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Sovereign Risk Matters: The Effects of Endogenous Default Risk on the Time-Varying Volatility of Interest Rate Spreads

Sergio de Ferra*

Enrico Mallucci†

Abstract

Emerging market interest rate spreads display substantial time-varying volatility. We show that a baseline model with endogenous sovereign default risk can account for such volatility, even in the absence of shocks to the second moments of the exogenous stochastic variables. In particular, the model features a key non-linearity that allows it to replicate the volatility of interest rate spreads and its comovement with other economic variables. Volatility correlates positively with the level of the spreads and the trade balance and negatively with output and consumption.

JEL classification: E43, E32, F32, F34

Keywords: Sovereign risk, time-varying volatility, interest rates

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†Board of Governors of the Federal Reserve System, Washington, D.C. 20551 U.S.A.. E-mail: enrico.mallucci@frb.gov. This paper substantially improves, extends, and replaces the previously circulated paper: “Endogenous Volatility in Emerging Market Interest Rates: The Role of Default Risk” by Sergio de Ferra. We thank Gianluca Benigno for invaluable guidance in the early stages of this project. We also thank Alberto Martin and Hélène Rey for very insightful comments. The views in this paper are solely the responsibility of the authors and should not be interpreted as representing the views of the Board of Governors of the Federal Reserve System or any other person associated with the Federal Reserve System.

1 Introduction

Emerging markets' interest rates display significant time-varying volatility. While this fact is well established in the literature (i.e., [Fernandez-Villaverde et al., 2011](#)), its root causes remain unclear. This paper shows that endogenous sovereign default risk can explain the presence of time-varying volatility in interest rates paid by emerging market economies (EMEs) on their external debt. In particular, we show that a canonical sovereign default model à la [Eaton and Gersovitz \(1981\)](#) and [Arellano \(2008\)](#) can replicate the volatility of interest rate spreads and their cyclical properties.

In our analysis, we first highlight a key feature that enables sovereign-default models to reproduce the observed time-varying volatility. This feature is the non-linearity of the policy function for interest rate spreads, which is non-linearly increasing in the level of debt and non-linearly decreasing in the level of output. Income shocks that occur in times of high output and low debt generate modest fluctuations of interest rate spreads, whereas income shocks that occur in times of low output and high debt generate pronounced fluctuations. Hence, the volatility of interest rate spreads fluctuates in equilibrium, even though the volatility of exogenous shocks is constant.

Second, we quantitatively investigate to what extent the standard sovereign default model can replicate the time-varying volatility observed in the data. We estimate the stochastic process of the volatility of interest rate spreads on Argentine data and on simulations obtained from a canonical sovereign default model. We find remarkable similarities between estimates obtained from the data and estimates obtained from the model. Motivated by this result, we also examine whether our model-based estimates of the volatility are able to replicate other key facts documented in [Fernandez-Villaverde et al. \(2011\)](#), such as the positive correlation between the volatility of interest rate spreads and their level as well as the negative correlation among the volatility, output, and consumption. We find this to be the case. Our paper, thus, reinforces the conclusions drawn by [Arellano \(2008\)](#), showing that a sovereign default model can not only account for the high average volatility of emerging markets' interest rates, but also for its cyclical properties.

Our paper contributes to two main strands of the literature. First, we contribute to the literature on time-varying volatility in macroeconomics. In EMEs, [Fernandez-Villaverde et al. \(2011\)](#) document the presence of time-varying volatility in interest rates, and they show its negative effects on consumption, output, employment, and investment, through the lens of a model. Yet, they do not provide a theory explaining why interest rate volatility fluctuates over time. Our paper contributes to this literature showing that the existence of time-varying, endogenous sovereign risk—and the non-linearities associated with it—can explain such fluctuations. In addition, [Fernandez-Villaverde et al. \(2011\)](#) suggest that fluctuations in the volatility of interest rates affect other economic variables such as output, whereas we suggest that the causation may go in the opposite direction: Exogenous shocks to the level

of output can generate fluctuations in the volatility of interest rates.¹

Second, we contribute to the quantitative literature on business cycles in EMEs. [Arellano \(2008\)](#) has shown that sovereign default models are able to replicate the correlations between interest rate spreads and key economic variables, such as output and the current account, as well as the volatility of the interest rate spreads that we observe in the data.² We contribute to this line of research by showing that these models are also successful in replicating the dynamic properties of the volatility of interest rate spreads, both in the magnitude of its fluctuations, as well as in its correlation with other business-cycle variables. Within this literature, the recent work of [Seoane \(2019\)](#) is especially related to ours. [Seoane \(2019\)](#) studies how fluctuations in the volatility of the output process affect sovereign risk. Our paper also focuses on the interaction between volatility and sovereign risk. However, our paper differs in that we focus on the volatility of interest rate spreads and we show that a baseline model without volatility shocks is able to account for it. Our paper also contributes to the debate on whether business cycles in EMEs are mainly driven by domestic or external shocks (see, e.g., [Uribe and Yue, 2006](#); [Neumeier and Perri, 2005](#)), showing that domestic shocks play an important role in driving fluctuations in the volatility of the interest rate.

The rest of the paper is organized as follows. Section 2 briefly describes the canonical sovereign default model. Section 3 presents our results on the ability of such a model to account for time-varying volatility in interest rate spreads. Section 4 concludes.

2 Model

The model economy consists of a small open economy trading goods and assets with the rest of the world. The government issues assets in the form of non-state contingent bonds with limited commitment. The government is benevolent and maximizes the welfare of the representative household.

The choice problem of the government is identical to [Arellano \(2008\)](#).³ When the government has access to international financial markets, it can choose to default or repay on external debt. If it defaults, the government loses access to markets. If it repays, the government decides on the amount of assets to issue or purchase in the current period. The state variables are the amount of foreign assets it holds b and the realization of the endowment process y .

¹Time-varying volatility in macroeconomic variables has been studied extensively also in the context of advanced economies, notably by [Bloom \(2009\)](#) and by [Justiniano and Primiceri \(2008\)](#), in the context of the exchange rate determination by [Benigno et al. \(2011\)](#), and in the context of sudden stops by [Reyes-Heroles and Tenorio \(2019\)](#), who find that the relationship between volatility and sudden stops depends heavily on the presence of external debt crises.

²[Garcia-Cicco et al. \(2010\)](#) also find that financial frictions and fluctuations in the country premium play a crucial role in explaining business-cycle fluctuations in emerging markets.

³We briefly describe here the key equations of the model. Refer to the original paper for a more thorough treatment.

Let $V_R(y, b)$ be the value function of the representative household when the government repays and maintains market access. And let $V_D(y)$ be the household's value function when the government defaults. The discrete choice default problem is given by

$$V(y, b) = \max_{D \in \{0,1\}} DV_D(y) + (1 - D)V_R(y, b), \quad (1)$$

where D is an indicator for the choice of default.

The value function of the representative household under default and autarky is defined by

$$V_D(y) = \{u(\delta(y)) + \beta \mathbb{E}[\lambda V(y', 0) + (1 - \lambda)V_D(y') | y]\}. \quad (2)$$

If the government chooses to default, household's consumption is given by the domestic endowment net of the default cost $\delta(y)$. Following a default, the economy is excluded from financial markets, but it can be readmitted in the following period with probability λ .⁴

When the government has access to international financial markets, it decides the amount of assets to trade with foreign residents. When issuing debt, the government takes the function $q(y, b')$ into account, understanding how the amount of debt it issues affects the price at which debt is traded. The value function of the representative household is given by

$$V_R(y, b) = \max_{b'} \{u(y + b - q(y, b')b') + \beta \mathbb{E}[V(y', b') | y]\}. \quad (3)$$

Households consumption depends on the income realization y and government net borrowings from abroad $b - q(y, b')b'$. The continuation value $V(y', b')$ takes into account the option for the government to default in the next period. The maximization problem defines the policy function for next-period debt $b'_{pf}(y, b)$.

Foreign investors have deep pockets and they are risk-neutral. They purchase government bonds and have access to a risk-free asset that pays the return r^{rf} . The price of government bonds is determined by arbitrage:

$$q(y, b') = \frac{\Pr[D(y', b') | y]}{1 + r^{rf}}. \quad (4)$$

Equation (4), together with the policy function for government debt $b'_{pf}(y, b)$, defines the policy function for the government bond price:

$$q_{pf}(y, b) = q(y, b'_{pf}(y, b)). \quad (5)$$

⁴If readmitted, the government regains access to markets with neither debt nor assets, so that the value function is given by $V(y, 0)$.

Finally, the policy function for the annual interest rate spread sp_{pf} rate is defined as

$$sp_{pf}(y, b) = \left(\frac{1}{q_{pf}(y, b)} \right)^4 - (1 + r^{rf})^4. \quad (6)$$

Section 5.1 in the online appendix formally defines the equilibrium of the model, which is standard.

2.1 Calibration and Functional Forms

The model is calibrated to reproduce, at quarterly frequency, the quantitative properties of the Argentinean economy from 1980 to 2001. Households' utility function takes the standard constant relative risk aversion (CRRA) form:

$$U(c) = \frac{c^{1-\gamma}}{1-\gamma}, \quad (7)$$

where the parameter γ determines the degree of risk aversion.

Following Arellano (2008), we assume that output costs of default are asymmetric and increasing in the endowment realization in a piecewise-linear fashion:⁶

$$\delta(y) = \begin{cases} y & \text{if } y \leq \delta \\ \delta & \text{if } y > \delta \end{cases}.$$

Parameter values, that we use in our calibration exercise, coincide with those in Arellano (2008). Parameter γ governing relative risk aversion is set equal to 2, as it is standard in the international real business cycles literature. The subjective discount factor β and the default cost threshold δ are jointly calibrated to match the average default incidence and the average debt-service-to-GDP ratio in Argentina and they are set equal to 0.953 and $0.969\mathbb{E}(y)$, respectively. Parameter λ , which governs the probability of re-admission to financial markets, is calibrated to 0.282, consistent with the short exclusion from financial markets found in the data (Gelos et al., 2011). Parameters ρ_y and σ_y are set equal to 0.945 and 0.025, respectively, and they are estimated from the series of Argentina's GDP, assuming that it follows a log-normal AR(1) process, $\log(y_t) = \rho_y \log(y_{t-1}) + \epsilon_t^y$, where $E[\epsilon^y] = 0$ and $E[\epsilon^{y,2}] = \sigma_y$.⁷

⁵The model is calibrated at quarterly frequency, hence inverse bond prices are elevated to the fourth power to be converted into annual interest rates.

⁶Arellano (2008) shows that asymmetric default costs are crucial for the model to deliver a realistic debt-to-GDP ratio.

⁷Parameter values for the calibration exercise are also summarized in Table 3 of the online appendix.

3 Results

This section presents the key results of our analysis and shows that a standard sovereign default model à la [Arellano \(2008\)](#) can reproduce the dynamic properties of the volatility of interest rate spreads. The section is organized as follows. First, we highlight a key non-linearity of standard sovereign default models that generates time-varying volatility even when exogenous shocks have constant variance. Second, we define the econometric model that we employ to analyze the volatility of interest rate spreads. Next, we present estimates for the time-varying volatility of interest rate spreads that we obtain from Argentinean data and from our model simulations. Finally, we document the cyclical properties of the volatility of interest rate spreads, including its correlation with the level of the spread and with the main business-cycle variables.

3.1 Non-Linearity in the Interest Rate Spread Policy Function

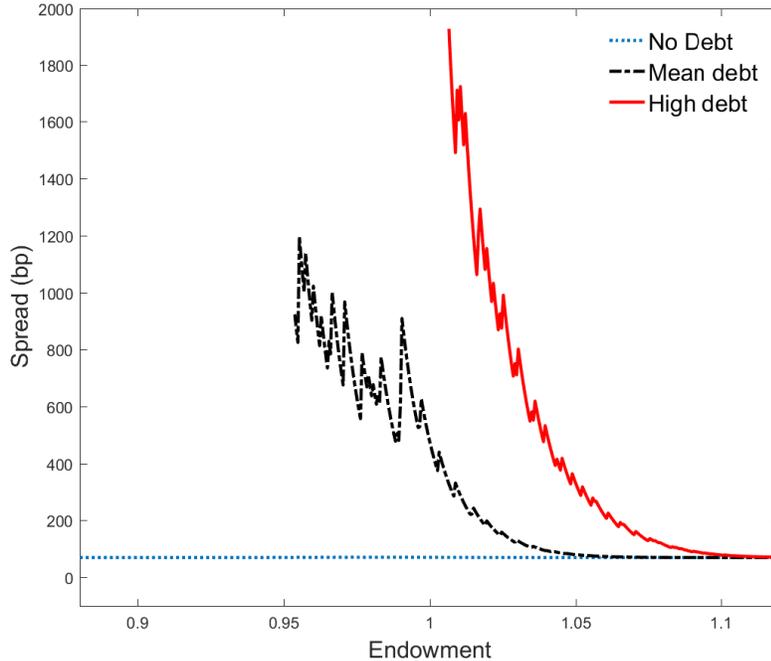
The policy function for the interest rate spreads that emerges from the model is highly non-linear in its two arguments: government debt and the endowment shock. This non-linearity is crucial to generate fluctuations in the volatility of interest rate spreads despite the constant volatility of the exogenous endowment shocks. [Figure 1](#) graphically displays the policy function for the annual spreads defined in [equation \(6\)](#). The policy function is increasing in the size of debt and decreasing in the realization of the endowment, as governments borrow at a higher cost when the endowment is low and when debt is high. Crucially, the policy function is non-linear, as it becomes steeper when the level of debt increases and when the endowment decreases.

Two features of the policy function are key to generate dynamics of interest rate spreads volatility that replicate their empirical counterpart. First, spreads, like default risk, are bounded below by zero. Hence, they do not fluctuate in response to shocks when default risk is zero, while they do when default risk is positive. This feature generates fluctuations in the volatility of interest rate spreads, with spreads becoming more volatile when default risk is higher.

Second, in the region where default risk and spreads are positive, the steepness of the policy function is increasing with the level of the spreads. This positive relationship implies that the volatility of the interest rate spread increases with the level of the interest rate spread. Thus, the canonical sovereign default model is able to capture the positive correlation between the level and the volatility of the spread that [Fernandez-Villaverde et al. \(2011\)](#) document in the data, as we show in detail below.

The non-linearity in the policy function is quantitatively relevant. When the endowment falls 1% below its unconditional mean, spreads increase 80 basis points when debt is at its mean level, and by 190 basis points when debt is at the 90th percentile of the ergodic distribution

Figure 1. Policy Functions for the Interest Rate Spread



Policy function for interest rate spread, defined in equation (6), as a function of the endowment realization y and for three different levels of debt b . The three curves represent the policy function for a zero level of debt (dotted blue line), for debt given by the ergodic mean of this variable in the simulation of the model (dashed black line) and for debt given by the 90th percentile of this variable in the simulation (solid red line). The policy function is increasing in debt and decreasing in endowment, in a non-linear way. The steepness of the function is higher when debt is high and when the endowment realization is low.

of debt. When government debt is zero, the government borrows at the risk-free rate for all endowment realizations. At the same time, spreads are more sensitive to an endowment shock when the level of the endowment itself is low. As shown by the red line for high debt in Figure 1, spreads are little affected when income declines 1% from its maximal level. When, instead, income declines 1% from its mean level, spreads increase sensibly.

3.2 Stochastic Process for the Volatility of Interest Rate Spreads.

We describe here the econometric model that we employ in our analysis. The model, taken from Fernandez-Villaverde et al. (2011), serves as a tool to study the properties of the volatility of interest rate spreads that emerge from the data and from the simulations of the theoretical sovereign default model. Of note, in the sovereign default model, interest rate spreads and their time-varying volatility are endogenous outcomes and the only exogenous process fed into the quantitative framework is the constant-volatility one for the endowment.

Let sp_t be the interest rate spread on debt issued by an EME at time t . We can decompose sp_t as the sum of the average spread sp and $\epsilon_{sp,t}$, which is the difference between the spread at time t and its average:

$$sp_t = sp + \epsilon_{sp,t}. \quad (8)$$

Following [Fernandez-Villaverde et al. \(2011\)](#), we assume that $\epsilon_{sp,t}$ follows an AR(1) process:

$$\epsilon_{sp,t} = \rho_{sp}\epsilon_{sp,t-1} + e^{\sigma_{sp,t}}u_{sp,t}, \quad (9)$$

where $u_{sp,t}$ is a normally distributed random variable with mean zero and unit variance. Crucially, interest rate spreads display time-varying stochastic volatility, as the standard deviation $\sigma_{sp,t}$ is not constant but follows an AR(1) process. The stochastic process for the volatility of interest rate spreads writes

$$\sigma_{sp,t} = \rho_{\sigma_{sp}}\sigma_{sp,t-1} + (1 - \rho_{\sigma_{sp}})\sigma_{sp} + \eta_{sp}u_{\sigma_{sp},t}, \quad (10)$$

where errors $u_{\sigma_{sp},t}$ are normally distributed random variables with mean zero and unit variance. Parameter σ_{sp} determines the mean volatility of the spread, and parameter η_{sp} governs its stochastic volatility. The terms $u_{sp,t}$ and $u_{\sigma_{sp},t}$ are innovations to the interest rate spread and to the volatility of the spread itself, respectively.

3.3 Estimates of the Volatility of the Interest Rate Spread

We estimate the parameters of the process for the volatility of the interest rate spread in equations (9) and (10) using the method proposed by [Fernandez-Villaverde et al. \(2011\)](#). This method uses the particle filter to evaluate the likelihood of the process and it takes a Bayesian approach to inference in that it combines the likelihood function with a prior.⁸

First, we define the priors for the parameters of the process for Argentine spread. Column (1) in [Table 1](#) reports them. In line with the literature, we choose a Beta prior for ρ_{sp} and $\rho_{\sigma_{sp}}$, and we pick a normal prior and a truncated normal prior for σ_{sp} and η_{sp} respectively. We also take the values for the mean and the standard deviation of our priors from [Fernandez-Villaverde et al. \(2011\)](#).

Second, we compute our posterior estimates using quarterly Argentine data from the first quarter of 1993 to the fourth quarter of 2001, the same sample considered by [Arellano \(2008\)](#) in her quantitative analysis.⁹ Estimates are obtained drawing 20,000 times from the posterior of Argentine spreads using a random walk Metropolis-Hastings and are reported in column (2). We find that the average standard deviation of the innovation to Argentine spread σ_{sp} and the stochastic volatility parameter η_{sp} are both large, suggesting that the mean volatility

⁸The particle filter is necessary as the two innovations $u_{sp,t}$ and $u_{\sigma_{sp},t}$ interact in a non-linear way. See [Fernandez-Villaverde et al. \(2011\)](#) for further details on the estimation methodology.

⁹Quarterly spreads data are taken from the Emerging Market Bond Index Plus made available by J.P. Morgan.

Table 1. Priors and Posterior Means

Parameter	Priors	Posteriors	Posteriors
	(1)	Data (2)	Model (3)
ρ_{sp}	\mathcal{B}	0.89	0.92
	(0.9, 0.02)	[0.85, 0.94]	[0.88, 0.95]
σ_{sp}	\mathcal{N}	-5.54	-5.47
	(-5.3, 0.4)	[-6.30, -4.79]	[-6.28, -4.66]
$\rho_{\sigma_{sp}}$	\mathcal{B}	0.93	0.93
	(0.9, 0.1)	[0.80, 1.01]	[0.82, 1.04]
η_{sp}	\mathcal{N}^+	0.43	0.68
	(0.5, 0.3)	[0.17, 0.69]	[0.41, 0.96]

Column (1) reports the priors for the parameters that govern the process of Argentinean spreads. \mathcal{B} , \mathcal{N} , \mathcal{N}^+ stand for Beta, Normal, and truncated Normal distributions. Mean and standard deviations are reported in brackets. Column (2) reports posterior estimates for the parameters of the spreads process that we obtain from quarterly Argentinean data from the first quarter of 1993 to the fourth quarter of 2001, respectively. Column (3) reports posterior estimates for the parameters of the spreads process that we obtain from our simulations. Numbers in brackets are the 95% probability sets.

of the interest rate spread as well as its stochastic fluctuations are large. At the same time, parameters ρ_{sp} and $\rho_{\sigma_{sp}}$ are close to 0.9, implying that shocks to the level and to the standard deviation of the spread are persistent. Of note, our estimates are close to those reported in [Fernandez-Villaverde et al. \(2011\)](#), that analyze monthly Argentine data.

Finally, we compute posterior estimates for the spreads process using simulations from our calibrated model. In particular, we proceed as follows. We simulate our model economy 200 times for 5,000 periods and we impose that in the last 36 periods, our model economy is always hit by the same sequence of productivity shocks that perfectly replicates the time series of Argentine GDP in the 36 quarters between the first quarter of 1993 and the fourth quarter of 2001. Next we compute the mean interest rate spread in every period of our simulations averaging across our simulations and estimate the volatility of the spreads over the last 36 periods of our simulation using the methodology proposed by [Fernandez-Villaverde et al. \(2011\)](#). Estimates obtained from model simulations, reported in column (3), are remarkably close to those obtained from the data. This similarity is especially true for the autocorrelation parameters ρ_{sp} and $\rho_{\sigma_{sp}}$ and for the average standard deviation of the Argentine spread σ_{sp} . The point estimate for the stochastic volatility parameter η_{sp} is just a touch higher than the one obtained from the data. Yet, it falls comfortably within the 95% probability set. On net, our results show that a standard sovereign default model can generate time-varying

volatility of the interest rate spread, which is consistent with the empirics.¹⁰

Figure 2. Time-Varying Volatility of Spreads

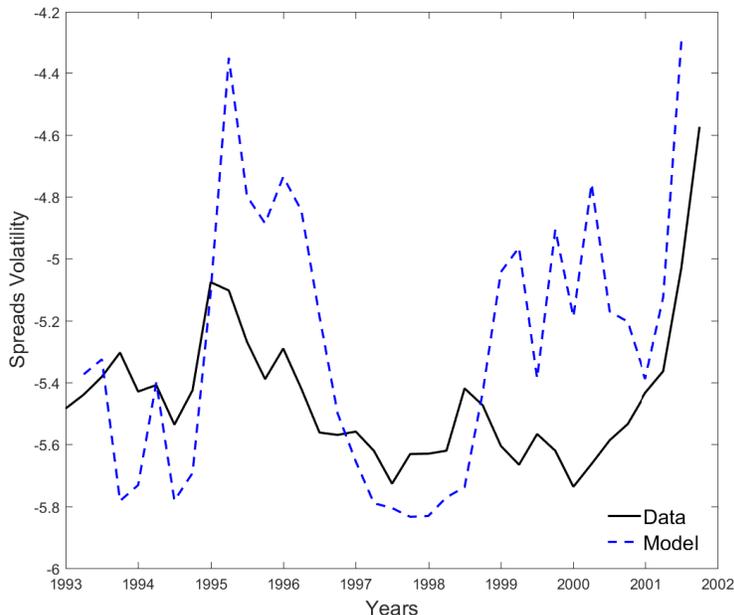


Figure 2 plots the time series of the volatility of the spreads that we extract from quarterly Argentine data from 1993 to 2001 (solid black line) and from simulations of the model economy (dashed blue line).

3.4 Volatility and Economic Dynamics

We now turn to investigate the relation between the volatility of interest rate spreads and key economic variables.

We compute a time series of the volatility $\sigma_{sp,t}$ of Argentine spreads both in the data and in our model simulations, making use of equation (10) and our parameter estimates reported in Table 1.¹¹ Figure 2 plots the time series of the volatility of the spreads that we extract from the data and compares it with the time series of the volatility that we extract from our

¹⁰In Table 4 in the online appendix, we report parameter estimates for the risk-free rate. The stochastic volatility parameter η_{sp} for the interest rate spread is about three times larger than the corresponding one for the risk-free rate, suggesting that most of the stochastic volatility of government interest rates stems from spreads.

¹¹More precisely, we compute the average smoothed volatility conditional on the mean of the posterior of the parameters. The time-series for the volatility of the spreads in our model are obtained from the model simulations using the last 36 periods of each simulations in which we imposed that our model economy is hit by the same sequence of endowment shocks that replicate the evolution of Argentina's GDP from the first quarter of 1993 to the fourth quarter of 2001.

simulations. As the figure shows, the model successfully replicates the increase in volatility observed in the mid-1990's and early 2000's. However, the model also predicts an unobserved rise in volatility in the late 1990's.

We begin our analysis of the cyclical properties of the volatility by inspecting the relation between the volatility of interest rate spreads and their level. Figure 3 summarizes the relationship between the two variables. We find that both in the data and in the model, high spreads are associated with high volatility, confirming the intuition presented in Section 3.1: Spreads become more volatile in bad times, when sovereign risk increases. Table 2 compares the correlation between the level and the log-volatility of the spread in the data and in the model. Such correlation is 0.23 in the data and 0.32 in our simulations.

Figure 3. Spreads and Volatility

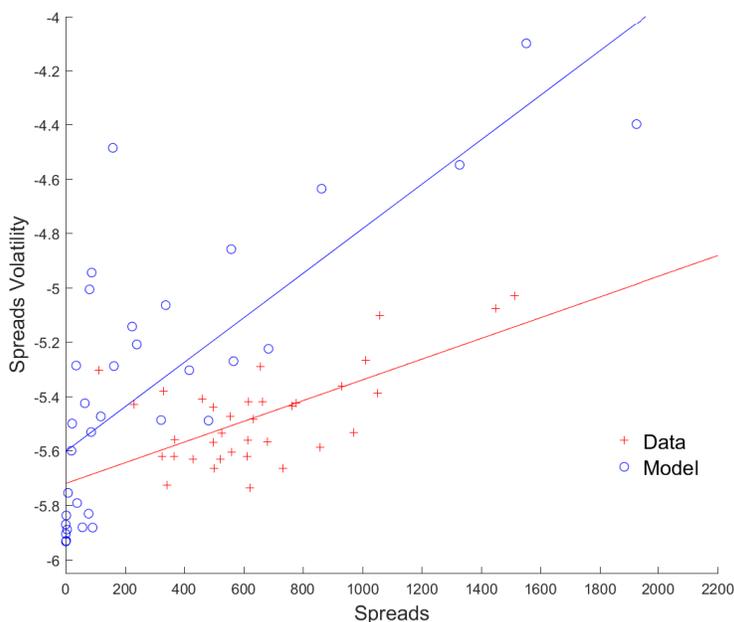


Figure 3 plots the two-way relation between spread levels (on the horizontal axis) and the volatility of the spreads (on the vertical axis). Each cross reproduces a combination of spreads and volatility observed in the data. Each circle reproduces a combination of spreads and volatility observed in the model simulations. The red line is the best linear fit for Argentine data. The blue line is the best linear fit for the model simulations.

Next, we analyze the properties of interest rate spreads in relation to other key business-cycle variables. The model is able to correctly account for the correlation of volatility with the trade balance, output, and consumption. In particular, while the model, in general, slightly overstates the magnitude of the correlations, it captures well the correlation of volatility with households' consumption, the trade balance, and output. These results confirm that in an EME such as Argentina, times of high interest rate spread volatility are associated with high spreads, low consumption, low output, and a positive trade balance.

Table 2. Cyclical Properties of Spread Volatility

	Data	Model
	(1)	(2)
$corr(\sigma_{sp}, spread)$	0.23	0.32
$corr(\sigma_{sp}, y)$	-0.24	-0.31
$corr(\sigma_{sp}, c)$	-0.25	-0.34
$corr(\sigma_{sp}, nx)$	0.20	0.28

Column (1) reports correlation between the volatility of the spread and key economic indicators computed using quarterly data for Argentina from the first quarter of 1993 to the fourth quarter of 2001. Column (2) reports correlation between the volatility of the spreads and key economic indicators in simulated data from the standard sovereign default model.

4 Concluding Remarks

This paper highlights an important property of the canonical quantitative model of endogenous sovereign default, based on [Arellano \(2008\)](#). We document that, even in the absence of exogenous uncertainty shocks, this model generates time-varying volatility of interest rate spreads. The non-linearity of the policy functions of interest rate spreads lies at the heart of this result. When the model is calibrated to Argentina, it reproduces closely the volatility of interest rate spreads that we observe in the data, as well as for the correlation between the volatility with the level of the interest rate spreads and with the main business cycle variables, such as the trade balance, output and consumption.

We see the results of this paper as complementary to those of [Fernandez-Villaverde et al. \(2011\)](#), who document the real effects of interest rate volatility. In particular, we believe that integrating sovereign default models in which interest rate volatility arises endogenously, with models in which volatility amplifies fluctuations of real economic variables (such as the one in [Fernandez-Villaverde et al. \(2011\)](#)) could be an exciting avenue for future research and provide new insights on the economic costs of sovereign risk.

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5 Online Appendix

5.1 Equilibrium

Equilibrium In equilibrium, the government sets the policy for default or repayment and for issuance or purchase of an asset, in order to maximize the welfare of the representative household, subject to the resource constraint of the small open economy and to the constraint implied by foreign lenders' pricing of debt. The equilibrium is formally defined below.

Definition 1. *A recursive equilibrium in the small open economy is characterized by*

- a set of value functions for the representative household V , V_R , and V_D ,
- government policies for default D and asset holdings b' ,
- a government debt price function q

such that:

- the debt price function is consistent with optimization by foreign lenders, (4),
- given the debt price function q , the value functions of the household and the policy functions of the government solve the maximization problem (1), (2), (3).
- the resource constraint of the small open economy is satisfied

5.2 Additional Material

Table 3. Parameter values

Panel A: Income Process and Model Parameters			
Moment		Value	Source/Target Statistic
Discount factor	β	0.953	Default frequency
Relative risk aversion	γ	2	Standard
Output cost of sovereign default	δ	0.969 $\mathbb{E}(y)$	Debt-service-to-GDP ratio
Readmission probability	λ	0.282	Arellano (2008)
Endowment, autoregressive	ρ_y	0.945	Argentina GDP
Endowment, standard deviation	σ_y	0.025	Argentina GDP

Table 3 reports parameter values that are used for the calibration exercise and the associated target statistics.

Table 4. Priors and Posterior Means

Parameter	Priors	Posteriors Risk-free
	(1)	(2)
ρ_{rf}	\mathcal{B} (0.9, 0.02)	0.91 [0.89, 0.95]
σ_{rf}	\mathcal{N} (-5.3, 0.4)	-5.17 [-5.59, -4.74]
$\rho_{\sigma_{rf}}$	\mathcal{B} (0.9, 0.1)	0.90 [0.74, 0.99]
η_{rf}	\mathcal{N}^+ (0.5, 0.3)	0.12 [-0.01, 0.25]

Column (1) reports the priors for the parameters that govern the process of the risk-free rate. \mathcal{B} , \mathcal{N} , \mathcal{N}^+ stand for Beta, Normal, and truncated Normal distributions. Mean and standard deviations are reported in brackets. Column (2) reports posterior estimates for the risk-free rate parameters. Estimates are obtained applying the methodology developed by [Fernandez-Villaverde et al. \(2011\)](#) to quarterly data on the yields of 5-year T-bills from the first quarter of 1993 to the fourth quarter of 2001.