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Authors	Maximiliano A. Dvorkin, Juan M. Sánchez, Horacio Sapriza, and Emircan Yurdagul
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Federal Reserve Bank of St. Louis, Research Division, P.O. Box 442, St. Louis, MO 63166

News, sovereign debt maturity, and default risk*

Maximiliano Dvorkin	Juan M. Sánchez	Horacio Sapriza	Emircan Yurdagul
FRB of St. Louis	FRB of St. Louis	Federal Reserve Board	Universidad Carlos III

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Abstract

Leading into a debt crisis, interest rate spreads on sovereign debt rise before the economy experiences a decline in productivity, suggesting that *news* about future economic developments may play an important role in these episodes. An empirical VAR estimation shows that a news shock has a larger contemporaneous impact on sovereign credit spreads than a comparable shock to labor productivity. A quantitative model of news and sovereign debt default with endogenous maturity choice generates impulse responses and a variance decomposition similar to the empirical VAR estimates. The dynamics of the economy after a bad news shock share some features of a productivity shock and some features of sudden stop events. However, unlike during sudden stop episodes, long-term debt does not shield the country from bad news shocks, and it may even exacerbate default risk. Finally, an increase in the precision of news allows the government to improve its debt maturity management, especially during periods of high stress in credit markets, and thus face lower yield spreads while increasing the amount of debt.

JEL Classification: F34, F41, G15.

Keywords: Crises, News, Default, Spreads, Maturity, Country Risk, Sovereign Debt.

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1 Introduction

Several financial crises in emerging and advanced economies have highlighted how shifts in expectations about the future path of the economy affect sovereign debt decisions and prices, reinforcing the view that news about future fundamentals are a relevant driving force in international credit markets. Our paper analyzes the extent to which changes in expectations driven by news matter for sovereign credit risk dynamics, and how the effect depends on the maturity of sovereign debt.[1]

The role of news about future productivity for sovereign credit events is illustrated in Figure 1. The plots in the figure show the evolution of labor productivity and country risk around sovereign financial distress episodes.[2] The sample contains 20 years of data for 12 emerging economies. The analysis focuses on episodes involving significantly high country risk. We define a debt crisis, or high country risk event, as a period in which the EMBI+ doubles relative to the previous year. The main takeaway from the figure is that country risk reacts *prior to* any sharp reduction in productivity, suggesting that bond prices may be responding to news about *future* productivity.

We complement the suggestive evidence offered by the figure with a more formal empirical analysis, estimating a panel-VAR that follows the identification strategy of news shocks introduced by Beaudry and Portier (2006). Our results show that news shocks have a significant contemporaneous effect on country risk, and that such effect is larger than that of a labor productivity shock of similar magnitude.

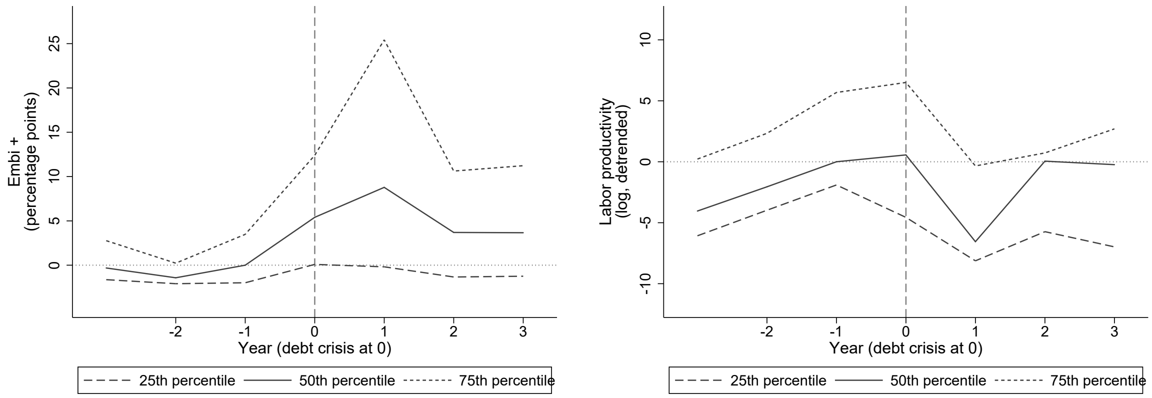
The empirical VAR results provide us a motivating starting point to study the role of news for sovereign debt dynamics, and we advance our analysis further by developing a structural model with news, debt maturity choice, and default risk.

Our contributions can be framed in terms of the answers to three questions: First, we consider different sources of macroeconomic fluctuations in small open economies, so every period our

[1] In this paper, sovereign credit risk, or country risk, refers to the risk that a government will default on its debt commitments.

[2] We measure country risk with the Emerging Market Bond Index Plus (EMBI+) spread. The EMBI+ is a JP Morgan index that tracks total returns for traded foreign currency denominated debt instruments issued by emerging market economies.

Figure 1: Labor productivity and country risk (EMBI+ spread) at times of distress



Note: Authors' calculation using yearly data from the International Labor Organization and The World Bank for Argentina, Brazil, Colombia, Ecuador, Mexico, Panama, Peru, Philippines, Russia, Turkey, Venezuela, and South Africa. Labor productivity is in logs, in deviations from a country-specific log-linear trend, and multiplied by 100. Debt crisis is defined as the period in which the EMBI+ doubles relative to the previous year. The values for EMBI+ and labor productivity are normalized to those of the year before the debt crisis for the median country in the sample.

model economy receives shocks to productivity, credit markets access (sudden stop), and a noisy signal about next period productivity (news shock). Thus, a natural question that arises in this context is: *How different are the debt profile and default risk responses to shocks to productivity, news, and sudden stops?* The economic dynamics after a bad news shock share some features of a response to a productivity shock and other features of a response to a sudden stop event. In particular, after the realization of bad news, the country experiences an immediate jump in the default probability as in the case of a bad productivity shock, though significantly smaller. The reason for the smaller response of the default probability is that the anticipation of averse future fundamentals allows the country to reduce its liabilities ahead of the decline in productivity. This deleveraging is nevertheless smaller than the one that typically follows a sudden stop episode, so the default probability remains elevated long after the bad news shock occurs. Thus, an important first contribution of our study is that it helps understand how different key sources of macro fluctuations affect sovereign debt and default risk dynamics in small open economies.

To moderate the impact of shocks on the economy, sovereigns manage their sovereign liabilities. The debt management process involves not only decisions about the total amount of debt but also, crucially, about when the debt is due. Then, our second question is: *Does long debt maturity help shield countries from bad news shocks?* Our study is the first to analyze news shocks in a sovereign default model with long-term bonds, so it is well equipped to address the question. Intuitively, as bad news increase the cost of borrowing, countries limit their debt issuance after a bad news shock. Accordingly, after receiving bad news, countries reduce their debt in the amount of payments due that period. As the due payments are smaller the longer the maturity, there is less default in the period of a bad news shock when the country has longer debt maturity. While this intuitive line of thought suggests that long maturity shields countries from bad news shocks, such conclusion would be misleading because the reduced deleveraging in the period of the shock implies that there is higher default in the period after the news shock. In fact, we find that long debt maturity implies a larger default probability in the following years, which yields a higher cumulative default probability.

The answers to our first two key questions indicate that debt maturity choice is a very relevant dimension of a country's response to news shocks. The main advantages of an endogenous maturity approach over a fixed-maturity setup for the purpose of our study can be summarized as follows: First, our analysis focuses in part on comparing the macro dynamics following news shocks to those following sudden stops. As sudden stop episodes are periods during which the country cannot issue new debt, to best capture these episodes we need a model in which maturity can change over time. In our setup, during a sudden stop, the country is faced with the choice of defaulting or making payments. If the country decides to make the payments, maturity naturally decreases by one period per year. To keep maturity fixed, the country must issue bonds every period, which by definition is not possible during a sudden stop. Thus, to implement a sudden stop as a period during which the country cannot issue new external debt, the model should accommodate maturity changes. Second, after calibrating the model with endogenous maturity, one can obtain the maturity in the stationary distribution and fix it at that level. With that fixed maturity, most moments are similar to the model with endogenous maturity. However, without solving the model with endogenous maturity, we do not know what maturity we should set given the calibration (for more details, see the Appendix and the references therein to the Online Appendix). Also, as shown in Sánchez et al. (2018), models with exogenous maturity often fix it at a level that is much higher than what the government would choose given the calibrated shocks in the economy, and more broadly, the economic environment. In particular, higher risk aversion and sudden stop shocks are necessary to sustain long maturity as an equilibrium choice. Moreover, several key moments would be different at alternative fixed maturities, suggesting that the level we impose as the fixed maturity would affect the calibrated parameters targeting these moments. Third, having endogenous maturity enables us to exploit the variation in the maturity dimension in the model, for instance comparing default probabilities across maturities, or comparing economies with different equilibrium maturities (there must be a reason for the difference in maturities, it cannot just be imposed) by varying the probability of a sudden stop shock. Fourth, we can compare the cyclicality of debt maturity in the model and the data. In our model with endogenous long-term debt, higher productivity decreases the cost of long-term borrowing due to a lower future default probability, despite the effects of debt dilution. As in the quantitative default literature, the cost of default in the model is more severe with higher productivity, reducing even more the default probabilities in those states, which makes long term debt less costly, and hence increases its correlation with output.

After analyzing the role of debt maturity when assessing a country's response to news, we use the model to understand the role of a key property of news. Specifically, our third main question can be formulated as follows: *What is the role of the precision of news for debt dynamics?* In the benchmark calibration, the precision of news is calibrated such that the model replicates the dynamics of labor productivity after a news shock as estimated in the data. We then vary the precision of news and analyze key changes in the long run statistics of the economy and on the dynamics after a news shock. We find that as news precision increases, the sovereign manages debt better, increasing the level of indebtedness with similar or even lower spreads, especially during distress periods. These spreads become less negatively related with output because there is more deleveraging in anticipation to bad productivity, and the countries can reduce the volatility of consumption.

For completeness, we evaluate if our model can replicate the key long run debt statistics and dynamics observed in emerging economies while addressing the three main questions described above. We find that the calibrated model closely mimics the indebtedness and default features documented for emerging countries. Our framework also captures several moments of the debt profile of these economies, such as the level and dynamics of debt duration, maturity, and spreads for different debt maturities. Furthermore, we compare the impulse responses of the model with empirical counterparts estimated with a structural panel-VAR with data for emerging market economies. We find that the model's implications for the dynamics of debt and default risk leading to sovereign debt crises are similar to the data. Incorporating news shocks calibrated to replicate the VAR dynamic relationship between TFP and EMBI does not alter materially the fit of an otherwise standard sovereign default model for standard statistics of emerging markets business cycles. Thus, the quantitative model offers a structural interpretation of our empirical findings.

1.1 Related literature

Our paper is related to two strands of the literature. First, we borrow from the news and learning literature. Cochrane (1994) and Beaudry and Portier (2006) find that news about total factor productivity or stock prices can explain a significant portion of the forecast variance of consumption, output, and hours worked. Building on the real business cycle literature, Jaimovich and Rebelo (2008, 2009) and Schmitt-Grohe and Uribe (2012) explore the importance of news using log-linear approximation methods. Recently, Kamber et al. (2017) have analyzed the effect of news about future TFP shocks in four advanced small open economies subject to financial frictions. However, these studies abstract from debt default as an equilibrium outcome, a salient feature of emerging markets, and rely on log-linear approximation methods that are not well suited to analyze nonlinear events like debt crises. In addition, papers like Zeev et al. (2017) and Schmitt-Grohe and Uribe (2018) explore the effects of terms-of-trade shocks and news about them on emerging countries. In contrast to these papers, we focus on how news shocks in emerging economies interact with *default risk* and *debt maturity*. We consider a dynamic stochastic quantitative model of endogenous sovereign debt maturity and default, and we employ nonlinear methods that are crucial to capture the movements in default risk and yield spreads, as they relate to the likelihood of future income or productivity falling below a threshold.

Second, our analysis borrows from the literature on sovereign debt and default. Following the seminal work on international sovereign debt by Eaton and Gersovitz (1981), a large portion of the literature on quantitative models of sovereign debt default has used only one-period debt (Aguiar and Gopinath, 2006; Arellano, 2008; Cuadra et al., 2010; Mendoza and Yue, 2012; Yue, 2010, among others). Models of long debt duration, such as Chatterjee and Eyigungor (2012) and Hatchondo and Martinez (2009), feature exogenous maturity. In contrast, our quantitative model features endogenous sovereign debt maturity and repayment. Only recent work on quantitative default models allows for endogenous debt maturity, but it does not consider the role of news shocks (Arellano and Ramanarayanan, 2012; Bai et al., 2014; Hatchondo et al., 2016). We consider a quantitative default model that uses the tractable endogenous maturity framework developed in Sánchez et al. (2018), and we solve the model numerically using the techniques proposed by Dvorkin et al. (2018).

A related paper that incorporates news shocks in a sovereign default model is Durdu et al. (2013). The contribution of that study is to link the precision of news to the level of development of the country, and to compare some predictions of their one-period debt setup with the data as the precision of news varies. Instead, we focus on the macro dynamics created by news shocks relative to productivity and sudden stop shocks, and we explore the extent to which debt maturity management, a dimension absent in Durdu et al. (2013), may be effective to deal with news shocks. Moreover, our last section also analyzes the role of the precision of news, and goes beyond the work by Durdu et al. (2013) by showing how duration, maturity, and the term structure of interest rate spreads are affected by the precision of news. Hence, in this section we also focus on debt profile features that cannot be addressed in the one-period model of Durdu et al. (2013). To our knowledge, our paper constitutes the first effort to integrate news about future fundamentals, endogenous debt maturity and default risk in a nonlinear dynamic stochastic quantitative model.

The rest of the paper is organized as follows. Section 2 estimates a panel-VAR to identify the effects of news on sovereign default risk. Section 3 presents the economic environment and the theoretical framework. Section 4 presents the model's calibration and compares key non-targeted moments from the model with data. Section 5 studies the responses of model variables to news, sudden stop, and productivity shocks, evaluates the effectiveness of debt maturity management to deal with news shocks, and the role of the precision of news. Section 6 concludes.

2 Empirical Evidence

We start our analysis by conducting an empirical study on the effects of news shocks following the seminal work of Beaudry and Portier (2006). News about the future path of productivity has an impact on economic conditions today, which is typically reflected in the contemporaneous behavior of financial variables. For an emerging economy that borrows in international markets, future productivity has important effects on the *current* and *future* default decisions. Thus, emerging market interest rates typically react to news about future productivity.

Our analysis deviates from Beaudry and Portier (2006) in two important ways. First, while the study of Beaudry and Portier (2006) considers exclusively the U.S. economy, we focus on emerging market economies. By using a multi-country panel data approach we overcome limitations with data availability, and we increase the number of observations and the precision of our estimates. Second, we look at sovereign borrowing costs, captured in the data by the Emerging Markets Bond Index Plus (EMBI+) spread. In contrast, Beaudry and Portier (2006) look at movements in domestic stock market prices due to news.

Our empirical identification strategy relies on short-run restrictions to the effects of news. Let $\epsilon_{1,t}$ denote the conventional innovation to productivity at time t, and let $\epsilon_{2,t}$ denote the news shock at time t anticipating movements in future productivity. Let A_t denote the state of (log) productivity at time t, and assume that productivity depends on current and past values of these economic shocks, i.e.,

$$A_t = [B_{11}(L)\, B_{12}(L)] \begin{bmatrix} \epsilon_{1,t} \\ \epsilon_{2,t} \end{bmatrix}, \tag{1}$$

where the notation follows Barsky and Sims (2011). $B_{11}(L)$ and $B_{12}(L)$ are polynomials in the lag operator. The main restriction derived from the theory is $B_{12}(0) = 0$, so news shocks do not have a contemporaneous impact on productivity. Thus, a simple process describing the effect of these shocks on productivity is

$$A_t = \rho A_{t-1} + \sigma_1 \epsilon_{1,t} + \sigma_2 \epsilon_{2,t-j}.$$

This special case of equation (1) shows that the innovation $\epsilon_{1,t}$ is able to affect productivity contemporaneously, while the news innovation $\epsilon_{2,t}$ cannot, and its impact on productivity, while known today, will be realized j periods in the future.

We aim to identify the effect of news shocks on interest rate spreads and productivity in emerging market economies. For this purpose, we estimate a VAR system that includes measures of these two variables. In particular, we use the EMBI+ spread and labor productivity. Our sample consists of quarterly data from 1995q1 to 2016q4 for eight developing countries: Argentina, Brazil, Colombia, Ecuador, Mexico, Peru, Philippines, and South Africa. The sample is very similar to the one used by Uribe and Yue (2006), extended to include more recent years.

The VAR system of order one can be written in reduced form as

$$\begin{bmatrix} A_t \\ r_t \end{bmatrix} = C_0 + C_1 \begin{bmatrix} A_{t-1} \\ r_{t-1} \end{bmatrix} + \begin{bmatrix} u_{1,t} \\ u_{2,t} \end{bmatrix},$$

where A_t is labor productivity, r_t is the EMBI+ spread, and $u_{1,t}$ and $u_{2,t}$ are the reduced-form disturbances. C_0 and C_1 are matrices of coefficients. Following Uribe and Yue (2006), we allow C_0 to vary by country in our panel –i.e., a country fixed-effect– and we estimate the system equation-by-equation employing the instrumental-variable method they use for dynamic panel data. The estimation uses the procedure of Anderson and Hsiao (1981). Our results are robust to using simple OLS estimators for the panel VAR.

We use the estimated VAR system to extract information about the role of news. To identify the structural shocks, we assume that the reduced-form innovations and the structural shocks follow a linear relationship,

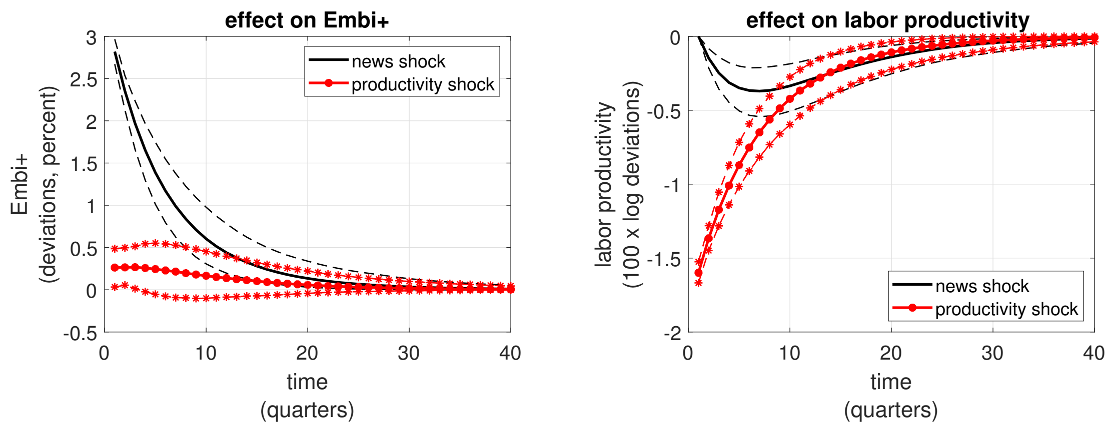
$$\begin{bmatrix} u_{1,t} \\ u_{2,t} \end{bmatrix} = \Omega \begin{bmatrix} e_{1,t} \\ e_{2,t} \end{bmatrix},$$

where Ω is a matrix of coefficients. Note that equation (1) is a special case of our VAR under our assumed structural relationships. As is well known in the literature, it is not possible to identify all the elements in Ω using only information from the reduced-form estimates. Our identification strategy assumes that news shocks cannot affect productivity contemporaneously. In this way, we assume that the element $\Omega_{12} = 0$. As is usual in the literature, we also assume that the structural shocks have unit variance. These restrictions are sufficient to identify the effects of news shocks in our empirical model.

The impulse-response functions of the estimated VAR to news and productivity shocks are depicted in Figure 2. The left panel shows the response of the EMBI+ spread to each shock, and similarly, the right panel shows the responses of labor productivity. The dashed lines represent 95 percent confidence bands. In both cases we show the effects of news and current productivity shocks that have a negative impact on productivity. As shown in the left plot, both negative shocks increase the EMBI+ spread in emerging countries, but news shocks have a substantially larger effect on the EMBI+ spread than contemporaneous productivity shocks. The spread response to news is stronger on impact, and exhibits some persistence, decaying gradually and monotonically. The right plot shows that news shocks have the largest impact on labor productivity between one and two years after they occur. These results are robust to estimating our VAR considering sudden stop episodes, which we include as dummy variables that we interact with the coefficients of the lagged variables in the VAR model.

To quantify how important each shock is in explaining the variation in each of the variables in the system over time, Table 1 shows the variance decomposition at different horizons. On the one hand, given our empirical identification strategy, news shocks do not contribute to the variance of productivity one quarter ahead. Nevertheless, they are a source of uncertainty in the longer run, accounting for 8 percent of the forecast error variance 2 years ahead and 18 percent 10 years ahead. On the other hand, as shown in the last two columns of the table, news shocks account for the bulk of the variance in the EMBI+ at both the short and long run. The very dominant role of the news shock for credit risk dynamics is consistent with strongly forward-looking prices in financial asset markets.

Figure 2: Impulse responses for the structural VAR



Note: Impulse response functions for the structural VAR model with short-run identification restrictions. Responses are for a one standard deviation shock. Confidence bands computed via bootstrap. Dashed lines encompass the central 95 percent of the simulations.

Table 1: Forecast Error Variance Decomposition

(Percent)

	Productivity		EMBI+	
	Prod Shock	News Shock	Prod Shock	News Shock
1 quarter	100.00	0.00	0.90	99.10
1 year	97.56	2.44	1.62	98.38
2 years	92.24	7.76	2.49	97.51
5 years	83.78	16.22	3.69	96.31
10 years	82.19	17.81	3.91	96.09

Note: Forecast error variance decomposition for the structural VAR model with short-run identification restrictions at different horizons.

The recent work by Zeev et al. (2017) studies the role of news shocks estimating a VAR for five emerging economies, and show that news about future commodity terms of trade have a large contribution to the cyclical fluctuations in GDP in these economies. Moreover, they find that positive news about terms of trade has a positive impact on future GDP and net exports, and a negative impact on countries' credit spreads. The exercise in Zeev et al. (2017) differs from ours, but both suggest that news is an important source of macro fluctuations and sovereign credit spreads dynamics in emerging economies.

A number of papers, including Schmitt-Grohe and Uribe (2012) and Beaudry and Portier

(2014), have identified potential issues with this empirical strategy. Therefore, we use the findings presented above only as a starting point of our study, which we develop by performing a structural analysis using a model with news, debt maturity and default risk. In the next section we present a quantitative model of sovereign debt that incorporates news about the direction of changes in productivity. Consistent with the empirical evidence discussed earlier, the model suggests that news shocks have a large impact on the risk of default and predict a future drop in productivity. Also in line with our empirical findings, the model shows that yield spreads react more to adverse news shocks than to a drop in productivity of similar magnitude. In particular, we simulate data with our quantitative model and use these data to estimate the same empirical VAR we presented in this Section, which allows us to connect our model to our empirical findings. The comparison between the empirical VAR estimated with actual data and the VAR estimated with simulated data is common in other other areas of macroeconomics, but to the best of our knowledge, our comparative analysis is the first one performed with models of sovereign default in the tradition of Eaton and Gersovitz (1981).

The close alignment of the model dynamics with the data allows us to use our setup to study the role of news on debt management, specifically the level and maturity of debt, and on the term structure of sovereign bond spreads. Furthermore, it allows us to use our setup to understand why the data suggests that news is a crucial driver of country risk dynamics. Therefore, next we provide an in-depth description of the economic environment.

3 Economic environment

This section discusses the key features that characterize our economic setup and underlie the mechanisms generating our results. We start by describing agents' preferences and the shocks affecting the economy. We explain in detail how we model the news shock, its precision, and its joint transition with productivity. Next, we describe credit markets: the long maturity bonds that are traded, and how the government operates in these markets. Finally, we introduce the formal decision problem of the government and present the equilibrium bond prices.

3.1 Preferences and shocks

We build on the sovereign default setup with maturity choice introduced in Sánchez et al. (2018). Time is discrete, and the small open economy receives a stochastic labor productivity shock, A_t, that follows a finite-state first-order Markov chain with state space $A \subset \mathbb{R}_{++}$ and transition probability $\Pr(A_{t+1} = A_i \mid A_t = A_l)$. We discretize the labor productivity space into a grid with N_A points, with N_A large enough so that $\Pr(A_{t+1} = A_i \mid A_t = A_l)$ is sufficiently small for all l and i.

In this economy there is a benevolent government that trades bonds in international credit markets to maximize the lifetime utility of the representative household. The discount factor is $\beta \in (0,1)$ and the period utility is $u(c, \ell)$, a function of consumption, c, and labor, ℓ, with standard properties. Production takes place using a constant returns to scale technology that uses only labor.

3.2 News

We now discuss how we model news shocks in our economy. To gain intuition, assume for a moment that productivity is a continuous random variable that follows the process,

$$A_{t+1} = \rho\, A_t + \sigma_1\, \epsilon_{1,t+1} + \sigma_2\, \epsilon_{2,t},$$

where, as discussed in Section 2, $\epsilon_{2,t}$ are news shocks about productivity next period. In this way, the current value of productivity, A_t, and the news shock, $\epsilon_{2,t}$, provide information to form an optimal forecast about future productivity. This forecast, while optimal, will not be perfect due to the contemporaneous shock to productivity $\epsilon_{1,t+1}$.

The main challenge in modeling the news shock using a discrete random variable is to approximate the stochastic process using a Markov chain. Since productivity is a discrete random variable that follows a Markovian process, we model news as information about the likelihood that productivity next period attains some values. In this way, the news provides useful information to forecast the value of productivity next period. We first formalize this in a rigorous way and then we provide some intuition.

Every period, the government receives a signal $s \in \{1, 2, .., N_s\}$ about the realization of labor productivity next period, where $N_s \leq N_A$ is the number of grid points for the signal. Given N_s and the way we define the news, it will be clear that we need that $\Pr(A_{t+1} = A_i \mid A_t = A_l) < 1/N_s$ for all l and i.

We define the sets of productivity values associated with each signal $j \in \{1, 2, ..., N_s\}$ as

$$\Delta_j(A_l) = \Big\{ A_i : (j-1)/N_s < \sum_{n=1}^{i} \Pr(A_{t+1} = A_n \mid A_t = A_l) \leq j/N_s \Big\},$$

where these sets depend on current productivity, A_l, because there is persistence in labor productivity.

The signal associated with future productivity, $A_i \in \Delta_j(A_l)$, and current productivity, A_l, is $S(A' = A_i, A = A_l) = j$. Note that by construction, the news is better the larger the value of j. Also, since we assumed that $\Pr(A_{t+1} = A_i \mid A_t = A_l)$ is sufficiently small for all l and i, the probability of receiving each signal is approximately the same; i.e., $\Pr(s_t = j | A_t = A_l) \approx 1/N_s$.

News precision is introduced assuming that the probability of realizing a signal s if the future productivity shock is A_i and the current one is A_l, is given by:

$$\Pr(s_t = j | A_{t+1} = A_i, A_t = A_l) = \begin{cases} \eta, & \text{if } j = S(A_i, A_l) \\ \frac{1-\eta}{N_s - 1}, & \text{otherwise.} \end{cases} \tag{2}$$

Note that if $\eta = 1/N_s$, we have $\frac{1-\eta}{N_s-1} = 1/N_s$, so the signal is not informative; i.e.,

$$\Pr(s_t = j | A_{t+1} = A_i, A_t = A_l) = 1/N_s \ \forall j, A_i, A_l.$$

We consider cases with $1/N_s < \eta < 1$, so news are informative but imperfect.

After some algebra, it can be shown that the forecast of the probability of receiving a productivity shock A_i given the current productivity A_l and the signal j is

$$\Pr(A_{t+1} = A_i | A_t = A_l, s_t = j) = \Pr(A_{t+1} = A_i | A_t = A_l) \frac{\Pr(s_t = j | A_{t+1} = A_i, A_t = A_l)}{\Pr(s_t = j | A_t = A_l)}, \tag{3}$$

where the actual transition probability $\Pr(A_{t+1} = A_i | A_t = A_l)$ is adjusted by a factor equal to 1 if $\eta = 1/N_s$ (non-informative signals), and greater than 1 if $1/N_s < \eta \leq 1$ and $j = S(A_i, A_l)$. In other words, the last term in (3) is larger than one, and thus the signal leads to an upward revision of the probability of A_i next period given A_l today, when the signal received is pointing to a realization of future productivity that is in the set that includes A_i.

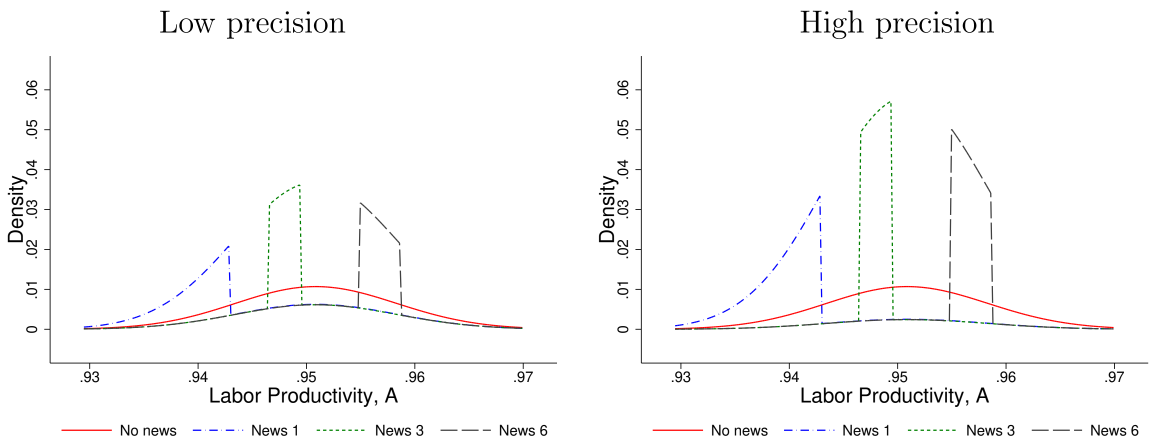
It is also useful to describe the implied joint transition of productivity and signal, which is:

$$\Pr(A_{t+1} = A_i, s_{t+1} = k | A_t = A_l, s_t = j) = \Pr(A_{t+1} = A_i | A_t = A_l, s_t = j)/N_s. \quad (4)$$

Intuitively, what does the news do? The news "changes" the probability distribution of next-period productivity given the current level of productivity.[3] Figure 3 shows two cases with different level of precision for current productivity $A = 0.946$ and 7 possible values of news, $N_s = 7$. The solid red lines show the unconditional probability distribution, i.e., the distribution of probabilities for next period's labor productivity in the absence of news. In these cases, on average, labor productivity is expected to increase because current productivity is below the mean and there is mean reversion. The dashed blue lines represent bad news. They correspond to values of tomorrow's productivity at the bottom 14.3 percent ($1/N_s$=1/7, or 14.3%) of the unconditional distribution. After the bad news signal is observed, the distribution is very concentrated in these values for productivity; it is much more likely that labor productivity will decrease tomorrow. Notice that the concentration of probability on these points is starker on the right panel than on the left panel, which illustrates the role of higher news precision (larger η). The long-dashed brown lines represent good news, which is associated with productivity values between the percentiles 71.4 and 85.7 of the unconditional distribution. In this case, the probability of increasing productivity rises. The short-dashed green lines represent signal 3, which corresponds to slightly negative news (productivity values between percentiles 28.6 and 42.9).

[3] We incur in some abuse of language in our description. The news does not "change" the law of motion of productivity, but rather provides information about the likelihood that productivity tomorrow will assume some values. Essentially, this is *as if* the the probability distribution of next-period productivity, conditional on the current level of productivity, would change. For the formal derivation of expressions (3) and (4), see the Appendix and references therein.

Figure 3: News and the probability distribution of next period productivity



Note: These figures have 7 possible news, $N_s = 7$. The current level of productivity $A = 0.946$. The left panel has $\eta = 0.5$ and the one in the right $\eta = 0.8$.

3.3 Credit markets

Countries may issue bonds with different maturities, but modeling a debt portfolio with many different types of bonds in terms of per-period payments and maturity would make the problem computationally intractable. To overcome these difficulties we impose a restriction on the structure of the debt portfolio following Sánchez et al. (2018). We assume that at any point in time the debt portfolio is characterized by the promised level of per-period payment, b, and by the number of periods that these payments will be made (debt maturity), m. The government optimally chooses b and m when it borrows. The portfolio may consist of any number of bonds, and whether it is composed of a single bond or several bonds is irrelevant in this framework. The key restriction is that the profile of payments of the selected debt portfolio is fixed, so the portfolio can be characterized with just two state variables, (b, m), making the problem tractable.

The country in our setup cannot commit to repaying its obligations, so given an outstanding amount of debt, b (assets if $b > 0$), it has two actions to choose from. The first option is to pay its obligations and thus keep its good credit status. Alternatively, the country may decide not to make its debt payment (default).

A default brings immediate financial autarky and a direct productivity loss to the defaulting country. After the initial default decision, the country remains in autarky for a stochastic number of periods and then returns to international debt markets with no debt balance. Thus, we abstract from modeling debt restructuring and recovery, which is the subject of a number of studies in the quantitative default literature, including Yue (2010), and Dvorkin et al. (2018), among others. When in good credit status, the country may face a "debt rollover" (sudden stop) shock, a, where $a = 0$ if the country is facing a disruption in its access to financial markets and is hence impeded from rolling over or changing its debt portfolio, and $a = 1$ otherwise. When the country experiences this sudden stop event, world financial markets cease to lend to the economy, so the country may only choose between repaying or repudiating its obligations. We assume that these shocks can be persistent. We introduce sudden stop shocks in our model to get a sufficiently high level of debt maturity in normal times. It is well known that, for borrowers, long-term debt is more costly than short-term debt due to debt dilution. However, borrowers value long-term debt as a way to hedge against rollover crises or sudden stops (see Sánchez et al. (2018) for a discussion.) On the empirical side, Calvo et al. (1993); Calvo et al. (2006); Uribe and Yue (2006) and Forbes and Warnock (2012), among others, show that extreme capital flow episodes or sudden stops are a salient feature of emerging market economies and are typically driven by global factors external to the country. Additionally, Aguiar et al. (2016) construct a statistical model of emerging market spreads with unobserved factors that are common to all emerging markets (but orthogonal to individual country's fundamentals), and label these as global factors.

To understand this framework, we now introduce some additional notation. Consider a country that chooses a debt portfolio characterized by (b, m) for the next period. The country's exogenous states are its productivity, A, news, s, and the sudden stop status, a. Then, we denote the market value of the outstanding debt portfolio of the country as $b\, q(A, s, a, b, m; m)$. The second term, $q(.)$, is the key element that allows us to price not only the debt portfolio of the country, but also other cash flows (or promises) derived from it. In particular, $q(A, s, a, b, m; m)$ represents the price of a debt portfolio that pays one unit of the numeraire every year for m years (note that this m is the last variable in the bond price). Thus, multiplying this price by the yearly payment b provides the market value of the debt. Default occurs on the entire debt portfolio, so the price of this bond depends on the country's exogenous state variables, that is, productivity, news and sudden stops (A, s, a), and on the characteristics of the entire portfolio

(b, m), as they affect default probabilities in the future.

This notation allows us to price alternative promises linked to this debt portfolio. For example, consider a country's debt portfolio with per-period total payment b and maturity m. Then, the value of a promise that pays $\tilde{b}$ for n periods is $\tilde{b}q(A, s, a, b, m; n)$.

To further illustrate the notation, consider another example. Suppose that the country has the portfolio $\{b, b, b, b\}$ and that the portfolio is made of three bonds with payment promises

$$\{\underline{b}, \underline{b}, \underline{b}, 0\}, \tag{bond 1}$$

$$\{b - \underline{b}, b - \underline{b}, b - \underline{b}, 0\}, \text{ and} \tag{bond 2}$$

$$\{0, 0, 0, b\}. \tag{bond 3}$$

The value of each bond is

$$\underline{b} \times q(A, s, a, b, 4; 3), \tag{bond 1}$$

$$(b - \underline{b}) \times q(A, s, a, b, 4; 3), \text{ and} \tag{bond 2}$$

$$b \times [q(A, s, a, b, 4; 4) - q(A, s, a, , b, 4; 3)], \tag{bond 3}$$

respectively. Adding the value of these three bonds we obtain the value of the portfolio, $b \times q(A, s, a, b, 4; 4)$. These prices provide very useful notation for the country's choice of maturity.

3.4 Decision problem

Each period the state variables for the government consist of the productivity shock, A, the signal about productivity next period, s, the sudden stop shock, a, the debt level, b, and the debt maturity, m. The government decides, among other things, whether to default on the existing debt:

$$V(A, s, a, b, m) = \max\left[V^G(A, s, a, b, m), V^D(A, s, b, m)\right],$$

where the value of defaulting is V^D, the value of not defaulting is V^G, and the default policy function $D(A, s, a, b, m)$ is 1 if default is preferred and 0 otherwise. If the country does not receive a sudden stop shock ($a = 1$) and decides not to default, it selects the maturity of the new portfolio, m', and the debt level, b'. The value in this case is:

$$V^G(A, s, 1, b, m) = \max_{b', m', \ell} u(c, \ell) + \beta E_{A', s', a' | A, s, 1} V(A', s', a', b', m')$$

subject to

$$c = A\ell + b - \underbrace{q(A, s, 1, b', m'; m')b'}_{\text{issue new debt}} + \underbrace{q(A, s, 1, b', m'; m - 1)b}_{\text{retire old debt}}$$

$$b' \in \mathbb{R}_-, m' \in \mathbf{M}.$$

Note that while this notation can be interpreted as retiring all the old debt at market prices and issuing new debt, the same constraint can be rewritten to show the split between the change in resources due to the change in yearly payments, and the change in resources due to the change in maturity,

$$c = A\ell + b - \underbrace{q(A, s, 1, b', m'; m')(b' - b)}_{\text{change in yearly payment, given } m'} - \underbrace{[q(A, s, 1, b', m'; m') - q(A, s, 1, b', m'; m - 1)]\, b}_{\text{change in maturity, given } b}.$$

Notice that the third argument of the debt price function is set at 1, corresponding to not receiving a sudden stop shock this period.

In contrast, a country that receives a sudden stop shock ($a = 0$) and therefore has no access to credit markets, may pay to its creditors but cannot issue new debt, so the next period payment will remain at today's amount b and the maturity will be one year shorter at $m - 1$. Thus, the value today can be expressed as:

$$V^G(A, s, 0, b, m) = \max_{\ell} u(A\ell + b, \ell) + \beta E_{A', s', a' | A, s, 0} V(A', s', a', b, m - 1).$$

The policy functions for the amount of debt and the maturity are $B(A, s, a, b, m)$ and $M(A, s, a, b, m)$. When the country makes only its debt payment, the policies are $B(A, s, a, b, m) = b$ and $M(A, s, a, b, m) = m - 1$. Therefore, if $a = 0$, it must be that $B(A, s, 0, b, m) = b$ and

$M(A, s, 0, b, m) = m - 1.$

Default brings immediate financial autarky for a stochastic number of periods and a direct productivity loss to the defaulting country. Formally, the value of default is:

$$V^D(A, s, b, m) = \max_{\ell} u\left(\phi(A)\ell, \ell\right) + \beta E_{A', s'|A, s}\left[(1 - \lambda)V^D(A', s', b, m) + \lambda V(A', s', 1, 0, 0))\right],$$

where the parameter λ captures the probability of reentry to international capital markets after default, and $\phi(A)$ is a function that captures the cost of default. After exclusion, the country reenters credit markets with no debt and without a sudden stop shock.

3.5 Equilibrium bond prices

Given the world interest rate r, and the existence of risk-neutral lenders, the price of the country's debt must be consistent with zero expected discounted profits. Thus, the price of a bond of maturity $n > 0$ of a country with productivity A, news about the future productivity, s, sudden stop shock, a, and debt portfolio taken to the next period, (b', m'), can be represented by $q(A, s, a, b', m'; n) =$

$$\frac{E_{A', s', a'|A, s, a}}{1 + r}\Big[(1 - D(A', s', a', b', m'))\times(1 + q(A', s', a', B(A', s', a', b', m'), M(A', s', a', b', m'); n - 1))\Big].$$

Notice that the sudden stop is an argument of the price function because it is a persistent shock. Even though in the value functions the price only appears when the government can issue debt $(a = 1)$, we need to solve the price function also for the case of receiving the sudden stop $(a = 0)$ since the latter affects the expected returns.

The key term added by long term debt is that the policy function for borrowing, B, must be included in the next period prices. This extra term captures the debt dilution mechanism emphasized by Hatchondo et al. (2014). Finally, the endogenous maturity feature adds the policy function for maturity choice M into tomorrow's prices. Thus, this framework also captures debt dilution generated via extensions of maturity, as discussed in Sánchez et al. (2018).

4 Quantitative model

To solve the model numerically, we first consider functional forms and perform the calibration. We then explain some of the dynamics of the model with regressions that we run on model-simulated data.

4.1 Functional forms

We consider GHH (Greenwood et al., 1988) preferences using a CRRA flow utility function with risk aversion $\gamma \geq 1$,

$$u(c, \ell) = \frac{1}{1-\gamma}\left(c - \frac{\ell^{1+\theta}}{1+\theta}\right)^{1-\gamma}, \tag{5}$$

where the parameter θ is the inverse of the Frisch elasticity.

Our choice of GHH preferences for the calibrated model follows the work by Mendoza and Yue (2012) in the quantitative sovereign default literature, among other studies. A number of papers have pointed out the advantages of considering these preferences: for instance, in a macroeconomic model with news shocks for the United States, Schmitt-Grohe and Uribe (2012) find that estimates favor this type of preferences with no wealth effects on labor, and the work by Correia et al. (1995) shows that a small-open-economy RBC model with GHH preferences can better match the cyclical moments of small open economies.

The GHH specification implies that the labor supply is not affected by actual or expected changes in wealth, and therefore it is an increasing function of the wage only, $\ell_t = w_t^{1/\theta}$. Since we assumed that production takes place using a constant returns to scale technology that uses only labor, we have that $w_t = A_t$, so $\ell_t = A_t^{1/\theta}$ and output is $Y_t = w_t \, \ell_t = A_t^{1+\frac{1}{\theta}}$.

4.2 Calibration

We calibrate the model to a yearly frequency, which compared to the quarterly frequency also used in this literature, reduces the time it takes to solve the model but does not affect our results. Below we discuss how we set our parameter values, and then we explain the numerical method that we implemented to solve the model.[4]

We set some model parameters at standard values that help keep our results comparable with the literature. As shown in Table 2, households in the economy have a constant relative risk aversion (CRRA) utility with risk aversion coefficient γ=2. We set the maximum possible maturity to 20 years, which is significantly larger than the maturity observed for emerging markets. Moreover, our results are robust to allowing for longer maximum maturities. We set the yearly risk-free real interest rate to 0.042, which matches the long-run average of 10-year U.S. Treasury bonds. We set the probability of returning to financial markets exogenously to 0.17, which implies an average exclusion period of 6 years. This number is consistent with the evidence in Tomz and Wright (2013). The parameter θ, which determines the Frisch elasticity, and the parameters for the law of motion for labor productivity are computed using moments of detrended (log) real GDP per capita and (log) employment to population for Colombia and the model specification of the labor supply and output. In this way, we obtain $\theta = 0.538$, which implies a Frisch elasticity of 1.89 that is close to the value used by Mendoza and Yue (2012). The standard deviation of the innovation in labor productivity is set to 0.0078 and the autocorrelation to 0.9044. These numbers, together with the value of θ, replicate the autocorrelation and volatility of detrended GDP per capita for Colombia.

We estimate the probabilities of entering and exiting sudden stops using the definition in Comelli (2015) for these events. In doing so, we control by the effects of country's own fundamentals in the availability of credit. This gives us a probability of entering a sudden stop episode of 0.12, and a probability of continuing in the sudden stop of 0.42. During sudden stops, countries experience higher difficulty in receiving international lending, and are episodes usually associated with international financial crises.[5] While we use a very different statistical model to recover the sudden stop process, our results are consistent with Aguiar et al. (2016) and Bianchi et al. (2018).

[4]For robustness, we also solved the model at the quarterly frequency and with wealth effects in preferences, obtaining results consistent with the baseline results that we present here. For additional details, see the Appendix and references therein to the Online Appendix.

[5]In the Online Appendix we show that our sudden stop periods are more global and related to well-known emerging market debt crises. Details on the estimation and results are also presented there. In addition, we show the robustness of our results to using the calibration of Bianchi et al. (2018) for the probability of sudden stops.

Table 2: Calibrated parameters

Parameter	Value	Reference
Interest rate, r	0.042	10-year U.S. yield minus PCE inf. (Avg. 1980-2010)
Risk aversion, γ	2	Literature
Redemption prob., λ	0.17	6 year average exclusion
Discount factor, β	0.87	Debt/output 25% (model, 24.8%)
Cost of default, ϕ_1	-1.53	Default rate 2.0% (model, 2.0%)
Cost of default, ϕ_2	1.60	Std. Dev. EMBI+ spread 2.5% (model, 3.7%)
Precision of news, η	0.74	10-yr. variance decomp. of productivity to news shock
Variance of ϵ shock, σ	0.001	Std. Dev. Debt/GDP, 12.5% (model, 8.6%)
Correlation of ϵ shock, ρ	0.25	Corr(duration, $log(y)$), 0.34 (model, 0.35)
Sudden stop entry prob., $p_{ns,s}$	0.12	Estimated (see Appendix)
Sudden stop staying prob., $p_{s,s}$	0.42	Estimated (see Appendix)
Labor prod. shock std, σ_A	0.0078	Estim. using data for Colombia (see Appendix)
Labor prod., ρ_A	0.904	Estim. using data for Colombia (see Appendix)
Inverse of Frisch elasticity, θ	0.54	Estim. using data for Colombia (see Appendix)

Note: The targeted moments on Std. Dev. of debt to GDP and Corr(duration, $log(y)$) are estimated moments for Colombia. Targeted values for Debt/output and default rate are from Tomz and Wright (2013). The standard deviation of the EMBI+ spread is estimated using the category "developing countries in Latin America and the Caribbean" from 1998 to 2014 from the Global Economic Monitor of the World Bank.

We follow Chatterjee and Eyigungor (2012) and use a quadratic cost of default function, $\phi(A) = A - \max(0, \phi_1 A + \phi_2 A^2)$ as these costs bring the model closer to the data in terms of matching moments for spreads. As standard in the literature, β and costs of default (ϕ_1, ϕ_2) are calibrated jointly to replicate the debt-to-output ratio, the default rate and the volatility of the EMBI+ spread. In particular, we calibrate these parameters to obtain a default rate of 2.0% and a debt-to-output ratio of 25%. These two numbers are consistent with the empirical evidence discussed in Tomz and Wright (2013). We target a standard deviation of 2.5% for the EMBI+ spread. We obtain this number by computing the standard deviation of the EMBI+ spread for the category "developing countries in Latin America and the Caribbean" from 1998 to 2014, as reported in the Global Economic Monitor of the World Bank. See the data appendix for details. In addition to these two parameters, we calibrate the precision of news, η, to replicate the effect of a news shock on future productivity. Specifically, we search for the value of η—jointly with β, ϕ_1 and ϕ_2—such that the VAR estimated with model-simulated data replicates the following empirical moment: the news shock accounts for 17.8 percent of the forecast error variance of productivity 10 years ahead (see Table 1).

We solve the model numerically using the method developed in Dvorkin et al. (2018), which is helpful to achieve convergence in models with endogenous maturity. The Online Appendix contains detailed information of the computational method. In solving the model, we need to set two parameters governing the distribution of the ϵ shocks: one related to the overall volatility of shocks, σ, and the one related to the correlation between the portfolio choice components, ρ. We follow Dvorkin et al. (2018) in setting σ at 0.001 and ρ at 0.25 to match the standard deviation of debt (as a fraction of GDP), and the correlation of duration with GDP. Due to the way the ϵ shocks enter the model, they affect the standard deviations debt, duration and maturity and their correlations with GDP. As the parameter values increase, the ϵ shock plays a more important role in the choice of debt and maturity, thus being more decoupled from the borrower's fundamentals. On the one hand, larger values of σ and ρ increase the variance of duration, maturity and debt. On the other hand, larger values for these parameters decrease the correlation of duration, maturity, and debt, with GDP. Other moments are much less affected. The Online Appendix discusses in detail the effect of these parameter values on several moments.

4.3 Model mechanics

The mechanics of the model can be grasped by looking at Table 3. The table contains linear regressions of key variables on income, debt, and news. The regressions are performed on data simulated with the model. An advantage of using simulated data is that we capture the shape of the policy functions around the values of state variables that occur more frequently in equilibrium.

The first three columns show that maturity, duration, and borrowing are increasing in income and decreasing in current debt. The next two columns show that as income increases, there is a decrease in yield spreads such that the 10-years minus 1-year term premium increases (steeper spread curve). The opposite result is obtained as debt increases: yield spreads increase and the term premium decreases.

The bottom three rows of the table illustrate the impact of bad news of different severity, i.e., news anticipating a mild, moderate, or severe decline in future productivity. In general, bad news tend to be associated to shorter debt maturity and duration, to deleveraging, to higher yield spreads and to a lower term premium. Interestingly, as the worst news signal is associated to much weaker future fundamentals, and thus to much higher default risk, the associated mechanics differ from more modest bad news, because countries receiving the extremely adverse signal are more likely to try to avoid default. Receiving very bad news about tomorrow is more likely to materially increase expected financial distress, making repayment conditions very difficult. Thus, increasing maturity is a way of making repayment easier tomorrow, and of reducing the risk of default.

Table 3: The effects of news on key model variables

	Chg log maturity (1)	Chg log duration (2)	Chg log debt (3)	EMBI+ spread (4)	Term premium (5)
log GDP	0.260	0.088	0.303	-0.666	0.362
log Debt	-0.322	-0.174	-0.742	0.423	-0.235
dummy (mild bad news)	-0.053	-0.032	-0.108	0.062	0.038
dummy (moderate bad news)	-0.031	-0.031	-0.123	0.131	-0.017
dummy (severe bad news)	0.009	0.003	-0.148	0.393	-0.323

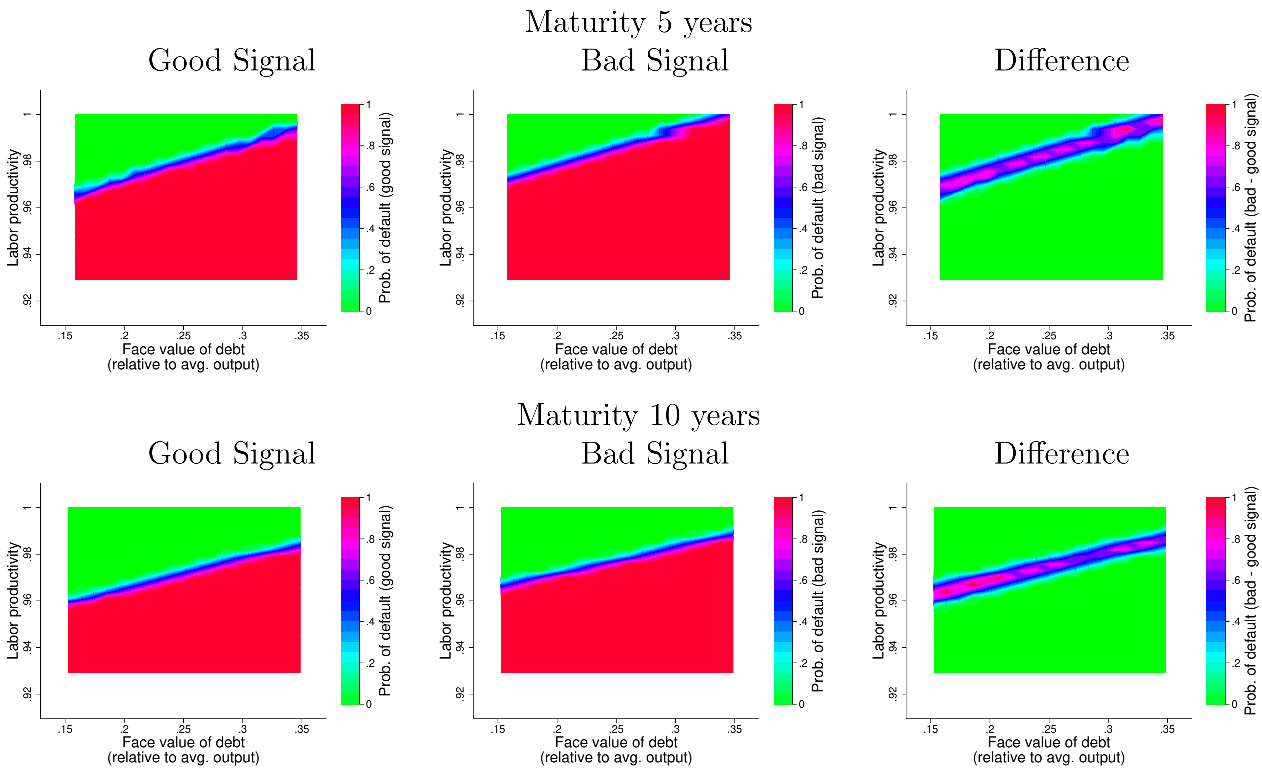
Note: Standardized regression coefficients. Regressions use model-simulated data. The dummy for mild bad news, moderate bad news and severe bad news take a value of one if the signal equals 3,2, or 1, respectively, and zero otherwise. In words, mild bad news are news about a likely mild drop in productivity next period relative to the current productivity level, while severe bad news are news about a likely large drop in productivity next period relative to the current productivity level, as implied by the model.

To gain insight into how the effect of news depends on debt maturity, Figure 4 shows default regions for good and bad news for 5- and 10-year maturity bonds. The upper left plot shows the default region (red area) for different values of the labor productivity and the face value of debt under good news (signal 6 in this case) for an economy with debt maturity of 5 years, the upper middle plot shows the same for bad news (signal 2 in this case), and the upper right plot shows the difference between these two plots, i.e., the difference in the default probability due to a shift from good to bad news. Note that because we model news as providing information of likely productivity next period conditional on productivity today, signal 6 implies that productivity is likely to increase, while signal 2 implies that productivity is likely to decrease, as shown in Figure 3.

The figure suggests that in our model, as expected, countries with more debt and lower productivity choose to default. Also, the top three plots illustrate that a bad signal is associated to a larger default region than a good signal. The broad red band in the right plot shows that the default probability increases dramatically for several states of the economy. Given debt, maturity, and productivity, the realization of bad news changes the country's decision from repayment to default. This suggests that an economy near its default threshold may experience a substantial increase in its sovereign yield spreads following a negative news shock.

The lower plots present the default region under good and bad news when debt maturity is 10 years. Intuitively, with longer maturity the economy is less exposed to increasing interest rates, so the default region is smaller, as the default threshold shifts toward lower productivity and more debt (worse fundamentals). As we will show later, this does not necessarily mean that long maturity shields the country from a bad news shock once the dynamics in the following periods are also considered.

Figure 4: Default regions and news



Note: Probabilities of default next period conditional current states. We consider a country that is not in sudden stop today. Good (bad) signal corresponds to 6th (2nd) signal out of seven.

5 Main Results

This section presents our main results, which we organize around the responses to the three key questions discussed in the introduction, namely: How different are the responses to news shocks from productivity shocks and sudden stop shocks? Does long maturity shield countries from bad news shocks? What is the role of the precision of news? Before we address each of these questions below, we briefly discuss how well the model replicates the debt and macro dynamics in emerging economies discussed in the literature.

5.1 Replicating the debt and macro dynamics of emerging economies

To evaluate the goodness of fit of the model for selected relevant statistical moments, we proceed in three steps. First, we compare non-targeted statistics generated with the stationary distribution of the model against their data counterpart. Second, we generate the dynamics of the model before default episodes, and we compare them with literature studying these dynamics. Finally, we estimate the VAR with model-simulated data and show that it looks quite similar to the empirical estimation in Section 2.

The non-targeted moments of interest generated by the model and the corresponding empirical statistics for a set of key emerging market economies are shown in Table 4. The model captures well the average level and the pro-cyclicality of the maturity and duration observed in the data. The table also provides information about sovereign interest rate spreads of instruments with different maturities. Consistent with the data, on average the 1-year spread is below the 10-year spread, i.e., the term premium tends to be positive, and yield spreads for all debt maturities tend to behave counter-cyclically, i.e., higher spreads are observed in bad times, both in the model and in the data. The two bottom rows show the EMBI+, which co-moves negatively with output both in the model and in the data.

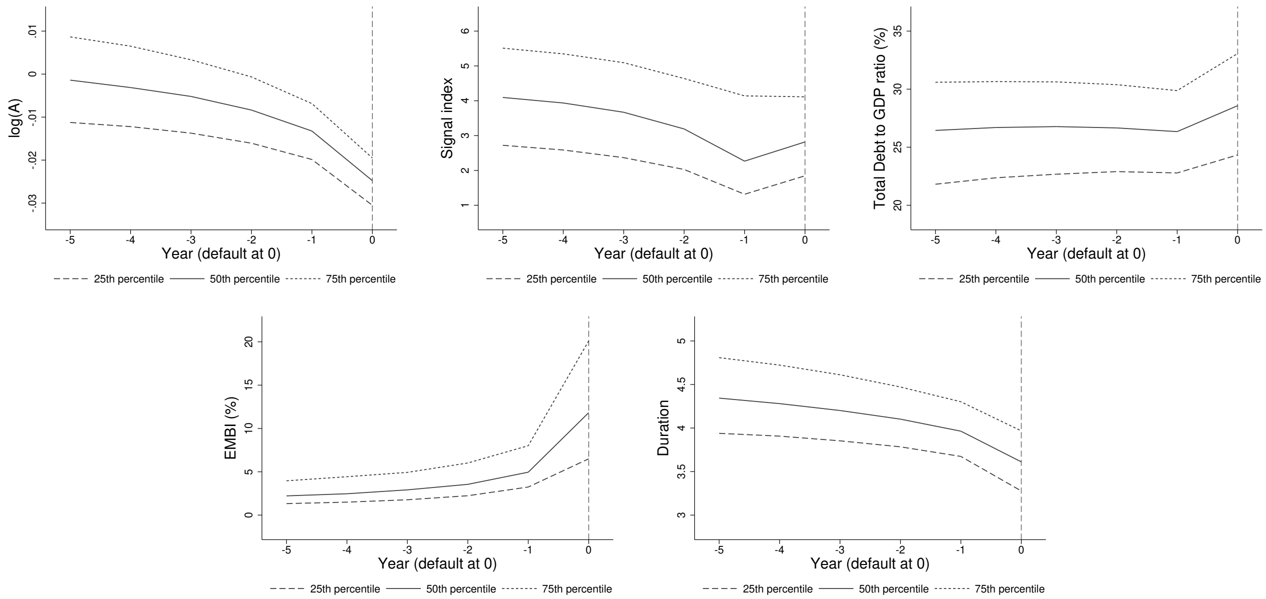
Table 4: Fit of non-targeted moments

Moments	Model	Brazil	Colombia	Mexico
Std. Dev. ($log(c)$) / Std. Dev.($log(y)$)	0.98	1.30	1.15	1.59
Corr. ($log(c), log(y)$)	0.97	0.40	0.82	0.67
Maturity (years)	8.57	6.47	9.62	11.43
Maturity (years, good times)	8.82	6.49	10.46	11.89
Maturity (years, bad times)	8.23	6.45	8.95	10.90
Duration (years)	4.40	3.65	5.23	5.76
Duration (years, good times)	4.54	3.67	5.71	5.79
Duration (years, bad times)	4.20	3.62	4.84	5.72
1-year spread (%)	1.78	1.93	0.82	1.32
1-year spread (%, good times)	0.44	2.02	0.75	1.35
1-year spread (%, bad times)	3.56	1.80	0.87	1.28
10-year spread (%)	2.28	4.52	2.11	3.41
10-year spread (%, good times)	1.71	3.93	1.53	3.18
10-year spread (%, bad times)	3.03	5.30	2.55	3.73
EMBI+ (%)	2.57	4.83	3.41	2.69
corr($EMBI+, log(y)$)	-0.39	-0.23	-0.44	0.10

Note: See the Appendix and references therein to the Online Appendix regarding data sources for the sample countries, further empirical details, and computational details on the model. Duration is computed using the Macaulay definition. EMBI+ in the model is the effective yield spread over the risk free rate given the secondary market price of the outstanding debt portfolio of the borrower. Good (bad) times are those with the detrended log-GDP per capita is positive (negative).

The statistics in Table 4 show that the model describes well the average and cyclical behavior of debt maturity, duration and interest rates spreads at different maturities. Figure 5 illustrates that the model also performs in line with the data leading into an extreme debt distress event, i.e., a sovereign default. The upper left plot suggests that the economy defaults following a declining path for labor productivity, A, hence for output, a similar pattern to that found in the literature (see for instance Mendoza and Yue (2012)). The second figure in the upper panel plots the path of the signals (index of the news out of seven, seventh being the best news) prior to default. It shows that the news gradually worsen before default, in line with the actual path of productivity on which they are providing information with a year ahead. The upper right panel shows that the debt-to-GDP ratio increases in the year going into the episode, consistently with the decline in output. With the lower output and the heavy debt burden faced by the economy, the interest rate spreads, represented by EMBI, sharply increase before the event. The lower right figure shows that debt duration decreases as the economy approaches default.

Figure 5: Behavior around default

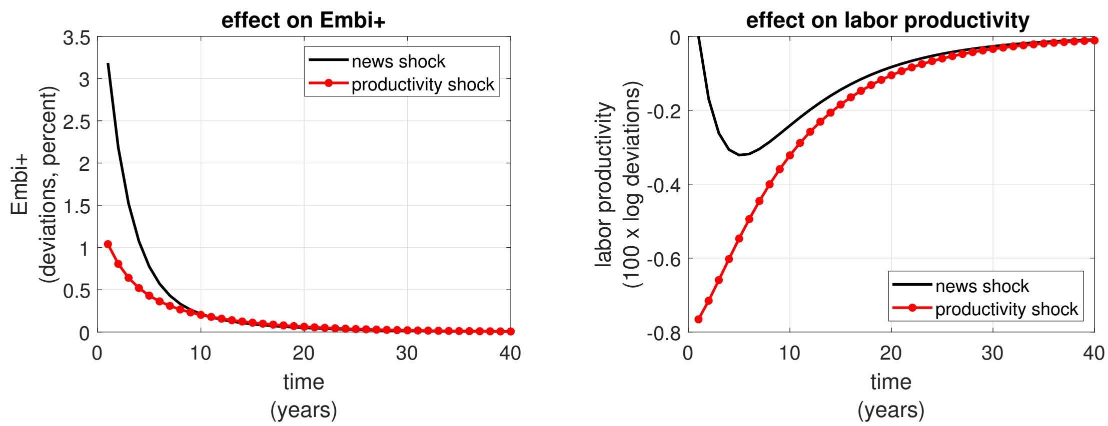


Note: Patterns prior to defaults. Only defaults without any other default in the past and future 10 years are selected. Total debt in upper right plot is the stock of the face value of the debt ($-b * n$). The Appendix provides the computation of EMBI and duration in model simulations.

We use model-simulated data to estimate a VAR like the one we specified with the empirical data. The impulse responses for the structural VAR using model-generated data, presented in Figure 6, show that our quantitative model of sovereign default with news replicates quite closely the main results found in the empirical VAR analysis regarding the dynamic evolution of spreads and productivity in response to news and contemporaneous shocks (see Figure 2 in Section 2 for the empirical results). The left panel in the figure shows that the EMBI+ spread increases more in response to a bad news shock than to an adverse contemporaneous productivity shock, and the magnitudes of the responses are close to those obtained in the empirical VAR. The right panel highlights that, as in the data, labor productivity declines markedly following a news shock, and then gradually recovers.

Table 5 presents the importance of each type of shock in explaining the variation of the EMBI+ spread and labor productivity in our simulations. The model replicates well the empirical forecast error variance decomposition between productivity and news shocks illustrated in Table 1. Our model only targets how much a news shock explains of the variation in labor productivity

Figure 6: Impulse responses for the structural VAR using model generated data



Note: Impulse response functions for the structural VAR with short-run identification restrictions using model generated data. Responses are for a one standard deviation shock.

after 10 years, which is 18.72% in the model vs. 17.81% in the data. Therefore, the close match between the model and the data obtained for the other periods highlights again the ability of our framework to capture the empirical dynamics of news and sovereign debt.

Table 5: Forecast Error Variance Decomposition using model generated data
(Percent)

	Productivity		EMBI+	
	Prod Shock	News Shock	Prod Shock	News Shock
1 year	100.00	0.00	9.63	90.37
2 years	97.46	2.54	10.40	89.60
5 years	88.17	11.83	12.04	87.60
10 years	81.28	18.72	13.17	86.83

Note: Forecast error variance decomposition for the structural VAR with short-run identification restrictions at different horizons using model simulated data.

5.2 How different are the responses to shocks to productivity, news, and sudden stops?

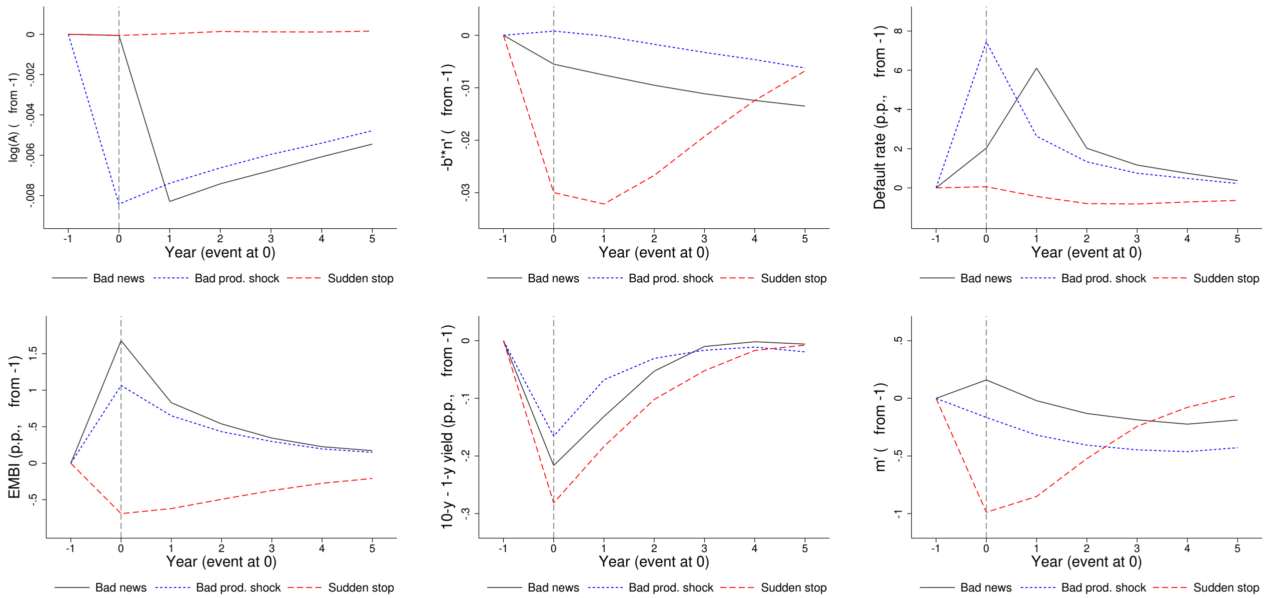
To answer this question, Figure 7 shows the evolution of key debt prices and quantities after the three possible shocks in the model: bad news (solid black line), bad productivity (short-dashed blue line), and a sudden stop (long-dashed red line). We construct these figures taking the stationary distribution as the starting point, so they are representative of the behavior of this economy.

The top-left plot shows the evolution of productivity. To make productivity and news shocks comparable, the bad productivity shock is selected such that the associated immediate drop in labor productivity is similar in magnitude to the decline in next period productivity after a bad news shock—the cumulative loss in productivity is almost the same in both cases. In contrast, a sudden stop shock has no effect on productivity.

In terms of the evolution of debt (top-middle plot), the magnitude of the effect of a bad news shock lies between the large deleveraging occurring after a sudden stop shock and the almost no change in debt after a productivity shock. This happens because lenders are somehow reluctant to rollover debt following a news shock. Remember that a sudden stop shock means that lenders do not extend credit to the country. After a bad productivity realization, lenders may be willing to lend to the country because mean reversion indicates that productivity is going to recover.

The top-right plot shows the evolution of the default rate after each of the shocks. The productivity shock generates the largest immediate effect on the default frequency, followed by the bad news shock, and the sudden stop shock. The debt maturity is sufficiently long so that the deleveraging after the sudden stops is enough to avoid default. The plots also show that the cumulative defaults generated by bad news is similar to bad productivity shocks.

Figure 7: Impulse responses in the model



Note: For each impulse response, we run the 15000 samples for 30 periods starting from the median productivity, maturity and debt. We then impose a given shock at period 31. For the "Bad news" impulse response, this shock is the lowest signal (out of seven in total). For the "Bad productivity shock", the shock is a drop in productivity to maintain a similar cumulative decline in the productivity over the 5 years after the shock. For the "Sudden stop" impulse response, the shock is a sudden stop. We then take averages across samples for each separate impulse response for all variables, except the EMBI and term premium, for which we use the median. We report the deviations from one period before the shock hits.

The first two bottom panels show the evolution of spreads. As in our VAR, the largest effect on the EMBI spread is after the bad news shock. Note that sudden stops reduce the EMBI spread, which occurs because of the deleveraging mentioned above. Because of mean reversion and deleveraging, 10-year spreads do not move much, so the term premium (10-minus-1-year yields), shown in the middle panel, decreases significantly after bad news shocks.

Finally, the bottom right panel shows the evolution of debt maturity. After a sudden stop shock, maturity decreases by one year because the country is temporarily unable to borrow in credit markets. After a bad productivity shock, maturity decreases slightly, as reported in Sánchez et al. (2018). The effect of a news shock on maturity is small for reasons that will be clear after the next subsection, which analyzes the role of maturity during bad news shocks.

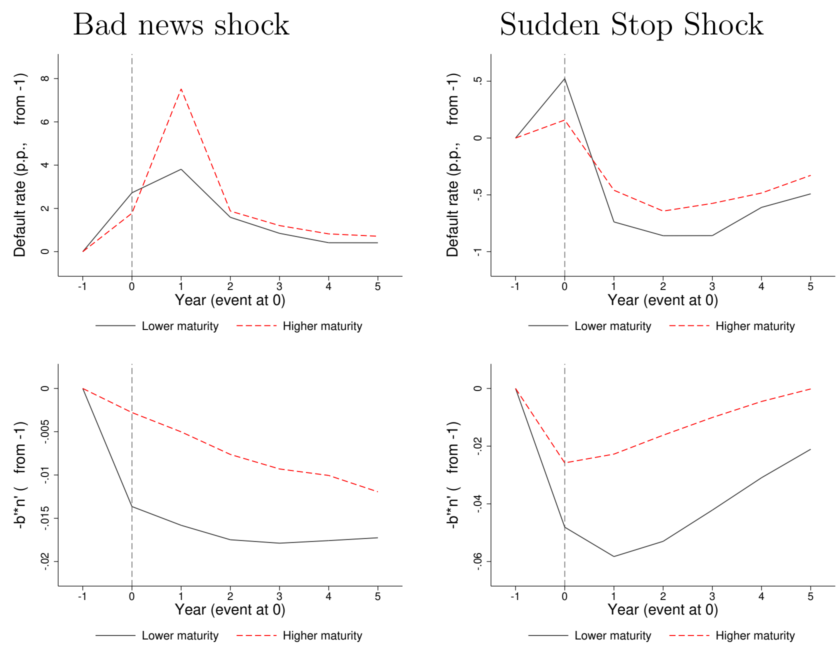
5.3 Does long maturity shield countries from bad news shocks?

To understand the interaction of maturity with news shocks, we computed two alternative economies with different average equilibrium maturities by varying the risk of a sudden stop. The average maturity in the lower maturity model is 4.6 years and in the higher maturity model is 10.9 years.

Figure 8 illustrates how the debt price and quantity responses to news and sudden stop shocks depend on debt maturity. The first column of plots shows how these two economies with different equilibrium maturity react after a bad news shock. For comparison, we also present the evolution after a sudden stop (second column of plots), for which it is well known that economies can protect themselves by borrowing with long maturity. The solid black lines correspond to the economy with lower maturity and the dashed red lines correspond to the economy with higher maturity.

As shown in the upper right panel, long debt maturity helps mitigate an increase in default risk due to a sudden stop shock. On impact, in response to a sudden stop shock, the default probability increases by half a percentage point with shorter maturity, while remaining almost unchanged with longer maturity. To understand this finding, note that the case of longer maturity is also associated to a smoother debt path around the sudden stop event, as there is less deleveraging on impact because the debt payments are more spread out over time. With a sudden stop, countries must decide whether to default or deleverage. Since with shorter term debt the due payment is larger, the deleveraging is larger and more countries prefer to avoid it by choosing to default.

Figure 8: Impulse responses in the model for different maturity economies



Note: “Lower maturity” and “Higher maturity” economies correspond to models with the same calibration as in our benchmark, except for the probability of entering sudden stop, which is set at 0.01 in the first case and 0.25 in the second. The average maturity in the lower maturity model is 4.6 years and in the higher maturity model is 10.9 years. The probability of exiting a sudden stop episode is set at 0.42 in both economies, the same as in the benchmark. For each impulse response, we run the 15000 samples for 30 periods starting from the median productivity, maturity and debt of the benchmark. We then impose a given shock at period 31. For the “Bad news” impulse response, this shock is the lowest signal (out of seven in total). For the “Sudden stop” impulse response, the shock is a sudden stop. We then take averages across samples. We report the deviations from one period before the shock hits.

Compared to the case of long term debt, with short term debt the default risk and debt dynamics after a news shock are more similar to those observed during a sudden stop event. The lower row of plots shows that the dynamics of debt for short and long maturities in response to a news shock are also similar to the case of a sudden stop event, with debt deleveraging associated to a news shock being milder under long term debt. The key difference between the response of a long and short maturity economy to news shocks, though, is in the dynamics of the risk of default, where long term debt magnifies the total (cumulative) increase in default risk from an adverse news shock. On impact the default probability due to a news shock increases about the same for long and short debt (4 percentage points), but with long term debt the increase is more persistent, peaking a year after default at almost 8 percentage points.

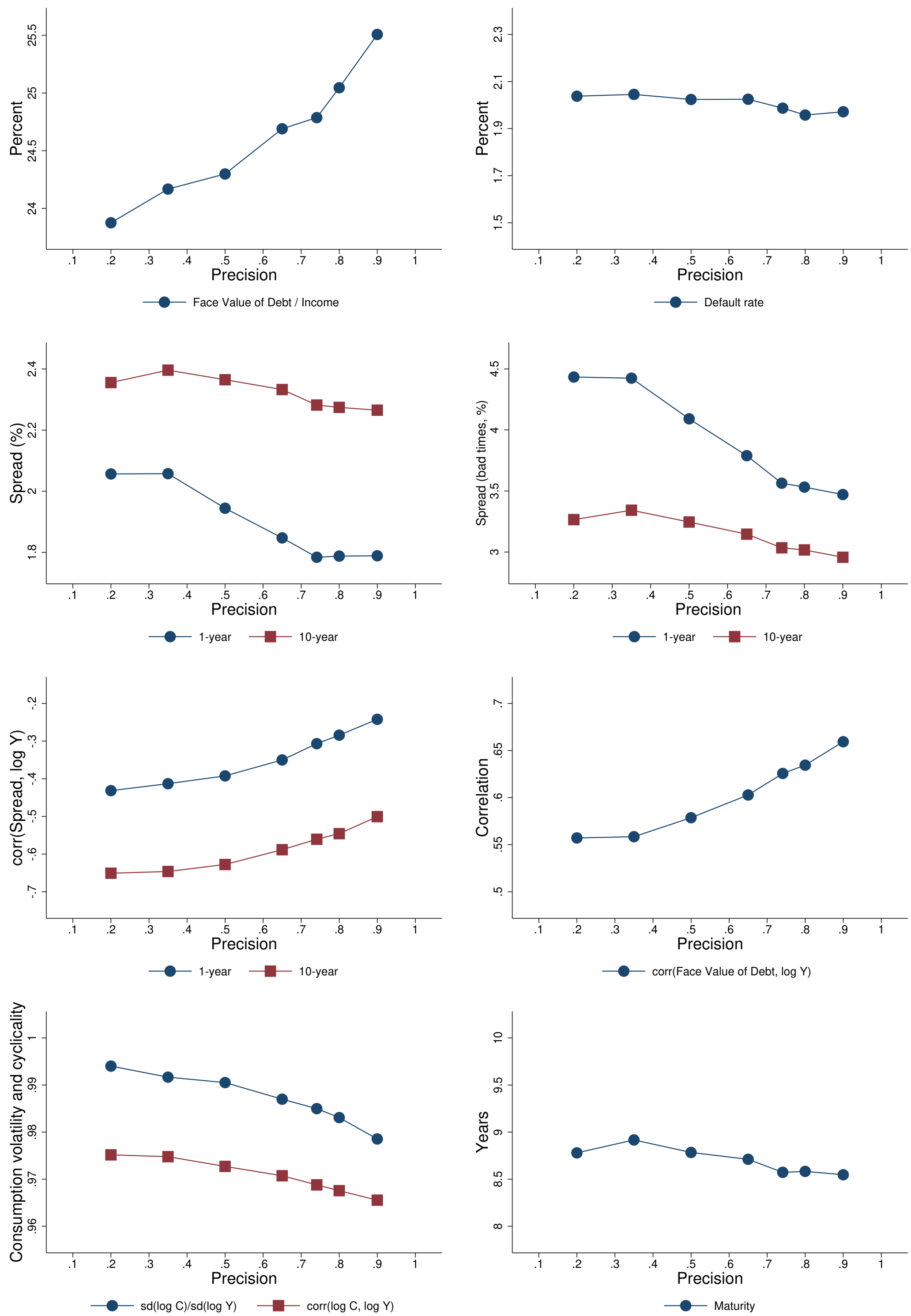
To understand this finding, consider a country that receives bad news with perfect precision. Immediately, the lenders would restrict the supply of credit because they are aware that productivity will be lower next period, forcing a deleveraging. This deleveraging will be costly, so some countries will prefer to default. But those that do not default in the current period will have low debt in the next period, and will more likely be able to avoid default. In the extreme case that all debt is due today, creditors will be willing to lend exactly until the point they know the country will not default tomorrow. With long term debt, lenders restrict the supply of credit as well, but since less debt was due in the period, the deleveraging is smaller. Because there is less deleveraging, there will be fewer countries defaulting in the current period. But in the next period, when the bad productivity realizes, countries will have excessive debt and many of them will decide to default. So, while long term debt may protect the country from a bad news shock in the period of the event, it will make things worse in the future, when the bad news materializes into a bad productivity outcome.

5.4 What is the role of the precision of news?

We have shown that the calibrated model with news about future fundamentals captures well the average moments and the default dynamics observed in the data. Next, we discuss the role of the precision of news for the behavior of key debt variables. To the best of our knowledge, Durdu et al. (2013) is the only other paper performing a comparison of economies with different news precision in a quantitative model with endogenous default risk. They conclude that economies with higher signal precision behave more similar to richer economies. The analysis in this section complements their work by considering not only the amount of debt but also its maturity, and how each interacts with news shocks and sudden stops.

Figure 9 shows the main moments generated by the model for seven news precision levels.

Figure 9: The Role of Signal Precision



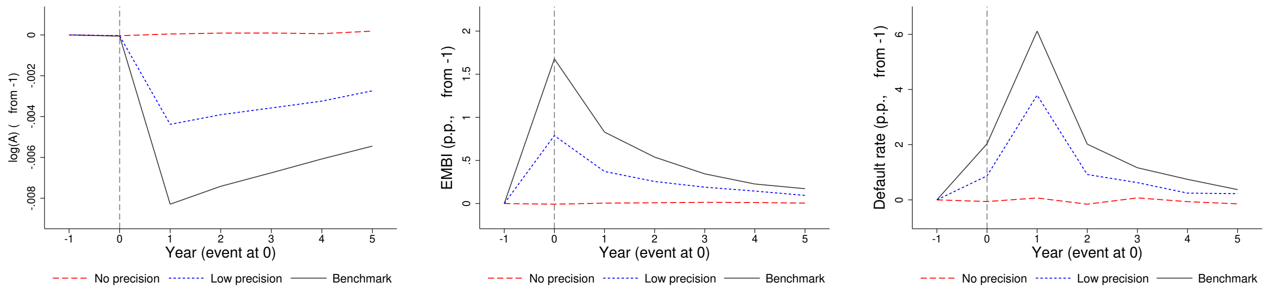
Note: The Figure presents moments from the ergodic distribution of the news shock computed from model-simulated data, and how these moments change with news precision. The model is solved for each precision level shown in the plots.

The first row of plots shows that as the precision of news increases, indebtedness also increases but the default rate remains roughly constant. This means that the country is improving its ability to manage debt. The second row of plots lends support to the intuition that debt management improves with news precision by looking at yield spreads: The plot on the left shows that the average spreads become lower, especially for the 1-year maturity bond, so the term premium tends to be wider with higher precision. The right plot shows that in bad times the spreads also decrease more at the 1-year maturity as the news precision increases, implying a less deep yield spread curve inversion in bad times for countries with more precise news. The left plot of the third row provides another way to see the better debt management when news signals become more precise. The negative correlation between yield spreads and income decreases as the precision of news improves. The weaker negative correlation implies that the borrowing costs for the country do not rise as much when economic growth weakens, so debt becomes a more affordable tool to support consumption when the marginal value of consumption is higher.

The correlation between total debt and income increases with the precision of news (right hand-side plot in the third row), as countries take advantage of more informative news by deleveraging more during bad times. The country's debt management improvement is reflected in the bottom-left plot, which shows that the country is better able to smooth consumption with higher precision of news. Finally, the plot next to it shows that the average maturity is not affected by the precision of news. This is because of the key difference between news shocks and sudden stops shocks that we discussed in the previous section.

Our study also focuses on the dynamics following news shocks around financial crisis, so in Figure 10 we present the effect of the precision of news on the impulse responses to news shocks.

Figure 10: Impulse responses after a bad news shocks in the model for different precision



Note: "No precision" ("Low precision) economy corresponds to a model with the same calibration as in our benchmark except for the signal precision, η, which is set at 0.145 (0.5). The benchmark has $\eta = 0.74$. For each impulse response, we run the 15000 samples for 30 periods starting from the median productivity, maturity and debt in the benchmark. We then impose a "Bad news" shock, which is the lowest signal (out of seven in total). We then take averages across samples for each separate impulse response for all variables, except the EMBI for which we use the median. We report the deviations from one period before the shock hits.

The impulse responses for productivity, EMBI, and default are presented in Figure 10 for three values of precision, $\eta = \{0.145, 0.5, 0.74\}$. The left panel shows the path of labor productivity over 5 years following a negative news shock. As the precision of news decreases, a bad news shock has a lower impact on future labor productivity. Consistent with this effect, the other two plots show that the EMBI spread and the default rate respond less to bad news when the precision is lower.

To further understand the role of news precision, Table 6 shows the variance decomposition for three levels of precision. Clearly, the news shocks account for a larger share of the variance of productivity and EMBI for all forecast horizons as the signal precision increases. Notice in particular the change in the share accounted for productivity in a 10 year horizon, which was the target with used to calibrate the precision in the model. It varies from 2.76 for $\eta = 0.5$ to 43.90 for $\eta = 0.9$.

Table 6: Variance Decomposition

	Percent			
	Productivity		Embi+	
benchmark ($\eta = 0.74$)	Prod Shock	News Shock	Prod Shock	News Shock
1 year	100.00	0.00	9.63	90.37
2 years	97.46	2.54	10.40	89.60
5 years	88.17	11.83	12.04	87.60
10 years	81.28	18.72	13.17	86.83
Higher Prec ($\eta = 0.9$)				
1 year	100.00	0.00	3.76	96.24
2 years	93.21	6.79	4.09	95.91
5 years	70.47	29.53	4.84	95.16
10 years	56.10	43.90	5.43	94.57
Lower Prec ($\eta = 0.5$)				
1 year	100.00	0.00	24.28	75.72
2 years	99.67	0.33	25.71	74.29
5 years	98.34	1.66	28.48	71.52
10 years	97.24	2.76	30.11	69.89

Note: Forecast Error Variance decomposition of the structural VAR model estimated using model simulated data. The top panel shows the decomposition for the benchmark model, the middle panel corresponds to an economy with higher precision, and the bottom panel corresponds to an economy with lower precision.

6 Conclusions

We provide empirical evidence that *news* about future productivity significantly affects the dynamics of sovereign debt and yield curve spreads near a debt crisis. Estimating a panel-VAR for several emerging economies, we find that a news shock has a significantly larger contemporaneous impact on sovereign credit spreads than a comparable shock to labor productivity. We rationalize our empirical results developing a quantitative model of news, sovereign debt default, and endogenous maturity. We show that a VAR estimated on simulated data can replicate well our empirical results. The model also closely mimics the debt maturity and business cycles statistics documented for emerging markets.

The dynamics of the economy after a bad news shock share some features of a productivity shock and others of sudden stop events: Similar to productivity shocks, the risk of default increases and yield spreads jump, while similar to sudden stops shocks, countries that avoid default following news shocks are forced to a significant deleveraging.

We find that the deleveraging after a bad news shock is related to debt maturity in an interesting way. With long term debt, countries need to deleverage less to avoid default in the period they receive bad news. But differently from sudden stop episodes, this small deleveraging means that the country is very likely to default next period, when news are realized. Thus, we find that borrowing at longer maturities does not shield the country from bad news shocks. In contrast, our results suggest that long maturity may exacerbate default risk after bad news shocks.

Finally, our model suggests that higher news precision improves sovereign debt management, as the country experiences a slight decline in the average default rate while increasing indebtedness. The improved debt management is reflected in lower spreads in bad times and less cyclical consumption.

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7 Appendix

Detailed explanations of the data and methods used in the present study are provided in the Online Appendix, specifically on:

- Data sources
- Calibration of the productivity process
- Transition probabilities with signals about productivity change
- Computational details: model variables, method, solution with dynamic discrete choice
- Calibration of Sudden Stops

The Online Appendix also contains multiple robustness checks:

- a model at quarterly frequency,
- a model with preferences capturing wealth effects on labor supply (non-GHH),
- alternative calibration of sudden stop probabilities,
- models with exogenous maturity,
- larger grid for TFP shocks and debt level,
- a model with non-informative news,
- a model with positive recovery of the debt in default, and
- a discussion of the calibration of the preference shocks.