BORROWING INTO DEBT CRISES[*]

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Abstract

Quantitative models of sovereign debt predict that governments reduce borrowing during recessions to avoid debt crises. A prominent implication of this behavior is that the resulting volatility of interest rate spread is counterfactually low. We propose that governments borrow into debt crises because of frictions in the adjustment of their expenditures. We develop a model of government good production which uses public employment and intermediate consumption as inputs. The inputs have varying degrees of downward rigidity which means that it is costly to reduce them. Facing an adverse income shock, the government borrows to smooth out the reduction in public employment, which results in increasing debt and higher spread. We quantify this rigidity using the OECD government accounts data and show that it explains about 70% of the missing bond spread volatility.

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1 Introduction

Sovereign debt crises are a recurring phenomenon in the financial markets and tend to coincide with sizable disruptions in the real economy. A recent literature has developed a class of quantitative models that are able to replicate many aspects of lending to risky sovereigns such as simultaneously high average debt-to-output ratios and spreads. However, one particularly elusive aspect of debt crises is the government inertia when faced with sudden fluctuations in borrowing costs. In the data, government expenditures are slow to adjust, interest rate spreads are volatile and high-peaking, and debt ratios often rise during crises. By contrast, quantitative models of sovereign default with long-term debt predict that governments adjust their fiscal policy fast in response to adverse income shocks, thus reducing overall debt levels. As a result, the predicted spreads are too low and not volatile enough, an observation pointed out by Aguiar et al. (2016), among others.

We propose a channel that bridges this gap in a straightforward way and quantify its importance. The idea is that government spending is imperfectly flexible, and governments are unable to adjust their fiscal policy freely when faced with negative income shocks. One aspect of government spending that tends to be particularly rigid, as we show in this paper using OECD data, is public employment. Government agencies often face barriers to laying off workers which constrains their actions. A story of the Hellenic Broadcasting Corporation (ERT) in Greece provides an illustrative example. In 2013, in the midst of its sovereign default crisis, the Greek government decided to shut down ERT, the public television company, and lay off all workers as a part of its effort to regain lenders' confidence following the 2012 default. This action sparked mass street protests and forced the government to ultimately reinstate the ERT two years later. In this paper we ask, how much do frictions in adjusting public expenditure, and in particular public employment, impede the government's ability to respond to debt crises? More precisely, to what extent can such frictions explain the increasing debt ratios during crises as well as the high volatility of interest rate spreads observed in the data?

We develop a model of sovereign default that builds on the framework of Hatchondo and Martinez (2009) and Chatterjee and Eyigungor (2012). An impatient government maximizes the expected lifetime utility by borrowing in defaultable non-contingent bonds. As is standard, bonds last for many periods and are priced competitively by risk-neutral foreign lenders. The main point of departure is that we model the production of the public good. The inputs to this production in the model are *intermediate government consumption*[1] and *public labor*, following the decomposition used by the OECD Government Accounts. We assume that both inputs are persistent in their nature. That is, these expenses are subjected to an asymmetric adjustment cost. The government is always free to purchase more inputs, but incurs the adjustment cost in order to reduce the rigid expenditures. With this friction in mind, the government chooses an optimal combination of public labor and intermediate consumption, as well as the new level of debt, to maximize its expected utility over a stream of public goods.

To discipline the rigidity in both inputs, we use data on different types of government spending from the aforementioned OECD Government Accounts. We estimate the elasticity of public employment expenditure with respect to intermediate consumption controlling for its own lag around debt crises, in a panel of 36 OECD countries in years 1995-2019. Our estimates indicate that public employment expenditure is only weakly related to intermediate government consumption and instead exhibits strong persistence. We use these estimates to calibrate our model for Mexico. Mexico is a frequent case study for sovereign default models and the volatility of its interest rate spread is much too high relative to what a standard model can predict (Aguiar et al., 2016).

As a main quantitative result, we find that our model generates a standard deviation of the spread of 1.82%, compared to 0.83% in the standard quantitative model. This accounts for about 70% of the gap between the standard model's prediction and its empirical counterpart of 2.21%. This result is mirrored by a reduced volatility of government deficit which aligns our model more closely with the data. To understand this finding, we contrast the simulated behavior of our model with the standard one around debt crises and defaults. Our main qualitative finding is that during these crises in our model the government increases its debt, "borrows into crises", whereas in the standard model it reduces it.

We identify two channels that lead to the "borrowing into debt crises" behavior: one is a direct effect of adjustment costs, while the other is an indirect effect that operates through equilibrium bond prices. The direct effect induces the country to maintain a borrowing buffer during good times and to use it during bad times. Simply put, it "borrows into crises" to reduce the cost of expenditure adjustments. The general equilibrium channel results in the government with adjustment costs facing a more favorable price sched-

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[1] Examples of intermediate government consumption are non-durable supplies, building rentals, energy, and military supplies.

ule, and lower default incentives, than the government without adjustment costs during crises. This in turn allows it to further pursue the strategy of "borrowing into crises". The reasoning behind the general equilibrium channel is that the buffer described above makes access to borrowing during downturns more valuable for a government with adjustment costs to spending than for one without them. This makes the country less willing to default which is reflected in a more favorable price schedule.[2]

As a second benchmark, we compare the behavior of our model to one that features fixed public labor. We show that this benchmark is equivalent to the standard model augmented with non-homothetic preferences that feature a "minimum consumption" level.[3] We show that the standard deviation of the spread in that model amounts to 1.34%, which represents about half of the improvement that our baseline model generates. Importantly, we show that while the fixed labor model indeed causes the government deficit to be less responsive to shocks in the run-up to debt crises, it does not qualitatively affect the path of government debt. Specifically, we show the debt level still declines in anticipation of the impending debt crisis, unlike in our model where it *increases*.

Our results hinge on the costly adjustment of inputs which is disciplined by two key empirical moments. First, we target the low elasticity of public employment expenditure to intermediate consumption. In our model, costly adjustment of public employment accounts for this low elasticity. Second, the data suggests that intermediate consumption expenditure is over 50% more variable than public employment expenditure. We achieve this target by pinning down the degree of rigidity in intermediate consumption relative to public employment expenditure. To show this, in an extension in Section 3.7, we calibrate a restricted version of our model where public employment is the only rigid input. In this calibration, intermediate consumption expenditure is 168% more variable than public employment expenditure. The government varies intermediate consumption aggressively to mitigate debt crises. This results in spread volatility that is barely higher than in the standard model without any rigidity in spending.

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[2] We also find that the default cost is greater in the specification with adjustment cost. This also contributes to making the price schedule more favorable for a country subject to adjustment costs. A question that remains is, if the default cost is greater in the adjustment cost specification then why is equilibrium borrowing not greater? The answer lies in the borrowing buffer in the adjustment cost specification. This buffer leads to less borrowing during good times which lowers average debt.

[3] The recent quantitative sovereign default literature has used such preferences as a shortcut to make government deficit less responsive to the underlying fundamentals, see for example Bocola and Dovis (2019) and Bianchi, Hatchondo and Martinez (2018).

An attractive feature of our model is that it allows us to identify the rigidity in government spending by targeting the elasticity of substitution inferred from the OECD data. Nevertheless, in Section 4 of the paper we show that this model also maps easily into a simpler model that uses habit formation, a standard tool in quantitative macroeconomics. We discipline this model by targeting the autocorrelation of government expenditures for Mexico, i.e., an intertemporal elasticity. All quantitative and qualitative results are similar to the ones produced by our baseline model. We also show that the calibrated parameter for the habit falls within the range of the values estimated in Fuhrer (2000). We view this result as an "external validation" as well as a desirable simplification of our model that makes the mechanism we highlight easier for practitioners to apply.

The model presented in this paper contributes to our understanding of the recent European debt crisis in two ways. First, as we show in Section 5, countries in the OECD data tend to respond to adverse revenue shocks by increasing their debt levels, a result that standard models generally struggle to replicate (Paluszynski, 2021). By contrast, this response is consistent with our model in which governments face frictions to adjusting their expenditures. Second, a number of European countries experienced high interest rate spreads, in excess of 10%. We show that the distribution of simulated spreads in our model has a fat upper tail, with positive mass extending up to the spread of 20%, while the two benchmark models we consider fail to generate any spreads higher than 8% on the equilibrium path.

1.1 Literature review

This paper is closely related to the quantitative sovereign default literature, in particular one building on the seminal works of Eaton and Gersovitz (1981), Aguiar and Gopinath (2006) and Arellano (2008). Chatterjee and Eyigungor (2012) and Hatchondo and Martinez (2009) introduce long-duration bonds to these models and show that it is an important element in accounting for the amounts of debt and average spreads observed in the data. However, Aguiar et al. (2016) point out that such models (with long-term debt) still fall short of replicating the interest rate spread *volatility* observed in the data for most sovereign defaulters other than Argentina.[4]

Our calibration relates to Bocola and Dovis (2019) and Bocola, Bornstein and Dovis (2019).

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[4] Argentina is a notable exception, as evidenced by the success of the Chatterjee and Eyigungor (2012) model, because it has an unusually volatile income process. See Aguiar et al. (2016) for more details.

Similarly to their work, we model the government budget constraint. We do so to highlight the role of government expenditure rigidities. In contrast to their work, which studies Eurozone countries, our application is for Mexico, a developing country. For this set of countries the overwhelming majority of the quantitative literature has calibrated to external public debt. As a result, we also target external public debt. Our calibration target reproduces the low spread volatility in the standard model highlighted in the literature, albeit slightly more volatile. Therefore, we view our calibration as giving the standard model the best chance to achieve the empirical spread volatility. While our model features a default driven by shocks to the country's own income, the empirical literature has pointed out that global factors are an important source of volatility in sovereign spreads (González-Rozada and Levy Yeyati, 2008). In Appendix C we show that the standard model augmented with shocks to creditors' risk aversion alone is unable to elevate the bond spread volatility. As such, the source of the shocks is less important than the way governments respond to them, which is our primary object of interest.

Our paper is naturally not the first attempt to raise the volatility of the spread. Aguiar et al. (2019) revisit a model with rollover crises and propose a new equilibrium selection mechanism to justify why bonds are often sold at large discounts. Chatterjee and Eyigungor (2019) obtain volatile spreads in a model with political frictions, while Paluszynski (2021) generates high standard deviation of the spread (especially relative to low mean) for Eurozone countries in a model with learning about rare disasters. Relative to these studies, we view the mechanism proposed in our paper as complementary and quantify its contribution to generating a volatile bond spread. In addition, other studies such as Bocola and Dovis (2019), Bocola, Bornstein and Dovis (2019) or Bianchi, Hatchondo and Martinez (2018), also accomplish this goal, but they all use the "subsistence consumption" utility which is a special case of our model. As such, our paper contributes by generalizing (and quantifying) this increasingly popular modeling technique.

Our paper is also related to a number of studies that highlight why an indebted government might fail to deleverage when facing a crisis. Conesa and Kehoe (2017) show in a model with sudden stops that, under certain conditions, the government may "gamble for redemption" by optimally increasing its debt in a recession. Further, Lorenzoni and Werning (2019) show that a model with equilibrium multiplicity à la Calvo (1988) can

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[4] Implicitly these two calibration targets correspond to two extremes on government tax policy. On the one extreme, targeting debt to GDP corresponds to the case where the government is able to use lump sum taxes. On the other extreme, debt to government revenues corresponds to the case where the tax rate is fixed to some value. Lump sum taxes offer more flexibility to the government leading to less variable spreads.

also produce borrowing into crises. Corsetti and Maeng (2020) contrast these two types of multiplicity and show that the incentives to leverage during crises are stronger with the multiplicity à la Calvo (1988). Müller, Storesletten and Zilibotti (2019) achieve debt accumulation during a recession in a model with stochastic default cost, renegotiation, and hidden effort to conduct structural reforms. In contrast to these papers, the quantitative sovereign default literature cited above assumes the government is impatient.[5] This assumption, while matching the data better, leads to countries deleveraging in debt crises. Notably, Bocola, Bornstein and Dovis (2019) achieve an increasing debt-to-GDP ratio at the beginning of a recession by using the "subsistence consumption" preferences. Finally, several recent papers, for example Tirole (2015), Gourinchas, Martin and Messer (2020), or Corsetti, Erce and Uy (2019), explain "borrowing in debt crises" with the presence of official lending by international financial institutions (IFIs) such as the IMF or the European Stability Mechanism. Our model abstracts from IFIs to isolate the role of "sticky" expenditures.

The remainder of this paper is structured as follows. Section 2 introduces our model. Section 3 presents the quantitative analysis of our model, along with main results and extensions. Section 4 compares our main results to a simplified model with habit formation. Section 5 provides some direct evidence for our main result from the panel consisting of OECD countries. Section 6 concludes.

2 Model

In this section we present the main environment of our analysis.

2.1 Economic environment

Endowment process Each period the economy receives a stochastic endowment Y_t. This process has the following autoregressive structure:

$$\log Y_{t+1} = \rho \log Y_t + \epsilon_{t+1}. \tag{1}$$

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[5] Müller, Storesletten and Zilibotti (2019) extend their model to include government impatience and GDP fluctuations. In this quantitative extension they achieve debt accumulation during crises. Their quantitative exercise differs from the quantitative sovereign default literature in two notable ways. First, it emphasizes low frequency GDP fluctuation. Second, the main source of default risk comes from stochastic default cost. As a result, it is not clear how their results would translate to an environment with high frequency GDP fluctuation. However, the driving forces behind their result could further improve the fit of borrowing dynamics in quantitative sovereign default models.

The innovation term, ϵ_{t+1}, is iid and is drawn from a normal distribution with zero mean and σ_ϵ standard deviation. Parameter ρ is the usual autoregressive coefficient. Finally, the unconditional mean of the endowment process μ_y is normalized to 1. Tax revenues are proportional to the endowment with tax rate τ. The history of endowments in period t is denoted $Y^t = (Y_0, Y_1, ..., Y_t)$.

Preferences The government values an uncertain stream of public goods $\{\{G_t(Y^t)\}_{Y^t}\}_{t=0}^{\infty}$ using a utility function, given by:

$$\mathbb{E}\sum_{t=0}^{\infty}\beta^t U(G_t(Y^t)).$$

$\mathbb{E}$ denotes the expectations on endowment process Y_t implied by the autoregressive structure specified above. We assume the function $U(\cdot)$ is strictly increasing, concave and twice continuously differentiable. The discount factor is given by $\beta \in (0,1)$.

Production Technology The public good G_t is produced using public labor L_t, and an intermediate government consumption good C_t, as inputs.[6] The production function, denoted $G(L_t, C_t)$, takes the Cobb-Douglas form:

$$G_t = G(C_t, L_t) = C_t^{\alpha} L_t^{1-\alpha}.$$

where the weight in the production function, α, is calibrated in the quantitative analysis.

Inputs Adjustment Friction We assume that government expenditures have a degree of persistence, captured by the function

$$H_t = \phi_0\, C_t + (1-\phi_0)\, wL_t$$

H_t can be thought of as a pool of legacy contracts consisting of both the employment contracts with public officials, as well as delivery and subscription contracts for intermediate government consumption. We assume a resource adjustment cost for H_t which takes the following functional form:

$$\phi_1\ \min\left\{\frac{H_t}{H_{t-1}} - 1, 0\right\}.$$

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[6] This decomposition is guided by the classification in the OECD Government Accounts data. We elaborate on it, and use it in our quantitative analysis in Section 3.

That is, the cost applies only when input expenditure H_t is reduced. Then, the cost is proportional to the rate of decline of H_t. The degree of proportionality, ϕ_1, along with the weight on the intermediate consumption expenditure, ϕ_0, are calibrated in the quantitative analysis.

Debt and Default The country enters each period with debt B_t. A δ fraction of the debt matures and has to be repaid. Outstanding debt receives coupon κ. Finally, the government decides on debt issuance $B_{t+1} - (1-\delta)B_t$. The price schedule in the recursive formulation, denoted Q, depends on borrowing B_{t+1}, weighted input cost H_t, and endowment Y_t. Parameters δ and κ are specified in the quantitative analysis.

Default allows the country to entirely erase debt B_t. However, there are two costs associated with default. First, there is resource cost $Y - Y^d(Y)$ where $Y^d(Y) = \min(Y, \bar{Y})$[7]. That is, endowment can at most be $\bar{Y}$ as a result of the default (Arellano, 2008). The cost is linearly increasing in Y for values of Y larger than $\bar{Y}$ and zero for values of Y less than $\bar{Y}$. Parameter $\bar{Y}$ is calibrated in the quantitative analysis. Second, the government is temporarily excluded from financial markets. Re-entry occurs stochastically with per period probability θ.

2.2 Decision Problem

In this section we formalize the economic environment by stating the problem faced by market participants in recursive form. The government enters a period with debt B, legacy contracts H_{-1}, and endowment realization Y.

Government The government that is current on its debt obligations decides between repayment or default. The value function is given by:

$$W(B, H_{-1}, Y) = \max_{d \in \{0,1\}} \left\{ d\, V^D(H_{-1}, Y) + (1-d) V^R(B, H_{-1}, Y) \right\} \tag{2}$$

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[7] Convex default cost is necessary to generate realistic average bond spreads in the model and has been given some empirical support by Mendoza and Yue (2012). Further, to generate realistic standard deviation of the spread the literature has utilized convex default costs with more curvature than the one offered by the Arellano (2008) one, see for example Chatterjee and Eyigungor (2012). We choose the Arellano (2008) default cost since understanding the determinants of the standard deviation of the spread is the main objective of this paper.

Repayment ($d = 0$) allows the government to borrow. The value function is given by:

$$V^R(B, H_{-1}, Y) = \max_{\substack{B' \geq 0, \\ C \geq 0, L \geq 0}} \left\{ U\left(C^{\alpha} L^{1-\alpha} \right) + \beta \mathbb{E}_{Y'|Y} W(B', H, Y') \right\} \tag{3}$$

subject to

$$C + wL = \tau Y - B\left(\delta + (1-\delta)\kappa\right) + Q(B', H, Y)\left(B' - (1-\delta)B\right) - \phi_1 \min\left\{ \frac{H}{H_{-1}} - 1, 0 \right\},$$

$$H = \phi_0\, C + (1 - \phi_0)\, wL.$$

A sovereign who defaults ($d = 1$) is excluded from international credit markets and has probability θ of being readmitted every subsequent period. The associated value is:

$$V^D(H_{-1}, Y) = \max_{C \geq 0, L \geq 0} U\left(C^{\alpha} L^{1-\alpha} \right) + \beta \mathbb{E}_{Y'|Y} \left[\theta W(0, H, Y') + (1-\theta) V^D(H, Y') \right] \tag{4}$$

subject to

$$C + wL = \tau Y^d(Y) - \phi_1 \min\left\{ \frac{H}{H_{-1}} - 1, 0 \right\},$$

$$H = \phi_0\, C + (1 - \phi_0)\, wL.$$

International Lenders The lenders are assumed to be risk-neutral and perfectly competitive. The actuarially fair bond price that compensates them for default risk is:

$$Q(B', H, Y) = \frac{1}{1+r} \mathbb{E}_{Y'|Y} \Big[\left(1 - d(B', H, Y') \right) \left(\delta + (1-\delta)\kappa + (1-\delta) Q(B'', H', Y') \right) \Big] \tag{5}$$

where

$$B'' = B'(B', H, Y')$$

$$H' = H(B', H, Y')$$

Definition 1 *A Markov Perfect Equilibrium for this economy consists of the government value functions $W(B, H_{-1}, Y)$, $V^R(B, H_{-1}, Y)$, $V^d(H_{-1}, Y)$; policy functions $C(B, H_{-1}, Y)$, $L(B, H_{-1}, Y)$, $B'(B, H_{-1}, Y)$, $H(B, H_{-1}, Y)$, $d(B, H_{-1}, Y)$; and bond price schedule $Q(B', H, Y)$ such that:*

1. *Policy function d solves the government's default-repayment problem.*

2. *Policy functions $\{C, L, B', H\}$ solve the government's consumption-saving problem.*

3. *Bond price function Q is such that international lenders make zero profit in expectation.*

3 Quantitative analysis

In this section we take the model to data by choosing parameter values. We calibrate the model to Mexico, which is a common subject of interest in the sovereign default literature (Aguiar et al., 2016), and at the same time is a member of the OECD, providing us with rich data on different subcategories of government spending. As is common in the literature, some parameters are set externally to standard values, while others are selected to match certain empirical moments.

3.1 Parameters set externally

Preferences Each period is assumed to be one year. We assume a CRRA utility function of the form $U(G) = \frac{G^{1-\gamma}}{1-\gamma}$, with the risk aversion parameter γ set to 2.

Endowment The persistence ρ of Mexico's annual GDP is 0.65, estimated using data from 1980, while the standard deviation of innovations σ is 0.03. The tax rate τ is set at 0.1 which is the average central government tax revenue to GDP as reported by the World Bank's WDI database.

Sovereign Debt The risk-free interest rate is set to 4% (annual value) and the probability of re-entry after default is fixed at 0.33, following Richmond and Dias (2009) who find that the median time to re-enter the credit market was 3 years in 1980-2005. To select the values for parameters that describe Mexico's debt structure we adhere closely to the calibration in related papers, such as Aguiar et al. (2016) or Bianchi, Hatchondo and Martinez (2018). The maturing probability δ is set to 0.285, while the (annual) coupon rate κ is 5%.

Table 1 summarizes the calibration of parameters selected outside the model equilibrium.

Table 1: Parameters calibrated externally

Parameter	**Meaning**	**Value**
γ	Risk aversion	2
θ	Prob. of exiting excl.	0.333
δ	Bond maturity prob.	0.285
κ	Coupon rate	0.05
r	Risk-free rate	0.04
τ	Tax rate	0.1
w	Wage rate	1

Notice that we assume for simplicity that the wage rate is fixed at 1, which is an extreme form of wage rigidity as in Bianchi, Ottonello and Presno (2019).

3.2 Solving the model

Sovereign default models with long-term debt have substantial difficulties in achieving convergence. The literature proposes a number of solution methods including interpolation of borrowing decision (Hatchondo and Martinez, 2009), noise in the endowment process (Chatterjee and Eyigungor, 2012), and noise in defaulting and borrowing (Dvorkin et al., 2019). This paper follows Dvorkin et al. (2019) by considering the discrete choices of defaulting and borrowing and introducing nested logistic shocks in these decisions (see Appendix A for the detailed formulation of our model with noise). The correlation of these shocks is fixed at a low value and the variance is set to the smallest value that allows for computation of the Markov Perfect Equilibrium. To make sure that the noise is not the driver of our main results, we hold these parameters constant for all variants of the model considered in the paper. In addition, Appendix B shows that, at least for the frictionless version of our model, the noise does not distort any of the quantitative results.

3.3 Calibrating the structural parameters

The remaining five parameters $(\beta, \bar{Y}, \alpha, \phi_0, \phi_1)$ are calibrated jointly using the simulated method of moments. The economy's endowment is simulated for 2 million periods, with the first 100 observations dropped. We also drop the observations for periods where the country is either in default or was in default less than 5 years prior. Five moments are used to identify the parameters. Two of them are related to the quantity and pricing of Mexico's debt. The other three are based on statistical relationships between the two subcomponents of government expenditure inferred from the OECD Government Accounts.

Debt Moments We match Mexico's average debt to GDP and bond spread.[8] Aguiar et al. (2016) report Mexico's average external debt/GDP in the data as 16%.[9] Further, Cruces and Trebesch (2013) report the average haircut in the 1978-2010 period as 29.72%. Because our model does not account for the possibility of debt renegotiation, we follow Chatterjee and Eyigungor (2012) and only consider the "unsecured" portion of government debt

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[8] Measured as B/Y and $(\lambda + (1-\lambda)z)/Q - \lambda - r^f$, where Q is current period borrowing price, respectively.

[9] This corresponds to the average public and publicly guaranteed external debt stocks since 2000 (WDI data). We focus on external debt, as well as the decomposition of the final consumption expenditure of the government, because our model is not suited to address the questions of transfers and redistribution.

which we round to 4.8% of GDP or 48% of government revenues (in Appendix D, we explore the sensitivity of our results to this moment by assuming a higher average debt target). Average Mexican bond spread, as measured by EMBI, from 1994 to 2019 was 3% which we set as our target.[10]

Government Consumption Moments To inform parameters that determine the government's choices over the two types of expenditure, we use the OECD Government Accounts. This source provides us with annual data on the subcomponents of central government spending for 36 OECD member countries in years 1995-2019. In particular, we focus on two major components of Final Government Consumption (by transaction):

1. Intermediate government consumption, which we denote $C_{i,t}$,
2. Compensation of public employees, which we denote $\overline{wL}_{i,t}$.[11]

We focus on these two components because they constitute on average over 90% of the Final Government Consumption Expenditure across OECD countries (Appendix E provides more details on the decomposition of government consumption, along with some summary statistics). These time series are made real using GDP deflator. Further, we de-trend them using each respective country's log-linear real GDP trend. We consider all OECD countries, rather than Mexico's data alone.[12] This is because Mexican data series are short making the moments less informative.

To inform α, the parameter representing weight on intermediate consumption in the production function for the public good, we target the mean share of public employment expenditure in total government expenditure, averaged across countries:

$$\text{average labor share} = \frac{1}{N_c}\sum_{i=1}^{N_c}\left(\frac{\frac{1}{T_i}\sum_{t=1}^{T_i}\overline{wL}_{i,t}}{\frac{1}{T_i}\sum_{t=1}^{T_i}\overline{wL}_{i,t}+\frac{1}{T_i}\sum_{t=1}^{T_i}C_{i,t}}\right).$$

In the OECD panel, public employment spending accounts for 63% of government consumption on average. For the 17 years of Mexican data this number is close to it, at 69%.

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[10] EMBI is a composite index of the performance of foreign-denominated bonds of emerging economies, relative to those of developed markets. Because we focus on external debt, and because almost all of Mexico's foreign denominated debt is externally held, EMBI is the most appropriate measure of the spread in our case.

[11] Due to data limitations, we are unable to separately observe the changes in public sector wages and employment for sufficiently many countries over long enough time period. For this reason, we treat them as a joint compensation variable throughout this analysis.

[12] We exclude Chile and Colombia due to the missing Government Accounts data.

To calibrate ϕ_0 and ϕ_1, the parameters that drive the adjustment cost for long-term government contracts, we jointly use two separate moments that are informative about the relationship between the two inputs into the production of government good. The first moment is the ratio of standard deviations of logged inputs, averaged across countries:

$$\text{ratio of input standard deviations (avg)} = \frac{1}{N_c}\sum_{i=1}^{N_c}\left(\frac{\text{st. dev.}\Big(\log\big(C_{i,t}\big)\Big)}{\text{st. dev.}\Big(\log\big(\overline{wL}_{i,t}\big)\Big)}\right).$$

In our sample, detrended logged intermediate consumption is on average 64% more variable than detrended logged public employment expenditure.

The second moment is the elasticity of public employment expenditure with respect to intermediate public consumption which arises from running the following regression:

$$\begin{aligned}\log\Big(\overline{wL}_{i,t}\Big) =& \hat{\alpha}_0 + \hat{\alpha}_1 \log\Big(\overline{wL}_{i,t-1}\Big) + \hat{\alpha}_2 \log\Big(C_{i,t}\Big) \\ &+ \hat{\alpha}_3 \log\Big(\overline{wL}_{i,t-1}\Big) \times crisis_{i,t} + \hat{\alpha}_4 \log\Big(C_{i,t}\Big) \times crisis_{i,t} + \hat{\alpha}_5\, crisis_{i,t} + u_i + e_{i,t}\end{aligned} \tag{6}$$

We use a form of indirect inference to inform the adjustment cost parameters. To do so, we pose an auxiliary specification (6) which captures the observed statistical relationship between compensation of public employees and intermediate consumption. Our model naturally generates persistence in the compensation of employees variable, which is why we use a dynamic regression that controls for its lagged value. It is also important to distinguish between adjustments to government spending around crises and normal times. For this reason, our specification includes a crisis dummy variable,[13] by itself as well as interacted with the main two regressors. We will target the elasticity of public employment expenditure with respect to intermediate consumption around debt crises, $\hat{\alpha}_2 + \hat{\alpha}_4$.

We estimate the regression equation (6) jointly for the 36 OECD countries using country fixed effects u_i. The first column in Table 2 presents the results of the fixed effects estimation. A 1% increase in lagged public employment expenditure during normal times is associated with a 0.79% increase in contemporaneous public employment expenditure. Public employment expenditure is therefore quite persistent in our data. Interestingly, in-

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[13] We associate a crisis with a peak of the bond spread (local maximum). In addition, we require that the level of the spread be at least one standard deviation above the mean for the given country (the results are very similar for the case of two standard deviations). Finally, we identify a crisis episode as ±1 period around the peak.

Table 2: Estimated law of motion for public employment

VARIABLES	Fixed Effects $\log\left(\overline{wL}_{i,t}\right)$	Arellano-Bond $\log\left(\overline{wL}_{i,t}\right)$
$\log\left(\overline{wL}_{i,t-1}\right)$	0.788***	0.680***
	(0.019)	(0.032)
$\log\left(C_{i,t}\right)$	0.130***	0.212***
	(0.015)	(0.021)
$\log\left(\overline{wL}_{i,t-1}\right) \times crisis_{i,t}$	-0.045***	-0.037***
	(0.013)	(0.013)
$\log\left(C_{i,t}\right) \times crisis_{i,t}$	0.024**	0.031***
	(0.012)	(0.012)
$crisis_{i,t}$	-0.054	-0.012
	(0.036)	(0.038)
Constant	-0.186***	-0.224***
	(0.055)	(0.085)
Observations	761	726
Number of countries	36	36

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

termediate consumption does not co-move strongly with public employment spending. Specifically, a 1% increase in intermediate government consumption during normal times is associated with a 0.13% increase in contemporary public employment expenditure.

We furthermore find that the effect of crisis times on these coefficient estimates is relatively modest, albeit statistically significant. As is intuitive, a debt crisis reduces the persistence of public employment expenditure and magnifies the effect of contemporary spending on intermediate consumption (i.e. a reduction in intermediate consumption is associated with higher reduction in contemporary public wage bill).

Dynamic panel regressions, i.e. specifications that contain at least one lag of the dependent variable, suffer from a well-known endogeneity problem. To correct for this endogeneity, we also use the estimator proposed by Arellano and Bond (1991). The second column in Table 2 presents the results of running this specification. The elasticity of public employment expenditure with respect to its lag during normal times becomes slightly weaker, at 68%. By contrast, the elasticity with respect to intermediate government consumption is considerably higher, at 21%. A debt crisis affects these estimates with the same direction and similar magnitude as in the first specification. Due to the potential endogeneity problem, we use the Arellano-Bond estimated coefficient as a target for our model. Specifically, as the subsequent section shows, our model will replicate the elasticity of public employment expenditure with respect to intermediate consumption around the crisis times, equal to 0.24.

3.4 Results

In this section we present the main results from our calibrated model. We do so by simulating the ergodic distribution of the main variables, as well as averaging their behavior around default episodes. To understand the main novelties of our model, we compare our baseline model to two benchmarks: a flexible version similar to Chatterjee and Eyigungor (2012), as well as a model with fixed labor which introduces a "minimum consumption" in the utility function (Bocola and Dovis, 2019).

3.4.1 Baseline v. Flexible

Table 3 summarizes the calibration of our baseline model, along with a fully flexible version of it which is analogous to Chatterjee and Eyigungor (2012). The achieved fit to the data is good. The main two moments - average debt and average spread - are targeted for both versions of the model and come out very close. Notice in particular that the value of the discount factor needed to achieve this fit is lower in our baseline model than in the flexible one. This is because in the presence of resource costs to adjust spending the government needs to be more impatient in order to take on the same level of debt. In terms of the new parameters (which are calibrated only in our baseline model), the weight on intermediate consumption α is 0.45 which pins down the labor share of just under two thirds. The parameters of the adjustment cost function, ϕ_0 and ϕ_1, are set to 0.44 and 0.47, respectively. This calibration arises from achieving the ratio of standard deviations of the two inputs of around 150% and the elasticity of public employment expenditure with respect to intermediate consumption of 0.21 simultaneously.

Table 4 analyzes the simulated behavior of our model by presenting a set of untargeted moments and comparing them to their counterparts from the literature benchmark (flexible) and the data. The first two rows convey our main quantitative result: in the baseline model, standard deviation of the spread is 1.82%, up from 0.83% in the flexible model

Table 3: Calibration of structural parameters: baseline v. flexible

Parameter		**Baseline**	**Flexible**
Discount factor, β		0.724	0.797
Max default endowment, $\hat{Y}$		0.846	0.832
Interm. consumption weight, α		0.448	0.448
Adjustment weight, ϕ_0		0.442	0.000
Adjustment scale, ϕ_1		0.474	1.000
Target	**Data**	**Baseline**	**Flexible**
Avg. debt/revenues (%)	48.00	48.70	48.78
Avg. spread (%)	3.03	3.01	3.01
Avg. labor share (%)	63.00	55.20	55.19
Elasticity of wL w.r.t. C in crises	0.24	0.21	-
Avg. ratio st. dev. of inputs (%)	164.00	150.74	-

and compared with 2.21% in the data. This is mirrored by the fact that the standard deviation of total government deficit[14] relative to the standard deviation of output is lower in our baseline model, 0.41, than in the flexible model, 0.6, and much closer to its empirical counterpart of 0.26. Notice in addition that the government deficit exhibits a considerably weaker correlation with revenues relative to the standard model, bringing it more in line with the data.[15] This implies that the government's responses to shocks in our model

Table 4: Untargeted moments: baseline v. flexible

Statistic	**Mexico Data**	**Baseline**	**Flexible**
$std(S)$	2.21	1.82	0.83
$std(D)/std(Y)$	0.26	0.41	0.60
$corr(S,D)$	-0.58	-0.34	-0.79
$corr(Y,D)$	0.00	0.36	0.55
$corr(Y,S)$	-0.42	-0.73	-0.83
$std(C+L)/std(Y)$	1.57	1.36	1.40
$corr(Y,Cost)$	-	-0.40	-
$corr(S,Cost)$	-	0.75	-
avg cost (% of avg revenues)	-	0.69	-

Note: the empirical moments are calculated for Mexico's data covering 1994-2019. The bond spread is the EMBI index, while government final consumption expenditure and output are taken from National Accounts. Government deficit data is acquired from Banco de Mexico.

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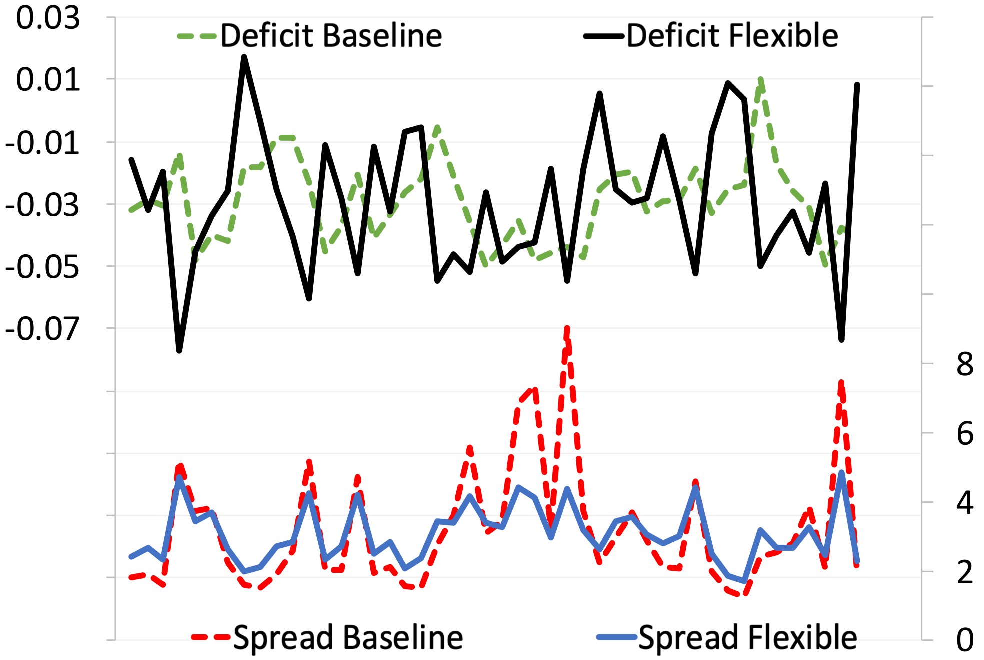
[14] For our baseline model, we define total deficit as $C + wL + \phi_1 \min\{H/H_{-1} - 1, 0\} - \tau Y$.

[15] In the Mexican data for 1994-2019, government deficit appears to be essentially acyclical, as opposed

are both *attenuated* and *desynchronized*. As a result, the government is exposed to higher spreads for more time periods.

In order to visualize our quantitative results, Figure 1 plots an excerpt from the simulated time series for deficit and spread. Notice that the spread in our baseline model is generally more volatile, and the difference is especially pronounced around debt crises, i.e. when the spreads are high. Again, this result is mirrored by the behavior of government deficit which is less volatile and moves more slowly in our baseline model during such episodes.



Note: the figure presents simulated paths for deficit and spread based on 50 consecutive income shock realizations (identical for both models).

Figure 1: Simulated behavior of deficit and spread

Figure 2 presents our main qualitative result by focusing on the paths of endogenous variables in the model during debt crisis, averaged out across the simulations. In particular, an episode is selected if its peak spread is at least one standard deviation above the mean and if it is not accompanied by a default in the five periods before and after.[16]

---

to procyclical as is the case for most emerging markets. However, this is a feature of the last ten years: the correlation of deficit with output calculated until 2009 only is 0.28, close to what our baseline model delivers.

[16] We also conducted our analysis for two standard deviations above the mean, and the results are very similar. We settled on the case of one standard deviation above the mean because that is also a measure we use to identify crises in the data and it allows us to include more episodes in the sample.

As government revenues gradually decline leading to a trough in period 0 (Figure 2a), both kinds of government expenditures drop (Figures 2c-2d) and spreads go up (Figure 2b). In the flexible model, there is no difference between expenditure on public employment or intermediate consumption, so the two decline proportionally. This is not the case for our baseline model, however. Because public employment contributes much more to the pool of legacy contracts of the government, H_{-1}, its decline is quantitatively smaller and slower to recover following the peak. On the other hand, this sluggishness is offset by a steeper drop, and faster recovery, in the intermediate consumption. Because the government chooses to reduce its labor force by much less, it maintains a higher deficit for a longer time and never allows for an increase in surplus as drastic as in the benchmark flexible model (Figure 2e). As a result, the government debt actually *increases* in the run-up to the crisis, rather than declines as predicted by the standard model (Figure 2f). This choice of higher debt during the crisis naturally translates into a tolerance for higher spreads. In our baseline model, the average peak spread during debt crises is over 7%, which in the standard model it is below 5% (Figure 2b). Section 3.6 investigates this last point more in depth.

Figure 3 shows that our qualitative result similarly holds during debt crisis episodes that culminate with a sovereign default. A default is always triggered by falling government revenues (Figure 3a) and results in exploding spreads (Figure 3b). As revenues are falling, the public employment in our baseline model declines more sluggishly than in the flexible one (Figure 3d), while intermediate consumption declines faster (Figure 3c). This results in the government deficit falling much more slowly in the run-up to default in our baseline model than in the standard model (Figure 3e), and consequently the government debt *increases* (Figure 3f). Not surprisingly, the rise in the spread is higher in the baseline model than in the standard flexible one (Figure 3b).

3.4.2 Baseline v. Fixed Labor

We now compare our baseline model with a second benchmark case which exhibits fixed public employment and fully flexible intermediate consumption. This specification boils down essentially to a standard sovereign default model with non-homothetic preferences that feature "minimum consumption".[17] Table 5 summarizes the calibration of that model along with our baseline case. Similarly as with the fully flexible model, the only relevant targeted moments are average debt and average spread, and we match them well. The

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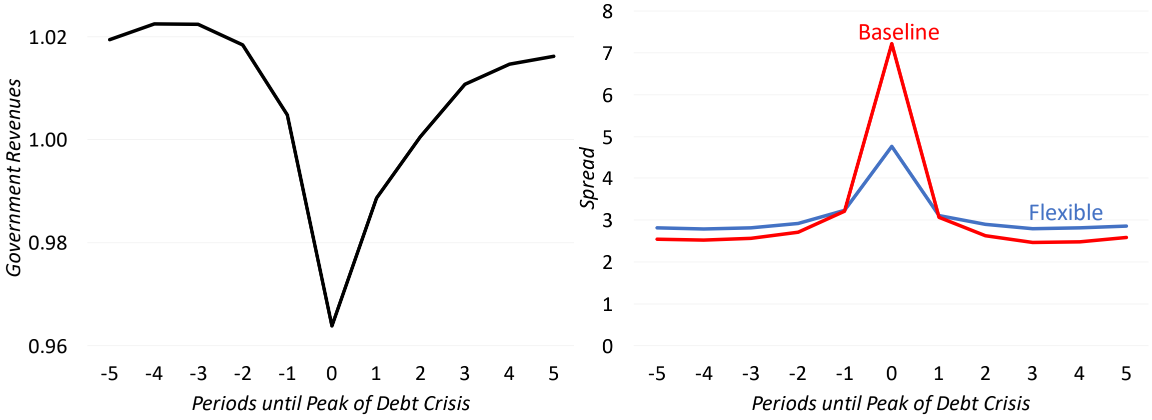
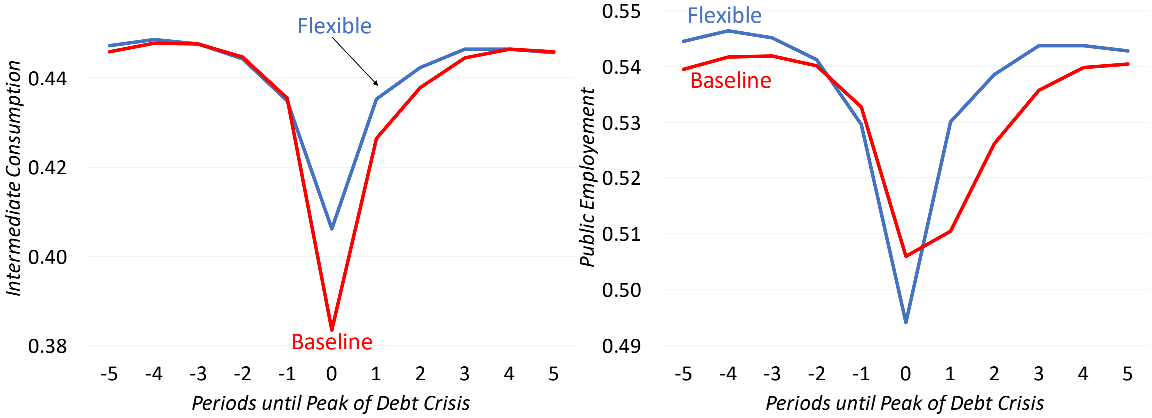
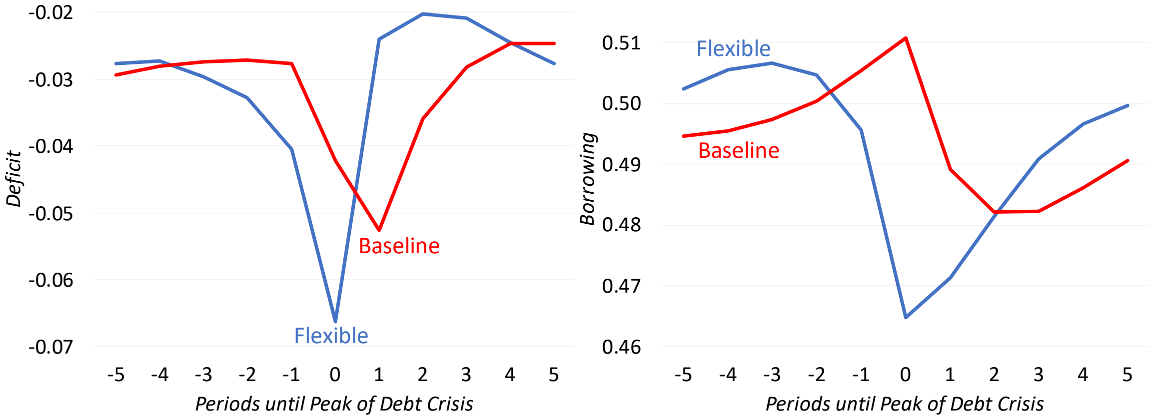
[17] Such preferences have recently been used by Bocola and Dovis (2019) or Bianchi, Hatchondo and Martinez (2018) to slow down the government's actions.



(a) Government Revenues (b) Spread

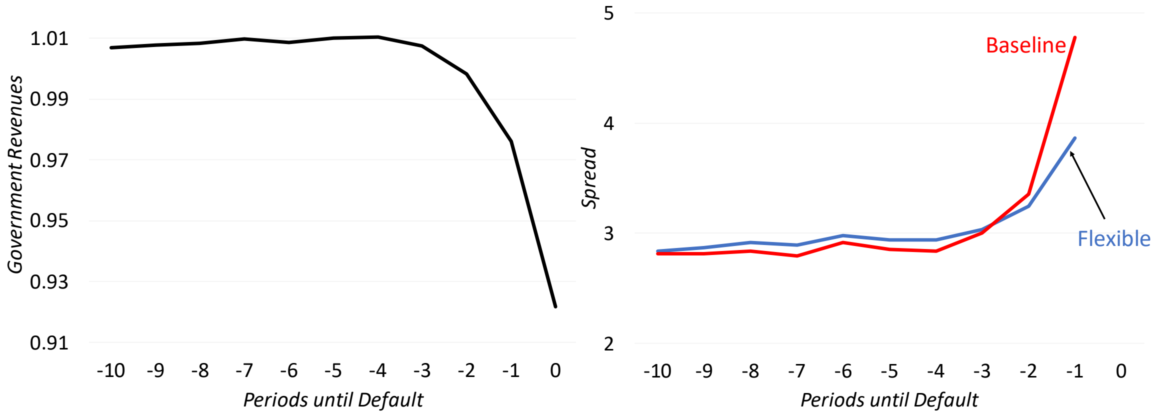


(c) Intermediate Consumption (d) Public Employment

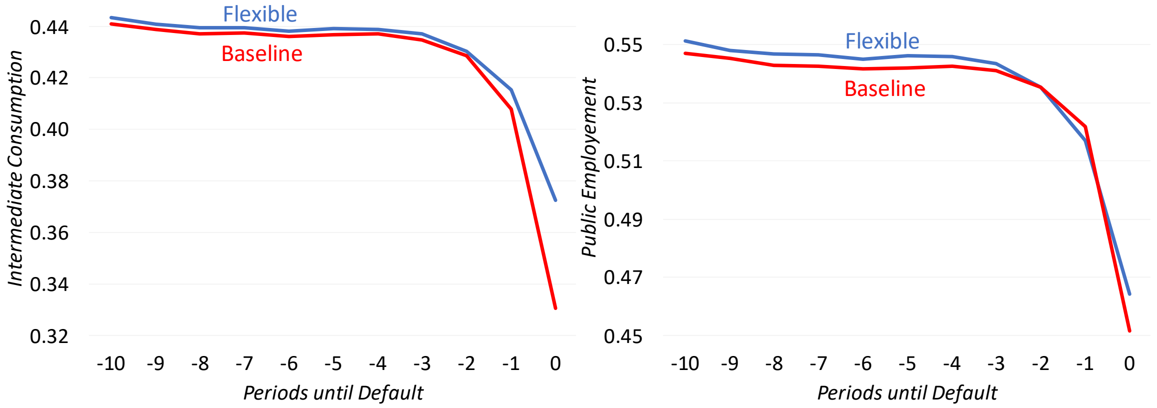


(e) Government deficit (f) Debt

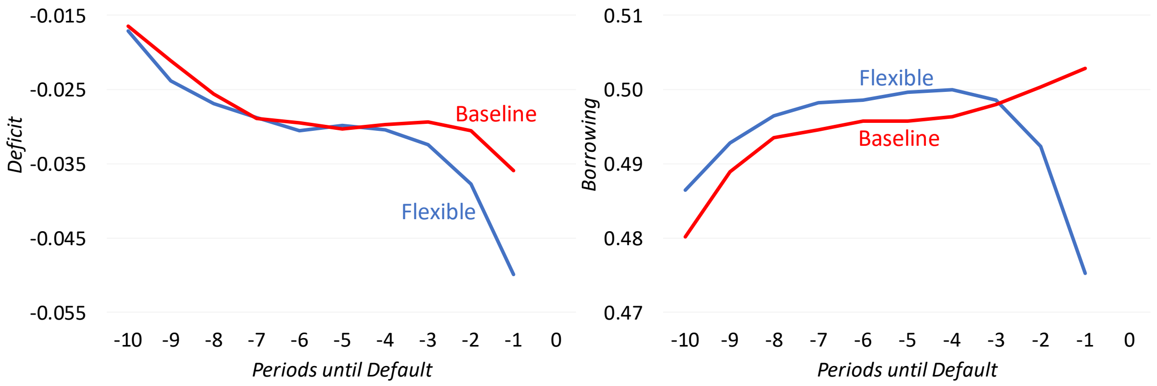
Figure 2: Behavior of the model around default crises: baseline v. flexible



(a) Government Revenues (b) Spread



(c) Intermediate Consumption (d) Public Employment



(e) Government deficit (f) Government debt

Figure 3: Behavior of the model in the run-up to defaults: baseline v. flexible

discount factor required for that is slightly lower than for the standard model.

Table 5: Calibration of structural parameters: baseline v. fixed labor

Parameter		**Baseline**	**Fixed Labor**
Discount factor, β		0.724	0.785
Max default endowment, $\hat{Y}$		0.846	0.851
Interm. consumption weight, α		0.448	1.000
Adjustment weight, ϕ_0		0.442	∞
Adjustment scale, ϕ_1		0.474	0.000
Target	**Data**	**Baseline**	**Fixed Labor**
Avg. debt/revenues (%)	48.00	48.70	48.70
Avg. spread (%)	3.03	3.01	3.01
Avg. labor share (%)	63.00	55.20	54.78
Elasticity of wL w.r.t. C in crises	0.24	0.21	-
Avg. ratio st. dev. of inputs (%)	164.00	150.74	-

Table 6 compares the untargeted moments produced by the two models. As expected, the variant with fixed labor features a higher standard deviation of the spread than the fully flexible one (1.34% v. 0.83%), but still way below the one in our baseline model of 1.82%. On the other hand, the volatility of government deficit falls considerably with fixed labor relative to the flexible model, but it is still slightly higher than in our baseline model. Notice also that the correlation of government deficit with revenue *does not* fall (in absolute value) in the fixed labor model relative to the flexible model. This suggests

Table 6: Simulated behavior: baseline v. fixed labor

Statistic	**Mexico Data**	**Baseline**	**Fixed Labor**
$std(S)$	2.21	1.82	1.34
$std(D)/std(Y)$	0.26	0.41	0.42
$corr(S,D)$	-0.58	-0.34	-0.86
$corr(Y,D)$	0.00	0.36	0.67
$corr(Y,S)$	-0.42	-0.73	-0.90
$std(C+L)/std(Y)$	1.57	1.36	1.29
$corr(Y,Cost)$	-	-0.40	-
$corr(S,Cost)$	-	0.75	-
Avg Cost (% of avg revenues)	-	0.69	-

Note: the empirical moments are calculated for Mexico's data covering 1994-2019. The bond spread is the EMBI index, while government final consumption expenditure and output are taken from National Accounts. Government deficit data is acquired from Banco de Mexico.

that while using a model with preferences that feature “minimum consumption” goes a long way in attenuating the government’s response to shocks, it does nothing to desynchronize it with the fundamentals and other macroeconomic variables. By contrast, our baseline model achieves both of these objectives.

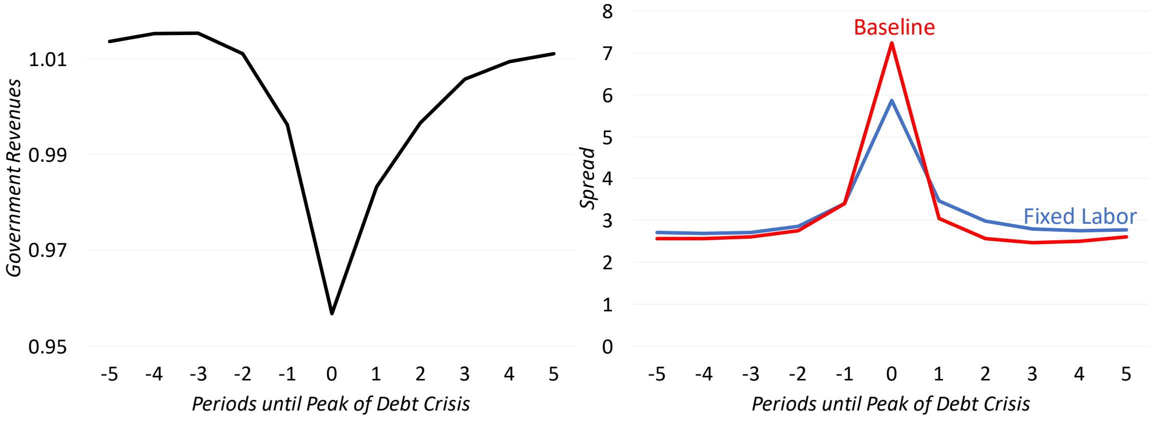
Figure 4 presents the behavior of endogenous variables in the two models focused around debt crisis episodes (without default) analogous to that in Figure 2. As revenues fall (Figure 4a), the government reduces its intermediate consumption while the expenditures on public employment remain fixed (Figures 4c-4d). It is worth noting that in the run-up to the crisis, the intermediate consumption for the fixed-labor government tends to be higher than for our baseline model which results in a steeper and faster decline in government deficit (Figure 4e). Notice also that, as previously mentioned in our discussion of Table 6, the government’s response in the fixed labor model is attenuated but still well-synchronized with the peak of the crisis, just as in the flexible model. Finally, Figure 4f shows that the government with fixed labor also tends to reduce its total debt in the run-up to debt crisis episodes which contrasts with the debt accumulation pattern generated by our baseline model.

Figure 5 compares the behavior of our baseline model with the fixed-labor model ahead of actual defaults. Analogously to Figure 3, government revenues are falling and spreads are increasing continuously. In response, the government is slashing intermediate consumption at a similar pace in the two models, although it is higher to begin with in the one with fixed labor (Figure 5c). Consequently, the government deficit is falling more slowly in our baseline model and government debt *increases*, resulting in a higher rise of the spread (Figure 5b).

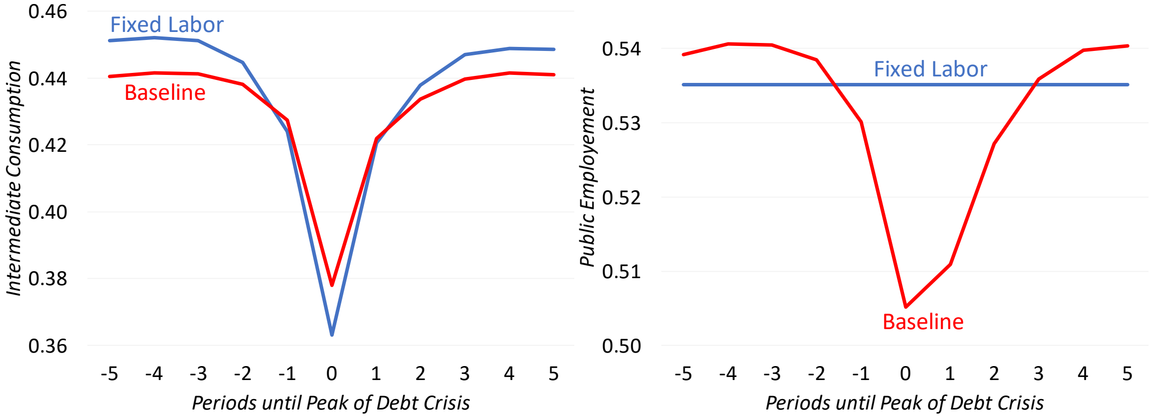
3.4.3 Taking stock

We now summarize our main results by providing a direct comparison of the three model variants. Table 7 illustrates our main quantitative result: the bond spread is much more volatile in the data than what is predicted by a standard fully flexible model of sovereign default. Our baseline model is able to bridge 72% of this gap in standard deviations, while an alternative variant with fixed labor (equivalent to a “preference for minimum consumption” model commonly used in the recent literature) can only close 36%. This result is mirrored by the opposite pattern in the volatilities of government deficit.

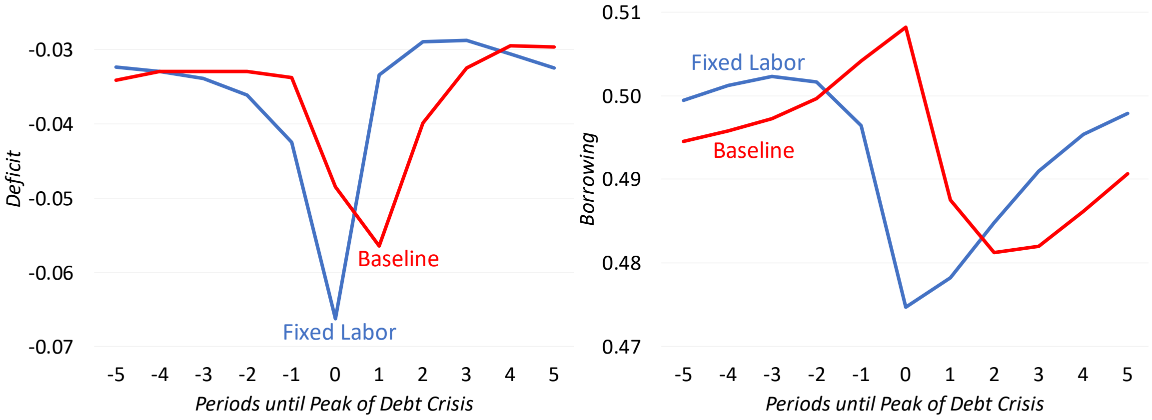
Figure 6 illustrates the main qualitative takeaway from our analysis by comparing the av-



(a) Government Revenues (b) Spread

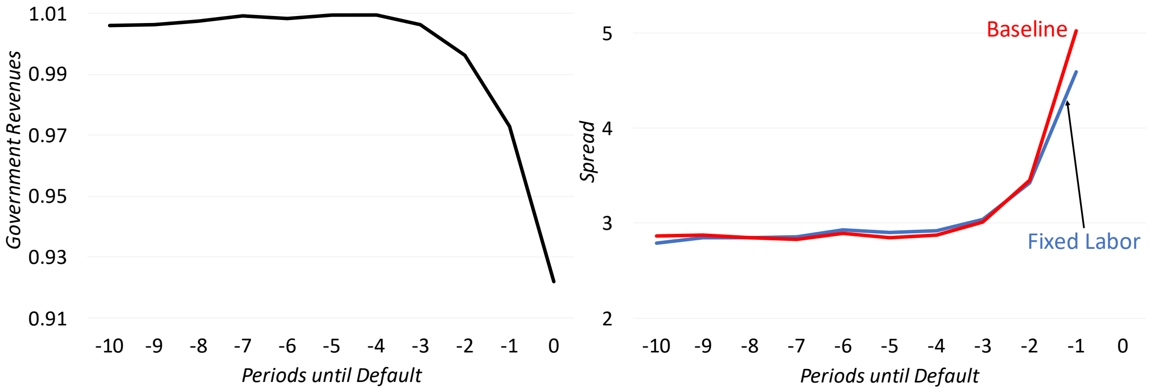


(c) Intermediate Consumption (d) Public Employment

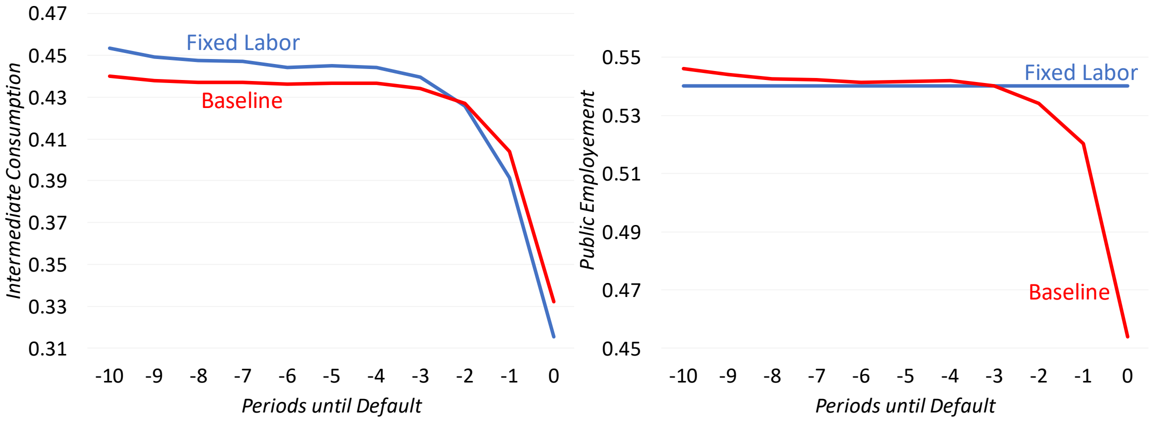


(e) Government deficit (f) Debt

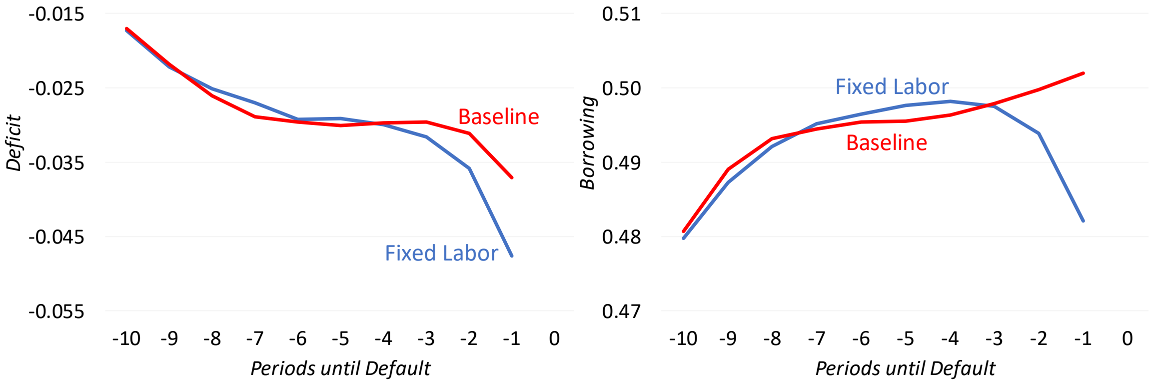
Figure 4: Behavior of the model around default crises: baseline v. constant labor



(a) Government Revenues (b) Spread



(c) Intermediate Consumption (d) Public Employment



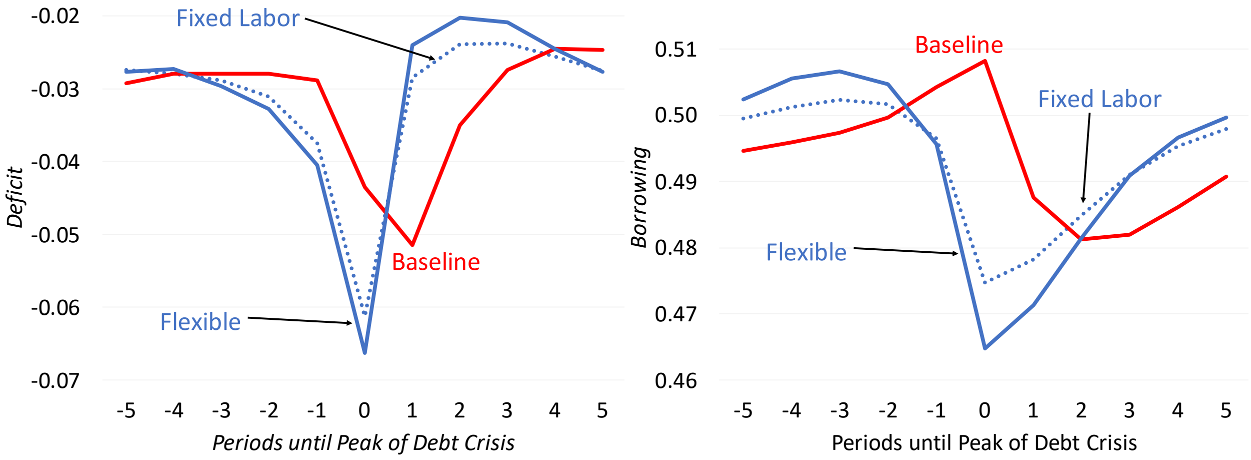
(e) Government deficit (f) Debt

Figure 5: Behavior of the model in the run-up to defaults: baseline v. fixed labor

Table 7: Main quantitative results

Statistic	Mexico Data	Baseline	Flexible	Fixed labor
$std(S)$	2.21	1.82	0.83	1.34
$std(D)/std(Y)$	0.26	0.41	0.60	0.42

erage dynamics of government deficit and debt around crisis episodes. When faced with plunging revenues, the government responds by reducing its deficit (Panel 6a) abruptly in the standard sovereign default model. This response is attenuated slightly in a fixed labor variant of the model, but nevertheless well-synchronized with the trough of the income processes. In our baseline model, by contrast, the response is dampened further and also delayed relative to the peak of the crisis. As a consequence of this dynamics, the government ends up *borrowing into debt crises* (Panel 6b), instead of deleveraging.



(a) Deficit during debt crises

(b) Debt during debt crises

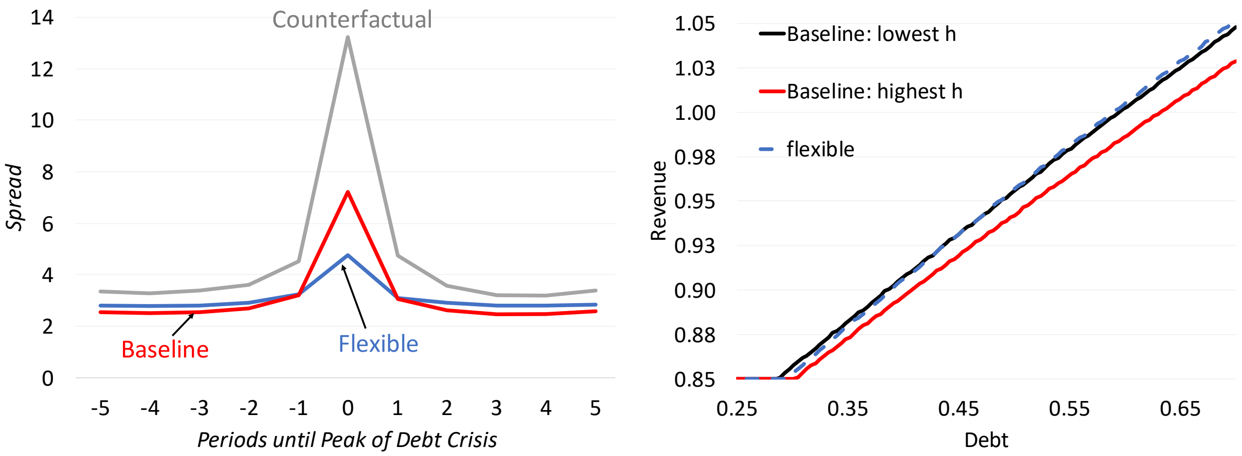
Figure 6: Comparison of government deficits across three models

Finally, it is important to understand the limitations of our mechanism. Appendix D shows, in particular, that under a calibration with much higher debt, the borrowing into debt crises behavior becomes weaker due to the fact that the government is much more impatient. On the other hand, our baseline mechanism still generates more than double the standard deviation of the spread compared to the flexible one.

3.5 Cost of borrowing into debt crises

One of the most striking results of the baseline model is the increasing borrowing during debt crises. At first glance this result may appear to be a direct byproduct of costly expenditure adjustment. That is, governments increase borrowing during downturns to prevent costly expenditure adjustment. In this section, we highlight an additional channel that leads to borrowing during debt crises in the baseline model. In particular, we show that the baseline government faces weaker default incentives and lower borrowing costs during downturns. Therefore, in addition to having a stronger desire to borrow in recessions the baseline government also finds it less costly to do so.

Let us return to the crises, as defined in Section 3.4.1. The question we ask is: how costly would it be for the flexible government to borrow like the baseline one? In particular, in each period we construct a counterfactual interest rate spread using the price schedule of the flexible government. This counterfactual spread would prevail if the flexible government borrowed exactly like the baseline one, i.e. maintained higher borrowing during debt crises as in Figure 2. The counterfactual spread as well as the spreads for the flexible and baseline specifications can be seen in Figure 7a. Figure 7a paints a clear picture of a flexible government that would face exorbitant borrowing costs if it chose to "borrow into debt crises".[18] In particular, at the peak of the crisis the flexible government would face double the spread of the baseline government.



(a) Simulated spreads around debt crises

(b) Default sets

Note: Panel (a) shows simulated spreads around debt crises (as defined in the main text) in the flexible specification, baseline specification, and under the counterfactual spread in which the flexible government borrows the same amount as the baseline one. Panel (b) plots default sets for the baseline model with $h = 0.3$, $h = 0.7$, *and the flexible one.*

Figure 7: Spreads and default sets: baseline vs. flexible model

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[18] The counterfactual spread is slightly higher than the flexible spread even 5 periods before the peak of the crisis. This may seem surprising since as seen in Figure 2 borrowing in the baseline specification is, on average, slightly lower than in the flexible specification. However, the price schedule is quite non-linear.

Panel 7b plots the default sets in the baseline model, separately for a high and low value of the legacy contracts H, along with the one from the flexible model. Because debt crises tend to occur when H is high (and when a series of bad shocks force the economy into recession), the figure makes it clear that our baseline government is less likely to default than the flexible one.

The "discount" the baseline government receives in its borrowing stems precisely from the frictions in adjusting its expenditure. That is, during downturns the baseline government relies heavily on external borrowing to smooth its expenditure reduction. To do so it maintains a borrowing buffer during good times.[19] This borrowing behavior makes financial markets more valuable for the sovereign which lowers the likelihood of default. This in turn reduces the cost of borrowing. This mechanism reinforces the government's desire to borrow during downturns.

3.6 Highest-peaking spreads

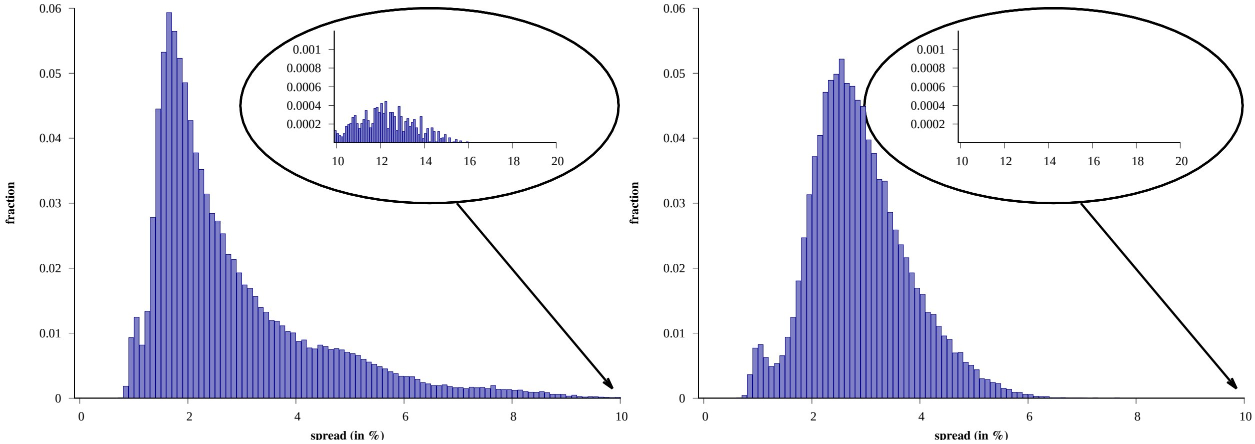
As evident from Figures 2b and 4b, a common feature in standard sovereign default models with long-term debt is the fact that spreads do not achieve realistically high levels during debt crises. In reality, during debt crises countries typically face bond spreads well in excess of 10%.[20] We will now show that our model is easily capable of generating such values, in contrast to the benchmark models.

Figure 8 presents the histograms of simulated spreads across the three analyzed models (along with the habit formation model, to be formally introduced in Section 4). Notice that the distribution of bond spreads is generally right-skewed, with a mode of just above 2%. Importantly, in both the flexible model and in the model with fixed labor, it is virtually impossible to observe a realized spread higher than 6% or 8%, respectively. By contrast, the upper right tail in our baseline model (as well as its simplified habit version) extends much further, and there is non-negligible mass of the distribution for spreads above 10%. This is due to the mechanism explained in Section 3.4: government prefers to reduce public employment gradually and thus tolerates higher-peaking spreads more often.

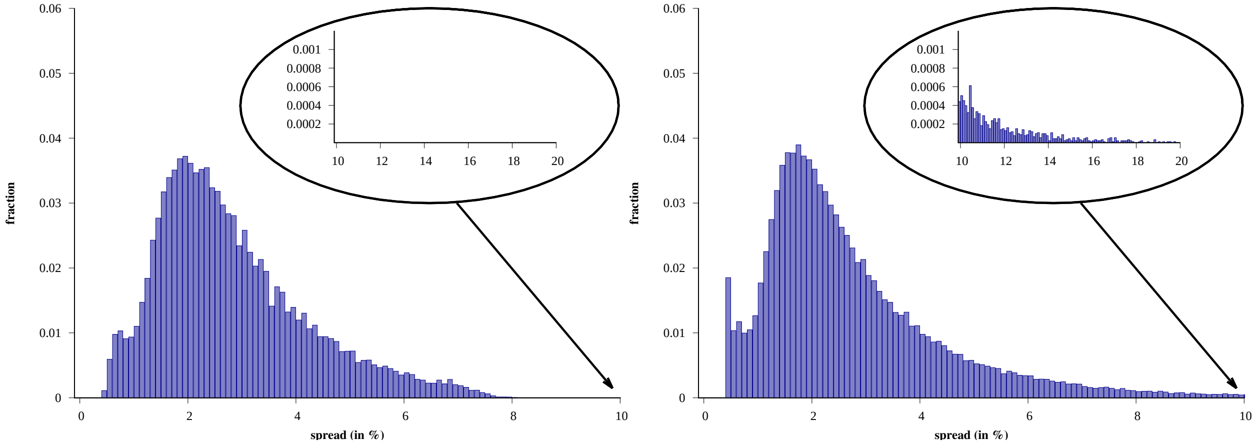
As a result, price declines due to the flexible government not reducing its debt swiftly dominate the effect of slightly less average debt. These factors lead to the spread increase seen in this graph.

[19] This buffer can be seen in Figures 2f and 4f where, in the early periods, borrowing is lower in the baseline specification. The borrowing buffer behavior discussed here provides a rationale for maintaining reserves beyond the ones highlighted in Bianchi, Hatchondo and Martinez (2018)

[20] For example, during the European debt crisis of 2010-2012, the Greek spread on 10-year bonds achieved almost 25%, while the Portuguese spread reached 12%.



(a) Baseline (b) Flexible



(c) Fixed labor (d) Habit

Figure 8: Histogram of simulated spreads in the models

3.7 The role of rigid intermediate consumption

In this extension, we consider a version of our model in which public employment is rigid while intermediate consumption expenditure is fully flexible. This exercise highlights the importance of imposing rigidity to both inputs. In particular, with fully flexible intermediate consumption spreads end up being only slightly more volatile than in the flexible specification.

Table 8 presents our calibration of this model, along with its performance in terms of fit to untargeted moments. Since ϕ_0 was used to match the ratio of standard deviations of the inputs, we no longer target this moment. As a result, the model produces a significantly higher ratio of 268.18%, i.e. intermediate consumption varies much more relative to public employment expenditure, compared to the data of 164%. Because of this excess volatility of intermediate consumption, the government deficit also varies much more (with standard deviation of 0.51 compared to 0.26 in the data) and it exhibits strong correlation with output and bond spread, similar to the benchmark fully flexible model. By the same token, the standard deviation of the bond spread is only slightly higher in this model (1.03%) than in the standard one (0.83%). Finally, it is worth pointing out that the average adjustment cost incurred by the government is an order of magnitude lower in this model (0.06) compared to our baseline model in which both inputs feature some degree of rigidity (0.69). This implies that by varying intermediate consumption, the government is able to smooth out the decline in public employment expenditure while at the same time reducing debt to avoid a potential default.

Table 8: Calibration and behavior of the model with flexible intermediate consumption

Parameter		**Value**
Discount factor, β		0.789
Max default endowment, $\hat{Y}$		0.835
Interm. consumption weight, α		0.430
Adjustment weight, ϕ_0		0.000
Adjustment scale, ϕ_1		0.081
Target	**Data**	**Model**
Avg. debt/revenues (%)	48.00	48.50
Avg. spread (%)	3.03	3.09
Avg. labor share (%)	63.00	56.87
Elasticity of wL w.r.t. C in crises	0.24	0.25
Untargeted	**Data**	**Model**
Avg. ratio st. dev. of inputs (%)	164.00	268.18
$std(S)$	2.21	1.03
$std(D)/std(Y)$	0.26	0.51
$corr(S,D)$	-0.58	-0.83
$corr(Y,D)$	0.00	0.61
$corr(Y,S)$	-0.42	-0.84
$std(C+L)/std(Y)$	1.57	1.36
$corr(Y,Cost)$	-	-0.30
$corr(S,Cost)$	-	0.59
Avg Cost (% of avg revenues)	-	0.06

Note: the empirical moments are calculated for Mexico's data covering 1994-2019. The bond spread is the EMBI index, while government final consumption expenditure and output are taken from National Accounts. Government deficit data is acquired from Banco de Mexico.

4 Habit formation

In this section, we show that a standard habit formation model produces results quantitatively similar to our baseline specification. In particular, we now assume that the government only chooses total government expenditure. To this specification we introduce habit formation as in Fuhrer (2000). We draw two conclusions from this exercise. First, the results produced by a simple habit formation model are consistent with our more "sophisticated" and carefully calibrated mechanism. Therefore, any researcher interested in utilizing our mechanism can do so in an environment that is far less challenging to implement. Second, in contrast to our baseline mechanism, a framework with habit entirely dispenses of resource costs of expense adjustment. This allows us to quantify the importance of these costs.

4.1 Recursive problem

We begin by presenting the problem in the recursive form.

Government The government that is current on its debt obligations decides between repayment or default. The value function is given by:

$$W(B, C_{-1}, Y) = \max_{d \in \{0,1\}} \Big\{ d\, V^D(C_{-1}, Y) + (1-d) V^R(B, C_{-1}, Y) \Big\} \tag{7}$$

where C_{-1} denotes the previous period consumption. Repayment ($d = 0$) allows the government to borrow, and the value associated with it is given by

$$\begin{aligned} V^R(B, C_{-1}, Y) &= \max_{B' \geq 0, C \geq 0} \left\{ U\left(\frac{C}{C_{-1}^{\chi}}\right) + \beta \mathbb{E}_{Y'|Y} W(B', C, Y') \right\} \\ &\textit{subject to} \\ &C = \tau Y - B\Big(\delta + (1-\delta)\kappa\Big) + Q(B', C, Y)\Big(B' - (1-\delta)B\Big) \end{aligned} \tag{8}$$

In formula (7), $\chi > 0$ is the standard habit-formation parameter (Fuhrer, 2000). A sovereign who defaults ($d = 1$) is excluded from international credit markets and has probability θ of being readmitted every subsequent period. The associated value is:

$$V^D(C_{-1}, Y) = U\left(\frac{\tau Y^d(Y)}{C_{-1}^{\chi}}\right) + \beta \mathbb{E}_{Y'|Y} \Big[\theta W(0, \tau Y^d(Y), Y') + (1-\theta) V^D(\tau Y^d(Y), Y')\Big] \tag{9}$$

International Lenders The lenders are assumed to be risk-neutral and perfectly competitive. The actuarially fair bond price that compensates them for default risk is:

$$Q(B', C, Y) = \frac{1}{1+r}\mathbb{E}_{Y'|Y}\Big[\Big(1 - d(B', C, Y')\Big)\Big(\delta + (1-\delta)\kappa + (1-\delta)Q(B'', C', Y')\Big)\Big] \tag{10}$$

where

$B'' = B'(B', C, Y')$

$C' = C'(B', C, Y')$

4.2 Quantitative analysis

We now turn to the quantitative analysis of this model. We adopt the same functional forms for the utility function and the default cost as in Section 3. Further, we assume the same "external" parameters as in Table 1. Table 9 summarizes the moment-matching exercise in this model. In addition to the two usual parameters $(\beta, \hat{Y})$, which are jointly identified using average debt and average spread, we also calibrate the habit-formation parameter χ. We do so by targeting the autocorrelation of final government consumption expenditure of 0.72.[21] As a result, we arrive at the value of $\chi = 0.89$. This is well within the confidence interval of the estimate in Fuhrer (2000).

Table 10 summarizes the selected untargeted moments generated by this model. The standard deviation of the spread is very close to the one in the baseline specification. Overall,

Table 9: Calibration of structural parameters: habit formation model

Parameter		**Habit model**
Discount factor, β		0.837
Max default endowment, $\hat{Y}$		0.810
Habit parameter, χ		0.891
Target	**Data**	**Habit model**
Avg. debt/revenues (%)	48.00	48.88
Avg. spread (%)	3.03	2.99
Autocorrelation of cons.	0.72	0.69

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[21] Calculated using the yearly series "General government final consumption expenditure (constant LCU)" from the World Bank's WDI from 1994 to 2019 for Mexico. We use the WDI series, rather than OECD as in the previous sections, because the latter only start from 2003 for Mexico.

the moments in the two models are quite similar. We conclude that the main quantitative result from our baseline model, a significantly increased volatility of the bond spread, can also be achieved with a standard habit formation friction.

Table 10: Untargeted moments: habit formation model

Statistic	**Mexico Data**	**Habit model**
$std(S)$	2.21	1.86
$std(D)/std(Y)$	0.26	0.50
$corr(S,D)$	-0.58	-0.37
$corr(Y,D)$	0.00	0.29
$corr(Y,S)$	-0.42	-0.80

Note: the empirical moments are calculated for Mexico's data covering 1994-2019. The bond spread is the EMBI index, while government final consumption expenditure and output are taken from National Accounts. Government deficit data is acquired from Banco de Mexico.

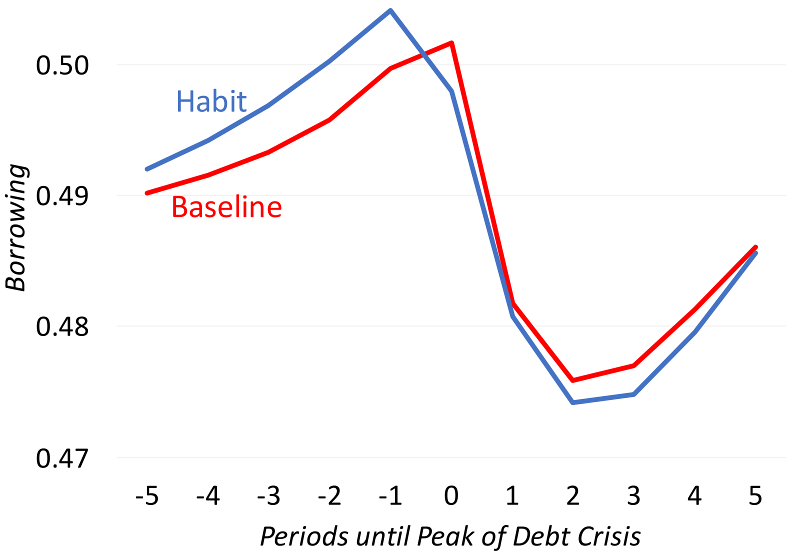
Finally, Figure 8d in Section 3.6 shows that the model with habit formation is equally capable, just as our baseline model, of generating high-peaking spreads in equilibrium, well in excess of 10% (in fact, the highest spread we obtain in the simulations is 22% for the habit model and 16% for the baseline model).

4.3 Qualitative analysis

We now use the calibrated habit-formation model to examine the behavior of government borrowing and spreads around the crisis episodes. The two models produce similar crises. A point of departure can be seen in Figure 9. In particular, in the habit specification borrowing is higher coming into the peak of the debt crisis. However, at the peak borrowing declines slightly. This departure raises the question of the extent to which realized adjustment costs may lead to increased borrowing during the peak of the debt crisis. We further investigate this question in Appendix F.

5 Evidence on “Borrowing into Debt Crises"

In this section, we provide empirical validation for the headline result of our paper, i.e. “borrowing into debt crises". To this end, we first identify “debt crisis” episodes in the data as events that satisfy three criteria. Specifically, we assume that a country experiences a debt crisis in a given year if: 1) its bond spread in that year is greater than its spread in the preceding and succeeding years; 2) its bond spread in that year is greater



Note: the figure presents simulated paths for debt during crises (as defined in the main text) in the habit model and the baseline specification.

Figure 9: Simulated behavior of borrowing

than the mean plus one standard deviation; and 3) it had not defaulted in that given year.[22] In other words, we are identifying episodes in which the bond spread peaks at a high enough level,[23] but the government has not defaulted yet.

Figure 10 presents average paths of bond spreads and external government debt around the crisis episodes defined as above.[24] Panel 10a verifies that the bond spread spikes, by construction, at the peak of the crises. Panel 10b shows that government debt tends to increase throughout the episode, with the pace of the increase accelerating at the height of the crisis, only to start declining three years after the peak.

6 Conclusion

This paper revisits several common issues with standard models of sovereign default. Quantitatively, such models struggle to generate the levels of bond spread volatility in line with what we observe in the data for most emerging countries. Qualitatively, the government in such models typically reduces debt sharply in anticipation of a looming

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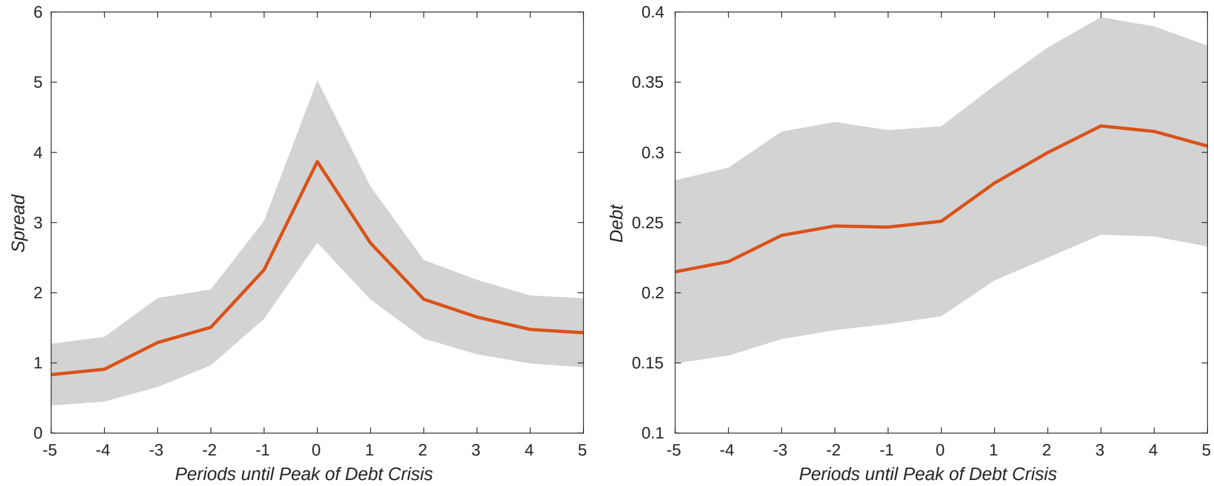
[22] Our model simulations in Figure 2 are conditional on the country not being in default.

[23] Similarly to the model analysis, we adopted one standard deviation above the mean spread and verified that the results are similar for the case of two standard deviations above the mean.

[24] In Appendix G, we investigate the behavior of the remaining variables of interest in the OECD data.



(a) Spread

(b) Debt

Notes: Solid lines present averages, while the shaded areas span the 5% and 95% confidence intervals.

Figure 10: Behavior of endogenous variables around debt crises: spread and debt

debt crisis, while in reality many countries struggle to deleverage effectively in response to adverse income shocks. We offer a solution to these problems by considering rigid government expenditure. When faced with negative income shocks, the government finds it costly to adjust its spending, in particular the public employment expenditure. As a result, it is optimal for the government to respond to debt crises slowly and tolerate high interest rate spreads for longer time periods while often actually borrowing into debt crises.

We quantify this channel using the OECD Government Accounts data and show that our preferred calibration for Mexico delivers a much higher volatility of the bond spread, able to close about 70% of the gap in standard deviations between the data and the prediction of the standard model. This is achieved by a government whose actions are also desynchronized relative to the income shocks and who on average ends up increasing its debt in anticipation of a looming debt crisis.

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Appendix (for online publication)

A Formulation of the model with noise

Government The government that is current on its debt obligations has the general value function given by:

$$W(B, H_{-1}, Y, \boldsymbol{\epsilon}) = \max_{d \in \{0,1\}} \left\{ d\left[V^D(H_{-1}, Y, \boldsymbol{\epsilon}) + \epsilon_{J+1}\right] + (1-d)V^R(B, H_{-1}, Y, \boldsymbol{\epsilon}) \right\} \tag{11}$$

where $\boldsymbol{\epsilon}$ is a $J+1$ dimensional vector of extreme value shocks. The distribution of these shocks is specified below.

The value of the government associated with repayment of debt ($d = 0$) is given by:

$$\begin{aligned}
&V^R(B_i, H_{-1}, Y, \boldsymbol{\epsilon}) = \max_{j, C \geq 0, L \geq 0} \left\{ U\left(C^{\alpha} L^{1-\alpha}\right) + \beta \mathbb{E}_{Y'|Y} \mathbb{E}_{\boldsymbol{\epsilon}'} W(B_j, H, Y', \boldsymbol{\epsilon}') + \epsilon_j \right\} \\
&\text{where} \\
&C + wL = \tau Y - \Big(\delta + (1-\delta)\kappa\Big) B_i + Q(B_j, H, Y)\Big(B_j - (1-\delta)B_i\Big) + \phi_1 \min\left\{\frac{H}{H_{-1}} - 1, 0\right\}, \\
&H = \phi_0\, C + (1-\phi_0)\, wL.
\end{aligned} \tag{12}$$

A sovereign who defaults ($d = 1$) is excluded from international credit markets and has probability θ of being readmitted every subsequent period. The associated value is:

$$\begin{aligned}
&V^D(H_{-1}, Y, \boldsymbol{\epsilon}) = U\left(C^{\alpha} L^{1-\alpha}\right) + \beta \mathbb{E}_{Y'|Y} \mathbb{E}_{\boldsymbol{\epsilon}'} \Big[\theta W(0, H, Y', \boldsymbol{\epsilon}') + (1-\theta) V^D(H, Y', \boldsymbol{\epsilon}')\Big] + \epsilon_{J+1} \\
&\text{subject to} \\
&C + wL = \tau Y^d(Y) \\
&H = \phi_0\, C + (1-\phi_0)\, wL.
\end{aligned} \tag{13}$$

The two constraints are the budget constraint and the law of motion for legacy contracts. $Y - Y^d(Y)$ reflects the output cost of defaulting.

International Lenders The lenders are assumed to be risk-neutral and perfectly competitive. The actuarially fair bond price that compensates them for default risk is

$$Q(B',H,Y) = \frac{1}{1+r}\mathbb{E}_{Y'|Y}\mathbb{E}_{\epsilon'}\Big[\Big(1-d(B',H,Y',\epsilon')\Big)\Big(\delta+(1-\delta)\kappa+(1-\delta)Q(B'',H',Y')\Big)\Big] \tag{14}$$

$where:$

$B'' = B'(B',H,Y',\epsilon')$

$H' = H(B',H,Y',\epsilon')$

The joint distribution of extreme value shocks takes the following standard form:

$$F(\epsilon) = \exp\left[-\left(\sum_{j=1}^{J}\exp\left(\frac{\epsilon_j-\mu}{\rho\sigma}\right)^{\rho}+\exp\left(\frac{\epsilon_{J+1}-\mu}{\rho\sigma}\right)\right)\right]$$

where loosely σ determines the the variability of the shocks and ρ determines the correlation of the debt shocks. To determine the values of ρ and σ we fix the former to 0.02 and find lowest σ for which our baseline specification converges. The resulting σ is 0.016. The same values are used in computing all other specifications. To assess the impact of the noise we recalibrate the flexible parametrization for smaller values of sigma. We find that the impact of lower σ on standard deviation of spreads and other key moments is small. We further investigate the impact of the extreme value shocks in the next Appendix.

B Comparison of solution methods

In this Appendix, we show that incorporating extreme value shocks in our solution technique has little impact on both quantitative and qualitative results. We first compare the solution with extreme value shocks to the solutions without these shocks in the flexible and fixed specifications. To achieve convergence without the extreme value shocks we use continuous choice of next period debt, numerical integration to calculate the expectations, and interpolation to evaluate off-grid points (Hatchondo and Martinez, 2009).[25] Importantly, we do not recalibrate the models but instead use the same parameter values as listed in Tables 3 and 5.[26] In the baseline specification, absence of extreme value shocks leads to non-convergence. To assess the importance of the extreme value shocks

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[25] We use 51 points for both the grid of assets and the grid of income. Off-grid points in the assets domain are evaluated using cubic spline interpolation, while off-grid income realizations are interpolated linearly.

[26] We recalibrate these models in Appendix C for the sake of evaluating the effects of global shocks.

in the baseline specification we follow (Dvorkin et al., 2019) in forcing the government to choose the most likely debt outcome, i.e., the most desirable debt level.[27]

Table 11 compares the relevant (targeted and untargeted) moments obtained with the two solution methods. We do this for both the flexible model, as well as the fixed labor variant (i.e. one that features a "minimum consumption" utility). As is evident, for both variants of the model, all moments are quantitatively close across the two solution methods. In particular, notice that the standard deviation of spread, the main object of interest in this paper, is 0.83% with noise and 0.79% with the exact computation in the flexible model, and it is 1.34% for both solution methods in the fixed labor model. Therefore, our extreme value shocks on debt choices add negligible volatility to the spread and have little impact on other moments in these two specifications.

Table 11: Simulated moments: noise vs. continuous

Statistic	**Data**	**Flexible**		**Fixed**	
		noise	*continuous*	*noise*	*continuous*
$ave(debt/Y)$	48.00	48.78	48.43	48.70	48.40
$ave(S)$	3.03	3.01	2.91	3.01	2.93
$std(S)$	2.21	0.83	0.79	1.34	1.34
$std(D)/std(Y)$	0.26	0.60	0.59	0.42	0.41
$corr(S,D)$	-0.58	-0.79	-0.86	-0.86	-0.89
$corr(Y,D)$	0.00	0.55	0.57	0.67	0.70
$corr(Y,S)$	-0.42	-0.83	-0.86	-0.90	-0.90
$std(C+L)/std(Y)$	1.57	1.40	1.44	1.29	1.34

Note: the empirical moments are calculated for Mexico's data covering 1994-2019. The bond spread is the EMBI index, while government final consumption expenditure and output are taken from National Accounts. Government deficit data is acquired from Banco de Mexico.

Naturally, the question remains whether the inclusion of extreme value shocks generates extra spread volatility in the baseline specification. In this specification, the continuous choice and interpolation technique is numerically much less stable. This is why we rely on the extreme value shocks to robustly compute the equilibrium. To assess the impact of these shocks we follow (Dvorkin et al., 2019) in supposing the government each period disregards the extreme value shocks and selects the most desirable debt level. Crucially, creditors continue to perceive the government as impacted by the extreme value shocks.[28]

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[27] We thank one of our referees for suggesting this exercise.

[28] In practice, this is implemented by solving the value function iteration and the resulting borrowing price assuming the extreme value shocks are in effect. However, in the simulations the debt level assigned

This allows us to compute the equilibrium while at the same time removing the "noise" from the governments decision.[29]

The results from this exercise are reported in Table 12. Columns labeled "noise" correspond to the government being subjected to the extreme value shocks as in the main text. "Modal" refers to the exercise described above in which the government does not take the extreme value shocks into account. First, notice that the change in spread volatility between "noise" and "modal" is of the same magnitude as "noise" and "continuous" in the flexible and fixed specifications. This gives us confidence in this exercise as one in which we are correctly "removing the noise". Second, in line with the results above all moments are very similar in "noise" and "modal" for all three specifications. Summarizing, this exercise further reinforces our argument that extreme value shocks have little impact in the volatility of spreads.

Table 12: Simulated moments: noise vs. modal

Statistic	**Data**	**Flexible**		**Fixed**		**Baseline**	
		noise	*modal*	*noise*	*modal*	*noise*	*modal*
$ave(debt/Y)$	48.00	48.78	48.79	48.70	48.71	48.70	48.70
$ave(S)$	3.03	3.01	3.01	3.01	3.01	3.01	3.00
$std(S)$	2.21	0.83	0.81	1.34	1.33	1.82	1.81
$std(D)/std(Y)$	0.26	0.60	0.58	0.42	0.42	0.41	0.41
$corr(S,D)$	-0.58	-0.79	-0.86	-0.86	-0.88	-0.34	-0.34
$corr(Y,D)$	0.00	0.55	0.57	0.67	0.69	0.36	0.37
$corr(Y,S)$	-0.42	-0.83	-0.86	-0.90	-0.90	-0.73	-0.74
$std(C+L)/std(Y)$	1.57	1.40	1.39	1.29	1.29	1.36	1.36

Note: the empirical moments are calculated for Mexico's data covering 1994-2019. The bond spread is the EMBI index, while government final consumption expenditure and output are taken from National Accounts. Government deficit data is acquired from Banco de Mexico.

Finally, we turn to our second result of increasing borrowing during crises. A natural concern in our baseline specification might be that "borrowing into debt crises" may be a result of the government swayed by the extreme value shocks. To address this concern we consider the same crises as in the main text and compare the simulated debt paths of the baseline model to the "modal" ones specified above. Figure 11 shows that the result of increasing debt during crises does not hinge on the extreme value shocks.

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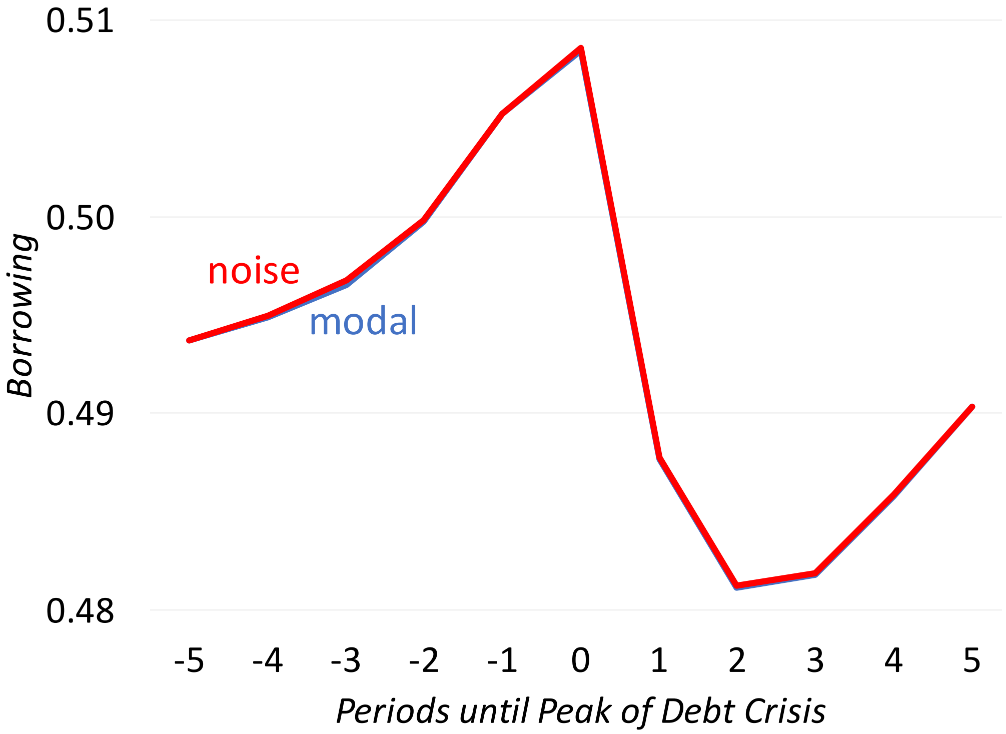
the highest probability prior to the realization of the extreme value shocks is selected.

[29] This approach allows us to remove one of the impacts of the extreme value shocks, namely the realized "noise" in the government's decisions. However, we are not able to rule out the possibility that creditors'



Note: the figure presents simulated paths for borrowing during crises (as defined in the main text) in the baseline specification with ("noise") and without ("modal") noise.

Figure 11: Simulated behavior of borrowing

C Standard model with global shocks

In this section, we augment a standard sovereign default model with shocks to foreign investors' risk aversion. Empirical literature in economics has shown that global factors are an important driver of sovereign spreads (González-Rozada and Levy Yeyati, 2008). The aim of this section is to investigate the contribution of such shocks to the volatility of the spreads.

Consider the standard sovereign default model (corresponding to the "flexible" version in our paper). To introduce global risk premium shocks, we closely follow Bianchi, Hatchondo and Martinez (2018) by imposing the following expression for the foreign investors' stochastic discount factor:

$$m_{t,t+1} = e^{-r-(\kappa_t \varepsilon_{t+1} + 0.5\kappa_t^2 \sigma^2)}, \quad \kappa_t \geq 0 \tag{15}$$

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perception of noise and the resulting impact on the price schedule affects equilibrium outcomes.

In expression (15), κ_t represents the two-state risk premium shock. In particular, this formulation implies that cash flows tend to be more valuable to foreign investors in the states of low income shocks, implying a positive risk premium. Similarly to Bianchi, Hatchondo and Martinez (2018), we normalize $\kappa_L = 0$, which represents normal times when creditors are risk-neutral, and set $\kappa_H = 23$. κ_t follows a Markov process with transition probabilities $\pi_{LL} = 0.85$ and $\pi_{HH} = 0.2$.

Table 13 presents the simulated moments without and with shocks to the lenders' stochastic discount factor, for the two variants of the standard model: flexible and fixed labor.[30] It is immediate to notice that while the inclusion of such shocks does increase the volatility of bond spread, the magnitude of this increase is small (from 0.82% to 0.85% for the flexible model, and from 1.35 to 1.40% for the fixed labor model).

Table 13: Simulated moments: models with and without global shocks

Statistic	**Data**	**Flexible**		**Fixed**	
		no SDF shocks	*SDF shocks*	*no SDF shocks*	*SDF shocks*
$ave(debt/Y)$	48.00	47.93	48.13	48.08	47.95
$ave(S)$	3.03	3.03	3.03	3.03	3.03
$std(S)$	2.21	0.82	0.85	1.35	1.40
$std(D)/std(Y)$	0.26	0.60	0.66	0.42	0.46
$corr(S, D)$	-0.58	-0.86	-0.86	-0.89	-0.88
$corr(Y, D)$	0.00	0.57	0.50	0.70	0.60
$corr(Y, S)$	-0.42	-0.86	-0.80	-0.90	-0.84
$std(C + L)/std(Y)$	1.57	1.44	1.47	1.34	1.34

Note: the empirical moments are calculated for Mexico's data covering 1994-2019. The bond spread is the EMBI index, while government final consumption expenditure and output are taken from National Accounts. Government deficit data is acquired from Banco de Mexico. All models are solved using continuous choice methods as described in Appendix B. The flexible model without and with SDF shocks is calibrated using the following parameters, respectively: $\beta = 0.794$, $\hat{y} = 0.833$ and $\beta = 0.796$, $\hat{y} = 0.829$. The fixed labor model without and with SDF shocks is calibrated using the following parameters, respectively: $\beta = 0.781$, $\hat{y} = 0.851$ and $\beta = 0.788$, $\hat{y} = 0.846$.

The results shown in Table 13 indicate that while global factors do play a role in driving sovereign spreads (the models in the table had to be recalibrated to hit the targets), alone they cannot raise the volatility of the bond spread. This is because the government in the model responds to such shocks in a similar way as it does to the local income shocks: by orchestrating a quick current account reversal and reducing its debt aggressively.

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[30] All four variants are recalibrated here to match the average debt and spread targets.

D Calibration with high government debt

In this section, we present a calibration of our model that matches a higher level of government debt. The purpose of this exercise is to explore the limits of our mechanism.

D.1 Calibration

In this extension, we calibrate the model to match average external *debt service* to government revenues (25.8%), rather than external debt as in our baseline parametrization. We also abandon the assumption that only a fraction of the debt observed in the data is unsecured, originally due to Chatterjee and Eyigungor (2012). Table 14 summarizes the calibration of our baseline model, along with a fully flexible version. The resulting debt stock to revenues comes out to 80%, considerably higher than 48% in our preferred calibration. This increase in the debt stock comes at the expense of extremely low discount factor of 0.575. In addition, this calibration is a worse match for the average labor share observed in the data.

Table 14: Calibration of structural parameters: baseline v. flexible

Parameter		**Baseline**	**Flexible**
Discount factor, β		0.575	0.710
Max default endowment, $\hat{Y}$		0.812	0.786
Interm. consumption weight, α		0.488	0.488
Adjustment weight, ϕ_0		0.482	0.000
Adjustment scale, ϕ_1		0.474	1.000
Target	**Data**	**Baseline**	**Flexible**
Avg. debt service/revenues (%)	25.80	25.83	25.86
Avg. spread (%)	3.03	3.05	3.04
Avg. labor share (%)	63.00	51.28	51.16
Elasticity of wL w.r.t. C in crises	0.24	0.24	-
Avg. ratio st. dev. of inputs (%)	164.00	161.80	-

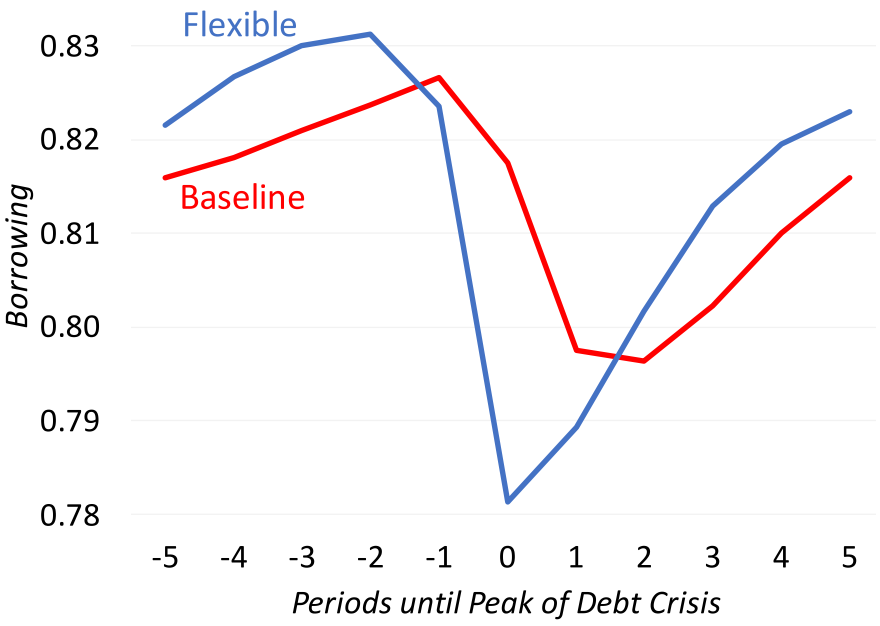
Table 15 reports the non-targeted moments in both models. As can be seen, the standard deviation of the spreads in this calibration declines for both, the baseline and the flexible variants of the model. Interestingly, this moment declines in both variants proportionally, as a result of which the standard deviation of the spread still more than doubles in our baseline model, as opposed to the flexible model. The decline in the standard deviation of the spreads is mirrored by the increase in the variability of the deficit (0.41 to 0.54 in the baseline and 0.60 to 0.80 in the flexible). We conclude that our key quantitative result is robust to a calibration with higher government debt.

Table 15: Untargeted moments: baseline v. flexible

Statistic	**Mexico Data**	**Baseline**	**Flexible**
$std(S)$	2.21	1.40	0.58
$std(D)/std(Y)$	0.26	0.54	0.80
$corr(S,D)$	-0.58	-0.62	-0.82
$corr(Y,D)$	0.00	0.58	0.53
$corr(Y,S)$	-0.42	-0.69	-0.79
$std(C+L)/std(Y)$	1.57	1.67	1.53
$corr(Y,Cost)$	-	-0.36	-
$corr(S,Cost)$	-	0.81	-
avg cost (% of avg revenues)	-	1.10	-

Note: the empirical moments are calculated for Mexico's data covering 1994-2019. The bond spread is the EMBI index, while government final consumption expenditure and output are taken from National Accounts. Government deficit data is acquired from Banco de Mexico.

Figure 12 highlights a main point of departure from our baseline results that follows the



Note: the figure presents simulated paths for borrowing during crises (as defined in the main text) in the baseline and flexible specifications when we target a higher average debt level.

Figure 12: Simulated behavior of borrowing

increased debt target. Specifically, the “Borrowing into Debt Crises" behavior presented in Section 3.4 is moderated. In particular, the government still borrows up to the eve of the crisis, but then chooses to reduce its debt when confronted with the worst spread. It should be emphasized that this debt reduction is slower and less drastic than in the baseline model. This behavior is a direct result of the discount factor falling so significantly. Due to a higher discounting of the future, the government no longer maintains a buffer for crises and is more forced to reduce its debt if one occurs. We conclude that our main qualitative result, on borrowing into debt crises, is sensitive to the value of the discount factor and thus the targeted debt level in the calibration.

E Decomposition of government consumption

We use the OECD Government Accounts decomposition of government expenditure by transaction which distinguishes the following components (classification code in parenthesis):

- Final consumption expenditure (P.3);
- Gross capital formation (P.5);
- Acquisitions less disposals of non-produced non-financial assets (K.2);
- Subsidies (D.3);
- Property income (D.4);
- Other current taxes (D.5);
- Social benefits other than social transfers in kind (D.62);
- Current transfers (D.7);
- Capital transfers (D.9).

We focus on the final consumption expenditure of the government because our model is not suited to capture elements such as investment or redistribution across households. For this reason we focus exclusively on Final consumption expenditure of the government which is calculated as follows:

$$\begin{aligned}
\text{Final consumption expenditure (P.3)} =& \text{Intermediate consumption (P.2)} \\
&+\text{Compensation of employees (D.1)} \\
&+\text{Consumption of fixed capital (K.1)} \\
&+\text{Other taxes on production (D.29)} \\
&-\text{Market output (P.11)} \\
&-\text{Output for own final use (P.12)} \\
&-\text{Payments for non-market output (P.131)} \\
&+\text{Social benefits in kind (D.631)}
\end{aligned}$$

In our analysis, for simplicity we focus on Intermediate consumption and Compensation of employees, and ignore the other elements that contribute to the Final consumption expenditure. We choose to do so because the data on other elements is not always complete and consistent across countries and time periods. This simplification is reasonable because the share of the sum of intermediate consumption and compensation of employees in final consumption expenditure is 92.6% on average across all countries and all time periods, with the minimum of 71.8%. In other words, these two elements are responsible for a vast majority of the final government consumption expenditure.

F Resource costs of adjustment

In this appendix we further investigate the impact of the realized adjustment costs, $\phi_1 \min \{H/H_{-1} - 1, 0\}$. In particular, we are interested in identifying the extent to which these costs are behind the higher standard deviation of spreads. As seen in Figure 13 the average adjustment cost is largest at the peak of the debt crisis. We assess the impact of these realized costs by removing them from the budget constraint in the following way. After the country has decided how much it wants to borrow b', the price of borrowing is set to q, and consumption has taken place we reduce the market value of debt by the realized adjustment cost. That is, we reduce future debt to $\hat{b}'$ found by solving the following equation:

$$q\hat{b}' = qb' - \phi_1 \min \left\{ \frac{H}{H_{-1}} - 1, 0 \right\}$$

We then recalculate the moments implied by the simulations.[31] The resulting moments can be seen in Table 16. Not surprisingly we see that average debt and spreads decline slightly. Further, the standard deviation of the spreads also declines but not drastically. In particular, the coefficient of variation for the spreads is 0.595 whereas in the baseline specification the same statistic was 0.605, a small decline. We conclude that the realized adjustment costs have a small impact in the standard deviation of spreads.

Table 16: Untargeted moments: habit formation model

Statistic	**Baseline**	
	with cost	*without cost*
$avg(B)$	48.70	47.76
$avg(S)$	3.01	2.82
$std(S)$	1.82	1.68

Note: both moments are calculated in the baseline specification. The first column (with cost) presents simulated moments from the baseline model in the main text. In contrast, the second column (without cost) removes the realized adjustment cost from the budget constraint as described in this appendix.

G Further comparison of model and data

In this section, we turn back to our original dataset in order to further investigate how the behavior of the model's endogenous variables compares to the data. We define a crisis episode here in the same way as in Section 5 of the main paper.

Figure 14, which is a direct counterpart of Figure 2 from the model, presents the dynamics of government accounts around debt crises in the data, averaged across countries.[32] The decline in government revenue (Figure 14a) coincides with an increase in bond spread towards its peak (Figure 14b). Further, while both types of government expenditure decline (Figures 14c-14d), the decline in public employment is smoother and smaller in size. We can also observe that the government deficit is positive throughout and goes up at the

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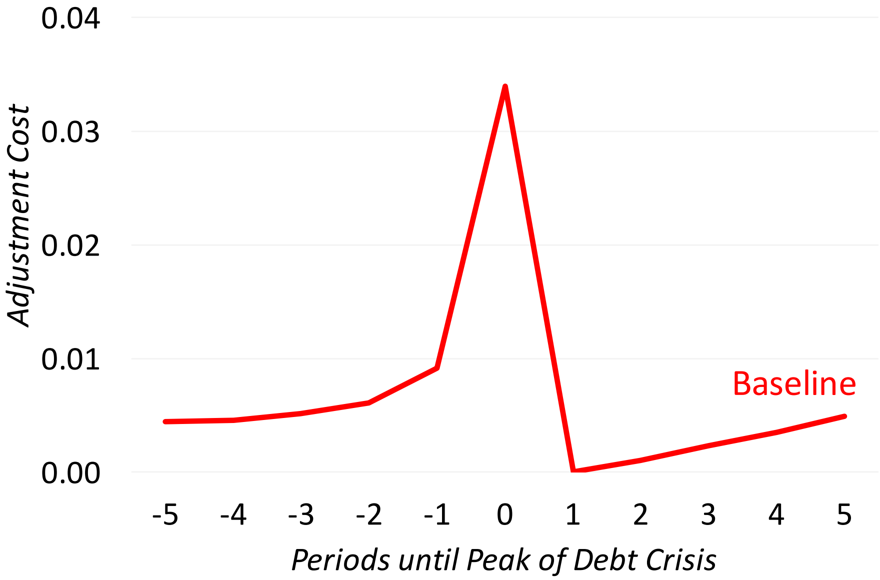
[31] Note that the value function iteration remains the same, i.e., the government expects to have to pay these adjustment costs. The reduction in adjustment cost takes place when simulating the model.

[32] Series on Government Revenues, Intermediate Consumption and Public Employment come from the OECD Government Accounts. Data on government deficit and bond spreads are acquired from OECD, with the latter being partly supplemented with EMBI when observations are missing. Government debt denotes the sum of external debt securities to GDP and the data is obtained from the Quarterly External Debt Statistics (QEDS). Because some values are missing in the data, we only consider the debt crisis events around which the entire path of data (±5 years) is available.



Note: the figure presents simulated paths for adjustment costs during crises (as defined in the main text) in the baseline specification. The units are in terms of average revenues, e.g., 0.01 is 1% of average revenues.

Figure 13: Simulated behavior of adjustment costs

peak of the crisis, a behavior that contrast with the results of our model.[33] Most importantly, government debt *increases* throughout the episode (Figure 14f), with the pace of the increase accelerating at the peak of the crisis, only to start declining three years after the peak.

The main discrepancy between Figures 14 and 2 stems from the path of government revenues following the peak of the crisis. In our model (Figure 2a), the revenue recovers promptly as a result of imposing an AR(1) income process, a reasonable assumption for our calibration target, Mexico. By contrast, in the data (Figure 14a), the recovery is very sluggish which further affects the paths of the two components of government spending (Figures 14c-14d), and overall debt (Figure 14f). The lack of recovery in government revenues arises from the fact that our data consists of OECD member states, mostly advanced countries. The simple AR(1) is not the best assumption for an income process in that case, especially in the aftermath of the European debt crisis (Paluszynski, 2021).

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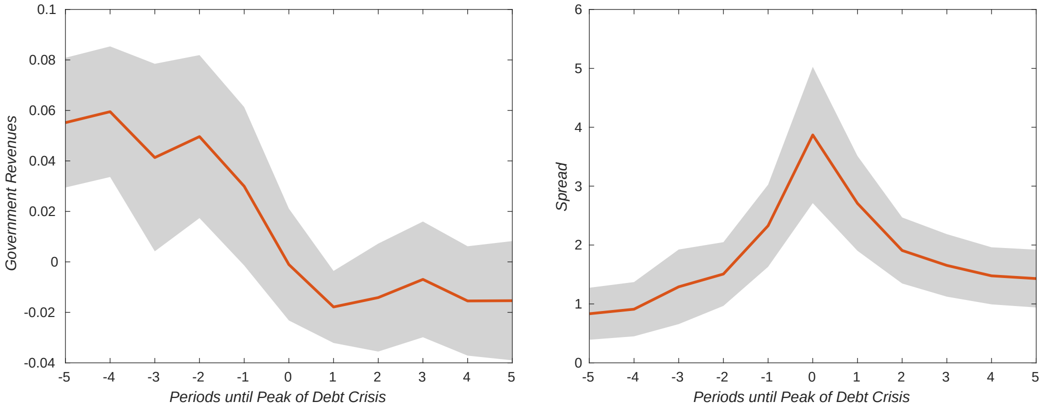
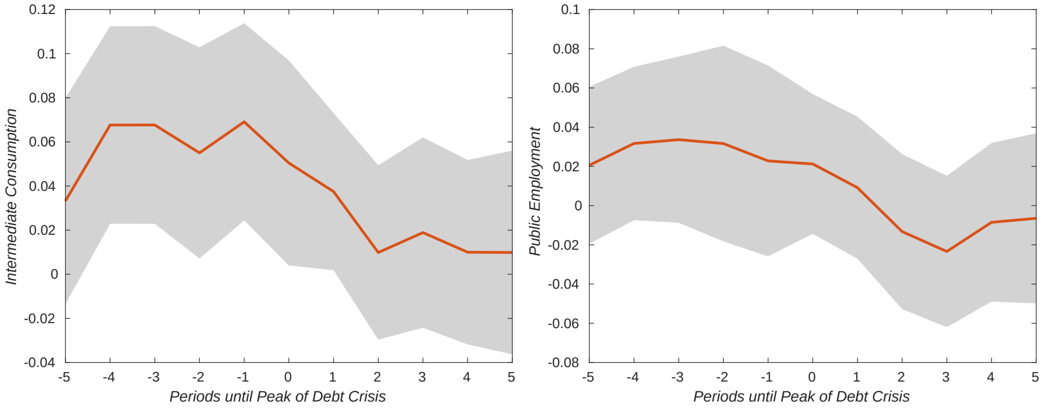
[33] The opposite sign of the deficit variable stems from the fact that in the data economies tend to grow continually, while growth is not present in our model. As a result, governments are able to run permanent deficits while maintaining sustainable debts. Although quantitative sovereign default models without growth are not capable of replicating the increase in deficit at the height of the crisis, we note that our baseline model makes progress in this dimension by dampening and delaying the reduction in deficit.



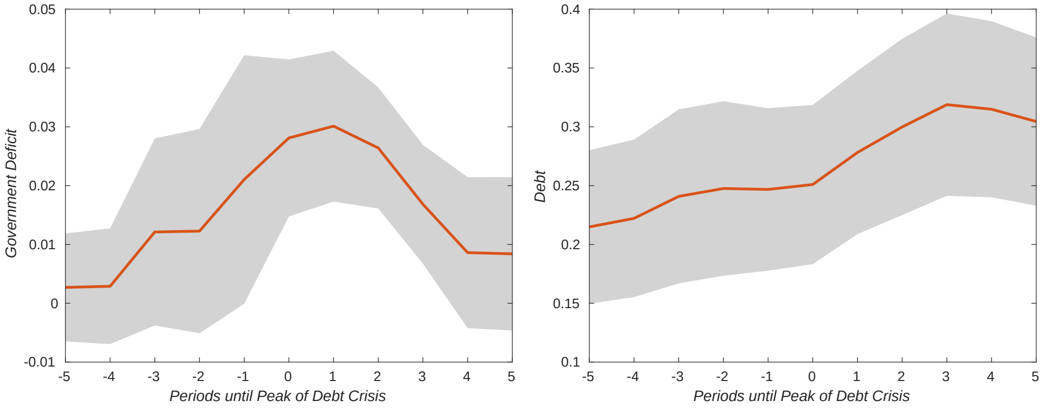
(a) Government Revenues

(b) Spread



(c) Intermediate Consumption

(d) Public Employment



(e) Government deficit

(f) Debt

Notes: Solid lines present averages, while the shaded areas span the 5% and 95% confidence intervals. The Government Revenues, Intermediate Consumption and Public Employment series are detrended using a common GDP trend and demeaned.

Figure 14: Behavior of endogenous variables around debt crises: data