# KNOW YOUR DEBTOR: POLITICAL UNCERTAINTY AND SOVEREIGN SPREADS[*]

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### Abstract

Sovereign debt spreads are very responsive to political uncertainty. We rationalize this empirical observation in a model where creditors learn the hidden propensity to honor debt obligations from government actions over time. We assume alternation in power of two types of government facing different costs of default on debt. Market participants do not know which type they are facing in each period. They form beliefs about it, which are updated according to observed fiscal policy decisions and political transition probabilities. We derive the conditions for the existence of pooling and separating equilibria on default and borrowing choices. As lenders beliefs about facing a government with low default costs strengthen, sovereign spreads increase, causing a contraction in public borrowing and spending. A version of our model calibrated to the Italian economy shows that the asymmetric information amplifies the increase in the level and the volatility of spreads stemming from political turnover, with negative implications for welfare.

# 1  Introduction

Sovereign bond spreads respond strongly to political events. Changes in borrowing terms are apparent not only at the time of actual fiscal actions, such as the approval of budget laws, but also in response to politicians' fiscal policy announcements and, more broadly, to the degree of uncertainty in a country's economic policy environment. We document this association in Section 2, where we show that a strong, positive, and significant correlation exists in many economies, both advanced and developing, between spreads and political uncertainty as measured by the Economic Policy Uncertainty (EPU) index of Baker et al. (2016). This correlation holds even after conditioning for economic fundamentals typically considered as the main determinants of spreads in the literature, such as aggregate income and the stock of public debt in a country.

The recent experience of Italy provides a case in point for this relationship. After the political and financial turmoil experienced during the European debt crisis, Italy was governed by "traditional" center-left governments between May 2013 and March 2018. The average sovereign spread of Italian bonds with respect to German bonds was about 160 basis points (bp) in that period. The following government, made up by the first self-declared Italian populist coalition, faced instead an average spread of about 250 bp during its June 2018-September 2019 tenure. Moreover, not only did the *level* of the sovereign spread increased, but also its *volatility* rose by more than 50%. These discrepancies occurred despite almost identical debt levels and economic growth performances (we provide more details in Section 2.1). The difference in market conditions is arguably a sign of sovereign lenders factoring in the high uncertainty surrounding the economic policies and, ultimately, the commitment to fiscal sustainability of the populist government.

In this paper, we rationalize the response of spreads to political uncertainty in a model that features sovereign borrowing by governments of different types alternating in power. Governments have private information about their default costs. Low-default-cost type of governments are generally more likely to default and are hence required to pay higher interest rates on their debt. They have therefore an incentive to imitate the actions of high-default-cost governments in order to obtain better borrowing terms. This kind of behavior gives rise to political uncertainty in the eyes of lenders, who infer the type of government they are facing based on prior beliefs and the actions they observe.

We find that lenders' beliefs affect lending conditions and, ultimately, fiscal policy and welfare. The possibility of "pooling" in the presence of asymmetric information amplifies the increase in sovereign spread levels and volatility that has been previously documented in models with political turnover and perfect information, with negative impli-

cations for welfare.

The experience of the formation of the 2018 Italian populist government offers several examples of actions that are arguably taken to positively influence markets' perception of a government's type in an environment characterized by high levels of asymmetric information. First, after having initially proposed an openly euro-skeptical finance minister, with the Italian president opposing its nomination and the spread increasing by almost 100 bp in five days, the new coalition opted for a moderate nonpartisan minister who could credibly reassure the markets. Moreover, after repeatedly hinting at the desirability for Italy to leave the Euro over the months leading to the elections, the coalition parties substantially toned-down the proposal and excluded any reference to it from the political agreement they signed at the beginning of their tenure.[1]

Our model builds upon Aguiar and Gopinath (2006) and Arellano (2008). A government with access to stochastic tax revenues borrows from risk-neutral lenders to finance public spending. The government has the option to strategically default on outstanding debt obligations, at a cost. The departure from the standard models is the presence of alternating governments of two types, with private information about their (different) costs of default. Political transitions happen stochastically at the end of each period. Sovereign lenders have prior beliefs about the type of government they are facing at any point in time—which affect the equilibrium interest rate on sovereign debt—and they update them according to the observed government's choices.

We consider stationary Markov perfect Bayesian equilibria in which the actions of all governments in terms of default and debt issuance choices are unrestricted. We derive the conditions that ensure the existence of pooling and separating equilibria on both repayment and borrowing. We assume that a pooling debt contract is preferred to a separating one in case both are sustainable in a given state of the economy. This assumption introduces more political uncertainty through pooling in our benchmark results, but we show it does not alter our main qualitative findings. The presence of political turnover allows for the (future) private information to remain relevant even when an action of the current government fully reveals its type.

In a version of our model calibrated to the Italian economy, we show that borrowing terms deteriorate as lenders become more convinced of facing a government with low default costs and hence a generally higher propensity to default. We confirm this finding

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[1] For a glimpse of markets early beliefs about economic policy and attitude toward the EU and the Euro of the two populist parties, see for instance the Financial Times' article "Populist beliefs: where Italy's League and Five Star stand" (*https://www.ft.com/content/8ca9a840-543e-11e8-b3ee-41e0209208ec*). The political agreement between the parties (in Italian) can be downloaded from *https://download.repubblica.it/pdf/2018/politica/contratto_governo.pdf*.

by analyzing the effects of a one-time negative shock to lenders' beliefs, i.e., a decrease in investors' confidence of facing a government with high default costs. Impulse response functions to this shock display a widening of sovereign spreads and, consequently, a contraction in sovereign debt and public spending. These results underscore the importance of lenders' beliefs, and their dynamics, on the ability of governments to conduct fiscal policy, a classical topic in the government's reputation literature.

Our findings rest on several assumptions about the political environment and the debt markets. The main ones are the presence of political turnover, the information asymmetry, and the debt contract order. To assess the individual contribution of each of these modeling features and to compare our results to existing ones in the literature, we obtain simulations of our model under alternative assumptions.

When analyzing the results of these exercises, we observe that introducing political turnover with full information in an otherwise standard sovereign default model increases the mean spread and its volatility, in line with existing studies in the literature. The main effect of asymmetric information is a substantial amplification of these effects, which is detrimental for welfare regardless of the contract order we assume. Nevertheless, intuitively, the level of spreads is higher under our baseline contract order—with the pooling contract coming first—vis à vis a model where the separating contract is offered first. The opposite is true for the volatility of spreads, which is higher when the separating contracts are offered first.

**Related Literature.** There is a large body of empirical literature that documents a significant relationship between sovereign risk and political factors, typically political instability and polarization. Hatchondo and Martinez (2010) provide a review, while Zoli (2013) focuses on Italy, as we do in several parts of our analysis. Our empirical contribution is to confirm that this relationship holds also when considering an aspect of the political environment that is relatively understudied in relation to sovereign spreads, namely, the (perceived) uncertainty surrounding economic policy as measured by the Economic Policy Uncertainty index of Baker et al. (2016). We then provide a more in-depth analysis of the relationship in the context of Italy.

Motivated by the ample empirical evidence, a long tradition of theoretical models of sovereign default analyzes the impact of politics on default rates, sovereign spreads, and debt. A stream of the literature has focused on reputation concerns in settings where alternating governments of different types have private information on their own preferences or on some payoff-relevant characteristics of the economy, which ultimately influence their willingness to default (Cole et al., 1995, Alfaro and Kanczuk, 2005, Amador and Phelan (2018)). Other papers have focused on asymmetric information—and the signal

that debt repayments can provide about it—as a motive for sovereign borrowing that is complementary to the more standard consumption smoothing and tilting reasons (Sandleris, 2008, Phan, 2017a, Phan, 2017b). To allow for analytical tractability, all those models limit the actions available to the government and/or the type of equilibrium considered, in most instances focusing on separating equilibria only. Our analysis is more general insofar as it leaves debt and default decisions unrestricted for all governments and considers pooling and separating equilibria in both actions. We also take a more quantitative approach to the study of the effects of asymmetric information and alternating government types on sovereign borrowing and cost of debt.

By so doing, our paper contributes to the stream of the literature that studies the implications of political elements in quantitative sovereign default models in the tradition of Eaton and Gersovitz (1981). The aim of those papers is typically to better align the quantitative predictions of the model vis à vis the data. Cuadra and Sapriza (2008) introduce a stochastic, though observable, alternation between two types of government. Although the types share the same willingness to repay debt, they differ in their preference for the distribution of resources between groups in the society. The authors show that this political element delivers higher spread level and volatility, and higher debt levels than a standard model à la Arellano (2008). Hatchondo et al. (2009) study a model economy with alternating governments with different discount factors in a perfect information setting. They show that political turnover contributes to delivering higher and more volatile spreads as compared to a model with no political alternation. Scholl (2017) studies how the degree of endogenous political turnover affects debt and default choices in a setting with heterogeneous preferences for public goods. Our contribution is to provide a quantitative assessment of the importance of political uncertainty—modeled as stemming from private information on default costs—and lenders' beliefs. We show that the asymmetric information generally amplifies the quantitative effects on sovereign spreads documented in the literature and we quantify its welfare consequences.

Previous papers that introduce private information stemming from politics in quantitative sovereign debt models are D'Erasmo (2011) and Egorov and Fabinger (2016).[2] The former shows how the interaction of exogenous political turnover, governments' private information on their discount factor, and endogenous post-default renegotiations can go

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[2] There are papers where the private information is on some economic fundamental. Paluszynski (2017) shows that a sovereign default model with government's private information on the growth regime in the country—which alternates stochastically—can quantitatively account for the delay between output drop and debt reductions and spreads surges observed around the European debt crisis. Chatterjee and Eyigungor (2019) propose a model of endogenous political turnover that is determined by hidden switched between growth regimes. They document an increase in the volatility of sovereign spreads as a consequence of their political setting.

a long way in increasing debt levels predicted by a sovereign default model. Our analysis is richer in terms of the type of equilibria considered. Moreover, we focus on the implications for spreads rather than debt, and we enrich the analysis with welfare comparisons. Egorov and Fabinger (2016) analyze a model where the government has a hidden cost of default that can change stochastically only after a default. Their main result is a rationalization of the process of graduation from default, focusing on an equilibrium that allows only for separation on default and pooling on debt choice.

**Layout.** The reminder of the paper is organized as follows. Section 2 presents empirical evidence on the relationship between political uncertainty and sovereign spreads. Section 3 describes our two-period model, which we extent to an infinite horizon in Section 4. We discuss the calibration of the infinite-horizon model and we provide a characterization of its equilibrium in Section 5. In Section 6 we present our main results on the effects of political uncertainty on sovereign spreads and debt decisions. Finally, Section 7 offers some concluding remarks.

## 2 Empirical Evidence

There exists compelling evidence that political events with economic implications are associated with sovereign spread movements. We show that this correlation is a feature of the data for many countries, both developed and developing, over the last three decades. We also document the importance of politics vis à vis GDP and debt levels in predicting sovereign spreads. These results motivate our interest in political uncertainty as an important determinant of sovereign spreads, on top of the typical variables considered in the sovereign default literature, namely, GDP and debt.

We begin by estimating the following regression:

$$spr_{i,t} = \gamma_i + \beta_1 epu_{i,t} + \beta_2 gdp_{i,t} + \beta_3 debt_{i,t} + \varepsilon_{i,t} \tag{1}$$

where $spr_{i,t}$ is the spread for the 10-year yield of government bonds of country $i$ at time $t$. The spread is the difference between the country's yield and the yield of German bonds (for Euro Area countries) or US Treasuries (for developing countries, considering the yield on their dollar-denominated bonds); $epu_{i,t}$ is the Economic Policy Uncertainty (EPU) index developed by Baker et al. (2016), which we use as our measure of political uncertainty; $gdp_{i,t}$ is real Gross Domestic Product; and $debt_{i,t}$ is outstanding gross government

debt.[3] We include country-fixed effects $\gamma_i$ to control for any time-invariant characteristic that is specific to each country. The regression is estimated for an unbalanced panel of 12 countries, with quarterly time series for the period 1990q1-2020q1 (the exact coverage is apparent in Figure 1).

Table 1 reports the estimates of regression (1), in terms of standardized beta coefficients. The sign of coefficients are all as expected. In particular, when focusing on column (4), one standard deviation increase in the EPU index increases the spread by about 0.1 standard deviations, an increase of one standard deviation in GDP reduces the spread by about 0.2 standard deviations, and one standard deviation increase in government debt increases the spread by 0.1 standard deviations. Only the effects of EPU and debt are statistically significant (at the 10% and 5% level, respectively). Results in Table 1 underscore the importance of political uncertainty in predicting sovereign spreads, even when controlling for debt and GDP.

Table 1: Spread, Economic Policy Uncertainty, and GDP

|  | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| EPU | 0.179* |  |  | 0.130* |
|  | (1.90) |  |  | (1.99) |
| GDP |  | -0.276 |  | -0.217 |
|  |  | (-1.32) |  | (-1.00) |
| Debt |  |  | 0.213* | 0.115** |
|  |  |  | (2.12) | (2.88) |
| $N$ countries | 12 | 12 | 12 | 12 |
| $N$ observations | 656 | 664 | 650 | 645 |

*Notes:* The dependent variable is the spread for sovereign bonds. The table shows standardized beta coefficients. t-statistics with clustered-robust standard errors at country-level are in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ Regressions include country fixed-effects.

Figure 1 shows graphically the relationship between spreads and the EPU index, for the sample used to derive the results in Table 1. The positive association is particularly strong for Italy—the country we choose for the calibration of our quantitative model—,

[3] Sovereign yields are generic 10-year yields-to-maturity (ytm) from Bloomberg. For Euro Area countries (and Croatia), we take the difference with respect to the German ytm. For non-Euro Area countries, we take the difference between the ytm for US dollar-denominated debt for the country and the ytm for US Treasuries. The EPU is an index based on textual search of the major newspapers in a country (see Baker et al., 2016 for details). We downloaded the data from *https://www.policyuncertainty.com* on 4/6/2020. GDP data are from the OECD Main Economic Indicators Dataset, except from the series for Singapore, which comes from the Singaporean Ministry of Finance, and the one for Croatia, which is from Eurostat. Debt is outstanding gross debt of the general government from the IMF's Fiscal Monitor. GDP and debt are HP-filtered in logs.

at least starting from 2008.

Figure 1: Spread and Political Uncertainty
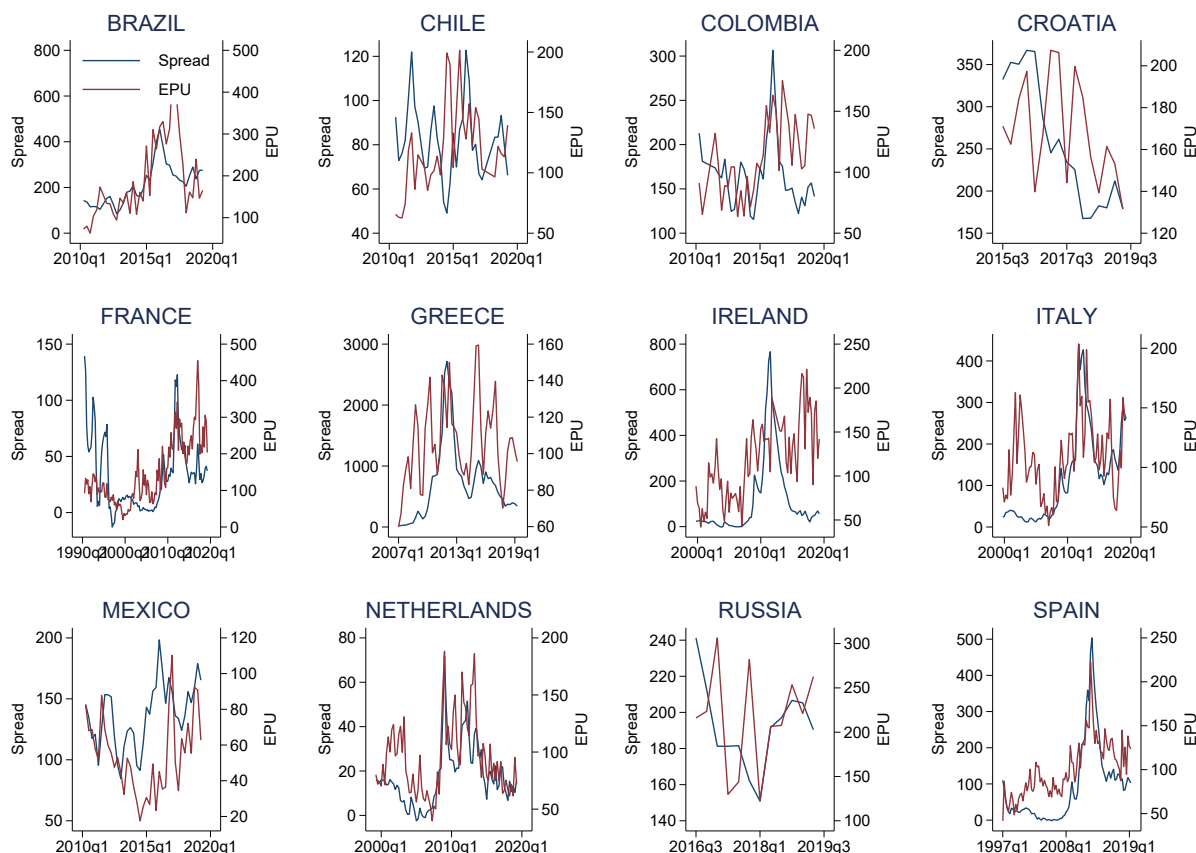


*Notes: Spread* is the difference between the 10-year yield-to-maturity of government bonds in a country and the one of Germany (for European countries) and the United States (for non-European). *EPU* is the Economic Policy Uncertainty index of Baker et al. (2016).

Finally, in Appendix A we report results for the relationship between spreads, EPU index, GDP, and government debt in each individual country, both graphically (Figure A1) and in terms of regressions (Table A1). Once again, political uncertainty appears to be a crucial determinant of spreads for the majority of the countries in the sample.

## 2.1 Politics and Spreads in Italy

The recent Italian experience provides a case in point for the relationship between political uncertainty and sovereign spreads. Figure 2 shows the spreads on 10-year Italian government bonds with respect to German ones during the formation of the 2018 Italian

populist government. Clearly, market participants were reacting to political news.[4]

Figure 2: Spread and Political Uncertainty in Italy
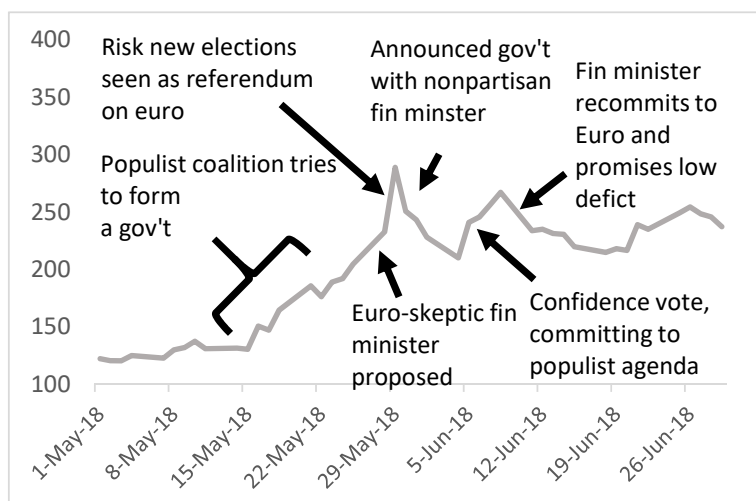


*Notes:* The solid line is the spread between the 10-year yield-to-maturity of government bonds for Italy and Germany. References to the events can be found here *https://en.wikipedia.org/wiki/2018_Italian_government_formation* and here *https://www.reuters.com/article/us-italy-economy-minister/new-italian-economy-minister-vows-to-stay-in-euro-cut-debt-level-idUSKBN1J60D9*.

Another piece of evidence of the relationship between economic uncertainty and sovereign spreads is provided by the comparison of the political and economic environment during the tenure of the populist government (from June 2018 to September 2019) with the one faced by the three previous "traditional" center-left governments (Letta, Renzi, and Gentiloni) that were in office during the previous 5-year legislation (April 2013 to March 2018). We perform this comparison in Table 2.

As one can see in Table 2, sovereign spreads were substantially higher and more volatile under the populist government, despite similar high debt-to-GDP ratios and lackluster growth performances. This can arguably be the result of markets being particularly uncertain about the fiscal stance and, ultimately, the commitment to debt sustainability of the populist government.[5] Indeed, the EPU index was higher during the populist government's tenure.

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[4] This relationship is not unique to 2018. For instance, Zoli (2013) presents a graph similar to Figure 2 that shows the same type of co-movements during the European debt crisis.

[5] Many articles on the financial press highlight the high degree of uncertainty surrounding the economic and debt policies of the populist governments. See the one we cite in footnote 1, "Dearth of Italian bond deals flashes long-term debt danger" by Routers in November 2018 (*https://uk.reuters.com/article/uk-italy-bonds-analysis/dearth-of-italian-bond-deals-flashes-long-term-debt-danger-idUKKCN1NP1VX*), or and The Economist's "Debt and discipline" in June 2019 (*https://www.economist.com/europe/2019/06/08/the-eu-edges-towards-punishing-italy-for-letting-its-debt-rise*).

Table 2: Financial and Economic Environment Under Different Italian Governments

| Statistics | Traditional Governments | Populist Government |
|---|---|---|
| Spread Mean | 160.27 | 252.82 |
| Spread Volatility | 7.47 | 11.51 |
| GDP Growth | 0.18 | 0.01 |
| Debt-to-GDP | 131.02 | 132.16 |
| EPU Index | 113.22 | 129.82 |

*Notes:* The period of the *Traditional Governments* covers the cabinets of Letta, Renzi, and Gentiloni, from April 2013 to March 2018. The period of the *Populist Government* covers the cabinet of Conte I, from June 2018 to September 2019. *Spread Mean* is the mean daily spread over the governments' tenures, in basis points. *Spread Volatility* refers to the average over the governments' tenures of the monthly standard deviation of daily spreads, in basis points. *GDP growth* is the average over the governments' tenures of the quarter-on-quarter growth rate of seasonally adjusted real GDP, in percentage points. *Debt-to-GDP* is the average over the governments' tenures of the Debt-to-GDP ratio, in percentage points. *EPU index* is the average over the governments' tenures of the monthly EPU Index by Baker et al. (2016).

# 3 Two-Period Model

We rationalize the association between political uncertainty and sovereign spreads that we documented empirically in the previous section as the result of asymmetric information between the government and sovereign lenders in a model of sovereign default. In this section, we describe a simple two-period version, with the aim of building some intuition around the main mechanisms at play in our setting. We will then move to an infinite-horizon version that we use for quantitative analysis in Section 4.

## 3.1 Environment

Consider an economy that lasts for two periods, $t = 1, 2$. The economic agents are a government and a large number of investors.

In each period, the government in office chooses an amount $g_t$ of public spending and receives tax revenues amounting to a fraction $\tau$ of the aggregate income $y_t$ in the economy. Income in the second period is stochastic and evolves according to a first-order Markov process. The government in office in period $t$ values public spending according to:

$$\mathbb{E}_t \sum_{j=0}^{T-t} \beta^j u(g_{t+j}),$$

where $T = 2$ ($T = \infty$ in the infinite-horizon version later on), $u(.)$ is a strictly increasing and concave utility function, and $\beta$ is the discount factor.

In period $t = 1$, an amount $b_1$ of outstanding sovereign debt comes due. We start by assuming that this debt is not defaultable. We relax this assumption starting from Section 3.5. The government can issue new debt, in the amount $b_2$, to be repaid in the second period. The price $q$ at which debt is issued is determined by the lenders.

In period $t = 2$, there is no borrowing, but the government can decide to default on the debt $b_2$ that comes due. If the government defaults, it suffers a one-time utility loss. This loss is typically used in the literature to capture various costs that arise upon default that could be related to, among other things, reputation, bailouts, sanctions, or financial friction.[6]

We assume that the government can be of two possible types, high ($H$) and low ($L$). The difference is in the cost incurred in case of default, $\varphi_i$, $i \in \{H, L\}$, with the $H$-type government having a strictly higher cost than an $L$-type government, i.e., $0 < \varphi_L < \varphi_H$. To provide the most transparent intuition, we abstract from transitions between government types in the two-period version of our model. We will introduce them in the infinite-horizon version.

The crucial assumption in our model is that the values $\varphi_H$ and $\varphi_L$ are common knowledge, but lenders do not know which government is in office in any given period. They have a prior belief about the probability that they are facing an $H$-type government, $\mu_0$, and they update it, according to Bayes law, to the posterior belief $\mu_P$ with the information they derive from the current government's choices. We discuss the information content of government's actions in the next sections.

Lenders have unlimited resources and are risk neutral, with the outside option of investing their funds at a risk-free rate $r$. They therefore offer a price $q$ for debt issued at $t = 1$ that is proportional to the probability of being repaid in $t = 2$. We adopt the timing of actions of sovereign default models in the tradition of Eaton and Gersovitz (1981), with the government moving first by choosing the amount of debt to issue and then lenders offering their price. If default is allowed in the period, that decision precedes any debt issuance (and pricing) choice.[7]

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[6] A microfundation of default costs is outside the scope of this paper. For references, see Bocola (2016), Hébert and Schreger (2017), or Perez (2018). Phan (2017a) and Phan (2017b) present models where the cost of default is not exogenous but arises endogenously in an economy with asymmetric information and production relying on foreign capital.

[7] Our timing assumptions, coupled with the choice of gross debt issuance, ensure the uniqueness of the debt price. See Ayres et al. (2018) and Lorenzoni and Werning (2019) for papers that study the implications of different timing and issuance assumptions in sovereign default models.

## 3.2 Equilibrium

We consider perfect Bayesian equilibria. In period $t = 2$, the value function of a government of type $i$ takes the following form:

$$V_{2,i}(s_2) = \max_{d \in \{0,1\}} (1-d)u(\tau y_2 - b_2) + d\left(u(\tau y_2) - \varphi_i\right), \tag{2}$$

where $s_2 = (b_2, y_2)$ is the state of the economy in the second period, $d$ is an indicator equal to one in case of a default. Note that we already substituted $g_t$ using the government budget constraint. We assume repayment in case of indifference.

The value function for a government of type $i$ in period $t = 1$ is:

$$V_{1,i}^R(b_1, y_1, \mu_0) = \max_{g_1, b_2 \in B} u(g_1) + \beta \mathbb{E}_{y_2|y_1}\left[V_{2,i}(s_2)\right]$$

$$\text{s.t.} \qquad \tau y_1 + q b_2 = g_1 + b_1, \tag{3}$$

where $q$ is the price offered by the lenders and $B = [0, \bar{B}]$ is the set of feasible debt issuance choices.[8] We add the superscript "$R$" to $V_{1,i}$ to later distinguish this value function that describes a situation of debt repayment to the one for the case of default.

The equilibrium pricing schedule consistent with lenders' break-even (in expectation) in $t = 1$ is:

$$q(b_2, y_1, \mu_P) = \frac{1}{1+r}\mathbb{E}_{y_2|y_1}\left[\mu_P\left(1 - d_{2,H}(s_2)\right) + (1 - \mu_P)\left(1 - d_{2,L}(s_2)\right)\right], \tag{4}$$

where $d_{2,i}$ is the indicator denoting the policy function for default in $t = 2$ for a government of type $i$.

We consider a particular order in which debt contracts are offered, and hence beliefs are updated, in equilibrium.

**Assumption 1.** *In proposing debt contracts, lenders adopt in the following order:*

1. *a pooling contract is offered, if feasible. Otherwise,*

2. *a separating contract is offered, if feasible. Otherwise,*

3. *the sovereign debt market "freezes", i.e., lenders refrain from providing any credit (i.e., $b_2 = 0$).*

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[8] We rule out public savings, consistently with Italian data. The debt limit $\bar{B}$ avoids Ponzi schemes but it does not otherwise bind in equilibrium.

The *market freeze* can be thought as a residual category that encompasses cases in which there is no debt pricing schedule consistent with lenders' no-arbitrage condition. In fact, we never observe it in the simulations of our quantitative model. We specify the precise type of pooling and separating contracts we focus on and the conditions for feasibility of the various options in the next sections.

We choose the order specified in Assumption 1—in particular, the pooling contract as the first option—because our ultimate interest is to study the effect of private information on sovereign bond markets, which manifests itself evidently in situations of pooling. We present results for an (infinite-horizon) version of the model where separation comes first in Section 6.2 and Appendix E.

The beliefs about the government's type are updated from the prior, $\mu_0$, to the posterior, $\mu_P$, according to $\mu_P = G(b_2; b_1, y_1, \mu_0)$. In particular, the function $G$ takes the form:

$$\mu_P = G(b_2; b_1, y_1, \mu_0) = \begin{cases} \mu_0 & \text{if } \textit{pooling on debt} \text{ or } \textit{market freeze} \\ 0 \text{ or } 1 & \text{if } \textit{separation on debt}. \end{cases} \tag{5}$$

## 3.3 Pooling on Debt

In this section we derive a condition for the existence of a pricing schedule that supports a pooling equilibrium, i.e., a situation in which, given lenders' prior, the debt choice $b_2$ does not convey information about the government's type and hence the lenders' posterior beliefs, $\mu_P$, equal their prior, $\mu_0$. Note that this is the only relevant dimension for pooling that we can have under our assumption of no default in $t = 1$. We consider the case of pooling (and separation) on default decisions when we allow for default in $t = 1$ in Section 3.5. For the sake of brevity, we refer to $b_2$ as debt, rather than debt issuance, whenever this does not generate confusion.

Let us introduce one assumption and some notation. First, throughout the paper, we maintain the following assumption about lenders' updating of beliefs off the equilibrium path:

**Assumption 2.** *Lenders consider any deviation from equilibrium actions as coming from the L-type government.*

Then, we define the following objects. First, the (expected present discounted) value in $t = 1$ of $b_2$ for a government of type $i$:

$$U_i(b_2; b_1, y_1, \mu) \equiv u(\tau y_1 + q(b_2, y_1, \mu)b_2 - b_1) + \beta \, \mathbb{E}_{y_2|y_1}[V_{2,i}(s_2)], \tag{6}$$

where $q$ is the equilibrium debt pricing schedule defined in (4).

Second, the maximum value that a government of type $i$ can derive from issuing debt when it is thought to be of type $L$ for sure, regardless of its action (i.e., when $\mu_P = 0$):

$$\tilde{U}_i(b_1, y_1) \equiv \max_{b_2} U_i(b_2; b_1, y_1, 0),$$

and the corresponding maximizer(s):

$$\tilde{b}_i \equiv \arg\max_{b_2} U_i(b_2; b_1, y_1, 0).$$

Note that, by Assumption 2, $\tilde{U}_i(b_1, y_1)$ is the maximum payoff that a government of type $i$ can get from any deviation from a pooling contract.

Finally, we denote by $\mathcal{B}_i^P$ the set of debt issuances consistent with pooling equilibria for the $i$-government, i.e., those $b_2$ at which the $i$-government does not want to deviate when offered a price consistent with (4) and $\mu_P = \mu_0$. This set is made up by all the debt issuances $b_2$ such that:

$$U_i(b_2; b_1, y_1, \mu) \geq \tilde{U}_i(b_1, y_1).^9 \tag{7}$$

Figure 3 provides a graphical representation of all the objects we just defined. It shows the functions $U_i(b_2; b_1, y_1, \mu_0)$ and $U_i(b_2; b_1, y_1, 0)$, together with the corresponding pooling set $\mathcal{B}_i^P$.

Figure 3: The Pooling Set
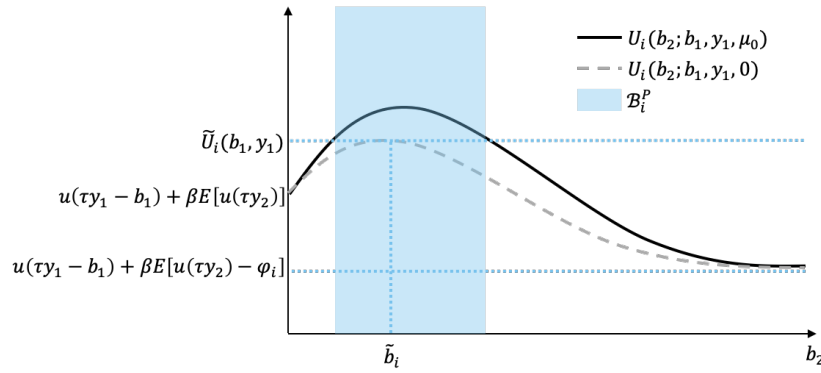


The vertical intercept of the $U_i$ curves in Figure 3, their horizontal asymptote as $b_2 \to \infty$, and the relative position of the two curves are general features that are always true under our assumptions. The first two properties are straightforward. We prove the third in Lemma 3 in Appendix B.

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$^9$ Throughout the paper, we assume that the government never deviates in case of indifference.

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The sign of $\partial U_i(b_2)/\partial b_2$ over $[0, \infty)$ is the result of the trade-off entailed by higher $b_2$: (potentially) higher debt revenues in the current period—which increase current spending—and higher debt repayments in the future—which lower future spending. In Figure 3 we present an intuitive case where the former effect dominates for low values of $b_2$—for which the debt price $q$ is high enough—while the latter dominates as $b_2$ becomes large enough—with a corresponding drop in $q$. However, it could be possible to visit states where $U_i$ is monotonically declining (leading to a singleton $\mathcal{B}_i^P$ containing only $b_2 = 0$) or even more involved cases in which $U_i$ has multiple (local) maximizers.[10]

We are now in the position to state the main result of this section, namely, the condition that ensures the existence of pooling equilibria on debt.

**Result 1.** *A pricing schedule of the form* $\{q(b \in \mathcal{B}^P, y_1, \mu_0), q(b \notin \mathcal{B}^P, y_1, 0)\}$*, with* $\mathcal{B}^P \equiv \mathcal{B}_H^P \cap \mathcal{B}_L^P$*, that supports a pooling equilibria on debt exists if and only if* $\mathcal{B}^P \neq \emptyset$*.*

## 3.4 Separation on Debt

In this section we derive a condition for the existence of a pricing schedule that supports a separating equilibrium, i.e., a situation in which, given lenders' prior beliefs, the debt choice $b_2$ reveals the government's type and so the lenders' posterior beliefs, $\mu_P$, equal 0 for an $L$-government and 1 for an $H$-government.

Let us start by introducing two additional pieces of notation. First, we denote by $\mathcal{B}_L^D$ the set of debt issuances, $b$, such that $U_L(b; b_1, y_1, 1) \geq \tilde{U}_L(b_1, y_1)$. These are all the debt choices for which an $L$-type government could have incentives to deviate, i.e., mimic the debt choice of an $H$-government so to obtain the (higher) price consistent with $\mu_P = 1$. Second, we define:

$$\hat{b}_H^S \equiv \arg\max_{b \notin \mathcal{B}_L^D} U_H(b; b_1, y_1, 1), \tag{8}$$

the debt choice the yields the highest payoff to the $H$-type in separation without inducing a deviation by the $L$-type.[11]

Finally, the following result states the conditions for the feasibility of separation on debt choices:

---

[10] The proof of the continuity and the existence of a unique global maximizer of $U_i$ is beyond the scope of our paper (see Auclert and Rognlie (2016) for a proof of the uniqueness of the equilibrium in a standard Eaton–Gersovitz framework). We only conjecture those intuitive properties, which are consistent with the shape of typical debt pricing and value functions in the literature. We provide some numerical results on the monotonicity of $U_i$ in the infinite-horizon version of our model (see Figure 6). Note that we solve the model with global solution methods that, for the most part, do not rely on any of these conjectured properties. When they do, we clearly specify which assumptions we adopt in our solution.

[11] In case multiple $\hat{b}_H^S$ exist, we assume the smallest one is chosen.

**Result 2.** *A pricing schedule of the form $\{q(\hat{b}_H^S, y, 1), q(b \neq \hat{b}_H^S, y, 0)\}$ that supports a separating equilibrium exists if and only if $\hat{b}_H^S$ (as defined in (8)) exists and*

$$U_H(\hat{b}_H^S; b_1, y_1, 1) \geq \tilde{U}_H(b_1, y_1).$$

Intuitively, this result ensures that neither of the two types of government have the incentive to deviate from the proposed contract. Therefore, a separating equilibrium can be sustained where, in equilibrium, the $H$-type government chooses to issue debt in the amount $\hat{b}_H^S$ while the $L$-type government chooses $\tilde{b}_L$.

Figure 4 gives a graphical representation of Result 2. The key condition for the feasibility of separation is the ranking between the value of the maximum of $U_H(b_2; b_1, y_1, 0)$ (the dotted dashed line) and $U_H(\hat{b}_H^S; b_1, y_1, 1)$ (on the red dashed line): if the former is larger, separation is supported; if not, the $H$-type government is better-off deviating from $\hat{b}_H^S$, issuing the (larger) amount $\tilde{b}_H$, even if this implies being perceived as an $L$-type.

Figure 4: Separation on Debt
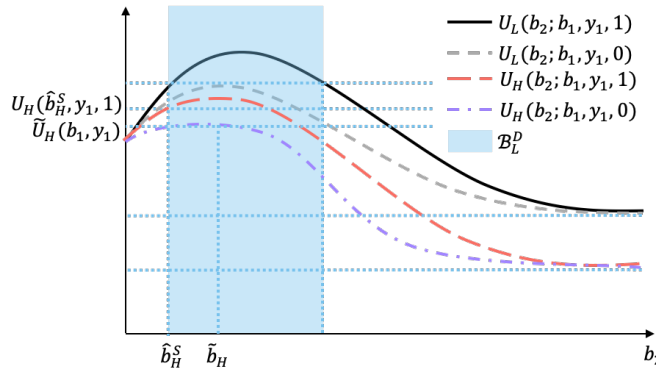


## 3.5 Default in the First Period

In this section we consider a situation in which default is allowed also in the first period. This case is informative for the extension of the results to the infinite-horizon version of the model in Section 4.

Our timing assumption à la Eaton and Gersovitz (1981) requires the default decision to take place before lenders set the current debt price. Therefore, the default decision can convey information about the type of government in office in the current period, which the lenders will use to update their prior beliefs, $\mu_0$. We denote by $\mu_1$ the posterior beliefs coming from Bayesian updating of $\mu_0$ with the information carried by the default decision. As in the previous sections, the beliefs $\mu_1$ will then be updated according to debt

choices to $\mu_P$. We refer to $\mu_0$ as *prior beliefs*, $\mu_1$ as *interim beliefs*, and $\mu_P$ as *posterior beliefs*.

Formally, the default decision in $t = 1$ entails choosing the option that yields the highest payoff between repaying and defaulting.[12] That is:

$$
\begin{aligned}
d_{1,i}(b_1, y_1, \mu_0) = \underset{d \in \{0,1\}}{\arg\max} \ \ (1-d)V_{1,i}^R(b_1, y_1, \mu_1) + dV_{1,i}^D(y_1) \\
\text{s.t.} \qquad \mu_1 = G_0(d; b_1, y_1, \mu_0),
\end{aligned}
\tag{9}
$$

where the value function of repayment (in equilibrium) was defined in (3)-(5), whereas the one of default is:

$$
V_{1,i}^D(y_1) = \ u(\tau y_1) - \varphi_i + \beta \mathbb{E}_{y_2|y_1}\left[V_{2,i}(0, y_2)\right].
$$

The function $G_0$ governs the update of lenders' beliefs from $\mu_0$ to $\mu_1$. We describe it shortly, after proving one useful lemma.

**Lemma 1.** *The equilibrium value function $V_{1,L}^R(b, y, \mu)$ is increasing in beliefs $\mu$ for all $(b, y)$.*

*Proof.* Note that $V_{1,L}^R(b, y, \mu) = \max_z U_L(z; b, y, G(z; b, y, \mu))$. Lemma 3 in Appendix B established that $U_L(b; b_1, y_1, x)$ is increasing in $x$. Therefore, to prove the result, it is sufficient to show that $G$ is increasing in $\mu$. Note the following:

1. the condition for separation on debt is independent from $\mu$ (see Result 2). Therefore, for any given pair $(b_1, y_1)$, when pooling is not feasible there is either *separation on debt* (if feasible) or *market freeze*;

2. the cardinality of the pooling sets $\mathcal{B}_i^P$ is increasing in $\mu$. This can be noticed by looking at (7), where the left-hand-side term increases in $\mu$ by Lemma 3 while the right-hand-side is fixed. Therefore, if there exist some $b \in \mathcal{B}^P$ for some $\mu$, the same $b$ would still belong to $\mathcal{B}^P$ also for $\mu + \varepsilon$, with $\varepsilon > 0$.

The definition of $G$ (see (5), where $\mu_0$ is replaced by $\mu_1$ now that default is allowed in the first period) and Assumption 1 then imply that $G$ is constant at 0 if there is *separation on debt* for some (low) values of $\mu$ and it increases linearly in $\mu$ in case there is *pooling on debt* or *market freeze*. ☐

The result in Lemma 1 formalizes the intuition that a government of the $L$-type gains by being more likely perceived as of $H$-type, because it can access more favorable debt

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prices. The same need not be true for an $H$-type government, which can suffer a payoff drop if a higher $\mu_1$ leads to a switch from separation—where the $H$-type gets the best possible price—to pooling.

We now describe the various possible cases of update of lenders' belief from prior beliefs, $\mu_0$, to interim beliefs, $\mu_1$, in response to default decisions.

**Pooling.** First, there are two instances in which the repayment/default decision is uninformative, leading to $\mu_1 = \mu_0$.

The first such a case is what we call *pooling on repayment*. It happens when governments of both types repay under prior beliefs, i.e., when:

$$V_{1,i}^R(b_1, y_1, \mu_0) \geq V_{1,i}^D(y_1), \tag{10}$$

for all $i \in \{H, L\}$). Note that neither the $H$ nor the $L$ government has an incentive to deviate and default, given that such a deviation would yield a payoff equal to $V_{1,i}^D(y_1)$, which is (weakly) smaller than $V_{1,i}^R(b_1, y_1, \mu_0)$ by (10).

The second case of uninformative choices is the one of *pooling on default*, which occurs when governments of both types default under prior beliefs (i.e., $V_{1,i}^R(b_1, y_1, \mu_0) < V_{1,i}^D(y_1)$, for all $i \in \{H, L\}$). In this case, the $L$-type has no incentive to deviate and repay, because, by Assumption 2, its payoff would drop to $V_{1,L}^R(b_1, y_1, 0)$, which is smaller than $V_{1,L}^R(b_1, y_1, \mu_0)$ by Lemma 1. However, the feasibility of *pooling on default* requires that also the $H$-type does not deviate. This is the case if $V_{1,H}^R(b_1, y_1, 0) < V_{1,H}^D(y_1)$.

**Separation.** There are also cases in which the two types separate, by choosing different actions in equilibrium. One possible scenario is that, under prior beliefs, the $H$-type repays (i.e., $V_{1,H}^R(b_1, y_1, \mu_0) \geq V_{1,H}^D(y_1)$) while the $L$-type defaults (i.e., $V_{1,L}^R(b_1, y_1, \mu_0) < V_{1,L}^D(y_1)$). We call this *separation on L-default*. In order for this case to be feasible, we need to check that there are no profitable deviations for the two types. Namely, we must verify that:

$$V_{1,H}^R(b_1, y_1, 1) \geq V_{1,H}^D(y_1) \tag{11}$$

and

$$V_{1,L}^R(b_1, y_1, 1) < V_{1,L}^D(y_1). \tag{12}$$

In this case, beliefs are updated to $\mu_1 = 1$ ($\mu_1 = 0$) if a repayment (default) is observed.

The case in which the $H$-type repays while the $L$-type defaults and (12) does not hold requires a more thoughtful treatment because satisfying the no-arbitrage condition of the lenders is more difficult. First, no-arbitrage would break if lenders were to keep their

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beliefs at $\mu_0$ when repayment is observed, because then the $L$-type would default, only the $H$-type would repay, and so the equilibrium pricing schedule (equation (4)) consistent with lenders' break-even should require $\mu_P = \mu_1 = 1$, a contradiction.[13] Second, updating beliefs to $\mu_P = \mu_1 = 1$ in case of repayment would also not satisfy the break-even condition, because it would induce $L$-type governments to repay, resulting in expected future losses for the lenders.

We rely on a mixing strategy to solve this indeterminacy. In particular, we select a pair of posterior beliefs in case of repayment, $\mu^*$, and probability of repaying for the $L$-type, $x^*$, satisfying the following three conditions:

$$V_{1,H}^R(b_1, y_1, \mu^*) \geq V_{1,H}^D(y_1), \tag{13}$$

$$V_{1,L}^R(b_1, y_1, \mu^*) = V_{1,L}^D(y_1), \tag{14}$$

$$\mu^* = \frac{\mu_0}{\mu_0 + x^*(1 - \mu_0)}. \tag{15}$$

Condition (13) ensures that the $H$-type repays when lenders' beliefs are $\mu^*$, making therefore the entire logic of imitation of repayment by the $L$-type sensible in the first place. This condition also implies that a default fully reveals that the current government is of the $L$-type. Condition (14) ensures that the $L$-type is indifferent between imitating the $H$-type by repaying and revealing its type by defaulting when beliefs are $\mu^*$. Condition (15) describes the Bayes updating of the beliefs in accordance to the mixing strategy.[14, 15]

Another possible case of separation is when, under prior beliefs, the $H$-type defaults (i.e., $V_{1,H}^R(b_1, y_1, \mu_0) < V_{1,H}^D(y_1)$) while the $L$-type repays (i.e., $V_{1,L}^R(b_1, y_1, \mu_0) \geq V_{1,L}^D(y_1)$). Although counterintuitive, this instance can possibly occur if the larger current cost of

---

[13] Note that, by offering a price consistent with $\mu_0$ to $H$-type governments, lenders will make money (in expectation). Hence, competition in lending will attract other investors willing to offer a little lower $q$ and still ripe positive expected returns. Entry will continue until we reach a price consistent with no-arbitrage, such as the one that we derive later.

[14] Formally, we have:

$$\mu^* \equiv \Pr(i = H | d_1 = 0) = \Pr(d_1 = 0 | i = H) \frac{\Pr(i = H)}{\Pr(d_1 = 0)} = 1 \frac{\mu_0}{\mu_0 + x^*(1 - \mu_0)},$$

where $\Pr(d_1 = 0)$ is the sum of $\Pr(d_1 = 0 | i = H) \Pr(i = H) = \mu_0$ and $\Pr(d_1 = 0 | i = L) \Pr(i = L) = x^*(1 - \mu_0)$.

[15] There could be also the possibility that the $H$-type has an incentive to deviate (i.e., condition (23) does not hold). It would be possible to specify a mixing strategy for the $H$-type in analogy to the case of $L$-mixing. That would have to satisfy the conditions: (i) $V_{1,H}^R(b_1, y_1, 1) = V_{1,H}^D(y_1)$, (ii) $V_{1,L}^R(b_1, y_1, 1) < V_{1,L}^D(y_1)$, and (iii) $\mu^{**} = \frac{(1 - x^{**})\mu_0}{(1 - x^{**})\mu_0 + 1 - \mu_0}$, where $\mu^{**}$ is the (posterior) probability of facing the $H$-type after a default is observed, and $x^{**}$ is the probability of observing the $H$-type repaying. However, this case is counterintuitive and, we conjecture, very unlikely. For the sake of simplicity, we therefore prefer to simply include it among the *lockdonw* instances.

default for an $H$-type is more than compensated by the future benefit of having no debt to repay in the next period, which is more valuable for the $H$-type given the higher default cost. We call this situation *separation on L-repayment*.[16] It entails $\mu_1 = 1$ if default is observed and $\mu_1 = 0$ if repayment is observed. The absence of profitable deviations is ensured by $V_{1,H}^R(b_1, y_1, 0) < V_{1,H}^D(y_1)$ and $V_{1,L}^R(b_1, y_1, 0) \geq V_{1,L}^D(y_1)$.[17]

If none of the cases we characterized are feasible, then we assume a *lockdown*, i.e., a situation in which both types of government default and $\mu_1 = \mu_0$.

We summarize the update from prior to interim beliefs (i.e., the function $G_0$ in (9)) in the following result:

**Result 3.** *Lenders update their prior beliefs, $\mu_0$, to interim beliefs, $\mu_1$, as a result of the repayment/default decision, $d_{1,i}$, according to:*

$$
\mu_1 = \begin{cases}
\mu_0 & \text{if } \textit{pooling on repayment } (d_{1,H} = d_{1,L} = 1). \text{ This requires:} \\
& \quad V_{1,i}^R(b_1, y_1, \mu_0) \geq V_{1,i}^D(y_1), i \in \{L, H\}; \\[4pt]
\mu_0 & \text{if } \textit{pooling on default } (d_{1,H} = d_{1,L} = 0). \text{ This requires:} \\
& \quad V_{1,i}^R(b_1, y_1, \mu_0) < V_{1,i}^D(y_1), i \in \{L, H\}, \\
& \quad V_{1,H}^R(b_1, y_1, 0) < V_{1,H}^D(y_1); \\[4pt]
0 \text{ or } 1 & \text{if } \textit{separation on L-default } (d_{1,H} = 0, d_{1,L} = 1). \text{ This requires:} \\
& \quad V_{1,H}^R(b_1, y_1, \mu_0) \geq V_{1,H}^D(y_1) \text{ and } V_{1,H}^R(b_1, y_1, 1) \geq V_{1,H}^D(y_1), \\
& \quad V_{1,L}^R(b_1, y_1, \mu_0) < V_{1,L}^D(y_1) \text{ and } V_{1,L}^R(b_1, y_1, 1) < V_{1,L}^D(y_1); \\[4pt]
0 \text{ or } \mu^* & \text{if } \textit{L-mixing } (d_{1,H} = 0, d_{1,L} = 0 \text{ or } 1). \text{ This requires:} \\
& \quad V_{1,H}^R(b_1, y_1, \mu_0) \geq V_{1,H}^D(y_1) \text{ and } V_{1,H}^R(b_1, y_1, 1) \geq V_{1,H}^D(y_1), \\
& \quad V_{1,L}^R(b_1, y_1, \mu_0) < V_{1,L}^D(y_1) \text{ and } V_{1,L}^R(b_1, y_1, 1) \geq V_{1,L}^D(y_1), \\
& \quad \exists(\mu^*, x^*) \text{ satisfying } (13) - (15); \\[4pt]
0 \text{ or } 1 & \text{if } \textit{separation on L-repayment } (d_{1,H} = 1, d_{1,L} = 0). \text{ This requires:} \\
& \quad V_{1,H}^R(b_1, y_1, \mu_0) < V_{1,H}^D(y_1) \text{ and } V_{1,H}^R(b_1, y_1, 0) < V_{1,H}^D(y_1), \\
& \quad V_{1,L}^R(b_1, y_1, \mu_0) \geq V_{1,L}^D(y_1) \text{ and } V_{1,L}^R(b_1, y_1, 0) \geq V_{1,L}^D(y_1); \\[4pt]
\mu_0 & \text{if } \textit{lockdown}.
\end{cases}
$$

---

[16] This instance does never occur in our calibration of the quantitative, infinite-horizon version of the model.

[17] For the sake of simplicity, we do not consider the case of $H$-mixing, given that *separation on L-repayment* is rather counterintuitive and never arises in the quantitative analysis of our infinite-horizon model.

# 4 Infinite-Horizon Model

In this section we extend the two-period model of the previous section to an infinite horizon. This new specification allows for a meaningful quantitative analysis of the effects of political uncertainty on sovereign spreads and debt accumulation. We begin by reviewing the economic environment and the timing of events. We then formally present the infinite-horizon model in recursive form and we extend the results derived in the previous section for beliefs updating. We conclude with a formal definition of the equilibrium we consider.

## 4.1 Environment

The infinite-horizon model we analyze is an intuitive extension of the two-period one we presented in the previous section. Unless differently specified, all the assumptions are the same. We highlight that Assumptions 1 and 2 still hold, aggregate income follows a fist-order Markov process, and debt is one-period.[18] We allow the government to default on its debt obligations in every period.

A new element in the infinite-horizon version are stochastic transitions between government types happening at the end of period. These transitions prevent separation instances from being absorbing, allowing for more meaningful and realistic quantitative predictions of the model. Changes in government type are governed by the probabilities $\pi_{i,j}$, with $i, j \in \{H, L\}$, where $\pi_{i,j}$ is the probability of transitioning from a government of type $i$ to one of type $j$. Throughout the paper, we assume that $\pi_{i,i} > \pi_{-i,i}$ for both $i \in \{H, L\}$. This assumption is standard in models with stochastic political transitions. Intuitively, it posits that an $H$-type ($L$-type) government is more likely to be replaced by an $H$-type ($L$-type) next period, rather than an $L$-type ($H$-type). This introduces persistence in types and ensures the desirable property that posterior beliefs derived with Bayesian updating based on transition probabilities are increasing in prior beliefs.

We adopt the following terminology for lenders' beliefs. We refer to $\mu_{0,t}$ as *prior beliefs*. These are updated with default/repayment decisions to *first interim beliefs*, which we denote by $\mu_{1,t}$. We then call $\mu_{2,t}$ the *second interim beliefs*, resulting from the update of first interim beliefs with debt choices. Finally, the update of $\mu_{2,t}$ with political transition probabilities leads to $\mu_{0,t+1}$, the *posterior beliefs* that also correspond to next period's prior beliefs.

---

[18] We could introduce long-term debt à la Chatterjee and Eyigungor (2012). However, we do not expect it to alter our main economic intuitions and we therefore prefer the simplicity of the one-period debt specification.

**Timing.** The timing of events within each period $t$ is the following:

1. The shock to aggregate income realizes and agents observe the state, $(b_t, y_t, \mu_{0,t})$.

2. The government chooses whether to default or not (unless there is a lockdown, in which case it defaults).

3. Lenders' prior beliefs, $\mu_{0,t}$, are updated to first interim beliefs, $\mu_{1,t}$, in response to the repayment/default decision.

4. Lenders offer the pricing schedule consistent with first interim beliefs $\mu_{1,t}$.

5. The government chooses public spending (in the amount $g_t$) and, if borrowing is allowed, the new debt issuance (in the amount $b_{t+1}$).

6. Lenders' beliefs are updated to second interim beliefs, $\mu_{2,t}$, in response to the debt issuance choice

7. Lenders' beliefs are updated to posterior beliefs, $\mu_{0,t+1}$, according to the political transition probabilities.

8. Political transitions take place.

## 4.2 Recursive Formulation

We focus on stationary Markov perfect Bayesian equilibria. The infinite-horizon problem (in case of no lockdown) can be cast in the following recursive form:

$$
\begin{aligned}
V_i\left(b, y, \mu_0\right) = \max_d \ & (1-d)V_i^R\left(b, y, \mu_1\right) + dV_i^D\left(y, \mu_1\right) \\
\text{s.t.} \quad & \mu_1 = G_0(d; b, y, \mu_0),
\end{aligned}
\tag{16}
$$

where $d$ is an indicator equal to 1 in case of default, $V_i^R$ and $V_i^D$ are the value functions for a government of type $i$ associated to, respectively, repayment and default. With a slight abuse of notation, $G_0$ is again the function, which we specify shortly, governing the update of beliefs from prior, $\mu_0$, to interim, $\mu_1$, according to the default/repayment decision $d$. If the economy visits a *lockdown* state, then: (i) all types of government default, (ii) there is no borrowing, and (iii) $\mu_P = \mu_1 = \mu_0$.

The value function of repayment takes the following form:

$$V_i^R(b, y, \mu_1) = \max_{g, b' \in B} \ u(g) + \beta \mathbb{E}_{y'|y} \left[ \pi_{i,i} V_i(b', y', \mu_0') + (1 - \pi_{i,i}) V_{-i}(b', y', \mu_0') \right]$$

$$\text{s.t.} \quad \tau y + q b' = g + b \tag{17}$$

$$\mu_0' = G(b'; b, y, \mu_1),$$

where $G$ is again a function governing the update of beliefs according to debt choices and political transition probabilities that we characterize shortly. The value function of default is:

$$V_i^D(y, \mu_1) = \ u(g) - \varphi_i + \beta \mathbb{E}_{y'|y} \left[ \pi_{i,i} V_i(0, y', \mu_0') + (1 - \pi_{i,i}) V_{-i}(0, y', \mu_0') \right]$$

$$\text{with} \quad g = \tau y \tag{18}$$

$$\mu_0' = G(0; b, y, \mu_1).$$

The equilibrium pricing schedule (in case of repayment) that satisfies lenders' zero-profit condition is given by:

$$q(b', y, \mu_0') = \frac{1}{1 + r} \mathbb{E}_{y'|y} \left[ \mu_0'(1 - d_H(b', y', \mu_0')) + (1 - \mu_0')(1 - d_L(b', y', \mu_0')) \right]. \tag{19}$$

The function $G$ that governs the evolution of lenders' beliefs entails two steps (namely, $G$ can be seen as a composite function, $G = (G_2 \circ G_1)$). First, there is the update from first interim beliefs, $\mu_1$, to second interim beliefs, $\mu_2$, according to current borrowing choices:

$$\mu_2 = G_1(b'; b, y, \mu_1) = \begin{cases} \mu_1 & \text{if } \textit{pooling on debt} \text{ or } \textit{lockdown} \\ & \qquad \text{or } \textit{default} \text{ or } \textit{market freeze}; \\ 0 \text{ or } 1 & \text{if } \textit{separation on debt}. \end{cases} \tag{20}$$

The second step in $G$ is the update from second interim to posterior beliefs, $\mu_0'$, according to the probabilities governing end-of-period political transitions:

$$\mu_0' = G_2(\mu_2) = \pi_{H,H} \times \mu_2 + \pi_{LH} \times (1 - \mu_2). \tag{21}$$

Note that our assumption that $\pi_{i,i} > \pi_{-i,i}$ ensures the intuitive property that $G_2$ is increasing in $\mu_2$.

The main conceptual difference with respect to the two-period model is that there is now the possibility to borrow in every period—current and future—and hence the value functions depend on lenders' beliefs in every period. This prevents us to formally prove

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general results about the ranking of policy function for default across types and the monotonicity of $q$ in beliefs that we showed in the two-period setting (see Lemma 2 and the proof of Lemma 3). We will however show that those properties generally still hold numerically in our calibrated model.

## 4.3 Beliefs Updating

We now present the conditions that determine how lenders update their beliefs about the government's type according to the actions they observe: default/repayment and debt issuance. For the most part, these are immediate extensions of the ones we derived in the two-period case. The main difference is that we cannot prove a result analogous to Lemma 1, and therefore we have to explicitly verify more conditions to ensure that there are no incentives to deviate.

### 4.3.1 Default Decisions

The current period's default versus repayment decision determines the update of prior beliefs, $\mu_0$, to first interim beliefs, $\mu_1$. The government's choice is uninformative in case the economy is in a *pooling-on-default* or *pooling-on-repayment* state where both types choose the same action and hence $\mu_1 = \mu_0$; it is fully revealing in case of *separation on L-default* or *separation on L-repayment*, with $\mu_1$ equal to either 0 or 1 according to the choice observed; or it is partially revealing in case of *L-mixing*. There is again a residual case, a *lockdown*, in which we assume default by both types of governments and so $\mu_1 = \mu_0$.

We now revisit the conditions determining the emergence of any of these situations. In the case of *pooling on repayment*, we must ensure that both types prefer repayment over default under prior beliefs, i.e., $V_i^R(b, y, \mu_0) \geq V_i^D(y, \mu_0)$ for both $i \in \{H, L\}$. We must also verify that there are no incentives to deviate, i.e., $V_i^R(b, y, \mu_0) \geq V_i^D(y, 0)$ for both $i \in \{H, L\}$.

As for *pooling on default*, we must check that both types prefer default over repayment under prior beliefs, i.e., $V_i^R(b, y, \mu_0) < V_i^D(y, \mu_0)$ for both $i \in \{H, L\}$. The absence of deviation incentives is ensured by $V_i^R(b, y, 0) < V_i^D(y, \mu_0)$ for both $i \in \{H, L\}$.

*Separation on L-default*, arises when, under prior beliefs, the $H$-type prefers to repay (i.e., $V_H^R(b, y, \mu_0) \geq V_H^D(y, \mu_0)$) and the $L$-type prefers to default (i.e., $V_L^R(b, y, \mu_0) < V_L^D(y, \mu_0)$). To verify that there are no profitable deviations, we must also verify that:

$$V_H^R(b, y, 1) \geq V_H^D(y, 0) \tag{22}$$

and

$$V_L^R(b, y, 1) < V_L^D(y, 0). \tag{23}$$

If the $L$-type has an incentive to deviate (i.e., if condition (23) does not hold), then we consider a mixing strategy in which we select a pair of posterior beliefs after repayment, $\mu^*$, and probability of repaying for the $L$-type, $x^*$, satisfying the following conditions:

$$V_H^R(b, y, \mu^*) \geq V_H^D(y, 0), \tag{24}$$

$$V_L^R(b, y, \mu^*) = V_L^D(y, 0), \tag{25}$$

$$\mu^* = \frac{\mu_0}{\mu_0 + x^*(1 - \mu_0)}. \tag{26}$$

Condition (24) ensures that the $H$-type is willing to repay, condition (25) that the $L$-type is indifferent between defaulting and repaying, and condition (26) that beliefs are updated with Bayes law. This is a situation that we call *L-mixing*.[19]

*Separation on L-repayment* happens when, under prior beliefs, the $H$-type prefers to default (i.e., $V_H^R(b, y, \mu_0) < V_H^D(y, \mu_0)$), the $L$-type prefers to repay (i.e., $V_L^R(b, y, \mu_0) \geq V_L^D(y, \mu_0)$), and there are no profitable deviations, i.e., $V_H^R(b, y, 0) < V_H^D(y, 1)$ and $V_L^R(b, y, 1) \geq V_L^D(y, 0)$.[20]

Finally, when the state is such that none of the cases we characterized is feasible, we assume that there is a *lockdown*. In this instance, both types of government default and $\mu_1 = \mu_0$.

We summarize the cases for the update of the beliefs after the repayment/default decision (i.e., $G_0$ in (16)) in the following result:

**Result 4.** *Lenders update their prior beliefs, $\mu_0$, to first interim beliefs, $\mu_1$, as a result of the*

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[19] Again, we do not explicitly consider the counterintuitive case in which only the $H$-type has an incentive to deviate (i.e., when (22) does not hold while (23) holds). We set this case to *lockdown*. See also our discussion in footnote 15.

[20] This counterintuitive instance never occurs in our numerical results. For the sake of simplicity, we therefore refrain from specifying cases of mixing under this scenario, instead including them among the cases of *lockdown*.

*repayment/default decision according to the following:*

$$
\mu_1 = \begin{cases}
\mu_0 & \text{if } \textit{pooling on repayment } (d_H = d_L = 1). \text{ This requires:} \\
& \qquad V_i^R(b, y, \mu_0) \geq V_i^D(y, \mu_0), i \in \{H, L\}, \\
& \qquad V_i^R(b, y, \mu_0) \geq V_i^D(y, 0), i \in \{H, L\}; \\[2pt]
\mu_0 & \text{if } \textit{pooling on default } (d_{1,H} = d_{1,L} = 0). \text{ This requires:} \\
& \qquad V_i^R(b, y, \mu_0) < V_i^D(y, \mu_0), i \in \{H, L\}, \\
& \qquad V_i^R(b, y, 0) < V_i^D(y, \mu_0), i \in \{H, L\}; \\[2pt]
0 \text{ or } 1 & \text{if } \textit{separation on L-default } (d_H = 0, d_L = 1). \text{ This requires:} \\
& \qquad V_H^R(b, y, \mu_0) \geq V_H^D(y, \mu_0) \text{ and } V_H^R(b, y, 1) \geq V_H^D(y, 0), \\
& \qquad V_L^R(b, y, \mu_0) < V_L^D(y, \mu_0) \text{ and } V_L^R(b, y, 1) < V_L^D(y, 0); \\[2pt]
0 \text{ or } \mu^* & \text{if } \textit{L-mixing } (d_H = 0, d_L = 0 \text{ or } 1). \text{ This requires:} \\
& \qquad V_H^R(b, y, \mu_0) \geq V_H^D(y, \mu_0) \text{ and } V_H^R(b, y, 1) \geq V_H^D(y, 0), \\
& \qquad V_L^R(b, y, \mu_0) < V_L^D(y, \mu_0) \text{ and } V_L^R(b, y, 1) \geq V_L^D(y, 0), \\
& \qquad \exists (\mu^*, x^*) \text{ satisfying } (24) - (26); \\[2pt]
0 \text{ or } 1 & \text{if } \textit{separation on L-repayment } (d_H = 1, d_L = 0). \text{ This requires:} \\
& \qquad V_H^R(b, y, \mu_0) < V_H^D(y, \mu_0) \text{ and } V_H^R(b, y, 0) < V_H^D(y, 1), \\
& \qquad V_L^R(b, y, \mu_0) \geq V_L^D(y, \mu_0) \text{ and } V_L^R(b, y, 0) \geq V_L^D(y, 1); \\[2pt]
\mu_0 & \text{if } \textit{lockdown}.
\end{cases}
$$

### 4.3.2   Debt Choice

The debt issuance choices provide information that lenders use to update their beliefs from first interim beliefs, $\mu_1$, to second interim beliefs, $\mu_2$, according to $G(b'; b, y, \mu_1)$ (see equations (20)-(21)). First, note that if the government decides to default in the current period, then it is not allowed to borrow, and so $\mu_2 = \mu_1$. In case of repayment, according to Assumption 1, a pricing schedule that supports a pooling equilibrium is offered first, if it exists. The condition for its existence can be derived in analogy to Result 1 in the two-period setting. With a slight abuse of notation, we can define several objects in analogy to the two-period model. First, the (expected present discounted) value of $b'$ for

a government of type $i$:

$$U_i(b'; b, y, \mu) \equiv u(\tau y + q(b', y, G_2(\mu))b' - b) + \\ + \beta \mathbb{E}_{y'|y}[\pi_{i,i} V_i(b', y', G_2(\mu)) + (1 - \pi_{i,i}) V_{-i}(b', y', G_2(\mu))], \tag{27}$$

where $q$ and $G_2$ were defined in (19) and (21), respectively.

Second, we define the maximum value that a government of type $i$ can derive from issuing debt when it is thought to be of type $L$ regardless of its action (i.e., $\mu_2 = 0$):

$$\tilde{U}_i(b, y) \equiv \max_{b'} U_i(b'; b, y, 0); \tag{28}$$

Third, we denote by $\mathcal{B}_i^P$ the set containing all debt issuances consistent with pooling equilibria for an $i$-type government, i.e., those $b'$ at which an $i$-type government does not want to deviate when offered a price consistent with (19), $\mu_2 = \mu_1$, and (21). This set is made up by all the debt issuances $b'$ such that:

$$U_i(b'; b, y, \mu_1) \geq \tilde{U}_i(b, y).$$

The condition for the existence of pooling contracts is then $\mathcal{B}^P \equiv \mathcal{B}_H^P \cap \mathcal{B}_L^P \neq \emptyset$. If there are multiple debt levels that support a pooling equilibrium (i.e., if $\mathcal{B}^P$ is not a singleton), we assume that pooling happens for a level of debt equal to $\hat{b}^P \equiv \arg\max_{b'} U_H(b'; b, y, \mu_1)$. This is the most favorable contract for the $H$-type, which is the type of government hurt by pooling on debt.

If the pooling contract is not feasible, then lenders offer a separating one. That is a pricing schedule that induces different debt choices by $H$-type and $L$-type governments, without either of them having an incentive to deviate and imitate the other. We derive a condition for its existence by again defining $\mathcal{B}_L^P$ as the set of debt issuances, $b'$, such that $U_L(b'; b, y, 1) \geq \tilde{U}_L(b, y)$, and $\hat{b}_H^S$, the maximizer of $U_H(b'; b, y, 1)$ subject to $b \notin \mathcal{B}_L^P$.[21] The condition to check is then that $U_H(\hat{b}_H^S; b, y, 1) \geq \tilde{U}_H(b, y)$, provided that $\hat{b}_H^S$ exists.

We summarize the lenders' pricing decisions and their update from first to second interim beliefs in response to borrowing choices (the function $G_1$ defined in (20)) in the following result:

**Result 5.** *The update of beliefs from first interim, $\mu_1$, to second interim, $\mu_2$, happens as follows:*

*(i) If there is default or a lockdown in the current period, then no borrowing is allowed and $G_1(0; b, y, \mu_1) = \mu_1$. Otherwise, lenders offer debt contracts and update beliefs with sovereign borrowing choices as follows:*

---

[21] In case multiple $\hat{b}_H^S$ exist, we assume that the lowest is chosen.

*(ii) If $\mathcal{B}^P \neq \emptyset$, then a pricing schedule $\{q(\hat{b}^P, y, G_2(\mu_1)), q(b' \neq \hat{b}^P, y, G_2(0))\}$ exists and lenders offer it, leading to a pooling equilibrium in which beliefs are updated as:*

$$G_1(b'; b, y, \mu_1) = \begin{cases} \mu_1 & \text{if } b' \in \mathcal{B}^P \text{ is observed,} \\ 0 & \text{if } b' \notin \mathcal{B}^P, \text{ is observed;} \end{cases}$$

*(iii) If $\mathcal{B}^P = \emptyset$, then a pricing schedule $\{q(\hat{b}_H^S, y, G_2(1)), q(b' \neq \hat{b}_H^S, y, G_2(0))\}$ that supports a separating equilibrium is offered, if feasible. The necessary and sufficient condition for its feasibility is that $U_H(\hat{b}_H^S; b, y, 1) \geq \tilde{U}_H(b, y)$, provided that $\hat{b}_H^S$ exists. Lenders update beliefs as:*

$$G_1(b'; b, y, \mu_1) = \begin{cases} 1 & \text{if } b' = \hat{b}_H^S \text{ is observed,} \\ 0 & \text{if } b' \neq \hat{b}_H^S \text{ is observed;} \end{cases}$$

*(iv) If neither of the cases (i)-(iii) occurs, then there is market freeze, i.e., $b' = 0$ and beliefs are updated as:*

$$G_1(0; b, y, \mu_1) = \mu_1.$$

## 4.4 Equilibrium Definition

We now provide a formal definition of the stationary Markov perfect Bayesian equilibrium we consider for the infinite-horizon model, which is the one we numerically approximate in the next sections.

**Definition 1.** *The stationary Markov perfect Bayesian equilibrium considered is a collection of value functions $\{V_i, V_i^R, V_i^D\}_{i \in \{H,L\}}$, debt pricing function $q$, rules $G_0, G_1, G_2$ for beliefs updating on the equilibrium path, and belief updating off-equilibrium path that follow Assumption 2 such that:*

- *(i) governments optimize given prices and beliefs, i.e., $\{V_i, V_i^R, V_i^D\}_{i \in \{H,L\}}$ are determined by (16)-(18);*

- *(ii) lenders break-even in expectation, i.e., $q$ satisfies (19);*

- *(iii) lenders update beliefs with default/repayment decisions according to the function $G_0$ specified in Result 4;*

- *(iv) lenders offer sovereign debt contracts $q$ and update beliefs with borrowing choices according to the function $G_1$ as specified in Result 5;*

*(v) lenders update beliefs with political transition probabilities according to the function $G_2$ specified in (21).*

# 5   Quantitative Analysis

In this section we parametrize, calibrate, and numerically solve the model described in Section 4. We calibrate the model to match features of the Italian economy. We chose Italy given the strong co-movements of spreads and political events we documented in Section 2.1. Moreover, the Italian case is interesting also because of the country's high level of sovereign debt, high level of spreads (at least in the last ten year), and very high degree of political turnover, with 43 governments since 1946. That is roughly a new cabinet every 1.8 years.[22]

In the rest of this section, we first introduce functional forms for the relevant objects of the model and present the model's calibration. We then outline our computational strategy for solving the model numerically.[23] Finally, we analyze the fit of the model with respect to the data. We specify our data sources in Appendix C.

## 5.1   Parametrization

The functional forms adopted in this paper follow the sovereign default literature, whenever appropriate. The per-period utility function is of the constant relative risk aversion form:

$$u(g_t) = \frac{g_t^{1-\sigma} - 1}{1 - \sigma},\tag{29}$$

where $\sigma$ is the coefficient of relative risk aversion parameter.

The output process, $y_t$, follows a Gaussian AR(1) process in logarithms:

$$\log(y_t) = (1 - \rho)\mu + \rho \log(y_{t-1}) + \sigma_y \varepsilon_t.\tag{30}$$

Tax revenues are assumed to be a constant fraction $\tau$ of output and thus equal to $\tau y_t$.

---

[22] We do not count changes that involve reshuffles of cabinets under the same Prime Minister, given that those are likely to entail lower degrees of political uncertainty. For the full list of Italian governments, see *https://en.wikipedia.org/wiki/List_of_prime_ministers_of_Italy*

[23] We describe the solution and simulation algorithms in detail in Appendix D.

## 5.2 Calibration

We assume that one period in the model corresponds to one quarter in the data. The quantitative model contains 11 structural parameters: the risk free rate, $r$; the discount factor, $\beta$; the degree of relative risk aversion, $\sigma$; the mean, $\mu$, persistence, $\rho$, and volatility, $\sigma_y$, of output; the tax rate, $\tau$; the default costs, $\varphi_L$ and $\varphi_H$; and the political transition probabilities, $\pi_{H,H}$ and $\pi_{L,L}$. We perform the calibration in two steps. First, we set some parameters at values that are either conventional in the literature, or consistent with the data. Then, we jointly calibrate the remaining parameters by matching some relevant targets in the data.

Consistent with most of the literature, we set the degree of relative risk aversion, $\sigma$, to 2. Persistence and volatility of output are estimated from Italy's GDP (linearly detrended, in logarithms). We obtain a persistence, $\rho$, of 0.943 and volatility, $\sigma_y$, of 0.007. Bocola and Dovis (2019) document that government revenues for Italy are 41% of output, on average, so we set $\tau$ to 0.410. We set $\mu$ to 0.892 so to normalize tax revenues to one at the mean. We follow Bocola et al. (2019) in setting the risk-free interest rate, $r$, to 0.45%, to match the real rate of 1-year German government bonds (1.8% in annual terms). Finally, we set the political transition probabilities to match the average term duration of Italian Prime Ministers since 1946. To that end, we set $\pi_{H,H}$ to 0.880 and $\pi_{L,L}$ to 0.820. This implies and average government duration of 7.2 quarters (1.8 years), consistent with the data.[24]

The remaining parameters, i.e., $\Theta \equiv [\beta, \varphi_L, \varphi_H]$, are jointly calibrated with the method of simulated moments. This technique consists in choosing parameter values as to achieve the best match between some moments in the data and their model's analogues. We choose to target government debt as a fraction of GDP, the average interest rate spread between Italian and German sovereign bonds, as well as the volatility of this spread. The parameters are then chosen to minimize the distance between the data target and their model analogues, according to the loss function $L(\Theta) = [M^d - M^m(\theta)]'W[M^d - M^m(\Theta)]$. The vector $M^d$ and $M^m(\Theta)$ collect data targets and model analogues (mean across simulations), respectively. The matrix $W$ weights the targets according to the inverse of the moment in the data.

Most papers in the sovereign default literature study the problem of a benevolent government that chooses the consolidated external debt position of both the private and public sector. This choice has been successful in matching data for developing countries. We instead follow Bocola et al. (2019), who show that a model featuring a government that chooses total public debt better fits the data for advanced economies. Our model

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[24] We also set the share of $H$-type governments to be 60% in the ergodic distribution. See Appendix D.4 for more details on the calibration of the political transition parameters.

features one-period bonds. Therefore, our object of interest is the amount of debt due each period rather than the total stock of public debt. Hence, we map debt in the model to a maturity-adjusted version of the stock of Italian public debt, computed by dividing the outstanding stock of debt by the average maturity observed over the 2000q1–2018q4 period, which is 6.9 years. The maturity adjustment translates the average public debt-to-GDP ratio of 119% to 17%. The interest rate spread is calculated considering the yield on the benchmark one-year sovereign bonds for Italy and Germany. Our choice of parameters is summarized in Table 3.

Table 3: Model Parameters

| Parameter | Notation | Value | Source |
|---|---|---|---|
| Interest rate | $r$ | 0.450% | German bonds, as in Bocola et al. (2019) |
| Risk aversion | $\sigma$ | 2 | Standard in macroeconomics |
| Output persistence | $\rho$ | 0.943 | Quarterly GDP, 2000-2018 |
| Output volatility | $\sigma_z$ | 0.007 | Quarterly GDP, 2000-2018 |
| Steady state output | $\mu$ | 0.892 | Normalization |
| Tax rate | $\tau$ | 0.410 | Tax revenues, 2000-2018 |
| Political transitions | $\pi_{H,H}; \pi_{L,L}$ | 0.88;0.82 | Average Govt. tenure, 1946-2018 |
| Discount factor | $\beta$ | 0.893 | Method of Simulated Moments |
| Low default cost | $\varphi_L$ | 0.326 | Method of Simulated Moments |
| High default cost | $\varphi_H$ | 0.913 | Method of Simulated Moments |

## 5.3 Model Fit

The quantitative model does a good job in matching the data targets. In Table 4 we compare the average moments computed from model simulations with those calculated from Italian data.[25] During the period between 2000q1 and 2018q4, maturity adjusted public debt in Italy averaged 17.18%. The average debt-to-output ratio over 10,000 simulations of our model is 17.68%. The average spread on one-year government bonds over the same time period was 0.42% in the data. It is 0.25% in our simulations. The standard deviation of the spread was 0.79% in the data and it is 0.15% in the model. The discrepancy in these spread statistics are in line with the well-known difficulty of sovereign debt models of achieving high levels and volatility of interest rate spreads for government bonds (see, e.g., Hatchondo et al., 2009). In particular, matching high spread volatility is particularly difficult with state-independent default costs, as in our setting (see the discussion

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[25] In Appendix D.3 we provide further details on how we characterize the ergodic distribution of the model's simulations.

in Chatterjee and Eyigungor, 2019).

Table 4: Empirical Targets

| Target | Data | Model |
|---|---|---|
| Debt/GDP | 17.18% | 17.68% |
| Average spread | 0.42% | 0.25% |
| Std. dev. spread | 0.79 % | 0.15% |

*Notes:* This table presents statistics for targeted moments. Data is for the period from 2000q1 to 2018q4. Output is linearly detrended in logarithms. Model targets are the average moment across 10,000 simulations of 76 periods each.

The quantitative model matches relatively well also other non-targeted statistics, such as the correlations between GDP and spreads, between GDP and primary balance, between GDP and the primary balance-to-GDP ratio, and, with lower accuracy, the correlation between spreads and the primary-balance-to-GDP ratio. We report these empirical statistics in Table 5.

Table 5: Non-targeted Moments

| Statistics | Data | Model |
|---|---|---|
| Correlation GDP and spread | -0.24 | -0.26 |
| Correlation GDP and primary balance | -0.10 | -0.18 |
| Correlation GDP and primary balance/GDP | -0.28 | -0.19 |
| Correlation Spread and primary balance/GDP | -0.17 | -0.02 |

*Notes:* This table presents statistics for non-targeted moments. When applicable, data is for the period from 2000q1 to 2018q4. Output is linearly detrended in logarithms. Statistics from the model are the average moment across 10,000 simulations of 76 periods each.

## 5.4 Results

Before moving to the study of the effects of political uncertainty on sovereign debt and spreads, it is constructive to review some of the properties of the equilibrium of our quantitative model.

**Debt pricing schedule.** Lenders' beliefs about the type of government that they are facing map into perceived sovereign risk and hence into debt prices. In Figure 5 we show the

equilibrium pricing schedule of debt for two different values of the lenders' beliefs (in particular, next period's lenders' prior beliefs, $\mu'_0$, which is the relevant argument in the pricing schedule. See equation (19)). The panel on the left shows the change in the price of debt for different levels of debt issuance, keeping tax revenues fixed at the mean of the ergodic distribution. In the right panel, we fix the level of debt issuances at the mean value in the ergodic distribution and instead show how the debt price varies with tax revenues.

Figure 5: Pricing Schedule
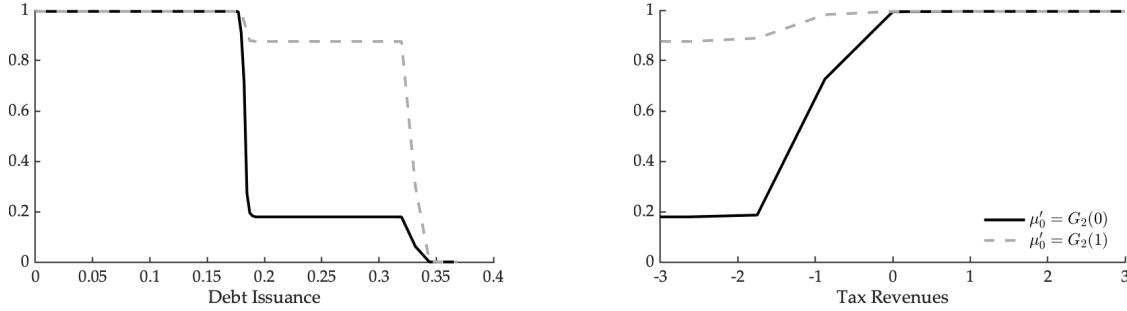


*Notes:* This figure presents some elements of the equilibrium pricing schedule. The vertical axis corresponds to the price of debt. In the left panel, *Debt Issuance* is relative to mean output in the ergodic distribution. In the right panel, *Tax Revenues* are reported in terms of standard deviations from their ergodic mean. The left panel is drawn for a level of tax revenues $\tau y = 1$ and the right panel for debt level $b' = 0.43$. Both correspond to the mean values in the ergodic distribution.

As expected, debt prices are decreasing in the level of debt that the government issues and carries over to the next period. The price of debt is also increasing in output. With respect to lenders' beliefs, the pricing schedule of debt shifts out (i.e., it is more favorable to the government) as lenders become more convinced that they will face a government with high default cost next period when the default decision about debt issued in the current period is made. As we discussed in Section 4.2, the monotonicity of the pricing schedule in (future) beliefs cannot be established as a general result in the infinite-horizon version of our model. However, our numerical results are almost everywhere consistent with the intuition that the higher default cost makes the $H$-type government less likely to default than the $L$-type, which translates into more favorable prices.

From the left panel, we can deduce that an $L$-type government is expected to default next period for debt levels (over current mean output) approximately larger than 0.2, while it will take a level around 0.33 for the $H$-type to default. The "saddle-segments" in the pricing schedule for intermediate debt levels are a typical feature of sovereign default models with political transitions (see Hatchondo et al., 2009). They are a consequence of the political turnover and, in particular, its impact on the probability of a future default.

Consider, for instance, a level of debt issuance of 0.25. If lenders are convinced that they are facing an $L$-type government in the current period (i.e. $\mu'_0 = G_2(0)$, corresponding to the solid black line), then they expect to be repaid only if there is a change of government type, from the current $L$-type to an $H$-type. This event happens with probability $\pi_{L,H}$, equal to 0.18 in our calibration. Hence the price offered for a debt issuance of 0.25 is about $\pi_{L,H}/(1 + r)$. The reasoning is similar when they think they are facing an $H$-type government in the current period (i.e., when $\mu'_0 = G_2(1)$, corresponding to the gray dashed line). In this case, lenders expect to be repaid only if the $H$-type government stays in power, which happens with probability $\pi_{H,H}$, equal to 0.88 in our calibration. They therefore offer a price close to that level.[26]

The panel on the right conveys similar information. At the mean level of current tax revenues or above, both types of governments are expected to almost surely repay next period and hence the price offered is close to $1/(1 + r)$. For lower values of tax revenues, the $L$-type will default with a likelihood that is increasing the lower tax revenues are, with a default becoming almost sure for values of current tax revenues below -2 standard deviations. On the contrary, the $H$-type is not expected to default even for values of current tax revenues as low as -3 standard deviations. As a result, the pricing function drops as current tax revenues decrease, stabilizing at levels consistent with political transition probabilities.

It is worth highlighting that the drops and flat-looking segments in the pricing schedule of debt induced by the political transitions imply government's objective functions under repayment that are not globally concave, as already documented by Hatchondo et al. (2009). In Figure 6 we present an example of the objective function under repayment (defined in (27)) for each government type, as well as the pricing schedule consistent with those functions, for a case of *pooling on debt*.

As we discussed in Section 3.3 with respect to Figure 3, when the price of debt is high and does not respond sharply to an increase in debt, the objective function of the government is increasing in debt. This happens at low debt levels, at which the future cost of repayment is small and default unlikely. The objective function then drops as debt issuance approaches the level corresponding to the first sharp drop in the pricing schedule.

---

[26] Note that the flat-looking segments for intermediate values of debt in the solid and dashed pricing functions are in fact downward sloping and below $\pi_{L,H}/(1 + r)$ and $\pi_{H,H}/(1 + r)$, respectively. The reason is that the repayment probability is never exactly one at any debt issuance greater than zero. As debt increases, the default region increases, albeit the probability of visiting those new "default zones" might be so small that it becomes numerically negligible. Incidentally, this very same reasoning applies also to the flat-like segments at $1/(1 + r)$ and $0$.

Figure 6: Non-concavity of the Government's Objective Function in *Pooling on Debt*



(a) High Type           (b) Low Type           (c) Price Schedule
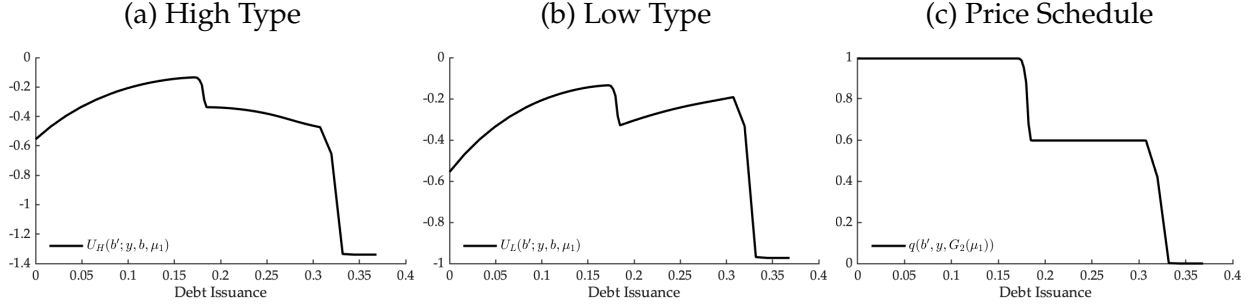
*Notes:* This figure presents the objective function under repayment for both types of government (see (27)) and the price schedule of debt. *Debt issuance* is relative to mean output in the ergodic distribution. Tax revenues, outstanding debt, and first interim beliefs are set at the mean value in the ergodic distribution.

For values of debt issuance corresponding to the second flat section of the pricing schedule, a similar argument can be made. Raising debt issuance has small effects on debt prices (which, however, now differ in lenders' beliefs), allowing for more government spending—and hence utility—in the current period. However, higher current issuance entails higher repayments in the future. The $L$-type can escape them by defaulting more cheaply (and hence more often) than the $H$-type. This can make the continuation value for the $L$-type less responsive to the current choice of debt issuance, to the point of having the beneficial effect of the higher current spending outweighing the cost of higher future debt, and hence an increasing objective function. The same is not true for the $H$-type, for which the latter effect is dominant given the higher cost of default, resulting in an objective function decreasing in debt issuance. In light of this discussion, we conduct a global search to find the optimal debt issuance policy when solving the model.

**Pooling and separation on default.** We now study the default decision by the different types of government. Figure 7 provides a useful representation of the optimal default choice across the state-space. As we discussed in Section 4.3.1, the possible scenarios are *pooling on default* (DD), when both types default; *separation on L-default* (DR), with the $H$-type repaying and the $L$-type defaulting; *L-mixing* (MR), which is solved with the $L$-type mixing on whether to repay or default; *pooling on repayment* (RR), when both types repay; *separation on L-repayment* (RD), with the $L$-type repaying and the $H$-type defaulting; and *lockdown* (LL), the residual category in which we assume that both types default.

Our first observation is that both types of government are more likely to default when tax revenues are low and debt is high, so we observe pooling on default. For high levels of tax revenues and low levels of debt, both governments find it optimal to repay and so we observe pooling on repayment. For intermediate values of debt and tax revenues, the

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*L*-type has a higher tendency to default than the *H*-type. This different attitude leads to separation in the default decision, with the *L*-type defaulting and the *H*-type repaying. This implies that the default decision will reveal the type of government in this region of the state space, conveying new information to lenders. If default (repayment) is observed, lenders will update their beliefs from prior to first interim beliefs $\mu_1 = 0$ ($\mu_1 = 1$).

Figure 7: State-Space Default Regions
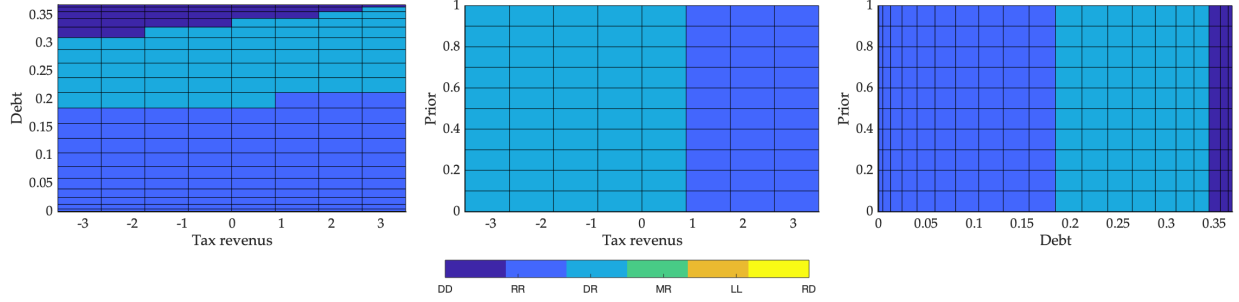


*Notes:* This figure presents the default decision across the state-space. The regions are: *pooling on default* (DD), *separation on L-default* (DR), *L-mixing* (MR), *pooling on repayment* (RR), *separation on L-repayment* (RD), and *lockdown* (LL). *Debt* is outstanding debt relative to mean output. *Tax revenues* are reported in terms of standard deviations from the mean. In each panel, the fixed dimension is set at the mean value in the ergodic distribution.

To convey some additional intuition on the effects that lenders' beliefs have on the default decision, in Figure 8 we redraw the middle and right panels of Figure 7 for a higher level of debt and a lower level of tax revenues, respectively. This new figure shows that the first interim prior can also play an important role in the optimal default decision of a government. As previously discussed, negative investors' beliefs—i.e., a lower prior of facing the *H*-type in the current period—lead to lower debt prices. This makes it harder for the government to deal with high outstanding debt or low tax revenues, tilting the balance in favor of a sovereign default.

We conclude this discussion noting that we observe very few instances in our model solutions where the default decision leads to the low type mixing (LR). These occur at the boundary between *pooling on repayment* (RR) and *separation on L-default* (DR). This is intuitive. At the boundary, the *L*-type government would default under the prior, how-ever it will choose to repay if it had access to the more favorable funding conditions of the *H*-type. We never observe the less intuitive cases of *separation on L-repayment* (RD), or *lockdown* (LL). In fact, we are able to verify that the following conditions are always satisfied in our numerical solution:

*(i)* If $V_L^R(b, y, \mu_0) \geq V_L^D(y, \mu_0)$, then $V_H^R(b, y, \mu_0) \geq V_H^D(y, \mu_0)$,

Figure 8: State-Space Default Regions, High Debt and Low Tax Revenues
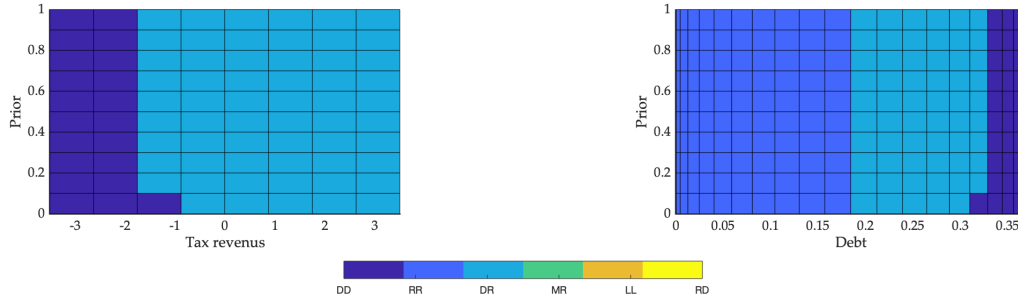


*Notes:* See notes to Figure 7. The fixed state values correspond to tax revenues 1.5 standard deviations bellow the mean of the ergodic distribution, and debt level of 0.31 relative to the mean level of output in the ergodic distribution. See the notes to Figure 7 for details on the variables and the color-region correspondence.

(ii) If $V_H^R(b, y, \mu_0) < V_H^D(y, \mu_0)$, then $V_L^R(b, y, \mu_0) < V_L^D(y, \mu_0)$.

This confirms the intuition that the $L$-type government defaults more often than the $H$-type government also in our infinite-horizon model, as we proved in Lemma 2 in our two-period setting.

**Pooling and separation on debt.** In Figure 9 we describe graphically an instance of equilibrium pooling on debt, in analogy to what we did in Figure 3 for the two-period model. Panels (a) and (b) in the figure show the functions $U_i(b'; b, y, \mu)$ (see (27)) for governments of type $i = H$ and $i = L$, respectively. The solid black lines correspond to beliefs equal to the (mean value in the ergodic distribution of the) first interim beliefs in the simulations, while the gray dashed lines are drawn for beliefs $\mu = 0$, i.e., when lenders are sure that the government is of the $L$-type. The blue shaded region in each panel corresponds to the pooling set $\mathcal{B}_i^P$ for each type $i$. Although these sets look very similar, they are numerically different. Their intersection constitutes the feasible pooling set, $\mathcal{B}^P$. The horizontal dashed blue lines correspond to $\tilde{U}_i(b, y)$ (as defined in (28)). By Assumption 2, they correspond to the maximum payoff achievable by deviating from the pooling contract. The fact that this value is lower than what both government types get from pooling (see the black dot) ensures that there are no profitable deviations and pooling can be sustained.

Panel (c) in Figure 9 displays the corresponding debt pricing schedule. The solid black line shows the schedule consistent with pooling on debt (i.e., $\mu_0' = G_2(\mu_1)$), while the gray dashed line shows the price that would be offered to an $L$-type government. Consistently with Assumption 2, the latter is the relevant price for any deviation. The black dot in the three plots denotes the debt issuance choice under pooling (i.e., $\hat{b}^P$, as defined in Section 4.3.2). Therefore, Panel (c) in Figure 9 allows us to visualize the pooling contract

$\{q(\hat{b}^P, y, G_2(\mu_1)), q(b' \neq \hat{b}^P, y_1, G_2(0))\}$ we characterized in Result 5. It corresponds to the gray dashed line for any debt issuance apart from $b' = \hat{b}^P$, for which the price is given by the ($y$-coordinate of the) black dot on the black solid line.

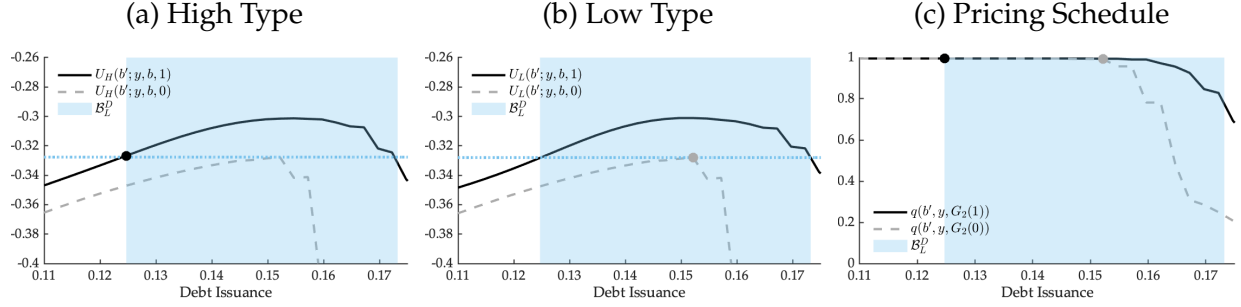Figure 9: Pooling on Debt in the Quantitative Model
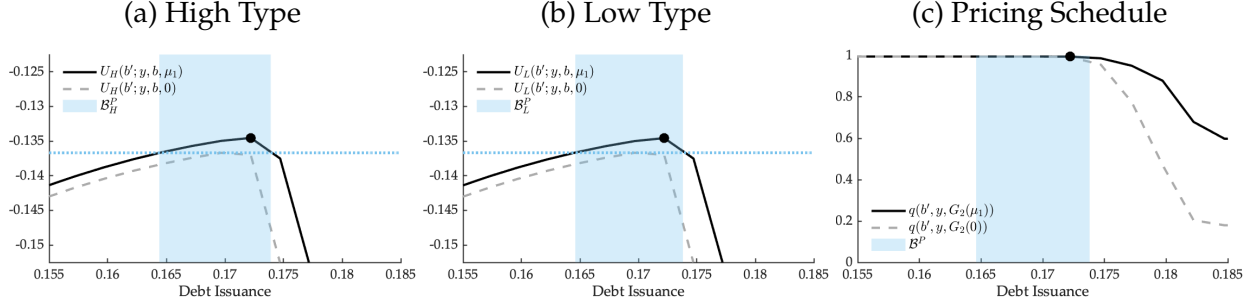


*Notes:* This figure presents the optimization problem for both type of governments under different values for first interim beliefs, as well as the price schedule of debt consistent with these beliefs. *Debt issuance* is relative to mean output in the ergodic distribution. Tax revenues, outstanding debt, and first interim beliefs are set at the mean value in the ergodic distribution.

Next, in Figure 10 we present graphically an instance of separation on debt choices, as we did in Figure 4 for the two-period model. The solid black lines in panels (a) and (b) show the objective functions of a government (the function $U_i$, defined in (27)) when it is perceived as being of the $H$-type. The gray dashed lines show the same functions when lenders are convinced to face the $L$-type. The shaded blue regions correspond to the profitable deviations for the $L$-type government, $\mathcal{B}_L^D$. The separating choices of debt are marked with a dot. The black dot corresponds to the equilibrium debt choice for the $H$-type, $\hat{b}_H^S$, while the gray dot corresponds to the $L$-type's choice, $\tilde{b}_L$. The horizontal dashed blue lines correspond to $\tilde{U}_i(b, y)$, the maximum payoff each type can obtain from a deviation. Since it is difficult to appreciate it from the figure, it is important to highlight that in panel (a) the black dot lies above the blue dashed line. This ensures that there are no profitable deviations for the $H$-type.

Panel (c) shows the pricing schedule of debt consistent with the extreme (second interim) beliefs entailed by separation. In particular, the black solid line corresponds to the scheduled offered by lenders to an $H$-type, while the gray dashed line is the one offered to an $L$-type. The separating contract $\{q(\hat{b}_H^S, y, G_2(1)), q(b' \neq \hat{b}_H^S, y_1, G_2(0))\}$ we characterized in Result 5 corresponds to the gray dashed line for any debt issuance apart from $b' = \hat{b}_H^S$, for which the price is given by the ($y$-coordinate of the) black dot on the black solid line.

Finally, we explore how the equilibrium debt choice varies across the state space. as we discussed in Section 4.3.2, the possible scenarios are *pooling on debt* (Pool), where no new information is acquired by investors; *separation on debt* (Separate), where investors

## Figure 10: Separating on Debt in the Quantitative Model

(a) High Type        (b) Low Type        (c) Pricing Schedule



*Notes:* This figure presents the optimization problem for both type of governments under different values for first interim beliefs, as well as the price schedule of debt consistent with these beliefs and separation on debt. Tax revenues are 1.6 standard deviations bellow the ergodic mean and outstanding debt is 0.16 percent of the mean level of output.

are able to update their beliefs with the true nature of the government in office; or *market freeze*, where neither of the cases above is feasible.

In Figure 11 we show cross-sections of the state space holing beliefs constant at two different values. In the left panel, investors' beliefs are set to zero, i.e., investors are sure to face the *L*-type. In the right panel, we fix investors' beliefs of facing the *H*-type at the mean value in the ergodic distribution (0.6 in our simulations). We observe pooling across most of the state space. This is in part due to our Assumption 1 that imposes an on order in the debt contracts that investors propose to the government. We conduct further analysis reverting this order in Appendix E. Finally, the few instances of separation occur for low levels of debt and tax revenues when first interim beliefs are also low.

## Figure 11: State-Space Debt Equilibrium Regions
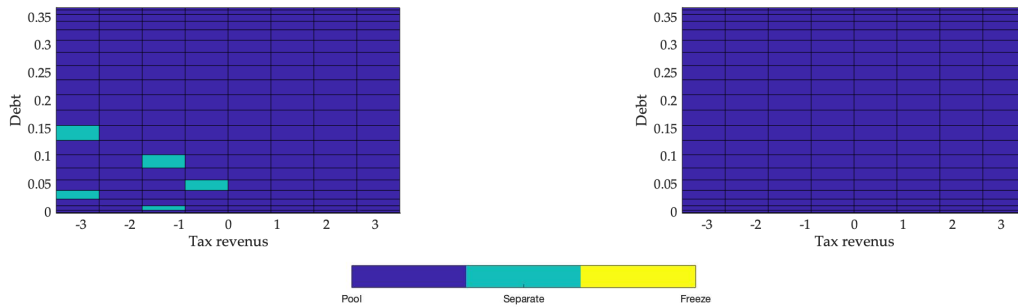


*Notes:* This figure presents the debt equilibrium across the state-space. The regions are: pooling (pool) on debt choice; separating on the choice of debt (Separate); or market freeze (Freeze). *Debt* is outstanding debt relative to mean output. *Tax revenues* are reported in terms of standard deviations from the mean. First interim beliefs are fixed at 0 and 0.6 for the panels in the left and right respectively.

# 6  Quantitative Effect of Political Uncertainty

We conduct two exercises to study the implications of lenders' beliefs and political uncertainty in the model. First, we analyze the effect of an unexpected shock to the lenders' prior about the type of government they are facing. The second exercise consists in a set of comparisons of our benchmark results with the ones derived under alternative versions of the model that differ in terms of some assumptions about the market and political environment.

## 6.1  A Shock to Lenders' Beliefs

Investors' beliefs about the type of government that they are facing are important in forming their expectations about future defaults. Hence, beliefs have a direct impact on the pricing schedule of debt and, potentially, on equilibrium spreads. Moreover, changes to the debt pricing schedule could also impact the equilibrium level of borrowing and spending.

We analyze the effect that lenders' beliefs have in our model economy by studying a one-time unexpected shock to their beliefs. This exercise is especially interesting given that we mostly observe pooling on debt as the equilibrium outcome in model simulations. Otherwise, the shock would be short lived as the government in office would immediately reveal its type, leaving no bite to the shock.

We consider a reduction in investors prior $\mu_{0,t}$ at time $t = 1$ by three standard deviations (the mean of $\mu_{0,t}$ is 0.60 and its standard deviation is 0.02). This implies a decrease (increase) in the perceived likelihood that the government in office has a high (low) cost of default. The drop in $\mu_{0,t}$ could be interpreted, for example, as the result of a new economic policy announced by the government that threatens debt sustainability and is not captured endogenously in the model, which leads to a downward revision of investors' beliefs. We analyze the economic impact of the shock through impulse response functions for the lenders' prior, the interest rate spread on government debt, the level of debt, and government spending.

It is important to stress that models of sovereign debt are known to exhibit considerable nonlinearities. For this reason, we compute impulse response functions as the mean response over 10,000 simulations. We set the initial state of each simulation at the mean value in the ergodic distribution. We then introduce a one-time unexpected shock to the initial lenders' prior. The prior then gradually returns to its stochastic steady state value as lenders update their beliefs in accordance to fiscal choices and political transitions. In practice, at time $t = 1$ we reduce investors prior $\mu_{0,t}$ by 0.05 for all 10,000 simulations. We

then simulate each path forward for 20 periods and take the difference with respect to the same simulation without the shock. The impulse response functions we present are then means and medians across these differences.

We report the results in Figure 12. We show the impulse response functions in terms of means (black solid lines) and medians (gray dashed lines). The values reported for the prior correspond to simple differences while values for interest rate spreads corresponds to basis points difference. For debt and government spending, the values correspond to percentage change relative to their mean value in the ergodic distribution.

Figure 12: Impulse Response Functions to an Unexpected $\mu$ Shock



(a) Prior, $\mu_0$ — (b) Spread — (c) Debt — (d) Government Spending
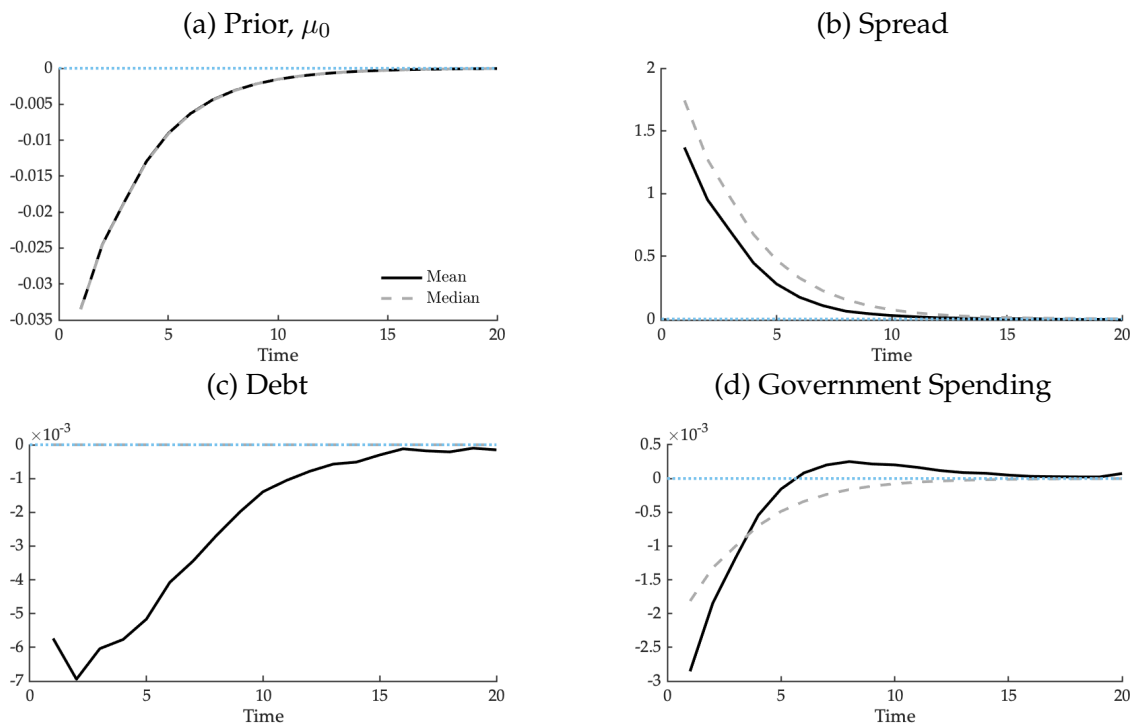
*Notes:* This figure presents the impulse response functions (IRFs) for investors prior, interest rate spreads, debt, and government spending. Debt and government spending values correspond to percent change relative to the mean value of the ergodic distribution. Spreads correspond to basis points difference. IRFs are the average response across 10,000 simulations initiated at the mean of the ergodic distribution.

Figure 12 show that the negative shock to lenders' prior beliefs induces an increase in borrowing costs, reflected in an increase in spreads. In response, the government is forced to cut borrowing and government spending to avoid the lower prices. Borrowing and spending then revert back to their mean ergodic values as $H$-type governments' take actions that reveal their type and so prior beliefs ameliorate.

## 6.2 Effects of Imperfect Information and Political Transitions

In a second set of exercises, we compare results from our benchmark model with those derived under different specifications in order to illustrate the effects of imperfect information and political transition in the model. For each different version, we first re-solve and then simulate the model. We maintain the same parameter specification as in the benchmark model. In Table 6 we report the results for the debt-to-output ratio, the level of the spread, and its volatility.

We also perform welfare comparisons across different model specifications, considering the (expected present discounted value of the) utility-value of the stream of government spending, net of the costs paid in default. Specifically, our comparisons are based on the compensating variation (CV) in government spending in each alternative model relative to our benchmark model. This metric corresponds to the percent by which government spending has to permanently change in the alternative economy in order to achieve the same welfare as in our benchmark model. We focus on a "conditional" CV measure, where welfare in both economies is calculated with respect to the ergodic distribution of the state in our benchmark model. Appendix F provides further details our approach.

**Reverse contract order.** Our first modification consists in changing the order in which debt contracts are offered (Assumption 1). We now assume investors offer the separating contract first, if feasible. We present a more thorough analysis of this alternative model specification in Appendix E.

Comparing the results derived under the two different debt contract orders, we notice that the widespread pooling on debt in our benchmark setting gives rise to higher average spreads. This is because the $H$-type governments in the benchmark economy are able to separate less often than in the alternative economy, hence facing higher spreads in the latter. However, the separating contract requires $H$-type governments to borrow less than under pooling, in order to discourage $L$-type governments from deviating (see Figure 10). This leads to lower debt levels in the alternative scenario. We also observe that, intuitively, the extensive pooling on debt in the benchmark model limits the volatility in spreads. This result stems from investors less frequently updating their beliefs in the benchmark model—as pooling conveys no new information about the type of government they are facing—, which reduces shifts in pricing schedules and, in turn, equilibrium spreads variability.

Reversing the order in which debt contracts are offered has implications also for welfare. A government in the alternative model would require a permanent increase in government spending of about 0.5 percent to enjoy the same welfare as in our benchmark

setting. Increasing the frequency of separation instances is particularly hurtful for $L$-type governments, which would face higher borrowing costs. However, these costs would also filter into the welfare of $H$-type governments through the possibility of future political transitions.

**Type revelation.** Our second exercise consists in simulating our benchmark model assuming that at each time period, and before the default decision, lenders learn the true type of government in office and update their prior accordingly. For example, if they learn that the government is of the $H$-type, they would set $\mu_{0,t} = 1$. It is important to stress that we do not re-solve the model, but just study the implications of such information disclosure in simulations of the model. This implies that lenders, despite learning the government's type at the beginning of each period, still act thinking that the cost of default will be private information of future governments.

When comparing results for this exercise vis à vis the benchmark model, the main difference we observe is a slightly higher (lower) mean debt-to-output ratio for the $H$-type ($L$-type) relative to the benchmark scenario. When investors learn about the type of government they are facing, they reflect their updated beliefs in market conditions. An $H$-type ($L$-type) government then faces more (less) favorable prices, reflected in the mean spreads, and is able to issue more (less) debt.

Comparing welfare in this exercise is very informative. Relative to our benchmark model, an $H$-type government would be better-off (the CV is negative), while the $L$-type government would be worse-off (the CV is positive). This is because, by revealing its type, the borrowing constraint is relaxed for the $H$-type, allowing for more borrowing and spending. The opposite is true for the $L$-type. Nevertheless, the magnitude of the CVs is small since lenders still act thinking that the cost of default will be private information in the future.

**Perfect information.** The third comparison is done against a model with perfect information, namely, a model identical to our benchmark apart from lenders being able to observe the type of current and future governments. This implies that we do not need to impose any ordering in the offer of contracts as there is only one equilibrium contract for each type.

While the mean debt-to-output ratio is only marginally lower than the one in the benchmark model, spreads are substantially lower and less volatile in the perfect information setting. Looking at the CVs, we observe that these changes in market conditions induced by private information entail welfare costs for governments of both types.

It is worth highlighting that, while asymmetric information is arguably the main dif-

ference between our benchmark and this alternative model, it is not the only one. For instance, the debt contract order and the existence of market freeze and market lockdowns could also be playing a role in our results. Therefore, it would be more correct to say that our comparison highlights the costs of private information when accompanied by all these other features of our benchmark model

**No political transitions.** In our fourth and last alternative version of the model, we derive results for a setting that corresponds to a rather standard sovereign default model in the tradition of Eaton and Gersovitz (1981). Specifically, we independently solve and simulate two versions of our model with perfect information and no political transitions, which differ only in the value of the government's default cost that we set to $\varphi_H$ and $\varphi_L$.

The comparison is very illustrative. Without political transitions, the $H$-type government is able to issue considerably more debt at a price close to the risk-free one. On the contrary, the $L$-type government is still constrained in its debt choices by borrowing costs because of its relatively low default cost. Spreads are substantially lower and less volatile than an economy with political turnover and both perfect information (a result in line with Cuadra and Sapriza, 2008 and Hatchondo et al., 2009) and asymmetric information.

Eliminating political turnover on top of private information is particularly beneficial for $H$-type governments. It would take a reduction of up to almost 5% of government spending for the welfare in the alternative scenario to align with the one in our benchmark setting. That is because $H$-type governments face more relaxed borrowing constraints in the alternative economy, allowing for higher debt issuance, government spending, and, ultimately, welfare. In fact, note that the lower and less volatile spreads yield gains also for $L$-type governments.

**Summary of the results.** From these comparisons, we conclude that: *(i)* the information asymmetry is partially responsible for the relatively high level and volatility of spreads we observe in our benchmark version of the model; *(ii)* our Assumption 1 on the order of debt contracts plays a role in determining the variation in interest rate spreads and, to a lesser extent, their level and the level of equilibrium debt. With widespread pooling, as in our benchmark economy, spreads are higher and less volatile, and a bit more debt can be sustained; *(iii)* political transitions also contribute to high spreads and limit the amount of debt that the $H$-type government is able to issue, in line with existing results in the literature; *(iv)* political turnover and private information have welfare implications. By inducing higher and more volatile spreads, political alternation is detrimental for welfare. This is especially true for $H$-type governments, but also $L$-type ones are negatively impacted. By amplifying the effects on the spread of political turnover, private information

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exacerbates the welfare costs of political uncertainty.

Table 6: The Effects of Private Information

| Model Version | Empirical Statistics | | | |
|---|---|---|---|---|
| | $b/y$ | $spread$ | $\sigma(spread)$ | $CV$ |
| Data | 17.18 | 0.42 | 0.79 | - |
| Benchmark model | 17.683 | 0.253 | 0.154 | - |
| *High type* | 17.704 | 0.252 | 0.153 | - |
| *Low type* | 17.650 | 0.254 | 0.150 | - |
| Reverse contract order | 16.863 | 0.196 | 0.336 | 0.568 |
| *High type* | 16.750 | 0.150 | 0.318 | 0.561 |
| *Low type* | 17.029 | 0.261 | 0.252 | 0.578 |
| Type revelation | 17.699 | 0.220 | 0.279 | 0.003 |
| *High type* | 17.785 | 0.190 | 0.277 | -0.026 |
| *Low type* | 17.564 | 0.263 | 0.243 | 0.045 |
| Perfect information | 17.509 | 0.084 | 0.083 | -0.105 |
| *High type* | 17.605 | 0.128 | 0.031 | -0.095 |
| *Low type* | 17.363 | 0.020 | 0.056 | -0.119 |
| No political transition | | | | |
| *High type* | 36.902 | 0.000 | 0.000 | -4.793 |
| *Low type* | 17.405 | 0.008 | 0.003 | -0.140 |

*Notes:* This table presents empirical statistics for different versions of the model under the same parameter specification. Data for Italy is for the period from 2000q1 to 2018q4. Empirical statistics are the average moment across 10,000 simulations of 76 periods each. $CV$ refers to the compensating variation in government spending variation estimated from model simulations. All data in the table are in percentage points. Statistics for the *High* or *Low* type are calculated over the subset of periods in which the corresponding type of government is in office.

# 7 Conclusion

In this paper, we first document empirically an association between political uncertainty and the spread on government debt yields. We then rationalize this relationship as the result of asymmetric information between the government and sovereign lenders in a model of sovereign default that features political turnover between two types of government that face different costs of default. These costs are common knowledge, but investors do not know which type they are facing each period. They form beliefs about it and update them according to observed fiscal policy decisions and political transition probabilities.

We find that lenders' beliefs affect lending conditions. We show that the government becomes more constrained in its borrowing possibilities as investors become more convinced of facing a government with low default costs. A negative shock to lenders' beliefs causes a widening of sovereign spreads and, consequently, a contraction in sovereign debt and public spending. These results highlight the importance of lenders' beliefs, and their dynamics, on the ability of governments to conduct fiscal policy.

Finally, we show that political turnover increases the level and volatility of sovereign spreads relative to a standard, full information sovereign default model. Moreover, the presence of asymmetric information substantially amplifies these effects, further hindering the government's ability to finance spending, thus reducing welfare.

# References

Aguiar, M. and G. Gopinath (2006). Defaultable debt, interest rates, and the current account. *Journal of international Economics 69*(1), 64–83.

Alfaro, L. and F. Kanczuk (2005). Sovereign debt as a contingent claim: a quantitative approach. *Journal of International Economics 65*(2), 297–314.

Amador, M. and C. Phelan (2018, June). Reputation and sovereign default. Working Paper 24682, National Bureau of Economic Research.

Arellano, C. (2008). Default risk and income fluctuations in emerging economies. *American Economic Review 98*(3), 690–712.

Auclert, A. and M. Rognlie (2016). Unique equilibrium in the eaton–gersovitz model of sovereign debt. *Journal of Monetary Economics 84*, 134–146.

Ayres, J., G. Navarro, J. P. Nicolini, and P. Teles (2018). Sovereign default: The role of expectations. *Journal of Economic Theory 175*, 803–812.

Baker, S. R., N. Bloom, and S. J. Davis (2016). Measuring economic policy uncertainty. *The quarterly journal of economics 131*(4), 1593–1636.

Bocola, L. (2016). The pass-through of sovereign risk. *Journal of Political Economy 124*(4), 879–926.

Bocola, L., G. Bornstein, and A. Dovis (2019). Quantitative sovereign default models and the european debt crisis. *Journal of International Economics 118*, 20 – 30.

Bocola, L. and A. Dovis (2019). Self-fulfilling debt crises: A quantitative analysis. *American Economc Review , forthcoming*.

Chatterjee, S. and B. Eyigungor (2012). Maturity, indebtedness, and default risk. *American Economic Review 102*(6), 2674–99.

Chatterjee, S. and B. Eyigungor (2019). Endogenous political turnover and fluctuations in sovereign default risk. *Journal of International Economics 117*, 37–50.

Cole, H. L., J. Dow, and W. B. English (1995). Default, settlement, and signalling: Lending resumption in a reputational model of sovereign debt. *International Economic Review*, 365–385.

Cuadra, G. and H. Sapriza (2008). Sovereign default, interest rates and political uncertainty in emerging markets. *Journal of International Economics 76*(1), 78 – 88.

D'Erasmo, P. (2011). Government reputation and debt repayment. Technical report, University of Maryland.

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

Egorov, K. and M. Fabinger (2016). Reputational effects in sovereign default. Unpublished Manuscript.

Hatchondo, J. C. and L. Martinez (2010). The politics of sovereign defaults. *Economic Quarterly 96*(3), 291–318.

Hatchondo, J. C., L. Martinez, and H. Sapriza (2009). Heterogeneous borrowers in quantitative models of sovereign default. *International Economic Review 50*(4), 1129–1151.

Hébert, B. and J. Schreger (2017). The costs of sovereign default: Evidence from argentina. *American Economic Review 107*(10), 3119–45.

Koop, G., M. H. Pesaran, and S. M. Potter (1996). Impulse response analysis in nonlinear multivariate models. *Journal of econometrics 74*(1), 119–147.

Lester, R., M. Pries, and E. Sims (2014). Volatility and welfare. *Journal of Economic Dynamics and Control 38*, 17 – 36.

Lorenzoni, G. and I. Werning (2019). Slow moving debt crises. *American Economic Review 109*(9), 3229–63.

Paluszynski, R. (2017). Learning about debt crises. Technical report, University of Houston.

Perez, D. (2018). Sovereign debt, domestic banks and the provision of public liquidity. *Manuscript, New York University*.

Phan, T. (2017a). A model of sovereign debt with private information. *Journal of Economic Dynamics and Control 83*, 1–17.

Phan, T. (2017b). Sovereign debt signals. *Journal of International Economics 104*, 157–165.

Sandleris, G. (2008). Sovereign defaults: Information, investment and credit. *Journal of international Economics 76*(2), 267–275.

Scholl, A. (2017). The dynamics of sovereign default risk and political turnover. *Journal of International Economics 108*, 37 – 53.

Zoli, M. E. (2013). Italian sovereign spreads: their determinants and pass-through to bank funding costs and lending conditions. IMF working paper no. 13/84, International Monetary Fund.

# Appendix

## A  Additional Empirical Evidence

We confirm the importance of political uncertainty in determining sovereign spreads for individual countries, by estimating country-specific regressions of the type:

$$spr_t = \beta_0 + \beta_1 epu_t + \beta_2 gdp_t + \varepsilon_t$$

By looking at the significance of coefficients and the $R^2$ in the results reported in Table A1, EPU appears to be a relevant predictor for spreads in many cases.

Figure A1 shows the relationship between all the variables in regression (1), for the sample used to derive the results in Table A1.

## B  Proofs and Additional Theoretical Results

**Lemma 2.** *In the two-period model, $d_{2,L}(b_2, y_2) \geq d_{2,H}(b_2, y_2)$ for all $(b_2, y_2)$.*

*Proof.* Suppose the result does not hold. Then it must exist one $(b_2, y_2)$ for which $d_{2,L}(b_2, y_2) < d_{2,H}(b_2, y_2)$, i.e., the $H$-type defaults ($u(y_2 - b_2) < u(\tau y_2) - \varphi_H$) whereas the $L$-type repays ($u(y_2 - b_2) \geq u(\tau y_2) - \varphi_L$). This implies

$$\varphi_H < u(\tau y_2) - u(y_2 - b_2) \leq \varphi_L,$$

which is a contradiction to $\varphi_H > \varphi_L$. $\qquad\square$

**Lemma 3.** *In the two-period model, $U_i(b_2; b_1, y_1, \mu)$ is increasing in $\mu$ for all $(b_2, b_1, y_1)$.*

*Proof.* $U_i(b_2; b_1, y_1, \mu)$ depends on $\mu$ only through $q(b_2, y_1, G_2(\mu))$ (see (6)). Being $G_2(\mu)$ increasing in $\mu$ (see (5) and the remark following it), all we have to show is that $q(b_2, y_1, x)$ is increasing in $x$. Recalling the definition of $q$ (see (4)), this property is an immediate consequence of Lemma 2. $\qquad\square$

## C  Data Appendix

*Real gross domestic product (GDP)* data are obtained from OECD Quarterly National Accounts. Values correspond to volume estimates in the GDP expenditure approach with

## Figure A1: Spread and Political Uncertainty
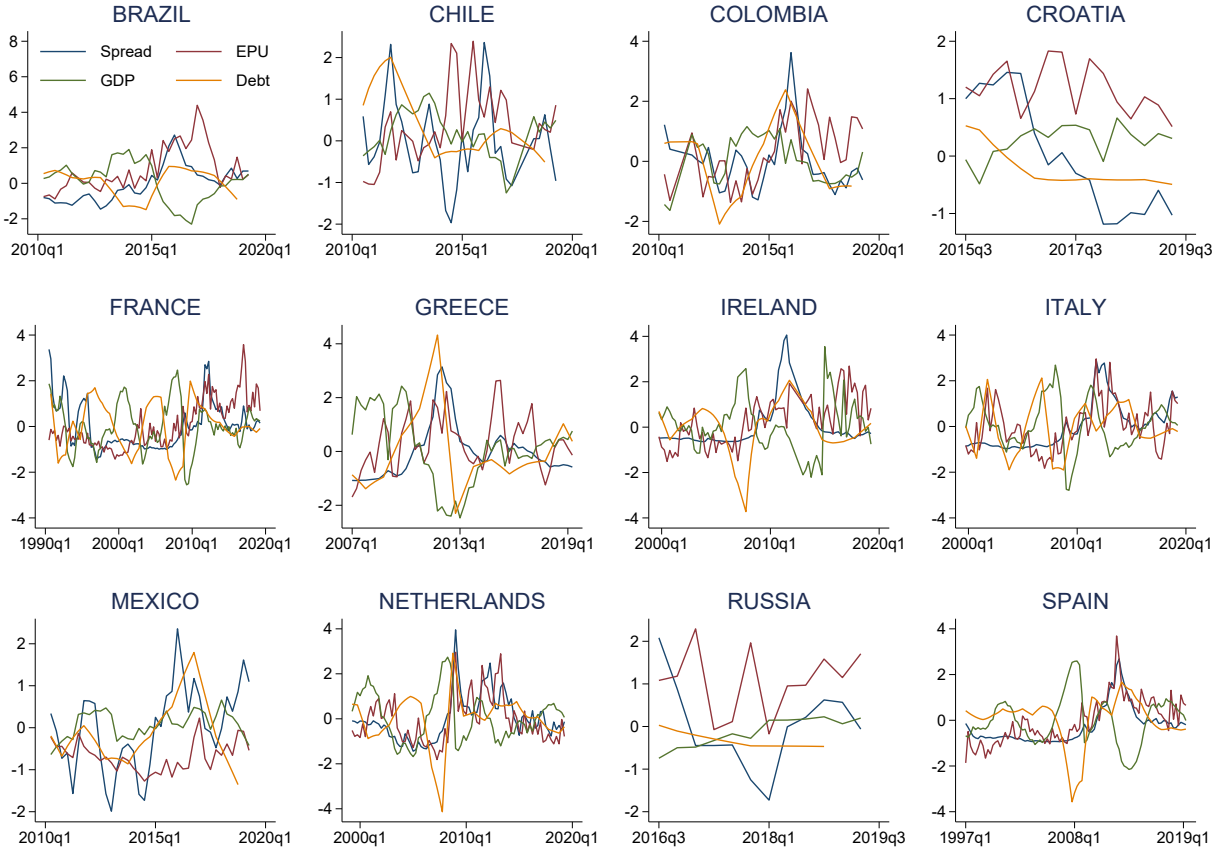


*Notes: Spread* is the difference between the 10-year yield-to-maturity of government bonds in a country and the one of Germany (for European countries) and the United States (for non-European). *EPU* is the Economic Policy Uncertainty index of Baker et al. (2016). *Debt* is gross government debt. *Debt* and *GDP* are HP-filtered (in logs). All variables are transformed in z-scores.

reference year 2015. Data are obtained for the period 2000q1–2018q4. We linearly detrend the series in logarithms.

*Public debt* data are obtained from the OECD Public Sector Debt database. Total gross debt in current prices is divided by the nominal GDP obtained from the Quarterly National Accounts database. Data are obtained for the period 2000q1–2018q4. Maturity of outstanding debt is obtained from the Bank of Italy.

*Interest rates* data on government bonds for Italy and Germany are obtained from the Bloomberg Terminal for the period 2000q1–2018q4. We consider the yield on generic one-year maturity government bonds in Euros. The spread is the difference in yield between Italy and Germany. The risk-free rate is estimated by subtracting inflation for the Euro

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Area from the German nominal interest rate data.

# D   Computational Appendix

In this appendix we describe the algorithms we use to solve and simulate the model. We also provide details on the ergodic distribution of our simulations and on how we calibrate the political transition probabilities.

## D.1   Model Solution Algorithm

To solve the model numerically we define four relevant value functions. These are the value functions for repayment (indexed as $V_i^R(\cdot)$, see (17)) and for default (indexed as $V_i^D(\cdot)$, see (18)) for both types of default cost governments (i.e. $i \in \{H, L\}$). The relevant state at which these value functions are evaluated is given by $s = (y, b, \mu_1)$. The assumption of a 100% haircut upon default simplifies the state space in default to only two variables, $(y, \mu_1)$. The value functions are defined once the default decision by the government has been taken. For this reason, the relevant state variable is the first interim beliefs, $\mu_1$ as opposed to the prior $\mu_0$.

The numerical solution of the model consists in approximating the value functions $\{V_H^R, V_L^R, V_H^D, V_L^D\}$ as well as the price function $q$ that must satisfy (19).

The value functions are approximated using a Chebyshev approximation. Specifically, $V^x(\cdot)$ is approximated as follows:

$$V_i^x(y, b, \mu_1) = \gamma_i^{x\prime} \boldsymbol{T}(y, b, \mu_1), \tag{31}$$

where $(y, b, \mu_1)$ is a realization of the state variables, $\gamma_i^x$ is a vector of coefficients, and $\boldsymbol{T}(\cdot)$ is a vector collecting Chebyshev's polynomials. The numerical solution is $\{\gamma_H^R, \gamma_L^R, \gamma_H^D, \gamma_L^D\}$ which is obtained via value function iteration.

Before solving, we select the bounds and number of grid points for the three state variables in $s$. For output, we consider 9 equally spaced points in an interval of plus and minus 3.5 standard deviations. We label this grid as $\mathcal{Y}$. For debt, we consider 21 points in the interval $[0.0, 0.9]$ located at the Chebyshev's nodes, $\mathcal{B}$. The upper bound of this interval is consistent with a maturity adjusted debt-to-output ratio of 37 percent at the steady-state level of output. Finally, for the beliefs about the likelihood that lenders place on a high cost of default type of government being in office, $\mu_1$, we set 11 equally space points for the unit interval, $\mathcal{M}$. The state-space grid $\boldsymbol{S}$ is constructed using tensor

multiplication of these nodes, $S = \mathcal{Y} \times \mathcal{B} \times \mathcal{M}$. These grid points, together with the Chabyshev's polynomials, are used in the approximation of the value functions using a collocation method. On the policy dimension for new debt issuances, $b'$, we set 101 points in the $[0.0, 0.6]$ interval. For the interval $[0.0, 0.2)$ we assign 6 equally spaced points. In the interval $[0.2, 0.75]$ we set 90 equally spaced points. Finally, the remaining 5 points are equally spaced in the $(0.75, 0.90]$ interval. Expectations are computed using a Gauss–Hermite quadrature of order 15. Table A2 shows the value for the relevant computational parameters.

The solution algorithm follows the following steps:

1. Initialize the algorithm with an initial guess for the value functions and the price schedule $\{\hat{V}_{H,0}^{R}, \hat{V}_{L,0}^{R}, \hat{V}_{H,0}^{D}, \hat{V}_{L,0}^{D}, \hat{q}_0\}$.

2. Let $\{\hat{V}_{H,n}^{R}, \hat{V}_{L,n}^{R}, \hat{V}_{H,n}^{D}, \hat{V}_{L,n}^{D}\}$ be the value functions at iteration $n$. Given these values use the projection method to update the value of $\{\gamma_H^R, \gamma_L^R, \gamma_H^D, \gamma_L^D\}$ used to approximate the value function.

3. Update the value functions using their definitions. To compute expectations, use Gauss–Hermite quadrature.

   (a) The equilibrium price schedule, debt choices, and beliefs' update from $\mu_1$ to $\mu_2$ follow Result 5. That is, if a pooling contract is feasible, that is offered and there is pooling on debt. Otherwise, a separating contract is offered, if feasible, resulting in separation. Finally, if none of them exists, there is market freeze.

   (b) Beliefs $\mu_2$ are updated to $\mu_0'$ according to political transition probabilities as specified in (21).

   (c) The first interim beliefs for the next period, $\mu_1'$, are obtained following the equilibrium default decision described in Result 4.

4. For each element in the pricing grid compute the pricing schedule using the most recent value function approximations to determine the governments default decision. Use a Gauss–Hermite quadrature to compute expectations.

5. Check for convergence in the value functions and pricing schedule using the norm of choice. If the value functions and pricing schedule have converged, then a solution has been achieved. If not, set $n = n + 1$ and repeat from Step 2.

For convergence of the value functions we consider the sup norm. Convergence is achieved at a level of $0.0086$ and $0.0.0096$ for the value function of default for the low and

high-type respectively; while a convergence level of $0.0918$ and $0.0920$ is achieved for the respective value functions in repayment.

## D.2   Simulation algorithm and impulse response functions

To simulate the model, we consider the solution to the model given by $\{\gamma_H^R, \gamma_L^R, \gamma_H^D, \gamma_L^D\}$. Before simulating the model we set the number of simulations $N_{sim}$ as well as the length period of each simulation $N_T$. We index the number of simulation with $i$, the time period with $t$, and the value of variable $x$ in simulation $i$ at time $t$ as $x(t, i)$. To simulate the model, we follow the following algorithm:

1. Initialize the state variables. That is, set a value for $\{z(0, i), b(1, i), \mu_0(1, i), type(1, i)\}$. Set $indefault(0, i) = 0$ to indicate the economy was not in default in the previous period. Finally set $t = 1$.

2. Draw innovations from a uniform distribution in the unit interval, $\varepsilon_{election}(t, i)$ and determine election outcomes (i.e. type transitions) from the political transition probabilities.

3. Draw innovations for output, $\varepsilon_y(t, i)$ from a standard normal distribution. Update $z$ following its law of motion, $z(t, i) = \rho z(t - 1, i) + \sigma_y \varepsilon_y(t, i)$

4. Use $\{\gamma^{nd}, \gamma^{ss}, \gamma^D\}$ to compute the value function $\{v_j^R(t, i), v_j^D(t, i)\}$ at the state given by $\{z(t, i), b(t, i), \mu_0(t, i)\}$ for $j = \{H, L\}$.

5. Determine the default decision of the government and update prior beliefs to first interim beliefs $\mu_1(t, i)$.

   (a) If the government defaults. Set $\delta(t, i) = 1$ and $indfault(t, i) = 1$. There is a complete wipeout of debt so set $b(t + 1, i) = 0$. Move to step 7.

   (b) Otherwise, set $\delta(t, i) = 0$ and $indfault(t, i) = 0$, then continue to the next step.

6. Compute the optimization problem for the government. Use a Gauss–Hermite quadrature to compute expectations which are relevant to compute the continuation values and the pricing schedule of debt. Obtain the choice of new debt issuance $b(t + 1, i)$, its respective equilibrium price $q(t + q, i)$, and update the first interim beliefs to second interim beliefs, $\mu_2(t, i)$.

7. If $t < N_T$, set $t = t + 1$ and set the prior tomorrow, $\mu_0(t + 1, i)$, by applying the political transition matrix to the second interim beliefs. Then return to step 2. Otherwise finish the simulation procedure.

In computing the empirical statistics from simulated data, we only consider periods when the government is not in default. Moreover, to avoid unintended effects coming from the state in which simulations are initialized, we drop the first 100 periods. In the paper, interest rate spreads are shown annualized. To compute spreads in the simulations we consider $spread(t,i) = (1/q(t,i))^4 - (1+r)^4$. Government spending is obtained from the budget constraint of the government.

**Impulse response functions.** It is well known that models of sovereign default exhibit non linearities. For this reason, we compute impulse response functions following Koop et al. (1996). The impulse response functions are computed as the average difference between simulations with and without the shock. We initialize each state variable in the simulation at its mean value in the ergodic distribution.

## D.3   Ergodic Distribution

We construct the empirical ergodic distribution as the distribution of model variables in a sufficiently large number of simulations after a sufficiently long period of time. The latter to avoid unintended effects coming from the state in which simulations are initialized. Figure A2 presents the cross-section of this distribution.

Figure A2: Ergodic Distribution
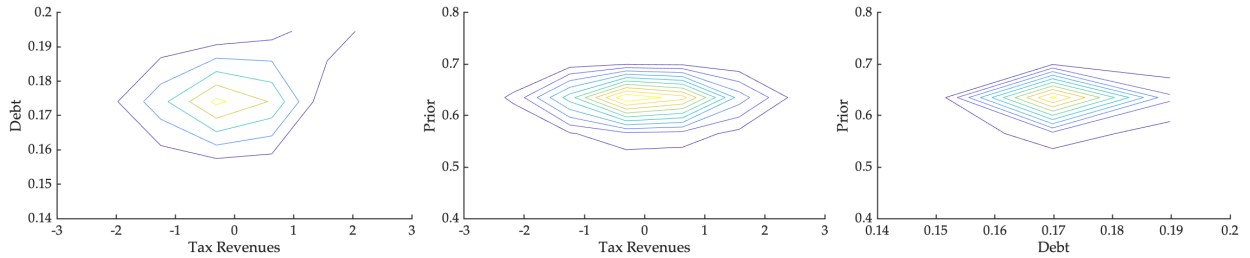


*Notes:* This figure presents the cross-section for the empirical ergodic distribution. The distribution is constructed from 10,000 simulations of 76 periods each. Debt is relative to mean output. Tax revenues are reported in terms of standard deviations from the mean.

## D.4   Calibration of the Political Transition Probabilities

The political transition probabilities, $\pi_{H,H}$ and $\pi_{L,L}$, are chosen to match the average duration of a Prime Minister's tenure in Italy in the post-war period. That is 1.8 years. In the ergodic distribution, the share of $i$-type governments in office is given by,

$$s_i = \frac{1 - \pi_{j,j}}{2 - \pi_{L,L} - \pi_{H,H}}.$$

for $i \in \{H, L\}$ and $j \neq i$.

The average duration, in quarters, of a government of type $i$ in the model is given by,

$$T_i = \frac{1}{1 - \pi_{i,i}}.$$

Hence, in the steady state the average duration of a government in the model is given by,

$$T = \frac{1 - \pi_{L,L}}{2 - \pi_{L,L} - \pi_{H,H}} \times \frac{1}{1 - \pi_{H,H}} + \frac{1 - \pi_{H,H}}{2 - \pi_{L,L} - \pi_{H,H}} \times \frac{1}{1 - \pi_{L,L}}.$$

We have one degree of freedom, so we set the share of high-type governments to be 60% in the ergodic distribution. We then select $\pi_{H,H} = 0.88$ and $\pi_{L,L} = 0.82$ in order to match the average duration of a government in office of 1.8 years (7.2 quarters) in the data.

# E   Alternative Debt Contracts Order

Assumption 1 establishes the order in which debt contracts are offered to the government in our benchmark model. First a pooling contract is offered, if not feasible then a separating contract is offered. If none of them is feasible, then there is a market freeze. In Section 6.2 we consider the alternative order specified in the following assumption.

**Assumption 3.** *In proposing debt contracts, lenders adopt in the following order:*

1. *a separating contract is offered, if feasible. Otherwise,*

2. *a pooling contract is offered, if feasible. Otherwise,*

3. *the sovereign debt market "freezes", i.e., lenders refrain from providing any credit.*

We then solve the model under the same parameter specification we used for the benchmark model. We highlight that convergence of the numerical solution in this case is not as accurate as the one we achieve in the benchmark model. Under the sup-norm, convergence in this alternative model is achieved at a level of $0.0125$ and $0.0125$ for the value function of default for the low and high-type respectively; while a convergence level of $0.3461$ and $0.3490$ is achieved for the respective value functions in repayment. This could imply numerical inaccuracies in computation of results.

We then use the solution to this version of the model to explore how the equilibrium choice of debt varies across the state space. As a remainder, the possible scenarios are *pooling on debt* (Pool), where no new information is acquired by investors; *separation on*

*debt* (Separate), where investors are able to update their beliefs with the true nature of the government in office; or *market freeze*, where neither equilibrium exist. Intuitively, under Assumption 3 we observe more instances of separation than under our benchmark model. Figure A3 shows the debt choices across the state space. It is important to note that pooling is still the most frequent debt choice equilibrium outcome. In our benchmark model, pooling occurs 98% of the times in the simulations. Under the modified environment, it occurs 75% of the times, while separation cases constitute the remaining 25% of the simulations.

Figure A3: State-Space Default Regions
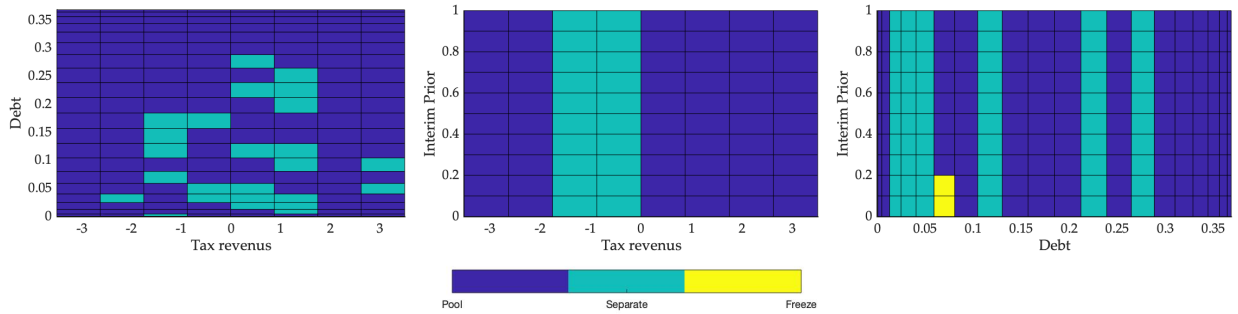


*Notes:* This figure presents the debt equilibrium across the state-space. The regions are: pooling (pool) on debt choice; separating on the choice of debt (Separate); or market freeze (Freeze). Debt is relative to mean output. Tax revenues are reported in terms of standard deviations from the mean. At each panel, the fixed dimension is set at the mean value in the ergodic distribution using the modified version of the model.

# F  Compensating Variation

We compute the compensating variation (CV), $\lambda$, our welfare measure, building upon Lester et al. (2014). First, we define the benchmark total welfare as:

$$\mathbb{E}[U_i(s_t)] \equiv \mathbb{E}\left[\sum_{j=0}^{\infty} \beta^j \left(u\left(c^*\left(s_{t+j}\right)\right) - d^*(s_{t+j})\varphi_i\right)\right],$$

where $c*, d^*$ are the equilibrium policy functions in the benchmark model and the expectations (over the states) are taken with respect to the ergodic distribution in our benchmark model.

We then define a similar object for the model we are comparing welfare with:

$$\mathbb{E}[\tilde{U}_i(s_t, \lambda)] \equiv \mathbb{E}\left[\sum_{j=0}^{\infty} \beta^j \left(u\left((1+\lambda)\tilde{c}^*\left(s_{t+j}\right)\right) - \tilde{d}^*(s_{t+j})\varphi_i\right)\right].$$

The functions $\tilde{c}^*, \tilde{d}^*$ are the equilibrium policy functions in the alternative economy. We evaluate the flow utility at the same states, $s_t$, as in the benchmark economy and we take expectations with respect to the benchmark ergodic distribution.

Finally, we obtain the CV as the $\lambda$ that solves:

$$\mathbb{E}[U_i(s_t)] = \mathbb{E}[\tilde{U}_i(s_t, \lambda)].$$

**Discussion.** Welfare comparisons are a delicate exercise in quantitative models of sovereign default. One would expect that an economy in which the government can borrow at better terms would enjoy higher welfare. However, this need not be the case. That is because the calibration of models of sovereign default typically requires impatient governments. Governments therefore tend to borrow up to the "cliff" of the pricing function, where expected future default costs balance out the desire for more current expenditure. Chatterjee and Eyigungor (2019) describe this property in page 38 "as if the sovereign has a target level of default risk and manages his borrowings to attain that target closely".

As a result, comparing the expected lifetime utility computed with respect to the ergodic distributions of the two alternative models could yield results that are hard to compare. For example, consider the stochastic steady-state in two different versions of the model. In one the government can hold a lower debt-to-output ratio than in the other. If the target level of default risk, and hence equilibrium debt price, is the same in both models (e.g., because of the same preferences, discount factor, and default cost), then the economy with higher debt would experience lower "long-run" welfare, as government spending would be lower.[27] However, the intuition that the economy with better borrowing terms enjoys higher welfare still holds true when considering the same state in the two models.

This discussion underscores the desirability in our context to include the "transitional effects" arising when moving from one economy to the other in the welfare comparisons. Hence our choice of, in the language of Lester et al. (2014), a "conditional" CV rather than an "unconditional" CV. Yet, conditioning on the entire benchmark ergodic distribution instead of a single state—the latter is the choice in Lester et al. (2014) for their conditional CV measure—gives us a more complete picture of welfare, less dependent upon the selection of any particular state.

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[27] Note that in a stochastic steady-state $b' = b$ (on average), so for $\tilde{b} > b$ we have that $\tilde{g} = \tau y + (q-1)\tilde{b} < \tau y + (q-1)b = g$.

Table A1: Spread, Economic Policy Uncertainty, and GDP

| | Brazil | | | | Chile | | | | Colombia | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) |
| EPU | 0.685*** | | | 0.245 | -0.137 | | | 0.083 | 0.306* | | | 0.064 |
| | (5.49) | | | (1.65) | (-0.76) | | | (0.39) | (1.82) | | | (0.40) |
| GDP | | -0.692*** | | -0.916*** | | 0.145 | | 0.222 | | 0.134 | | -0.030 |
| | | (-5.59) | | (-4.37) | | (0.80) | | (1.17) | | (0.76) | | (-0.20) |
| Debt | | | 0.255 | -0.502*** | | | 0.301 | 0.361* | | | 0.667*** | 0.648*** |
| | | | (1.49) | (-3.12) | | | (1.67) | (1.72) | | | (4.90) | (3.93) |
| N | 36 | 36 | 34 | 34 | 32 | 32 | 30 | 30 | 34 | 34 | 32 | 32 |
| $R^2$ | 0.470 | 0.479 | 0.065 | 0.700 | 0.019 | 0.021 | 0.091 | 0.136 | 0.094 | 0.018 | 0.445 | 0.450 |

| | Croatia | | | | France | | | | Greece | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) |
| EPU | 0.222 | | | 0.143 | 0.435*** | | | 0.487*** | 0.507*** | | | 0.242*** |
| | (0.85) | | | (0.80) | (5.15) | | | (5.97) | (4.07) | | | (3.63) |
| GDP | | -0.421 | | 0.324 | | 0.183** | | 0.226** | | -0.803*** | | -0.683*** |
| | | (-1.74) | | (1.21) | | (1.99) | | (2.28) | | (-9.35) | | (-10.44) |
| Debt | | | 0.749*** | 0.975*** | | | -0.002 | 0.107 | | | 0.491*** | 0.301*** |
| | | | (4.22) | (3.65) | | | (-0.02) | (1.08) | | | (3.91) | (4.60) |
| N | 16 | 16 | 16 | 16 | 116 | 116 | 115 | 115 | 50 | 50 | 50 | 50 |
| $R^2$ | 0.049 | 0.177 | 0.560 | 0.625 | 0.189 | 0.034 | 0.000 | 0.264 | 0.257 | 0.646 | 0.241 | 0.820 |

| | Ireland | | | | Italy | | | | Mexico | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) |
| EPU | 0.305*** | | | 0.249*** | 0.600*** | | | 0.612*** | 0.362** | | | 0.283* |
| | (2.70) | | | (2.68) | (6.59) | | | (6.37) | (2.30) | | | (1.93) |
| GDP | | -0.239** | | 0.167 | | -0.084 | | 0.088 | | 0.134 | | 0.049 |
| | | (-2.08) | | (1.46) | | (-0.74) | | (0.92) | | (0.80) | | (0.32) |
| Debt | | | 0.579*** | 0.650*** | | | 0.168 | 0.076 | | | 0.521*** | 0.503*** |
| | | | (5.98) | (5.67) | | | (1.50) | (0.82) | | | (3.50) | (3.36) |
| N | 73 | 73 | 73 | 73 | 79 | 79 | 79 | 79 | 37 | 37 | 35 | 35 |
| $R^2$ | 0.093 | 0.057 | 0.335 | 0.412 | 0.360 | 0.007 | 0.028 | 0.373 | 0.131 | 0.018 | 0.271 | 0.359 |

| | Netherlands | | | | Russia | | | | Spain | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) |
| EPU | 0.691*** | | | 0.637*** | 0.213 | | | 0.257 | 0.820*** | | | 0.771*** |
| | (8.51) | | | (7.32) | (0.69) | | | (1.10) | (13.42) | | | (13.20) |
| GDP | | -0.020 | | 0.236** | | -0.342 | | 1.202* | | -0.222** | | -0.041 |
| | | (-0.18) | | (2.56) | | (-1.15) | | (2.22) | | (-2.23) | | (-0.44) |
| Debt | | | 0.389*** | 0.235** | | | 0.664** | 1.714** | | | 0.267*** | 0.191** |
| | | | (3.75) | (2.34) | | | (2.51) | (3.23) | | | (2.67) | (2.03) |
| N | 81 | 81 | 81 | 81 | 12 | 12 | 10 | 10 | 90 | 98 | 95 | 90 |
| $R^2$ | 0.478 | 0.000 | 0.151 | 0.528 | 0.045 | 0.117 | 0.441 | 0.702 | 0.672 | 0.049 | 0.071 | 0.720 |

*Notes:* The dependent variable is the spread for sovereign bonds. The table shows standardized beta coefficients. t-statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A2: Computational Parameters

| Variable or Parameter | Min | Max | Points |
|---|---|---|---|
| Output, $\mathcal{Z}$ | $-3.5\dfrac{\sigma_y}{\sqrt{1-\rho^2}}$ | $3.5\dfrac{\sigma_y}{\sqrt{1-\rho^2}}$ | 9 |
| Debt, $\mathcal{B}$ | 0.0 | 0.6 | 21 |
| Prior, $\mathcal{M}$ | 0.0 | 1.0 | 11 |
| Debt choice, $\mathcal{B}'$ | 0.0 | 0.9 | 101 |
| Order of Gauss-Hermite quadrature | | | 15 |

*Notes:* This table shows the choice of computational parameters used in the solution of the model following the algorithm outlines in the current section. As a collocation method is used, the order of the Chebyshev polynomial is equal to the number of nodes. For notation purposes we define $z$ as the natural logarithm of tax revenues.