1}$$

for $Q_{jt} = \log Y_{jt}, \log C_{jt}$, where the X_{jt}'s are controls and μ_j and δ_t are country and time fixed effects.

Table 1 summarizes the estimation of equation (1). It shows that countries which saw larger increases in their spreads also saw larger contractions in output and consumption. The coefficients in the first four columns mean that a typical country experiencing the average increase in spreads (about 200bps) saw a fall in output of between 1.2% and 1.4% and a fall in consumption of between 1.8% and 2.7%. The two last columns informally test that the consumption coefficient is indeed larger than the output coefficient, by including output in the consumption regression.

Table 1: Correlation of Spreads and Macroeconomic Outcomes

	$\log Y_t$		$\log C_t$		$\log C_t$	
	(1)	(2)	(3)	(4)	(5)	(6)
Spread_t	-0.007	-0.006	-0.014	-0.009	-0.007	-0.004
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
B_t/Y_t		-0.001		-0.002		-0.002
		(0.000)		(0.000)		(0.000)
$\log Y_t$					0.995	0.807
					(0.091)	(0.067)
Country + Time FE	✓	✓	✓	✓	✓	✓
N	143	143	143	143	143	143
Within-R^2	0.274	0.325	0.420	0.677	0.715	0.857

Standard errors in parentheses.

3. Two Minimal Models

I begin by considering two highly stylized environments. In the first model, expectations of income losses in case of default depress aggregate demand in the present. The second model shows how expected redistribution (like the one induced by defaults when there are domestic holdings of sovereign debt) also contributes to a contraction in demand. Both the effects emphasized in this section will be important drivers of the quantitative results in the rest of the paper.

3.1 *The costs of default costs*

Consider a small open economy with a representative agent who lives for two periods and receives stochastic endowments y_t^T of a tradable good. The representative agent chooses to save an amount of resources $s_1 \geq 0$ in the first period. In the second period, some legacy debt d becomes due to foreigners. If the government fails to repay, output falls by a factor of Δ. The representative agent's consumption is

$$c_2 = \begin{cases} y_2^T - d + s_1 & \text{if the government repays} \\ y_2^T(1-\Delta) + s_1 & \text{if the government defaults} \end{cases}$$

Assuming that the government maximizes the utility of the representative agent, it follows that there is default if and only if $y_2^T < d/\Delta$.

In the first period, the small open economy also produces a nontraded good with labor, subject to wage rigidities, according to the production function $y_1^N = F(h_1) = h_1^\alpha$, where $\alpha \leq 1$.

Suppose also that the representative agent has standard CES preferences across traded and nontraded goods with elasticity of substitution η and relative weight ϖ for the nontraded good, so that

$$c_N = \left(\frac{\varpi}{1-\varpi}\frac{p_T}{p_N}\right)^{\frac{1}{1+\eta}} c_T$$

where p_T, p_N are the prices of traded and nontraded goods and c_T, c_N are quantities consumed. I normalize $p_T = 1$.

This first-order condition for consumption of traded and nontraded goods in the first period, combined with the firm's labor demand, implies that

$$h = \mathcal{H}(c_T, w) = \left(\frac{\varpi}{1-\varpi}\frac{\alpha}{w}\right)^{\frac{1}{1+\alpha\eta}} c_T^{1+\eta} \tag{2}$$

I assume nominal rigidities in the form of a wage floor $\bar{w}$, so that either $h = 1$ and the wage satisfies (2) or, when the constraint binds, $w = \bar{w}$ and $h = \mathcal{H}(c_T, \bar{w})$. Crucially, equilibrium employment is an increasing function of traded consumption in the constrained regime. A planner who could direct the representative agent's choices in the first period would solve

$$\max_{s_1} u(c_T, F(h)) + \beta\mathbb{E}\left[u\left(\max\{y_2 - d, y_2(1-\Delta)\} + s_1\right)\right] \tag{3}$$

$$\text{subject to } c_T + \frac{s_1}{1+r} = y_1$$

$$h = \min\{1, \mathcal{H}(c_T, \bar{w})\}$$

The first-order condition for problem (3) is the planner's Euler equation

$$u_T'(c_T, F(h)) + \mathcal{H}_c'(c_T, \bar{w})\mu = \beta(1+r)\mathbb{E}\left[u'\left(y_2 + s - \min\{d, y_2\Delta\}\right)\right]$$

where $\mu = u'_N(c_T, F(h))F'(h)$ is the multiplier on the wage floor constraint. The default cost Δ and the debt level d both enter this Euler equation the same way, increasing the marginal value of consumption in the second period (although the effect of Δ works through making the household worse off in the event of default, while making default itself less likely). An increase in either of them therefore boosts precautionary savings in the first period. The planner, however, understands that more savings in the first period may decrease employment, when $\mathcal{H}'_c(c_T, \bar{w}) > 0$. In a decentralized equilibrium the household solves the same problem, taking as given employment h (in other words, without the μ multiplier). Employment satisfies the second constraint only in equilibrium.

Figure 3 summarizes the effect of legacy debt d on the equilibrium, both for the planner and in the decentralized case. It is clear that sovereign risk increases the marginal value of consumption in the second period and consequently boosts the household's precautionary motive. It induces more savings in the first period. The planner, however, internalizes the aggregate-demand doom loop and curbs the individual household's savings.

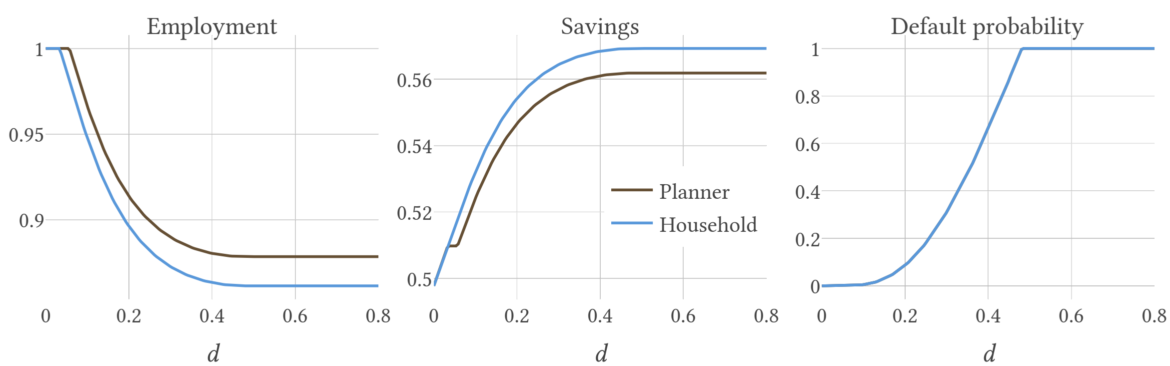

Figure 3: Anticipation of TFP Costs of Default

3.1.1 *Which interest rate?*

If the planner can repurchase the debt instead of having the household save at the risk-free rate, the Euler equation becomes

$$u'_T(c_T, F(h)) + \mathcal{H}'_c(c_T, \bar{w})\mu = \beta \frac{\mathbb{E}\left[u'(y_2 + s_1 - \min\{d, y_2\Delta\})\right]}{q(d - s_1, \Delta) + s_1 q_d(d - s_1, \Delta)}$$

where $q(d,\Delta) = \frac{1-\mathbb{P}(y_2<d/\Delta)}{1+r}$ is the price of debt in the first period and $q_d(d,\Delta)$ is its derivative with respect to indebtedness. In this case increases in d (or Δ) still push up the relevant marginal utility of future consumption. Increases in Δ now also push up the debt price, cancelling part of the effect. Increases in initial debt d, on the other hand, have a larger impact in this case as they push down the debt price, magnifying the effect of sovereign risk on desired savings. However, for a given change in expected marginal utility, the reaction of current consumption is muted, as repurchases of debt push up the price, resulting in a smaller required change in savings. The question becomes how much can current savings affect the total stock of debt and future default incentives. An exhaustive discussion of these effects, along with their implications for the ex-ante optimal default cost, requires a less stylized setting and is therefore left as an open question. In the quantitative model, I focus on the reaction of households to sovereign risk itself. The question of whether the government would like to repurchase its debt in such a case is also left as an open question.

3.2 *Propensities to consume and the anticipation of redistribution*

Consider now a closed economy populated by a measure χ of hand-to-mouth agents and $1-\chi$ of 'savers,' each endowed with one unit of labor in each period. The only good is produced with labor with constant returns to scale, $y = h$.

In the second period prices are fully flexible but with probability π there is a transfer of size k from savers to hand-to-mouth agents. Consumptions in the second period are

$$(c_1^s, c_1^h) = \begin{cases} (1-k, 1+k) & \text{with probability } \pi \\ (1,1) & \text{with probability } 1-\pi \end{cases}$$

In the first period, all prices are fixed. The wage rate is w, the price of the good is normalized to 1. Savers trade risk-free securities in zero net supply at a real interest rate r. Consumption of savers satisfies the Euler equation

$$u'(c_1^s) = \beta(1+r)\left[\pi u'(1-k) + (1-\pi)u'(1)\right]$$

Assuming CARA utility with absolute risk aversion γ (as in Philippon and Roldán, 2018), the first-period consumption of savers is

$$c_1^s = 1 - \frac{1}{\gamma}\log(\beta(1+r)) - \frac{1}{\gamma}\log\left(1 - \pi + \pi e^{\gamma k}\right)$$

The size of the potential transfer k unambiguously reduces savers' consumption. The size of the effect is also increasing in the probability π. The effect of the risk aversion parameter is a little more complicated. It both amplifies the effect (γ appears multiplying k inside the exponential) and dampens it. This is because γ is both risk aversion and the inverse of the intertemporal elasticity of substitution. Risk aversion makes savers dislike differences in consumption across states in the second period and induces more savings. But γ also controls how close of a substitute is consumption in one period relative to the other. This reduces the incentive to save (it also reduces the incentive to save in response to interest rates).

Hand-to-mouth agents' consumption, on the other hand, is entirely dictated by their budget constraint in the first period. In the simplest case, we have $c_1^h = wh$. For markets to clear, output must equal the total demand of both types, $y = \chi c_1^h + (1-\chi)c_1^s$, or, using that $y = h$,

$$y = \frac{1-\chi}{1-\chi w}c_1^s$$

If nominal rigidities prevent $w \leq \bar{w}$ once more, the presence of hand-to-mouth agents makes output a multiple of the consumption of savers. Figure 4 shows output in percent deviations from a no-transfer benchmark. It illustrates how the expected redistribution depresses output in the first period. Demand of savers (and hence output) is decreasing in both the probability of the transfer π and its expected size k.

This model illustrates how a potential transfer from unconstrained to constrained agents has the opposite effect on the economy than an actual transfer from unconstrained to constrained agents. In this extreme example, hand-to-mouth agents have an MPC of 1 out of current income but of 0 out of future income. Savers, on the other hand, are not affected by the timing of income: their MPC is smaller out of current income but remains positive as the transfer considered takes place further into the future.

Finally, suppose that the government attempted to reduce its stock of debt, as in the extension of the first model. Assume that, at least at the margin, it did so by collecting lump-sum taxes equal across types of agents. On the one hand, reducing the default probability might counteract

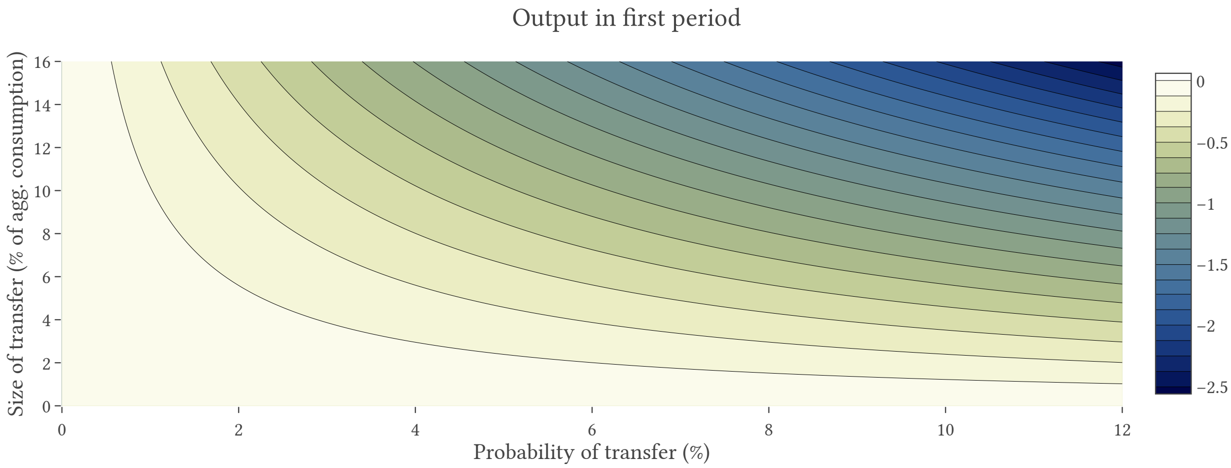

Figure 4: Anticipation of Redistribution in Case of Default

some of the savers' precautionary behavior. But it would also directly affect the hand-to-mouth agents, whose MPC out of this type of transfers is 1. This type of austerity-induced redistribution that hurts aggregate demand, which also features in the quantitative model below, is a well-understood effect (see for example Auclert, 2017, Anzoategui, 2020, or Bianchi, Ottonello and Presno, 2019, who also include transfers to foreigners whose MPC is zero as far as the domestic economy is concerned).

4. Quantitative Model

The response of the economy to sovereign risk depends on a variety of endogenous objects: the amount of debt outstanding when spreads increase, its distribution across foreign and domestic agents (as well as among domestic agents), the distribution of MPCs for various current and future transfers. The model presented here aims to provide the necessary elements for a quantitative evaluation of the Spanish crisis.

I consider a small open economy populated by a continuum of heterogeneous households and firms that produce tradable and nontradable goods. A government runs an exogenous, estimated fiscal rule for spending and debt issuance but chooses between default and repayment with discretion. There are incomplete markets and only two assets are traded: a one-period, risk-free private security and a long-term, noncontingent, defaultable government bond.

4.1 Households

There is a continuum of heterogeneous households who differ in the realization of an uninsurable idiosyncratic shock to their effective labor supply, ϵ, as well as in their asset holdings. Let a and b denote holdings of the risk-free asset and of government debt, respectively. Households are limited in their ability to hold negative positions in these assets: it is impossible to short the government, and there is an ad-hoc lower bound $\bar{a}$ on the risk-free asset. Respecting these restrictions, both assets trade at prices q^h and q^g.

Households value the consumption of traded and nontraded goods according to a CES aggregator

$$c = \left[\varpi^{\frac{1}{\eta}} c_N^{\frac{\eta-1}{\eta}} + (1-\varpi)^{\frac{1}{\eta}} c_T^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

where η is the elasticity of substition among the two goods. I assume an inelastic labor supply. Households have Epstein-Zin preferences over streams of consumption represented by the value function

$$v_t^{\frac{\psi-1}{\psi}} = (1-\beta)c_t^{\frac{\psi-1}{\psi}} + \beta\mathbb{E}_t\left[{v_{t+1}}^{1-\gamma}\right]^{\frac{\psi-1}{\psi(1-\gamma)}}$$

where β is the discount factor, γ is the coefficient of risk-aversion and ψ is the inverse elasticity of intertemporal substitution.

In period t, households observe the aggregate state of the economy $\mathbf{S}_t = (B_t, \lambda_t, \xi_t, \zeta_t, z_t)$, comprised of total government debt outstanding B_t, the current distribution of households over their idiosyncratic states λ_t, the current value of a shock to sovereign spreads ξ_t, the current state of the country in international credit markets ζ_t, and the current level of a productivity shock z_t. In equilibrium, this information is enough to recover the relative price of nontraded goods $p_N(\mathbf{S}_t)$ and the current wage rate $w(\mathbf{S}_t)$, as well as the price of government debt $q^g(\mathbf{S}_t)$, lump-sum taxes $T(\mathbf{S}_t)$, firms' profits $\Pi(\mathbf{S}_t)$, and the price of consumption (CPI)

$$p_C(\mathbf{S}_t) = \left[\varpi p_N(\mathbf{S}_t)^{1-\eta} + (1-\varpi)\right]^{\frac{1}{1-\eta}}$$

where the price of traded goods is normalized to $p_T = 1$.

Government debt is a long-term asset which promises a geometrically-decaying coupon payment denominated in the traded good, as in Leland (1998), Hatchondo and Martinez (2009), and Chatterjee and Eyigungor (2012). While the government is not in default, holders of debt purchased t periods ago receive $\kappa(1-\rho)^{t-1}$. This standard setup makes one unit of debt a perfect substitute of $(1-\rho)$ units of debt issued in the following period. When the government defaults, a haircut $\hbar$ is applied to all outstanding debt and coupon payments are suspended until the government regains market access.

The household's idiosyncratic states are the current level of its labor productivity ϵ as well as the total value of its asset portfolio $\omega_t = a'_{t-1} + R^b_{t-1,t} b'_{t-1}$. I adopt the convention that the risk-free asset pays one unit of the traded good while the government bond yields $R^b_{t-1,t}$. Let $\mathbf{s} = (\omega, \epsilon)$ denote the idiosyncratic state vector. Individual labor productivity follows an AR(1) process in logs so $\log \epsilon_{t+1} = \rho_\epsilon \log \epsilon_t + \sigma_\epsilon \nu^\epsilon_{t+1}$, where $\nu^\epsilon_t \overset{iid}{\sim} \mathcal{N}(0,1)$.

Labor supply is inelastic. Because of nominal rigidities (see below), there can be rationing in the labor market when labor demand falls short of supply. In that case, I assume that households are rationed proportionally so that everyone works the same amount of hours. These assumptions mean that a household with current shock ϵ receives (pre-tax) labor income equal to $y^L(\mathbf{s}, \mathrm{S}) = w(\mathrm{S})L(\mathrm{S})\epsilon$ at wage w and employment L in state S, of which a fraction τ is paid to the government as labor income taxes.

Households also receive income from ownership of the firms. I assume that this income is rebated lump-sum in proportion to the current value of the shock ϵ. Because the integral of ϵ is normalized to 1, households receive income $y^\Pi(\mathbf{s}, \mathrm{S}) = \Pi(\mathrm{S})\epsilon$.

The household's problem (4) summarizes the discussion above.

$$
\begin{aligned}
v(\mathbf{s}, \mathrm{S})^{\frac{\psi-1}{\psi}} &= \max_{a',b',c} (1-\beta) c^{\frac{\psi-1}{\psi}} + \beta \mathbb{E}\left[\left(v(a' + R_b(\mathrm{S},\mathrm{S}')b', \epsilon', \mathrm{S}')\right)^{1-\gamma} | \mathbf{s}, \mathrm{S}\right]^{\frac{\psi-1}{\psi(1-\gamma)}} \qquad (4) \\
\text{subject to } & p_C(p_N(\mathrm{S}))c + q^h(\mathrm{S})a' + q^g(\mathrm{S})b' = \omega + \ell(\mathrm{S})\epsilon - T(\mathrm{S}) \\
& \ell(\mathrm{S}) = w(\mathrm{S})L(\mathrm{S})(1-\tau) + \Pi(\mathrm{S}) \\
& R_b(\mathrm{S},\mathrm{S}') = 1_{(\zeta'=1)}\kappa + (1-\rho)\left(1 - \hbar 1_{(\zeta=1)\cap(\zeta'\neq 1)}\right) q^g(\mathrm{S}') \\
& b' \geq 0; \qquad a' \geq \bar{a} \\
& \mathrm{S}' = \Psi(\mathrm{S}, \xi', z', \zeta')
\end{aligned}
$$

This problem is affected by the presence of sovereign risk in at least three distinct ways. An increase in default risk depresses expected future income, generates capital losses through movements in realized R_b, and worsens the savings technology by making expected R_b more negatively correlated with future income. Section 5.3 discusses these effects in more detail.

The solution to the household's problem consists of policy functions $\varphi_a, \varphi_b, \varphi_c : \boldsymbol{s} \times \mathcal{S} \to \mathbb{R}$. It is important to notice that the value function $v(\mathbf{s}, \mathbf{S})$ describes a household *after* the government's default decision.

4.2 Relative prices and the real exchange rate

Because of the homotheticity of CES demand, each household consumes both goods in the same proportions. The first-order condition for the composition of consumption, summing over all agents, then reads

$$p_N(\mathbf{S}) = \frac{\varpi^{1/\eta}}{(1-\varpi)^{1/\eta}} \left(\frac{C_T(\mathbf{S})}{C_N(\mathbf{S})} \right)^{\frac{1}{\eta}} \tag{5}$$

4.3 Firms

There are two types of firms that produce traded and nontraded goods. Their technologies are concave in labor, as described by the functions f_i for $i \in \{N, T\}$. TFP depends on the productivity shock z_t and is reduced when the economy is in default. As a benchmark, I consider the case where the shock z_t only affects the production of traded goods

$$Y_{Nt} = f_N(z_t, \zeta_t) L_{Nt}^{\alpha_N} = \left(1 - \Delta 1_{(\zeta \neq 1)}\right) L_{Nt}^{\alpha_N} \tag{6}$$

$$Y_{Tt} = f_T(z_t, \zeta_t) L_{Tt}^{\alpha_T} = z \left(1 - \Delta 1_{(\zeta \neq 1)}\right) L_{Tt}^{\alpha_T} \tag{7}$$

where Δ is the output cost of default and $\zeta = 1$ denotes good standing in international markets.

In equilibrium, firms in both sectors must pay the same wage. However, because of nominal rigidities, the wage w_t cannot fall below $\bar{w}$, as in Bianchi, Ottonello and Presno (2019). When the constraint does not bind, the economy operates at full employment; otherwise, workers are rationed. I discuss this way of introducing nominal rigidities in more detail in Section B.2.

4.4 *Fiscal policy*

The government's policy determines four actions: whether to repay its current debt obligations in full, how much new debt to issue, the amount of government spending, and the level of lump-sum transfers it gives to households. While I specify borrowing and spending decisions exogenously (see Section 6.1), default decisions, and consequently lump-sum taxes or transfers, are chosen with discretion.

The government's budget constraint (8) equates resources from (net) debt issuance and labor income taxes to expenditures given by coupon payments, government spending, and lump-sum transfers

$$\underbrace{q_t^g}_{\text{debt price}} \underbrace{(B_t' - (1-\rho)B_t)}_{\text{new debt issued}} + \underbrace{\tau w_t L_t}_{\text{income tax}} = \underbrace{\kappa 1_{(\zeta=1)} B_t}_{\text{coupon}} + \underbrace{g_t}_{\text{spending}} - \underbrace{T_t}_{\text{lump-sum}} \tag{8}$$

This budget constraint means that, given q_t^g, the government's choice of transfers T_t can be obtained as a residual from its issuance B' and spending g policies.

When the government is in default (denoted by $\zeta = 0$), coupon payments are interrupted. However, holders can still trade the bonds in secondary markets. Defaulted debt remains valuable as the government recovers access to markets with probability θ each period. During default, new debt cannot be issued (even if it would out-of-the-equilibrium-path command a positive price), which restricts $B_t' = B_t$ in default states.

Finally, the strategies for spending g and debt issuances B' are exogenous. I estimate them as a function of the whole state vector to match observed correlations with key business cycles statistics (see Section 6). Finally, I assume that the government spends a constant fraction ϑ_N of its expenditures on the nontraded good.

4.5 *Defaults and the evolution of debt*

The repayment strategy of the government $h'(\mathbf{S}_t, \xi_{t+1}, z_{t+1})$ specifies a repayment probability in each state of the following period. The government makes its default choice in period $t+1$ having observed the exogenous states (ξ_{t+1}, z_{t+1}) and understanding which aggregate states $\mathbf{S}_{t+1}$ result from repayment and from default. The government also receives an *iid* preference shock ξ^{def}

orthogonal to all other variables, which plays the role of smoothing out the policy for numerical tractability. The mean of the shock also helps to match the average spread by controlling the unconditional default frequency, as discussed in Section 5.1.

If there is a default in period $t+1$, a haircut of $\hbar$ applies to the debt of the government. This means that $B(\mathrm{S}_{t+1}) = (1-\hbar)B'(\mathrm{S}_t)$, whereas $B(\mathrm{S}_{t+1}) = B'(\mathrm{S}_t)$ otherwise. When in default, there is a constant probability θ of reentering financial markets.

The budget constraint (8) captures a particular tradeoff. When resources from tax collections and debt issuance are low (for instance, when spreads are high), the government chooses between default or lump-sum taxes. In this context, one could interpret the second option as a regressive austerity plan.

4.6 *Monetary policy*

The small open economy defends a pegged exchange rate. Everywhere in the model, this assumption amounts to a normalization of the (constant) price of nontraded goods $p_T \equiv 1$. Importantly, I assume that the economy does not abandon the peg upon default, as Na et al. (2018) argue is a relevant case.

Relaxing this assumption to have devaluations accompany defaults would not be innocuous. It would certainly reduce the aggregate income losses from default by allowing real wages to fall. On the other hand, it would create wealth effects from the currency of denomination of contracts and assets that households own. The first consequence can be captured in this model by making the bound on wages depend on the default state ζ. However, addressing the second, probably more interesting (and quantitatively important) consequence requires a rich model of private currency choice and is beyond the scope of this paper.

4.7 *Foreign borrowing and the external sector*

I assume that a large quantity of foreigners have access to funds at a fixed international risk-free rate $r^\star$. This immediately implies that $q_t^h = \frac{1}{1+r^\star}$.

Furthermore, if foreigners hold the government's debt in state S, then by no arbitrage it has to be the case that

$$q_t^g = \frac{1}{1+r^\star}\mathbb{E}_t\left[\underbrace{1_{(\zeta_{t+1}=1)}\left(1-\xi_{t+1}\right)\kappa}_{coupon} + \underbrace{\left(1-\rho 1_{(\zeta_{t+1}=1)}\right)}_{depreciation}\underbrace{\left(1-\hbar 1_{(\zeta_t=1\cap\zeta_{t+1}\neq 1)}\right)}_{potential\ haircut}\underbrace{q_{t+1}^g}_{resale\ price}\right] \tag{9}$$

which reflects that debt is a claim to coupon payments while there is no default, that a default entails the haircut $\hbar$, and that the unmatured fraction $(1-\rho)$ of the bond can be resold in secondary markets. With respect to the coupon payments, I assume that foreigners price debt as if the coupon payment was $(1-\xi')\kappa$, where the stochastic process for ξ is constrained to remain within the interval $(0,1)$. This assumption artificially depresses the price of government debt in order to match the home bias in holdings (see Section 5.2 for a discussion).

Equation (9) only holds when foreigners hold some of the debt. I assume that, as in the data, domestic demand for government debt always falls short of the total amount outstanding. I then check in simulation that this is the case.

I measure the implicit (promised) interest rate r^b on a government bond as the discount rate that equalizes the promised payments to the debt price, which comes down to $r^b(\mathbb{S}) = \frac{\kappa}{q^g(\mathbb{S})} - \rho$. The spread on government debt is then the difference between r^b and the risk-free rate $r^\star$. Because of the normalization that $\kappa = r^\star + \rho$, the spread can be easily computed from the debt price as $spr(\mathbb{S}) = \kappa\left(\frac{1}{q^g(\mathbb{S})} - 1\right)$

When the small open economy is indebted with the rest of world, its consolidated intertemporal budget constraint states that the value of debt obligations must equal the expected discounted value of trade surpluses. If A denotes the total amount of risk-free debt and A^f, A^h that in hands of foreigners and domestic agents, respectively, and the same convention applies to government debt B, net foreign inflows are given by

$$\mathtt{NFI}_t = \underbrace{q_t^h A_{t+1}^f + q_t^g\left(B_t'^f - (1-\rho)B_t^f\right)}_{Capital\ inflows} - \underbrace{\left(\kappa B_t^f + A_t^f\right)}_{Capital\ outflows} \tag{10}$$

where resources flow into the small open economy when domestic agents borrow from foreigners and when foreigners purchase government debt. On the other hand, resources flow out when the government makes coupon payments to foreigners and when domestic agents repay their debts or save.

Because the distribution λ does not distinguish holdings of both assets separately, neither A_t nor its components are a function of the state variables $\mathbf{S}_t$. However, some manipulation allows to recast (10) in terms of flows as

$$\begin{aligned}\mathtt{NFI}_t &= q^g_t B'^f_t - \left(A^f_t + (\kappa + (1-\rho)q^g_t)B^f_t\right) + q^h_t A^f_{t+1} \\ &= \int \left(\omega - q^h_t \varphi_a - q^g_t \varphi_b\right) d\lambda_t - \kappa B_t + q^g_t(B'_t - (1-\rho)B_t)\end{aligned}$$

where government debt held by foreigners equals $B'^f_t = B'_t - \int \varphi_b d\lambda_t$, private debt held by foreigners equals $A^f_{t+1} = -\int \varphi_a d\lambda_t$, and $\int \omega d\lambda_t = A^h_t + (\kappa + (1-\rho)q^g_t)B^h_t$.

Finally, market clearing requires that

$$Y_{Nt} = C_{Nt} + \frac{\vartheta_N}{p_{Nt}} G_t \qquad \text{and} \qquad Y_{Tt} + \mathtt{NFI}_t = C_{Tt} + (1-\vartheta_N)G_t \tag{11}$$

as net foreign inflows must equal the trade deficit.

4.8 *Evolution of the distribution*

Before defining the equilibrium, I discuss the assumptions that allow me to solve the model parsimoniously. The state vector $\mathbf{S}$ contains the distribution of agents across their idiosyncratic states, which is an infinitely-dimensional object. As is usual in heterogeneous-agents models, I solve for a bounded rationality equilibrium where agents only have limited knowledge of the distribution λ.

Specifically, I assume that agents believe the distribution of wealth to be lognormal with

$$\omega_t \sim \log \mathcal{N}(\mu_t, \sigma_t) \tag{12}$$

This assumption allows me to summarize λ_t with (μ_t, σ_t). As for the law of motion of the distribution, the household's policy functions need not imply that λ_{t+1} is exactly lognormal even if λ_t is. This is the key place where the approximation is taken, as I compute laws of motion for the distribution parameters, effectively projecting λ_{t+1} onto the (two-dimensional) space of lognormal distributions.

Given all functions of the state (including the households' policy functions) and the current distribution, substituting λ_t for the corresponding lognormal in (13) yields a system for the joint evolution of the parameters of the distribution as well as the price of debt (which depends on the future distribution through the government's default incentives)

$$\begin{cases} R_b(\mathbf{S}_{t+1}) & = & 1_{(\zeta_{t+1}=1)}\kappa + (1-\rho)q^g(\mathbf{S}_{t+1}) \\ \int \omega d\lambda_{t+1} & = & \int \varphi_a(\mathbf{s}_t, \mathbf{S}_t) + R_b(\mathbf{S}_{t+1})\varphi_b(\mathbf{s}_t, \mathbf{S}_t) d\lambda_t \\ \int \omega^2 d\lambda_{t+1} & = & \int \left[\varphi_a(\mathbf{s}_t, \mathbf{S}_t) + R_b(\mathbf{S}_{t+1})\varphi_b(\mathbf{s}_t, \mathbf{S}_t)\right]^2 d\lambda_t \end{cases} \tag{13}$$

These approximations allow me to solve for the equilibrium of the model without the usual simulation step. Instead, I check in simulation that the agents' forecasting rule accurately predicts the dynamics of relevant variables. Appendix B.3 discusses the accuracy of this procedure.

5. Equilibrium

Definition. *Given government policies $h'(S, \xi', z')$, $B'(S)$, and $g(S)$, a* competitive equilibrium *consists of value and policy functions $\{v, \varphi_a, \varphi_b, \varphi_c\}(\boldsymbol{s}, \boldsymbol{S})$, aggregates $L_T(\boldsymbol{S})$, $L_N(\boldsymbol{S})$, $\Pi(\boldsymbol{S})$, $Y_N(\boldsymbol{S})$, $Y_T(\boldsymbol{S})$, prices $p_C(\boldsymbol{S})$, $p_N(\boldsymbol{S})$, $w(\boldsymbol{S})$, $q^g(\boldsymbol{S})$, taxes $T(\boldsymbol{S})$ and laws of motion for the distribution parameters $\{\mu', \sigma'\}(\boldsymbol{S}, \xi', z', \zeta')$ such that*

- *The policy functions solve the household's problem (4) given prices, aggregates, and the law of motion for the distribution.*
- *The price of nontraded goods $p_N(\boldsymbol{S})$ satisfies the household's first-order condition (5).*
- *Labor demands $L_T(\boldsymbol{S}), L_N(\boldsymbol{S})$ maximize firms' profits given prices $w(\boldsymbol{S})$, $p_N(\boldsymbol{S})$ and the quantities produced $Y_N(\boldsymbol{S})$, $Y_T(\boldsymbol{S})$ satisfy the production functions (6, 7).*
- *The lump-sum taxes $T(\boldsymbol{S})$ satisfy the government's budget constraint (8).*
- *The debt price $q^g(\boldsymbol{S})$ satisfies the no-arbitrage condition (9).*
- *Market clearing in traded and nontraded goods (11) and in labor: either $w(\boldsymbol{S}) = \bar{w}$ or $L_T(\boldsymbol{S}) + L_N(\boldsymbol{S}) = \int \epsilon d\lambda_S$.*
- *The laws of motion for the distribution parameters satisfy the consistency requirement (13).*

5.1 The government's strategy

The government's objective is to maximize current welfare in the economy. I assume that it places equal weights on every agent. In each state and without commitment, the government maximizes

$$\mathcal{W}(\mathbf{S}, h') = \int v(\mathbf{s}, \mathbf{S}) d\lambda_{\mathbf{S}}(\mathbf{s}) + 1_{(\zeta=1)} \left(\mu_g + \sigma_g \xi^{def}\right) \tag{14}$$

where $\xi^{def} \overset{iid}{\sim} \mathcal{N}(0,1)$ is a preference shock that serves the numerical purpose of smoothing the default policy. The mean of the shock μ_g helps me discipline the average default frequency in the model as, in contrast to standard models of sovereign default, here the discount factor and the risk aversion parameter are tied to moments of the private wealth distribution. The government is subject to equilibrium conditions and its budget constraint, where the notation $\lambda_{\mathbf{S}}$ emphasizes that the distribution is a part of the aggregate state $\mathbf{S}$. Importantly, the value function and the distribution correspond to the competitive equilibrium that results under the policy h'.

Definition. *A policy h' for repayment is a part of an* equilibrium *if, at each $(\boldsymbol{S}, z')$, the probability of repayment satisfies*

$$h'(\boldsymbol{S}, z') = \mathbb{P}\left(\mu_g + \sigma_g\, \xi^{def} \leq \underbrace{\mathcal{W}\left(\Psi(\boldsymbol{S}, \xi', z', \zeta' = 1), h'\right)}_{\text{value under repayment}} - \underbrace{\mathcal{W}\left(\Psi(\boldsymbol{S}, \xi', z', \zeta' \neq 1, h')\right)}_{\text{value under default}}\right) \tag{15}$$

where $\Psi(\boldsymbol{S}, \xi', z', \zeta') = \boldsymbol{S}'$ is the state that ensues when (ξ', z') are realized after $\mathbf{S}$ and the government chooses a default state ζ'.

After observing the realization of ξ' and z', the government understands which state $\mathbf{S}'$ results if it decides to default or to repay. This includes the level of debt remaining to be paid as well as the distribution induced in each case.

Condition (15) is a rational-expectations restriction: the policy that households, foreigners, and the current government expect of future governments, h', must coincide with the policy that the government would choose if allowed a deviation that did not alter future expectations. In other words, condition (15) insists that the policy h' be part of a Nash equilibrium. The restriction that all policies depend only on the current state $\mathbf{S}$ (and not on the whole history of play) further refines the solution concept to that of recursive equilibrium.

Appendix A describes the computation of a solution in detail.

5.2 *Euler equations and coupon payments*

The Euler equation (16) determines a household's purchases of government bonds:

$$q^g(\mathbf{S}) \geq \beta\mathbb{E}\left[\underbrace{R_b(\mathbf{S},\mathbf{S}')\frac{p_C(\mathbf{S})}{p_C(\mathbf{S}')}}_{\text{real repayment}}\underbrace{\underbrace{\left(\frac{\varphi_c(\omega',\epsilon',\mathbf{S}')}{\varphi_c(\omega,\epsilon,\mathbf{S})}\right)^{-\frac{1}{\psi}}}_{\text{Intertemp. subs.}}\underbrace{\left(\frac{v(\omega',\epsilon',\mathbf{S}')}{\mathbb{E}\left[v(\omega',\epsilon',\mathbf{S}')^{1-\gamma}\mid\mathbf{S}\right]^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma}}_{\text{Risk aversion}}}_{\text{Stochastic discount factor}}\;\middle|\;\mathbf{S}\right] \tag{16}$$

with equality if the household is purchasing a positive amount of bonds. It is also clear from (16) that $\gamma = 1/\psi$ recovers the standard case of expected CRRA utility. I employ an Epstein-Zin formulation as the main mechanism in the paper essentially stems from an asset-pricing effect (namely, the correlation between the repayment of different assets and the stochastic discount factor), which makes risk-sensitive preferences yielding realistic asset pricing implications a natural choice.

Being risk-averse, the household demands a risk premium to expose itself to the risk of the government. The shock ξ plays the role of creating such a risk premium in the return of the government bond when compared to the return of the risk-free asset. This allows the model to match the high proportion of sovereign debt held by domestic agents in the data on average. The dynamics of debt holdings, however, are determined endogenously.

5.3 *The household's reaction to sovereign risk*

There are at least three main ways in which sovereign risk affects the household's problem (4). The first effect concerns the aggregate income losses that happen in case of default. Conditional on default, TFP drops by Δ in both sectors for some time, which puts downward pressure on the market-clearing wage. If the constraint binds, unemployment increases. In either case, other things equal labor income $w(\mathbf{S})L(\mathbf{S})\epsilon$ is lower in default than in repayment. In states with a higher default probability, the household consequently feels poorer and reduces consumption.

Figure 5 shows expected labor income (integrating out heterogeneity in ϵ) as a function of next period's TFP for default and repayment. Various panels condition on current levels of debt and the risk-premium shock ξ. Labor income is clearly increasing in TFP and higher in repayment than in default. The effect of government debt on labor income in default is small, but large in repayment: higher debt means a higher default probability, hence lower aggregate demand and downward pressure on wages. In the end, when debt is very large, income can become almost unaffected by current default status.

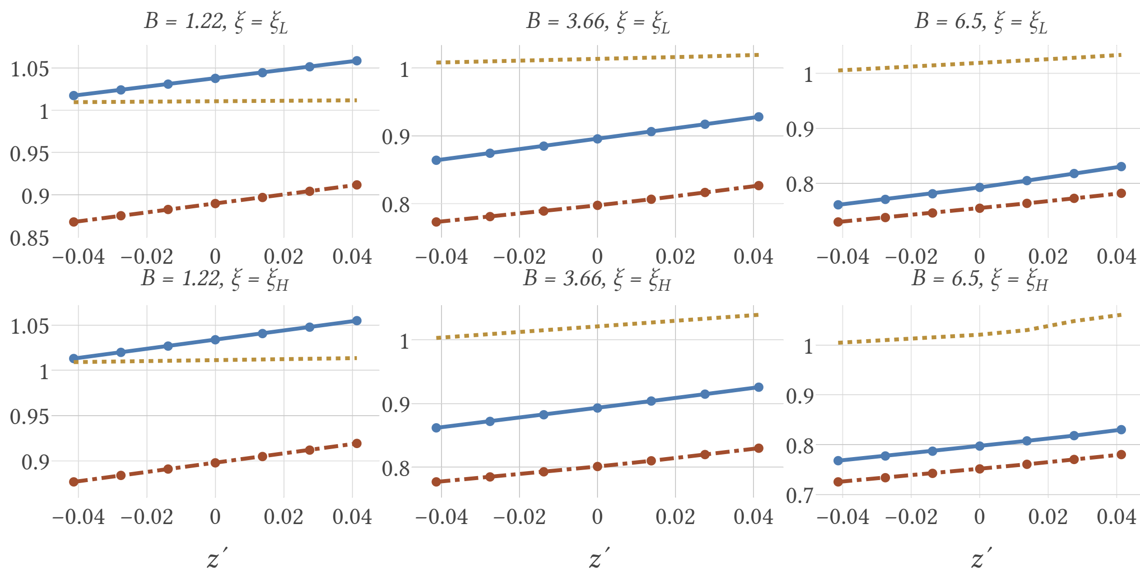

FIGURE 5: LABOR INCOME AND EXPECTED RETURNS

Note: Blue lines plot income in repayment, red dashed lines plot income in default, orange dotted lines plot the return of holding government debt

A second effect goes through the price of government bonds. $q^g(\mathbf{S})$ reflects the default probability and shocks that make it increase also decrease the resale value of bonds. Households who purchased these bonds in the past make an inmediate capital loss when q^g drops. In the aggregate, a distributional effect shifts the wealth distribution to the left when the default probability increases. The strength of this channel depends critically on the proportion of bonds held by domestic agents, as well as in the level of inequality in domestic bondholdings. On the other hand, it is useful to keep in mind that, if the default probability is positive but the government does not default, holders of debt make excess returns on their portfolios, which shifts the wealth distribution to the right.

Finally, the household cares about the insurance properties of government debt. Sovereign risk makes those very different in normal times and in crisis times. Recall the return of a government bond

$$R_b(\mathbf{S}, \mathbf{S}') = 1_{(\zeta'=1)}\kappa + (1-\rho)\left(1 - \hbar 1_{(\zeta=1)\cap(\zeta'\neq 1)}\right) q^g(\mathbf{S}')$$

In normal times, the variance of R_b is relatively low. Its variation comes mostly from variation in the future resale price $q^g(\mathbf{S}')$. However, as the default probability increases, more and more of the variance of R_b becomes driven by variation in the repayment probability. Moreover, repayment correlates with aggregate income as the government's incentives to default are stronger in bad times. Hence, the conditional covariance between the bond return and the stochastic discount factor of households tends to be larger in crises. This feature makes the bond a bad hedge always but an even worse one when spreads are high. In the aggregate, this ceteris-paribus force continuously battles distributional forces, as debt holdings are positively associated with wealth.

Figure 5 shows realized bond returns in addition to labor income. The variance of returns, as well as its covariance with income, increases when default becomes more *uncertain*. When default is very unlikely (left panels) or very likely (right panels), next period's shocks do not influence the default probability (and hence the return on holding the debt) very much. When debt is intermediate, holding it bears a volatile return which also comoves positively with income.

Appendix B.1 shows how these effects translate into who fears sovereign default more.

6. Calibration

6.1 *Fiscal rules*

I estimate fiscal rules for government spending and issuances of new debt, using quarterly data for Spain. Data are taken from Eurostat and cover the period 1999Q1 to 2017Q4. In the model, government consumption and net issuances as fractions of GDP depend on the whole state vector, so in the data I regress those against endogenous variables. Table 2 summarizes the results. For each dependent variable, the first column contains the preferred specification. The second one reports a simpler version of the same regression.

The fit for both government consumption and debt issuances is good, with adjusted R^2s at 90%

TABLE 2: ESTIMATED FISCAL RULES

	G_t/Y_t		$(B'_t - (1-\rho)B_t)/Y_t$	
	(1)	(2)	(3)	(4)
Constant	13.194	14.352	2.680	1.027
	(1.350)	(0.982)	(3.087)	(1.407)
Unemployment_t	1.078	0.330	0.410	0.286
	(0.086)	(0.028)	(0.197)	(0.042)
Unemployment_t^2	-0.020		-0.003	
	(0.002)		(0.005)	
B_t/Y_t	-0.187	-0.021	-0.099	-0.020
	(0.028)	(0.010)	(0.063)	(0.015)
$(B_t/Y_t)^2$	0.001		0.001	
	(0.000)		(0.000)	
Net Exports_t	-0.309	-0.167	0.233	0.212
	(0.070)	(0.096)	(0.162)	(0.138)
Observations	72	72	71	71
R^2	0.916	0.776	0.814	0.808

Standard errors in parentheses.

and 80%, respectively. Fiscal policy is countercyclical, with positive responses to unemployment for both spending and issuances. New issuances respond negatively to the debt-to-GDP ratio, consistent with debt stabilization. Figure 19 in the Appendix shows the fitted values for Spain from the preferred specification. The predicted rules track the observed series closely.

6.2 *Model parameters*

The current calibration of the model is able to generate a good match to some standard targets in the literature. Table 3 reports some critical parameter values. Because of the numerical complexity of the model, I rely on external calibration as much as possible. For the supply side of the economy, I closely follow Anzoategui (2020) and Stockman and Tesar (1995) and set preference parameters ϖ and ϑ_N to match the shares of traded and nontraded goods in both private and public consumption, as well as the elasticity η to the elasticity of relative consumption demand.

Table 3: Parameter Values

Description	Parameter	Value	Source / Target
	Debts and defaults		
Risk-free rate	$r^\star$	4% ann.	Anzoategui (2020)
Haircut in case of default	$\hbar$	45%	Philippon and Roldán (2018)
TFP loss in case of default	Δ	10%	Philippon and Roldán (2018)
Reentry probability	θ	0.04167	Cruces and Trebesch (2013)
	Traded and nontraded goods		
Share of N in production	ϖ	0.7397	Anzoategui (2020)
Labor share in production	α_N, α_T	0.67	Anzoategui (2020)
Share of N in G	ϑ_N	88%	Anzoategui (2020)
Elasticity of substitution	η	0.74	Anzoategui (2020)
	Idiosyncratic income and preferences		
Persistence log ϵ_{it}	ρ_ϵ	0.978	D'Erasmo and Mendoza (2016)
Std. deviation log ϵ_{it}	σ_ϵ	0.022	D'Erasmo and Mendoza (2016)
EIS	ψ	1	Standard
	Internally calibrated		
Discount rate of HHs	$1/\beta - 1$	5.31% ann.	Moments in Table 4
Risk aversion	γ	2.9	Moments in Table 4
Progressivity of tax schedule	τ	31%	Moments in Table 4
Wage minimum	$\bar{w}$	1.178	Moments in Table 4
TFP process	ρ_z, σ_z	(0.63, 0.0107)	Moments in Table 4
Mean risk premium	$\bar{\xi}$	0.025%	Moments in Table 4
Risk premium AR(1)	ρ_ξ, σ_ξ	(0.95, 0.0001)	Moments in Table 4
Mean utility cost of default	μ_g	0.0124	Moments in Table 4

The risk-free interest rate is set at a standard value in the literature. For the costs of default, I follow Philippon and Roldán (2018) and set the haircut $\hbar$ and conditional TFP losses Δ to a Greek-style default. The probability of reentry is set to give an expected duration of default of 25 quarters, on the lower end of the Cruces and Trebesch (2013) estimation for large haircuts.

As for the household idiosyncratic income shocks process, I follow the estimation of D'Erasmo and Mendoza (2016) based on the Spanish cross-sectional income distribution for the same period that I study.

Table 4 provides details on the fit of the model. Statistics in the Model column are computed by averaging 500 simulations of 200 years each (with a 400-year burn-in). The fit of the model is generally good. The Spanish sample has one crisis for 17 years of data, which is plausibly higher than the ergodic frequency. For this reason, in the calibration I informally target lower levels of unemployment and debt-to-GDP. One shortcoming is that the Gini coefficient does fall short of its empirical counterpart. While I opted for simplicity, enriching the taxation scheme could help match this target.

7. Analysis

7.1 Government policy

Figure 6 shows the government's value function $\mathcal{W}(\Psi(\mathbf{S}, \xi', z', \zeta'), h')$ of the following period as function of the realization of shocks. Each panel shows welfare as a function of next period's TFP realization z'. The first row corresponds to a low realization of ξ', while in the second row the risk premium is high. Finally, the columns consider different $\mathbf{S}$ for the *current* period: initial debt increases from left to right. Higher debt levels decrease the value of repayment relative to default. For intermediate amounts of initial debt, moreover, a higher realization of future TFP raises the relative value of repayment. Higher spreads also marginally raise the relative value of default.

Figure 7 shows the price of debt $q^g(\mathbf{S})$ at different states $\mathbf{S}$. The left panel shows that spreads rise (the price of debt falls) with the stock of debt and decrease with productivity. The right panel shows the impact of the distribution (for fixed values of B and z when the economy is not in

Table 4: Model Fit

Target	Model	Data
AR(1) autocorr. coef $\log(Y_t)$	0.941	0.966
AR(1) std coef $\log(Y_t)$	0.853%	0.617%
AR(1) autocorr. coef $\log(C_t)$	0.961	0.954
AR(1) std coef $\log(C_t)$	0.967%	1.22%
AR(1) autocorr. coef spread	0.968	0.967
AR(1) std coef spread	31.7	30.1
Avg Debt-to-GDP	58.1%	64.6%
Std Debt-to-GDP	10.1%	23.5%
Avg unemployment	14.3%	15.9%
Std unemployment	2.73%	6.09%
Median domestic holdings	48.9%	56.5%
Avg wealth-to-GDP	93.3%	94.5%
Avg wealth Gini	48.9%	57.5%

Source: All data from Eurostat 2000Q1:2017Q4, except Gini index from Eurostat 2010, private consumption from OECD 2000Q1:2017Q4, domestic holdings from Banco de España, 2004Q1:2017Q4

default). Higher spreads occur when the economy is poorer and more unequal. This is because the value of autarky depends strongly on how rich the economy is: with lower aggregate wealth, more agents are close to their borrowing limit and would suffer from the loss in TFP (and hence wages and employment) that follows a default. The effect of variance goes through the value of repayment: when inequality is greater, the increase in lump-sum taxes required to repay becomes more regressive and hence even less desirable. Defaults avoid this redistribution.

The unemployment rate is shown in Figure 8. Unemployment decreases with productivity and increases with government debt. The right panel shows that unemployment is related negatively to total wealth and positively to inequality.

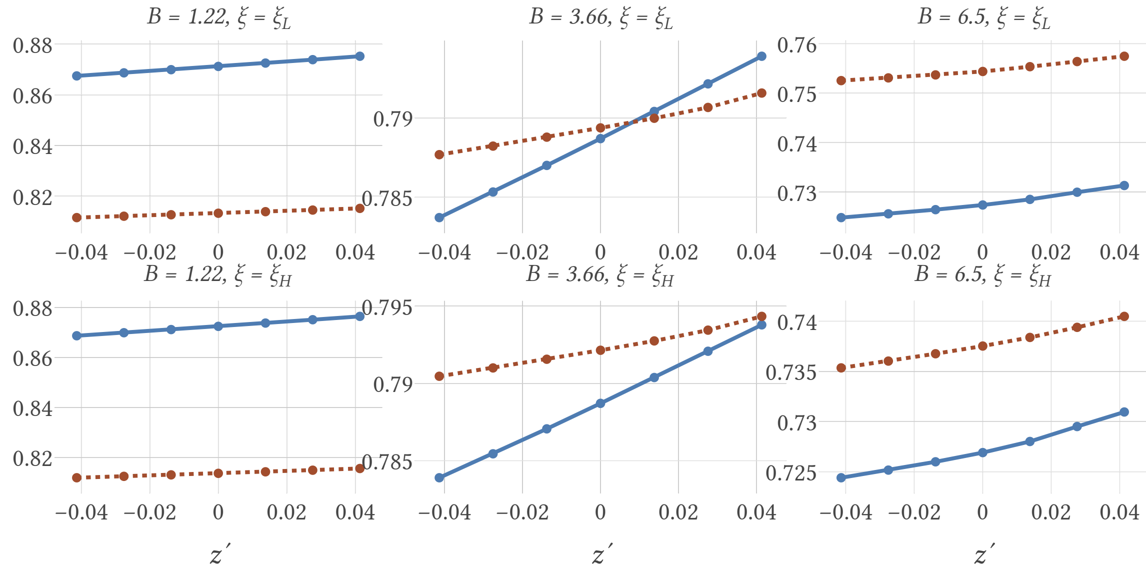

Figure 6: Welfare Functions

Note: Blue lines plot the value of repayment, red dashed lines plot the value of default

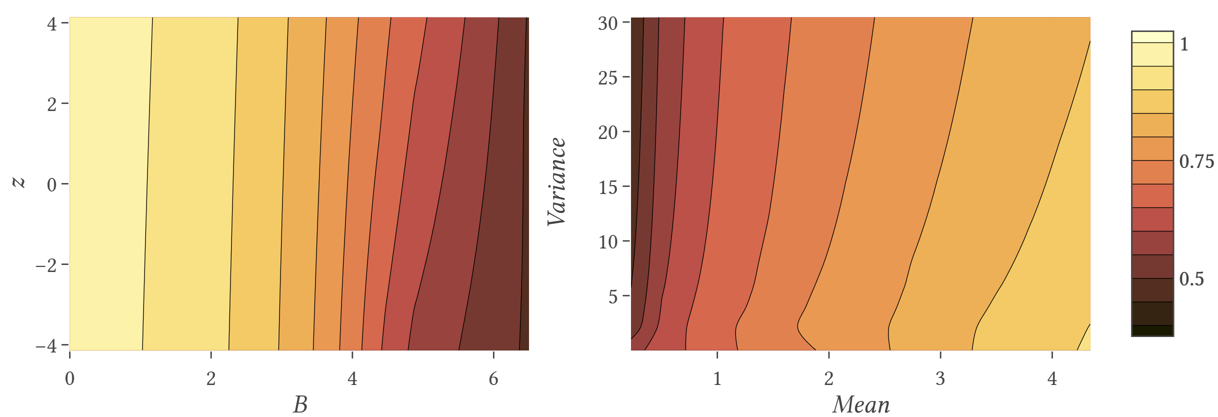

Figure 7: Price of Debt

7.2 The impact of default risk

Table 5 shows statistics from simulation of the both models. It illustrates how sovereign risk affects the economy even in normal times. The volatilities of output and consumption are 40% and 57% lower without the possibility of default. Spreads are obviously absent from the no-default simulation (they are only positive because of the ξ shock to risk premia). Unemployment

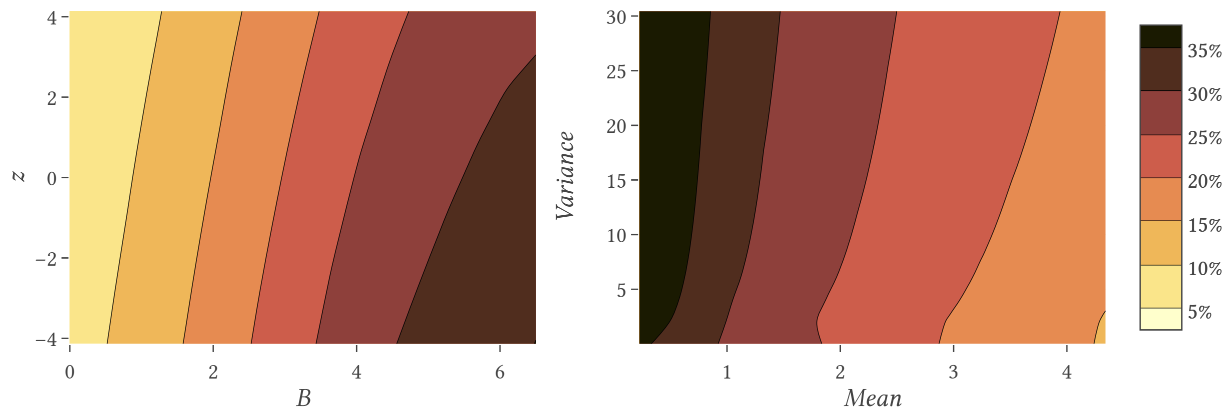

Figure 8: Unemployment

and government debt are both lower in the economy without default. Because the economy is less risky overall, the scope for precautionary savings is lower, which results in a lower private wealth-to-GDP ratio and a decrease in the Gini coefficient as wealth becomes more correlated with current income. As a result of these differences, the average household attains a value in the world without default which is equivalent to an increase of 4.2% in permanent consumption in the benchmark economy.

The results shown above quantify the impact of default risk on the economy while keeping fixed the distributional assumptions (given by estimated stochastic process for idiosyncratic risk ε) as well as the equilibrium features induced by (i) the portfolio problem faced by households and (ii) the anticipation of TFP costs. It would be natural to attempt to remove these features from the model to assess how much they interact with sovereign risk. However, removing either one of them results in dramatic changes in the equilibrium, well beyond the intended scope.

In the first case, removing the idiosyncratic shock takes away much of the normal-times precautionary motives of households, resulting in much lower levels of wealth, which in turn incentivize the government to default too often. This is true both when the government's default policy is reoptimized and when it is not. In the second case, removing households' access to government bonds once again greatly reduces the government's costs of default. Finally, removing the TFP costs of default (by setting $\Delta = 0$), with or without reoptimizing the government's policy, results in much larger levels of wealth (as well as holdings of government debt, which are now a much

Table 5: Models

Moment	Benchmark	No default
AR(1) autocorr. coef $\log(Y_t)$	0.941	0.773
AR(1) std coef $\log(Y_t)$	0.853%	0.514%
AR(1) autocorr. coef $\log(C_t)$	0.961	0.875
AR(1) std coef $\log(C_t)$	0.967%	0.419%
AR(1) autocorr. coef spread	0.968	0.87
AR(1) std coef spread	31.7	0.0537
Avg Debt-to-GDP	58.1%	43.3%
Std Debt-to-GDP	10.1%	1.47%
Avg unemployment	14.3%	9.57%
Std unemployment	2.73%	0.748%
Median dom holdings	48.9%	235%
Avg wealth-to-GDP	93.3%	94.4%
Avg wealth Gini	48.9%	47.8%
Default frequency	1.36%	0%
Welfare in repayment	0.891	0.928

better hedge as the correlation between default and individual income is much lower) which tend to make the government default much less. While quantifying the uncondicional effect of heterogeneity is challenging, I discuss the effect of the distribution on crisis events themselves in Section 8.1.

Finally, Table 6 summarizes the welfare gains of eliminating sovereign risk for different quantiles of the distribution, averaging over all time periods. The first two columns report the average of the welfare function for each percentile of the wealth distribution in the benchmark and no-default models, while the last column shows the welfare gains of moving from the benchmark to the no-default models keeping constant the position in the wealth distribution. Welfare gains decline with wealth and range between 4% and 4.3% of permanent consumption.

Table 6: The Welfare Costs of Sovereign Risk

Moment	Benchmark	No default	Gains
$p10$	0.821	0.856	4.29%
$p25$	0.847	0.883	4.27%
$p50$	0.887	0.925	4.24%
$p75$	0.93	0.969	4.18%
$p90$	0.967	1.01	4.04%
Average	0.891	0.928	4.2%

8. Crises

Using the simulated series, I focus on episodes of crisis. I define an episode of high spreads as a period of 11 quarters (to match the Spanish experience of 2010-late 2012) at the end of which the spread surpasses 400bps but a default does not happen. Even though it matches the spread volatility, an average crisis in the model does not feature such sharp accelerations of the spread as the 2010 crisis. For this reason, I further condition on lower spreads at the start of the episode, subject to keeping a reasonable number of episodes in the sample.

Figure 9 plots endogenous variables around episodes of high spreads, projecting about a year into the past for context. Time is shown in years (this means that the crisis episode starts around -2 in the charts). TFP, output, and consumption are significantly below their normal-times values. The government's finances deteriorate and lump-sum taxes increase. Furthermore, as unemployment increases tax collections worsen. A high propensity to save pushes up the mean of the wealth distribution while the Gini coefficient falls by about a point right before the crisis but picks up marginally during it. This is counterfactual as inequality went up in Spain between 2010 and 2014 (although it may an artifact of the right-skewed distribution for the Gini at the start of the episodes). Output hits a minimum of about 6% below its long-run mean, while TFP varies between 0.5% and -1% at the trough of the episode. Consumption also drops significantly below its long-run mean by about 7%. These numbers for the recession roughly match their data counterparts of 6% and 9%, respectively.

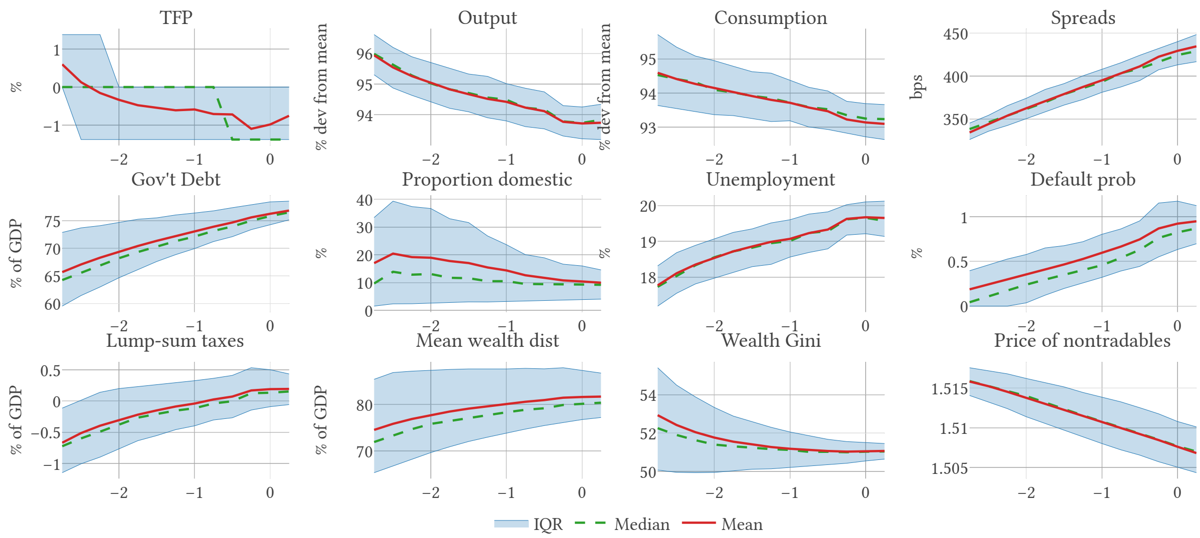

FIGURE 9: TIMES OF HIGH SPREADS

Figure 9 shows some of the dynamics at play. In the buildup to the crisis consumption falls both in levels and as a fraction of a measure of disposable income. There is also a significant fiscal contraction: a sustained increase in taxes along with a slight fall in government spending (not pictured). Government spending is the result of two forces: in the fiscal rule, the government spends more when unemployment increases but also has the stabilize the level of debt. The level of government debt accumulates rapidly during the crisis as a consequence of high spreads. Consistent with findings in Bianchi and Mondragon (2021), the price of nontraded goods falls but does not to depreciate the real exchange rate enough to boost aggregate demand back to its normal level.

8.1 *Amplification forces*

I now consider the benchmark economy and its episodes of high spreads and compare it with an alternate economy in which the government follows a policy of always repaying the debt.

Figure 10 presents a comparison between the times in which the benchmark economy is in crisis and the same time periods of a simulation of the no-default economy (with the same shocks).

Figure 10: Crises

Note: Interquartile ranges shaded

I show output, consumption, and government debt as percent deviations from their initial levels. The contractions in output and consumption are muted in the no-default economy. Because the no-default economy has a higher average propensity to consume (shown in levels), aggregate demand is at its normal level, meaning that output and consumption only fall because of the underlying shock to TFP. Moreover, in the benchmark economy the dynamics (as well as the higher level) of spreads induce an acceleration of the debt-to-GDP ratio. All in all, the no-default economy suffers an output and consumption contraction of between a half and a third relative to the benchmark. In this sense, sovereign risk explains about 60% of the recession.

Fiscal policy also differs across both models. The benchmark economy is forced to a larger increase in lump-sum transfers, while the no-default economy can keep a fiscal policy stance closer to neutral.

The differences in welfare are substantial. The specification of preferences is such that the value function equals the level of permanent consumption (a constant amount which would yield the same utility). At the height of a crisis, the average household would give up the equivalent of as much as 9.8% of consumption to be able to move to the economy with no default.

Comparing the benchmark economy with the version where default is not possible, crisis events are associated sharper contractions in output and especially in consumption. These events are also associated with an acceleration of debt as the price of debt deteriorates. Unemployment also diverges during crises, as the government is forced to implement what looks like a fiscal adjustment, by increasing lump-sum taxes and cutting on government spending.

8.2 *Amplification and inequality*

Figure 11 provides more details into the distributional aspect of the events studied so far. The left panel plots consumption by each percentile of the wealth distribution (as well as the average). The right panel shows the value attained by households at those quantiles, both as shares of their values at the start of the episode.

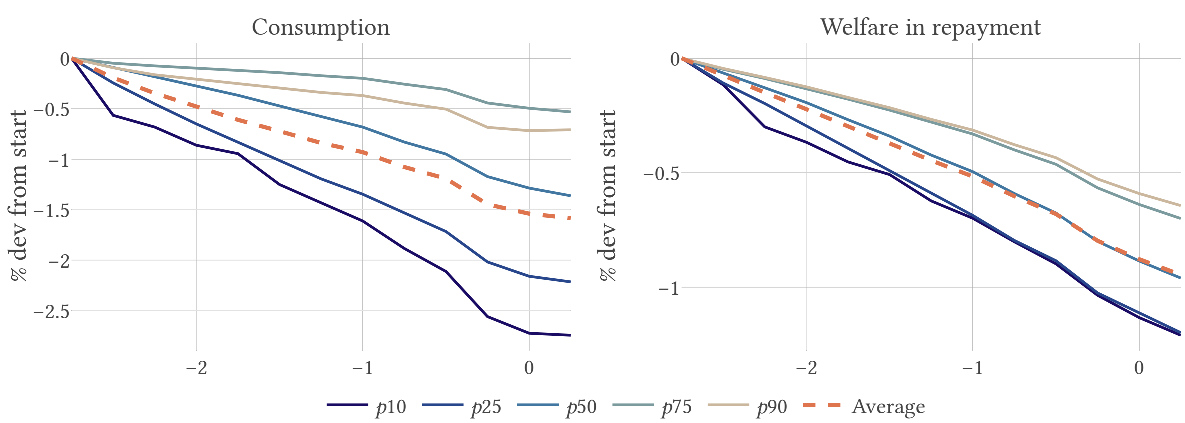

Figure 11: Crises across the Distribution

The left panel shows that consumption inequality increases during crises as poorer agents cut consumption by more. At the same time, crises also affect the dispersion in values (which coincide with the level of permanent consumption to which the household is indifferent). These events are about twice as costly for the bottom 25% of the distribution as they are for the top 25%.

Figure 12 sheds some light on the question of how much does inequality matter for the amplification mechanism I study. It does so by comparing aggregate consumption (marked 'Average') with the consumption of an agent at the median level of wealth (marked '$p50$'). The median household approximates the impulse that would be captured by a representative-agent version of the same model, while avoiding all the general-equilibrium differences discussed above.

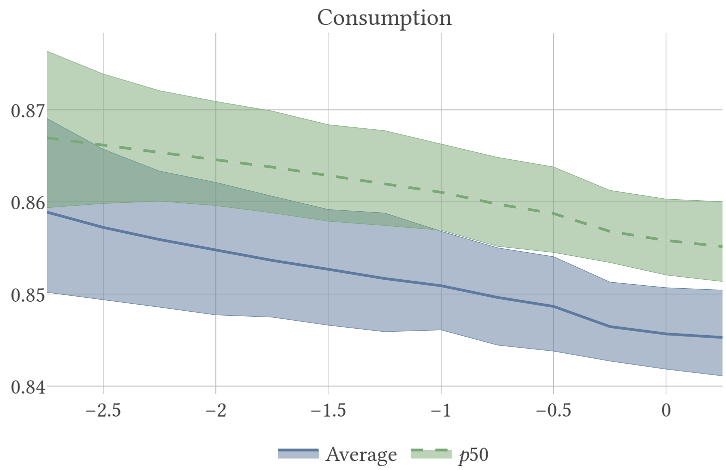

Figure 12: Distributional Amplification

Note: Interquartile ranges shaded

While aggregate consumption falls by 1.54% during the crisis, the median household is only cutting its consumption by 1.29% in the same periods, which suggests that heterogeneity is responsible for about 20% of the consumption response.

8.3 *A default-risk IRF*

The comparison between crisis episodes in the benchmark and no-default models ignores that average debt levels and the wealth distribution are different in both models. It also does not map directly to the Spanish experience in the crisis. For this reason, I consider the following experiment to complement the results above.

As an approximation, suppose that Spain did not face any default risk before the crisis. As shown in Figure 1, Spanish spreads were consistently below 100bps before 2010 (and basically zero before 2008). Suppose that after the Greek crisis in early 2010, Spain switched to an equilibrium where default was suddenly regarded as possible (the benchmark economy) and that, after Mario Draghi's famous "whatever it takes" speech, the economy reverted to the no-default equilibrium in late 2012 (Figure 1 reveals that spreads came down after 2012, although they slowly converged to a level around 100bps).

Motivated by this approximation, I consider the following impulse-response exercise. I simulate the no-default economy for 100 years to obtain a draw from its ergodic distribution. I then set the debt level to about 65% of average GDP (the observed level for 2012) and, after one quarter, unexpectedly switch the economy to its benchmark equilibrium with endogenous default risk. I simulate the economy forward for 11 quarters and then revert it back to the no-default case. I repeat this experiment 5000 times and keep the paths under which default did not materialize. To match the Spanish experience in the crisis, I further condition on paths that saw an output contraction of at least 5.26% (targeting an average output contraction of 6% in line with the data).

Figure 13 shows the distribution of outcomes, compared with a simulation where default risk is never activated (but the same shocks are realized). This comparison captures two effects: the direct effect of aggregate demand and the fact that the government engages in a quick deleveraging when borrowing costs are low. For this reason, I add a third comparison point: a simulation of the economy without default risk but that uses the same debt issuances as the benchmark one.

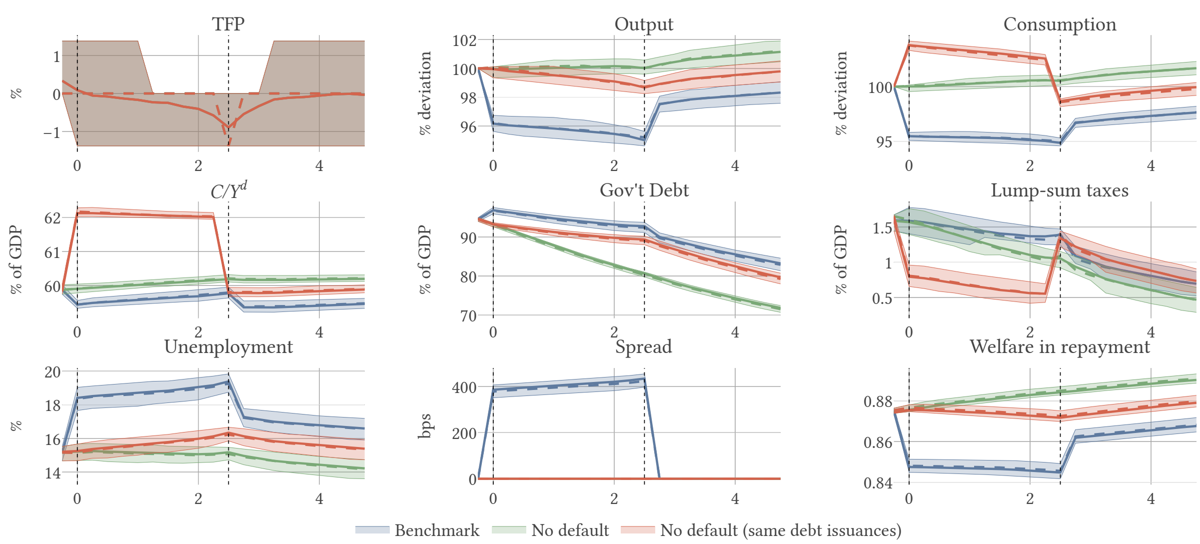

FIGURE 13: DEFAULT-RISK IRF

Note: Vertical dashed lines indicate switch from no-default to bencharK economy and viceversa

The no-default economies act as counterfactuals for Spain if expectations of default risk had not been triggered. The green line (labeled No default) is a pure counterfactual, while the orange line, which keeps debt issuances as in the benchmark, reflects how much of the crisis is explained by default risk. It implies that output would have fallen by 2.12% in the absence of default risk, leaving default risk to account for about 65% of the recession.

The last panel provides an estimate of the value of negating default risk in the crisis. The average household (or the government) would have given up 3.36% (red minus blue at time 0) of permanent consumption to make defaults impossible. A similar calculation (blue in the first period after the crisis minus blue in the last period of the crisis) places the value of the 'Whatever it takes' speech at 2.13% of permanent consumption from the last period of the crisis forward, or 1.76% on a time-0 basis. Lastly, the loss from spending 11 quarters with default risk can be computed in the following simple way: the loss in period 0 is the loss from switching to the benchmark economy forever, from which we need to subtract the (discounted) gain from switching back to the no-default economy at the end of the crisis. This calculation yields a cost of sovereign risk of 1.6% of permanent consumption.

8.4 *The distributional impact of sovereign risk*

Figure 14 plots the welfare costs of sovereign risk across the wealth distribution during the same paths studied earlier. The costs from triggering sovereign risk are heterogeneous, increasing in wealth, and range from 0.83% (1.01%) for the bottom 10% (25%) of the distribution to 2.41% (2.06%) for the top 10% (25%). The median (average) household would give up 1.5% (1.6%) of permanent consumption to stay in the no-default economy.

While all measures of costs of sovereign risk have been regressive so far, in this case the welfare cost is higher for the rich. In the previous experiments, by comparing equilibria with and without sovereign risk, I allowed the wealth distribution and portfolios to change. Therefore, rich agents could adjust the level and composition of their savings to the prevailing conditions. At the bottom of the distribution, such adjustment is at least more limited in scope. This makes the welfare costs of sovereign risk regressive. In the IRF experiment, on the other hand, I do not give agents time to adjust and they have to go through the crisis with their no-default-risk portfolios.

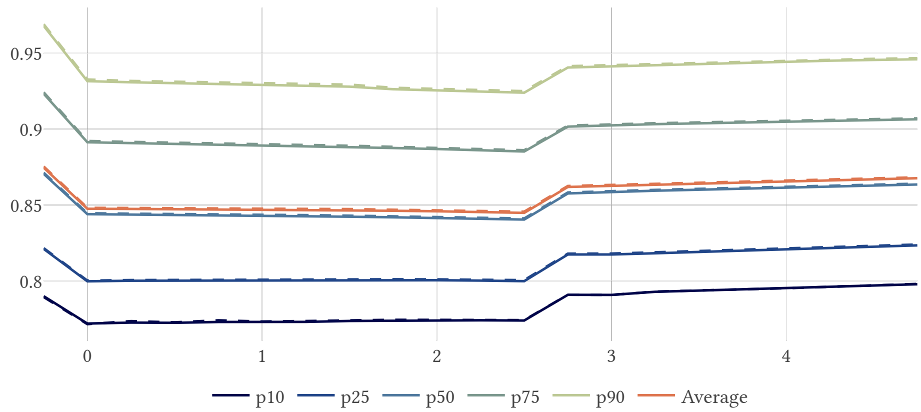

Figure 14: Value Functions in the Crisis

9. Concluding Remarks

Inspired by events in the Eurozone crisis, this paper analyzes a model in which households' consumption demand is negatively affected by the presence of sovereign risk. The mechanisms in the model generate substantial amplification of underlying shocks even if the risk of default does not materialize.

The amplification mechanism relies on the precautionary motives of households, which are magnified by sovereign risk. Sovereign risk creates endogenous shifts in demand conditions which exacerbate the equilibrium volatility of aggregate consumption. I find large and regressive welfare costs of sovereign risk, which range from about 4.2% of permanent consumption in normal times to almost 10% at the height of a crisis. The default-risk IRF exercise suggests that the average household would have given up 3.4% of consumption in order to avoid the crisis, of which about 1.8% were recovered 11 quarters later when the crisis ended.

Households increase their savings in response to sovereign risk because they anticipate income losses and redistribution in case of default. The anticipation of income losses in case of default explains most of the amplification. However, this effect interacts substantially with the anticipation of redistribution.

A common argument in policy circles during debt crises is that a lack of 'confidence' causes aggregate demand to fall. This paper addresses this argument as a rational, although inefficient, response to the evolution of fundamentals. Without commitment to future policies, the government's ex-post default incentives act during crises as large-scale increases in uncertainty (Bloom, 2009). More broadly, this type of amplification helps explain why emerging economies exhibit high volatility of consumption relative to output 'as if' they were subject to trend shocks, especially on the downside (Aguiar and Gopinath, 2007)

While I calibrate the model to Spain, the mechanism can help explain patterns in emerging-market business cycles, which also exhibit sovereign risk as a feature. Both the relative volatility of consumption to output and the volatility of output itself are typical calibration targets in the sovereign debt literature when applied to emerging-market economies. The setup presented here offers a more complete explanation of these phenomena by explicitly considering the saving behavior of private agents as well as the interest rate they face. The amplification mechanism and the welfare costs of sovereign risk are both natural consequences of this more granular description when private agents are net savers. This is the case of Spain in the 2000s but also of salient episodes in emerging markets, when the private sector's international investment position is positive even as the government is in debt.

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A. Solution method

The algorithm follows closely the definition of equilibrium: to solve for an equilibrium, I solve a series of nested problems. Given government policies, I find a competitive equilibrium by finding functions of the aggregate state that describe the aggregates in the economy, in such a way that they are consistent with the household problem and policy functions.

Given a policy for the government, I

1. Guess a law of motion for the distribution.
2. For each state $\mathbf{S}$
   (a) Compute $q^g(\mathbf{S})$ from the foreigners' sdf (9).
   (b) Guess a relative price of nontradables p_N
      - Get the wage rate w as well as total labor demand L^d and profits of the firms Π.
      - Compute lump-sum taxes T from gov't budget constraint (with τwL in hand).
      - Solve the household's problem at prices w, p_N, profits Π, and transfers T.
      - Check market clearing (11) for nontraded goods.

   (c) Iterate on the function $p_N(\mathbf{S})$ to convergence
3. Iterate on the law of motion for the distribution using the households' policy functions.

Finally, I update the government's policy according to (15) and iterate until a policy that respects it is found.

B. More model results

B.1 Who fears sovereign default? A robustness-based perspective

The household's Euler equation offers insights into how sovereign risk affects different types of households. I calibrate the model with a unitary elasticity of intertemporal substitution. With this parameterization, households act 'as if' they had logarithmic preferences combined with concerns about model misspecification (Maenhout, 2004; Hansen and Sargent, 2001; Tallarini, 2000). In this reinterpretation, the risk aversion parameter maps into a robustness parameter. I define the *subjective expectation*, taken by an agent in state $(\mathbf{s}, \mathbf{S})$, of a random variable X as

$$\tilde{\mathbb{E}}\left[X \mid \mathbf{s}, \mathbf{S}\right] = \mathbb{E}\left[\frac{v(\omega', \epsilon', \mathbf{S}')^{1-\gamma}}{\mathbb{E}\left[v(\omega', \epsilon', \mathbf{S}')^{1-\gamma} \mid \mathbf{S}\right]} X \mid \mathbf{s}, \mathbf{S}\right] \tag{17}$$

The subjective expectation twists expectations by attaching more weight to states in which the household's value function is lower. It overstates events feared by the household. Figure 15 shows the twisted probability of default for each household, computed setting X to the indicator of a default in the next period in (17). The computation is conditional on a state of crisis. Figure 15 also shows the actual probability of default for comparison. Richer and higher-income households fear default, while poorer and low-income households fear the prolongation of the crisis.

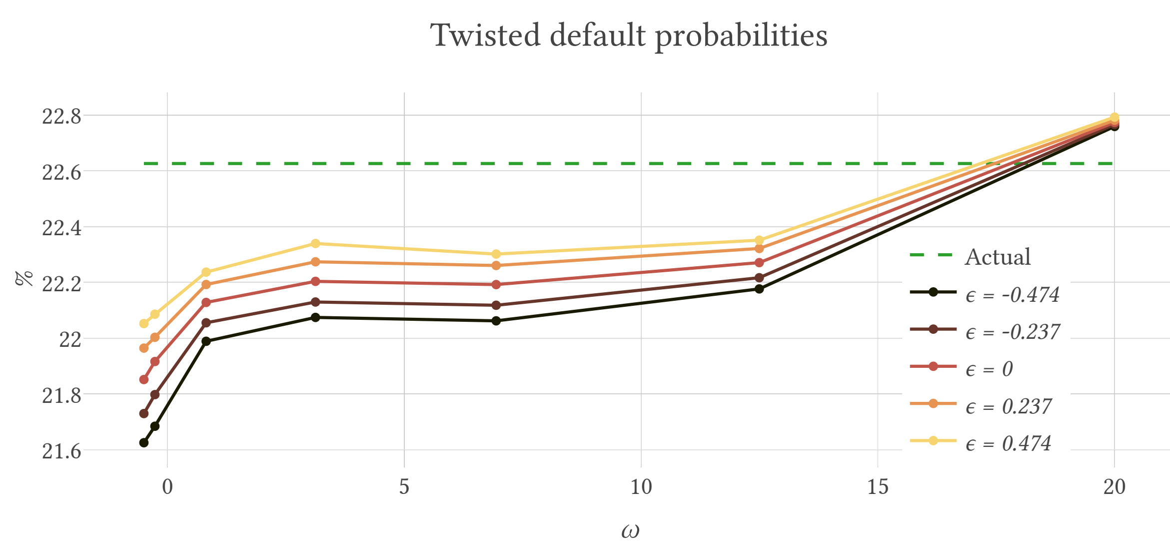


Figure 15: Subjective Probabilities of Default

B.2 Wage rigidities and aggregate demand

When sovereign risk increases, the demand for consumption is likely to fall. This feeds back to the rest of the economy mainly through the market for nontraded goods.

In the market for traded goods, firms can supply whatever quantities they produce at the international price. Therefore, for a given wage rate w_t prevailing in the economy, traded goods-producing firms observe the current level of TFP and choose employment accordingly.

The market for nontraded goods features more action, which is summarized by its supply curve. To trace it out, suppose a decrease in the relative price of nontraded goods. According to their first-order condition (18), firms respond to this decrease by cutting down production.

$$L_N^d = \left(\alpha_N \frac{p_N}{\max\{w, \bar{w}\}} \right)^{\frac{1}{1-\alpha_N}} \tag{18}$$

When firms in the nontraded sector retract their production they expell workers. This pushes down wages. In normal times, wages fall so some of these workers reallocate to the traded goods sector. At the same time, some others 'return' to work in the nontraded sector. When the constraint is binding, however, these second-round effects cannot happen: the fall in the price of nontradables results in an increase in unemployment and in a larger fall in the production of nontraded goods.

Figure 16 makes this point by showing that the supply curve is flatter when the constraint on wages is binding. This means that when demand falls, quantities fall more and prices fall less than in normal times. Wage rigidities create price stickiness.

The introduction of wage rigidities in this paper departs from the traditional approach of Schmitt-Grohé and Uribe (2016). In it, the wage in period t is constrained be no less than $\gamma_w w_{t-1}$, where $\gamma_w \leq 1$ is a parameter. I follow instead Bianchi, Ottonello and Presno (2019) and set a constant lower bound $\bar{w}$ on nominal wages. While both assumptions are similar, in this context there are some advantages to the second formulation.

The first obvious advantage is that not having to carry the previous period wage saves one state variable. But there is a second advantage: in the traditional formulation good TFP shocks can be welfare-decreasing if they push the current wage rate too high and generate future un-

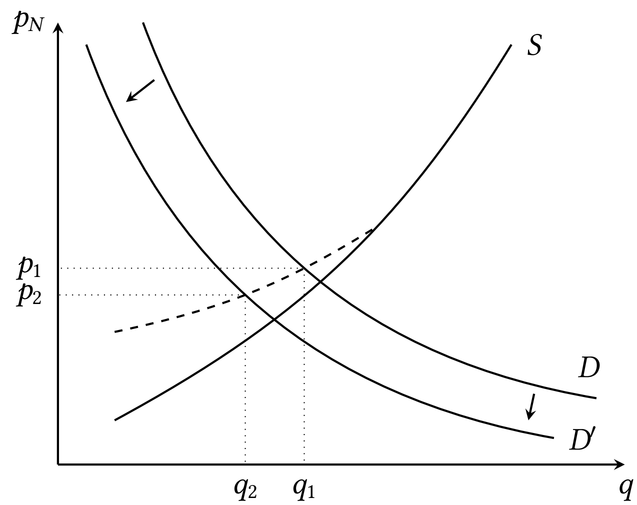


Figure 16: Market Clearing in the Nontradable Sector

employment. This is the 'overborrowing' externality emphasized by Schmitt-Grohé and Uribe (2016): individual households do not internalize that their consumption pushes up wages. In a scenario like this, where defaults also artificially depress TFP, a benevolent government might want to default on its debt only to suppress the overconsumption externality. This would lead to counterfactually many defaults in good times. If the government was allowed to choose spending and debt issuances, it could use fiscal policy to curtail the boom instead of defaulting. However, I am constraining the government to follow the estimated fiscal rules. Hence, the admittedly less realistic constant lower bound on wages is preferred.

B.3 Accuracy of the simulation

To evaluate the accuracy of the approximation to the actual distribution of households across their idiosyncratic states, in each simulation I conduct the following tests. In period t, given the aggregate state variables in $\mathrm{S}_t = (B_t, \mu_t, \sigma_t, \xi_t, \zeta_t, z_t)$, I compute the 'theoretical' value of some endogenous variables x_t from the model solution at this state. I then compare it with the 'actual' value which results from market clearing taking into account the actual distribution λ_t. Table 7 reports the average of the absolute value of the relative discrepancies and shows that assuming a lognormal distribution does not result in large errors.

Table 7: Discrepancies in Simulation

Variable	Avg. relative discrepancy
Price of nontraded goods	0.27%
Consumption	1.13%

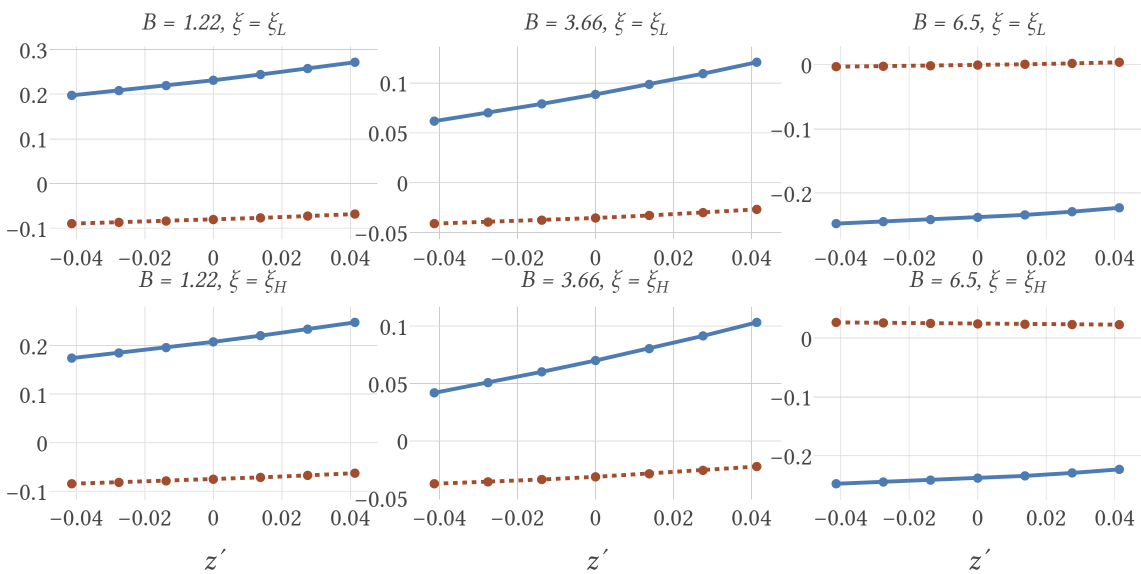


Figure 17: Transfers

Note: Blue lines plot transfers in repayment, red dashed lines plot transfers in default

C. Evidence

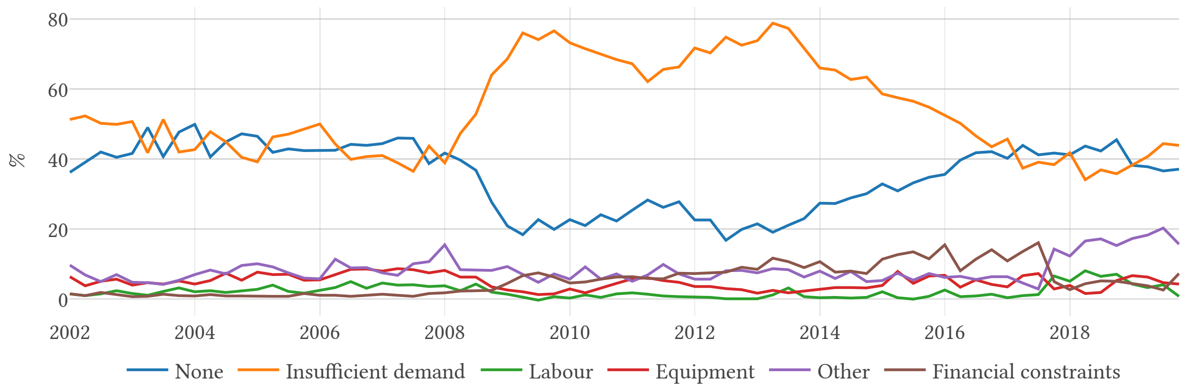


Figure 18: Factors Limiting Production

Source: Eurostat

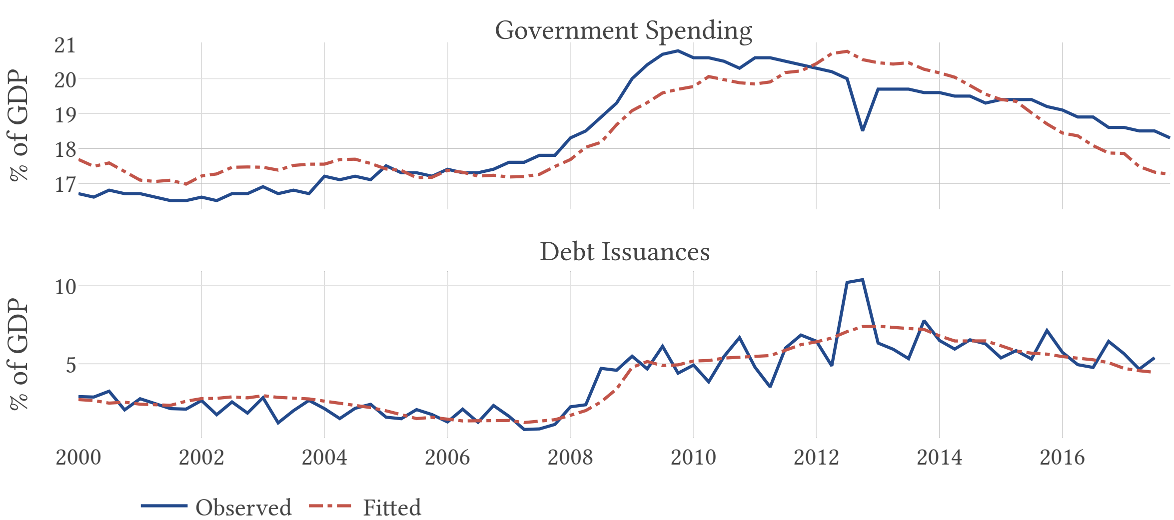
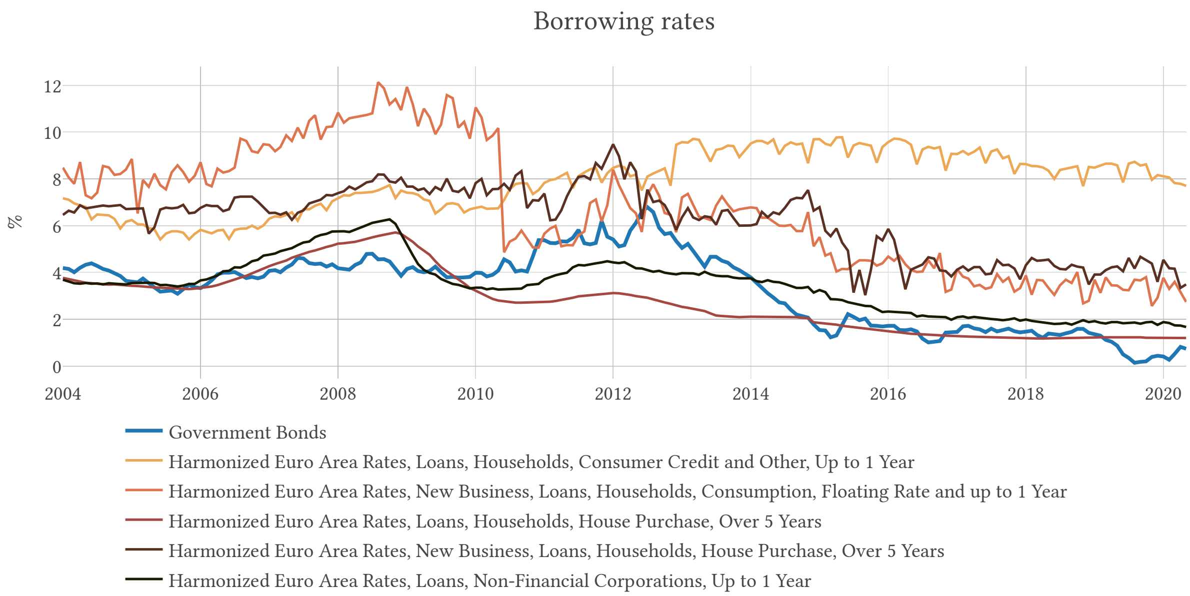


Figure 19: Estimated Fiscal Rules



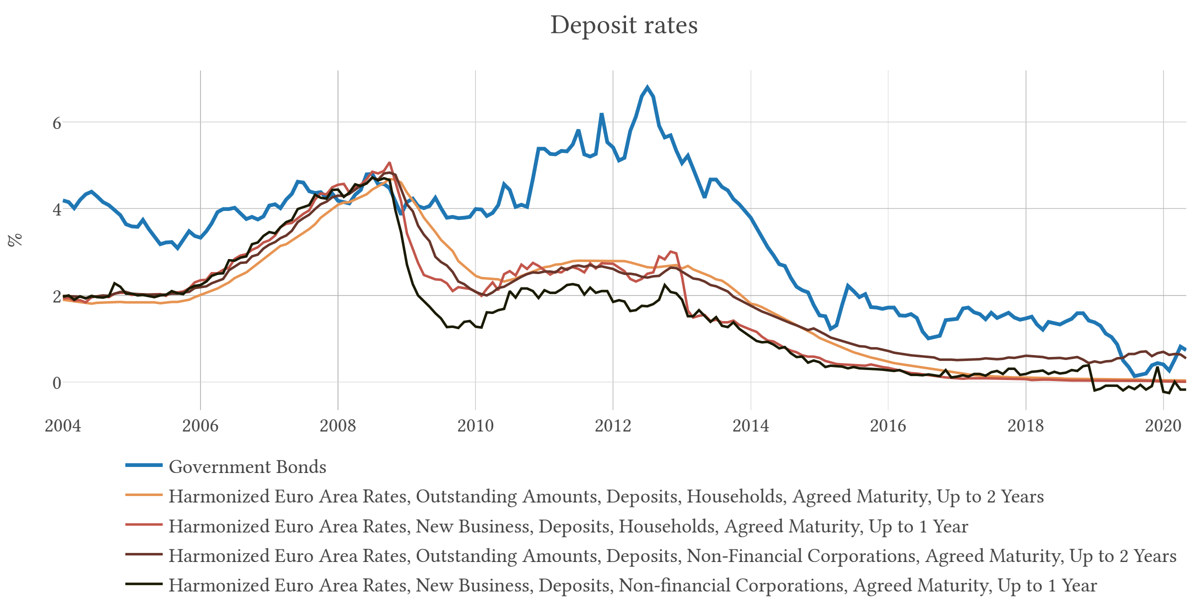


FIGURE 20: INTEREST RATES IN SPAIN

Source: International Financial Statistics, IMF