Corporate Balance Sheets and Sovereign Risk Premia

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JOB MARKET PAPER

This version: 9th Jan 2020  
Link to the latest version

Abstract

This paper studies sovereign debt pricing in the presence of corporate debt. We find that foreign currency (FC) corporate external debt empirically explains sovereign credit spreads in emerging countries, even after controlling for sovereign debt and global factors. Decomposing sovereign credit spreads into their default premium (default probability) and risk premium components, we find that a 1% increase in FC corporate external debt is associated with a 5 basis point increase in the sovereign risk premium but a small and insignificant change in the sovereign default premium. We incorporate a productive corporate sector and risk-averse foreign lenders into a quantitative sovereign default model. An increase in FC corporate external debt has three effects on tax revenue, and thus sovereign spreads. It increases the mean of tax revenue due to higher investment, increases the variance of tax revenue due to higher exposure to exchange rate risk, and changes the covariance of sovereign defaults and the state of foreign lenders. The first two effects counteract each other and help explain the insignificant change in the sovereign default premium, while the third effect results in a higher sovereign risk premium. Corporates do not internalize their effect on sovereign debt pricing, leaving room for policy improvement.

JEL Classification Codes: F34, F41, G12, G15, G38

Key words: Sovereign risk, corporate debt, currency mismatch

*Email: steve.wu@wisc.edu. I am especially grateful to Charles Engel (co-advisor), Kenneth West (co-advisor) and Menzie Chinn for their invaluable advice, guidance and support. I am grateful to Juan Carlos Hatchondo, Dean Corabe, Rishabh Kirpalani, Dmitry Mukhin, and Kim Ruhl for their very helpful advice and comments. For useful comments, I appreciate Manuel Amador, Yan Bai, David Cook, Tim Kehoe, Zehao Li, Erwan Quintin, Ivan Shaliastovich, Ilhyock Shim, Hyun Shin, Giorgio Valente, Jason Wu, Jing Zhang, and seminar participants in various conferences. Part of this paper was being written while I was visiting the Hong Kong Institute of Monetary Research in the summer of 2018 and the Bank for International Settlement in 2019. I am grateful for their hospitality and financial support during my stay. The financial support from the Summer Research Fellowship, the Walker Family Graduate Dissertation Fellowship, and the Ko and Ying Shih Graduate Fellowship of the Department of Economics at the University of Wisconsin Madison are greatly acknowledged. I received outstanding computational support from the Center for High Throughput Computing (CHTC). All errors are mine.
1 Introduction

In recent years, there has been a dramatic surge of corporate foreign currency-denominated (FC) external debt in emerging countries.\textsuperscript{1} According to the Bank for International Settlements (BIS) data, the size of external corporate debt in developing countries went up from 2.7 trillion USD equivalent in the first quarter of 2008 to 4.7 trillion USD equivalent in the fourth quarter of 2016. FC comprises a dominant share (over 90\%) of this debt. Figure 1 shows a time-series plot of the FC corporate external debt to GDP ratio in several emerging countries.\textsuperscript{2} In all cases, the ratio doubled in less than 10 years since 2008. This data shows that the increasingly leveraged corporate sectors in emerging countries are still highly dollarized when they seek funding from the rest of the world.

![Figure 1: Increasing foreign currency corporate external debt to GDP in emerging countries (%)](image)

Source: Author’s calculation based on BIS statistics and Bloomberg.

The rise of FC corporate external debt in many emerging countries raises concerns for policymakers,\textsuperscript{3} who worry about increasing macroeconomic vulnerabilities. This paper studies the implications of foreign currency-denominated corporate external debt for emerging countries’ sovereign credit spreads. Sovereign credit spreads are important for two reasons. First, it is a biometer of a country’s macroeconomic conditions. Second, it is the funding cost of the sovereign. We argue that the corporates’ increasing reliance on FC external debt does not necessarily increase sovereign default risk, but has a positive impact on the sovereign risk premium and therefore increases sovereign spreads. This argument consists of two main components. First, we empirically document the re-

\textsuperscript{1}Throughout the paper, corporates include both financial and non-financial corporates. External debt refers to both bonds and loans held by the rest of the world. McCauley et al. (2015), Chui et al. (2016) and Hardy and Safie (2019) find that this surge in FC debt is mainly driven by non-financial corporates.

\textsuperscript{2}The pattern is, in general, true for a larger set of emerging countries. We show only a few for exposition purposes.

relationship between FC corporate external debt, sovereign default risk, and the sovereign risk premium. Second, we build a quantitative sovereign default model that features a productive corporate sector with corporate debt and risk-averse lenders to account for the empirical findings.

Our key empirical findings are that there is a positive correlation between FC corporate external debt and sovereign credit spreads, and this positive relationship is mostly driven by the risk premium but not the default premium. We decompose the sovereign credit default swaps (CDS), a common measure of sovereign credit spreads, into their default premium and risk premium components, following the affine term structure approach developed by Longstaff et al. (2011) and the credit rating approach developed by Remolona et al. (2008). Figure 2 uses Brazil as an example to visualize the empirical findings. The left panel shows a scatter plot of the 5-year USD-denominated sovereign CDS versus the FC corporate external debt to GDP in Brazil, using quarterly data from 2004Q1 to 2016Q4. The panel displays a clear positive correlation between corporate debt and Brazilian sovereign CDS. In the middle panel, we decompose the CDS spreads into their default premium and risk premium components using the credit rating approach. Interestingly, FC corporate debt to GDP is positively correlated with the sovereign risk premium and (weakly) negatively correlated with the sovereign default premium. In the right panel, we plot the decomposed sovereign CDS spreads versus FC sovereign external debt to GDP. Both components are positively correlated with FC sovereign external debt to GDP. These figures show that the relationship between sovereign credit spreads and corporate debt is not same as that of sovereign debt.

Figure 2: Brazilian 5Y USD-denominated sovereign CDS and FC debt to GDP

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4 We use 5-year USD-denominated sovereign CDS spreads as the measure of sovereign credit spreads, which is commonly used in the literature. The cash-flow of shorting a risky coupon sovereign bond and investing in a coupon risk-free bond, generate exactly the same cashflow as buying a CDS contract. In the absence of market friction and arbitrage, the premium of a CDS should be equal to the yield difference of the two bonds. See Appendix A1 for an illustration.

5 The default premium component could be understood as the spread that compensates a lender in an actuarially fair sense; therefore it compensates the expected default probability. The risk premium component is the additional spread needed to compensate a risk-averse lender or a constrained investor. We discuss the methods in more detail in subsection 2.1 and Appendix A2.
In the next section, we document these relationships of FC corporate external debt and sovereign credit spreads systematically. Using a panel regression analysis for 17 emerging economies, we find a robust pattern that a one percent increase in FC corporate external debt to GDP is significantly associated with a sizable five basis point increase in the sovereign risk premium. However, a one percent increase in FC corporate external debt to GDP is not significantly associated with movements in the sovereign default premium. Contrastingly, an increase in FC sovereign external debt to GDP is associated with a significant increase in both sovereign default premium and risk premium. These stylized facts show that FC corporate external debt explains sovereign credit spreads, and the underlying sovereign spread components explained by corporate debt are not the same as sovereign debt. We also use exogenous event date analysis to establish that the FC corporate external debt is an important determinant of sovereign spreads.

To account for these empirical findings, we introduce a productive corporate sector with dynamic corporate debt and investment decisions and risk-averse foreign lenders into the canonical small open-economy sovereign default model (Eaton and Gersovitz (1981), Aguiar and Gopinath (2006) and Arellano (2008)). Both the sovereign and corporate sectors can borrow externally from risk-averse foreign investors. The model has three key components. First, firms optimally choose investment and corporate debt. Second, the sovereign relies on taxation of corporate profits as a source of income. Third, corporate revenue is denominated in local currency (LC) but debts are denominated in FC; thus corporates are subject to exchange rate risk and currency mismatch issue.

To understand the key mechanisms of the model, consider a scenario in which an exogenous reduction in the world risk-free interest rate occurs. The low risk-free rate incentivizes firms to borrow more in order to invest, leading to an increase in the corporate debt level and next period capital. These results have three different effects on the sovereign default risk. First, holding the exchange rate constant, the increase in capital leads to more production and a higher expected corporate tax revenue, resulting in a reduction in the sovereign default probability. This is the “investment effect” of corporate debt. Second, the increase in FC debt exposes corporate profits more to exchange rate risk and increases the variance of tax revenue, raising the sovereign default probability. This is the “exchange rate effect” of corporate debt. In the model, the investment and exchange rate effects counteract each other, resulting in FC corporate debt having an insignificant effect on the sovereign default probability, as documented by the panel regression. Finally, the increase in FC debt changes the state where sovereign default tends to happen. Specifically, an appreciation of FC results in lower tax revenue and a higher chance of sovereign default. Since FC tends to appreciate in foreign lenders’ bad times, sovereign defaults tend to occur more often when foreign lenders value repayment more. This “state switching effect” of corporate debt changes the covariance of sovereign defaults and how foreign lenders discount repayment in different states.

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6 As a reference, the average CDS spreads of the sample countries are 155 basis points.
7 Papers by Bruno and Shin (2017) and Bräuning and Ivashina (2019) show empirical support that the low world interest rate is an important factor for the increase in both bonds and loans to emerging markets.
8 This is often known as a behavior for a reserve currency. See Caballero et al. (2016) and Maggiori (2017).
This explains the positive relationship of FC corporate debt and sovereign risk premium in the data. In a simple sense, the corporate behavior alters the distribution of tax revenue (mean, variance, and covariance with lenders’ pricing kernel) and therefore sovereign default decisions.\(^9\)

We calibrate a quantitative version of the model to match moments in pre-2008 data from Mexico, as the pre-2008 period exhibited a high world risk-free interest rate. Then, we mimic the post-2008 period as a change from a high world risk-free rate regime to a low world risk-free rate regime, and evaluate the model performance by comparing the untargeted post-2008 moments. The model accounts well for the corporate and sovereign debt moments in the post-2008 period of Mexico such as quantitatively matching 80% of the increase in FC corporate external debt to GDP and the increase sovereign risk premium.

The policy implication of the model is that an externality arises as the corporate sector fails to internalize the effect of their borrowing decisions on sovereign debt pricing. We analyze the optimal trade-off from the private and social planner perspectives. Compared to the decentralized solution, the social planner solution has on average a 1.5 percentage point lower corporate debt to GDP, a 0.5 percentage point higher sovereign debt to GDP, and a 10 basis point lower sovereign risk premium. This suggests policies such as a tax to reduce FC corporate external debt.

**Related Literature.** The paper contributes to three strands of the literature on open macro emerging economies. First, it relates to work on empirical sovereign debt pricing. Extensive studies by Borri and Verdelhan (2011), Broner et al. (2013), Aguiar et al. (2016), and Tourre (2017) have shown that sovereign credit spreads are consistently larger than what would be implied by historical default probabilities. Two notable papers by Longstaff et al. (2011) and Remolona et al. (2008) develop methods to systematically separate the default premium and risk premium components from CDS spreads. They find a large risk premium component and it is mainly driven by global factors. This paper contributes to the literature by providing novel empirical evidence that FC corporate external debt to GDP, a domestic variable, is a robust predictor of the sovereign risk premium component.

Second, this paper bridges two popular literatures of open macro emerging economies that study public and private capital flows separately. We bring the dynamic corporate debt and investment consideration in corporate currency mismatch models (Aghion et al. (2001) and Céspedes et al. (2004)) into quantitative sovereign default models (Aguiar and Gopinath (2006) and Arellano (2008)).\(^{10}\) We contribute to a growing literature that studies spillovers from sovereign risk to the private sector, including Arellano et al. (2017), Bocola (2016), Sosa-Padilla (2018), and Perez (2015), by exploring spillovers occurring in the reverse direction (from the corporate sector to the sovereign) and develops a model that is consistent with the new empirical findings. Asonuma (2016) and Na et al. (2018) explore exchange rates and sovereign defaults. While Na et al. (2018)

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\(^9\)This extends Arellano (2008)’s model, where the sovereign receives stochastic endowments to repay the debt. In this paper, the sovereign repays the debt with stochastic tax revenue, in which the time-varying probability distribution is determined by the corporate sector behavior.

\(^{10}\)Bai and Zhang (2012), Park (2017) and Gordon and Guerron-Quintana (2018) are sovereign default models with public investment. None of these models has a private sector.
focuses on exchange rate devaluation as an optimal response to sovereign default, we instead focus on exchange rate triggered default and also the presence of corporate debt. This paper is most similar to Du and Schreger (2017), which studies how currency mismatch in the corporate sector could alter the sovereign incentive of inflating away the local currency sovereign debt. We share the idea of having a currency mismatched corporate sector in a sovereign default setting with Du and Schreger (2017). We decompose the sovereign spreads into the two different components and find the new empirical findings of an increase in the sovereign risk premium but no change in default premium when corporate debt increases. To account for the new findings, we additionally allow for dynamic optimal choices on corporate investment and debt to fully study the corporate sector effect on sovereign debt pricing.

Finally, the paper develops relevant insights for capital control policy in emerging countries. Following Korinek (2010) and Bianchi (2011), one way to rationalize capital control policy is to consider a collateral constraint on borrowing. Individual agents fail to internalize the pecuniary externality that arises when they sell their assets, thereby lowering the value of collateral for other agents. This leads to room for policy improvement when the constraint could be potentially be binding in some future states. Kim and Zhang (2012) and Wright (2006) also study externalities in a sovereign default setting where individuals decide how much to borrow and the sovereign decides whether to default or not. This paper provides an alternative way of rationalizing capital control regulation: individual firms fail to internalize their aggregate effect on tax revenue. Since foreign lenders price the sovereign bond by evaluating the sovereign’s repayment ability, this generates an externality on the sovereign. The externality in this setting calls for capital control policy at all times, rather than only when the constraint is potentially binding.

Layout. In section 2, we discuss in detail the empirical setup, key empirical findings and supplementary regressions that support the model. Section 3 provides the setup of the theoretical model. Section 4 presents the quantitative results and inspects the model mechanism. Section 5 discusses the social planner solution. Section 6 concludes.

2 Empirical evidence of corporate balance sheet spillovers

This section presents empirical results regarding the interaction between corporate debt and sovereign credit spreads. Subsection 2.1 describes the construction of variables of interest and the data sources used. Subsection 2.2 presents baseline regression results showing that an increase in FC corporate debt is associated with an increase in sovereign risk premium but not sovereign default risk. Subsection 2.3 then proceeds with additional empirical support that will guide underlying mechanisms of the model.

2.1 Construction of variables

Sovereign spreads and sovereign CDS premia reflect the funding costs of a country’s sovereign.\footnote{In the absence of market friction and arbitrage, the premium of a CDS should be equal to the coupon rate difference of shorting a sovereign bond and a risk-free bond, both trading at their face values. See Appendix A1 for an illustration.}
Therefore, throughout this analysis, sovereign CDS premia are taken as a measure for sovereign funding costs. We prefer the CDS spread to the actual bond yield for this measurement, due to the CDS market being typically more liquid than the underlying bond market of emerging countries. Additionally, unlike underlying fixed-rate bonds, CDS spreads are not directly subject to interest rate risk. Finally, because CDS are standardized and quoted in constant maturities, they can be more easily compared across countries with no need to conduct any yield curve interpolation to obtain the cost of funding for constant maturities.

Extensive studies consistently show that sovereign spreads and CDS premia are much larger than actuarially fair prices, or prices that would compensate for historically observed credit default probabilities.\textsuperscript{12} Therefore, the default probabilities only account for a fraction of the sovereign CDS premia. Due to this empirical phenomenon, this paper adopts two widely used methods from the finance literature to separate the sovereign CDS premia into their default premium and risk premium components. The default premium component is the component directly associated with the default probability of a sovereign borrower and is often understood as the hypothetical CDS premium if the investor were risk-neutral. In contrast, the risk premium component is measured as the difference between the observed CDS premium and the default premium component, and it is understood as the additional premium charged because of investors’ risk aversion or the presence of other frictions.\textsuperscript{13}

To separate CDS premia into these two components, we applied two methods from the finance literature: (1) a decomposition based on credit rating and (2) a decomposition based on an affine term structure model.\textsuperscript{14} We briefly describe the methods here and refer readers to Appendix A2 for technical details. The first method for separating CDS premia into their separate components relies on credit ratings, assigned by rating agencies to sovereign issuers, to infer expected default probabilities. The approach is developed by Remolona et al. (2008). We view the credit rating process as a function mapping a large set of time \( t \) information into expected default frequencies. Rating reports provide default probabilities associated with each rating.\textsuperscript{15} We use the assigned default probability to compute the corresponding default premium by assuming a constant default probability until maturity.\textsuperscript{16} This method imposes almost no restriction on the separation. Papers relying on credit ratings to measure default probabilities include Borri and Verdelhan (2011) and Tourre (2017). The second method relies on the term structure of sovereign CDS spreads to infer the expected default probability implied by the market and follows the affine pricing model made specific

\textsuperscript{12}See for example: Remolona et al. (2008), Longstaff et al. (2011), Borri and Verdelhan (2011), Aguiar et al. (2016) and Tourre (2017).

\textsuperscript{13}For example, lenders could be limited by some lending capacity constraints.

\textsuperscript{14}These are the most commonly used approaches for credit spread decomposition in the finance literature. See Manzo and Veronesi (2016) for a discussion.

\textsuperscript{15}Throughout this paper, we use Moody’s credit rating as the primary rating source.

\textsuperscript{16}One might worry that credit ratings are only updated infrequently and therefore limit the variation of the default premium. We improve the variation in two dimensions. First, even if there is no change in rating, the default probability could vary as new rating reports could change the default probability for the same rating. We update the rating corresponded default probability as soon as the new reports are released. Second, we also interpolate (cubic spline) the rating bins by using the outlook/watch-list information. The empirical findings are not sensitive to these refinements.
to the sovereign CDS market by Pan and Singleton (2008). The affine pricing model assumes the arrival rate of credit event follows a log-normal process and the market price of risk is affine in the arrival rate. The pricing model is consistent with a no-arbitrage condition. Leveraging the panel structure of CDS term structure data, we use the maximum likelihood estimation to estimate the arrival rates of credit events and lenders’ stochastic discount factor. Papers by Longstaff et al. (2011) and Hébert and Schreger (2017) also apply this method to estimate the default probability.

For each of the two methods, we obtain estimates of the default premium for each sample country individually. Default probabilities and default premia are updated every time period (with each period taken to be a quarter). For each estimate of the default premium, we compute the risk premium as follows:

\[
\text{Sovereign CDS}_{i,t}^{\text{Risk premium}} = \text{Sovereign CDS}_{i,t} - \text{Sovereign CDS}_{i,t}^{\text{Default premium}}
\]  

(1)

For the corporate and sovereign debt data, no publicly available dataset exists that provides external debt statistic measures by sector (sovereign vs. corporate) and by currency at a quarterly frequency. We follow the data cleaning procedure developed in Du and Schreger (2017) to construct these variables.\(^{17}\) The basic principle involves using BIS data as the baseline and filling in the gaps by combining various national data sources and aggregating transaction-level data to the country level from commercial databases.

Bloomberg is the primary source for CDS data, with the end-of-quarter observations being used here. Debt levels are obtained from BIS International Debt Securities, BIS Locational Banking Statistics, Bloomberg, and Arslanalp and Tsuda (2014). Other economic variables are obtained from FRED and IMF datasets, and detailed data source information is provided in the appendix. Data from the first quarter of 2004 to the fourth quarter of 2016 comprise the main sample period and, unless otherwise specified, the 17 emerging market countries in the sample are Brazil, Chile, China, Colombia, Croatia, Hungary, India, Indonesia, South Korea, Malaysia, Mexico, the Philippines, Poland, Russia, South Africa, Thailand, and Turkey.\(^{18}\)

2.2 Baseline regression analysis

We now turn to the investigation of the link between FC corporate debt and sovereign credit spreads and their components. For any observed CDS spread at time \(t\), we decompose the CDS spread into two components as in eq (1). We then estimate the following panel fixed effect regressions:

\[
\text{Sovereign CDS}_{i,t} = \alpha_i + \beta_1 \left( \frac{\text{FC Corp debt}}{\text{GDP}} \right)_{i,t-1} + \beta_2 \left( \frac{\text{FC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \beta_3 \left( \frac{\text{LC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \mu GC_t + \epsilon_{i,t}
\]  

(2)

\[
\text{Sovereign CDS}_{i,t}^{\text{Default premium}} = \eta_i + \gamma_1 \left( \frac{\text{FC Corp debt}}{\text{GDP}} \right)_{i,t-1} + \gamma_2 \left( \frac{\text{FC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \gamma_3 \left( \frac{\text{LC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \omega GC_t + \nu_{i,t}
\]  

(3)

\(^{17}\)See Appendix A2 for the details.

\(^{18}\)The start date of sample and country choice are limited by availability of CDS data.
Sovereign CDS \(^{\text{Risk premium}}\) \(_{i,t}\) = \(\chi_i t + \delta_1 \left( \frac{\text{FC Corp debt}}{\text{GDP}} \right)_{i,t-1} + \delta_2 \left( \frac{\text{FC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \delta_3 \left( \frac{\text{LC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \theta G_{C_t} + u_{i,t}\)

where \(\alpha_i, \eta_i, \chi_i\) are country fixed effects. Sovereign CDS \(_{i,t}\) denotes the 5-year USD-denominated sovereign CDS for country \(i\) at time \(t\). \(^{19}\) \(\frac{\text{FC Corp debt}}{\text{GDP}}\), \(\frac{\text{FC Sovereign debt}}{\text{GDP}}\), and \(\frac{\text{LC Sovereign debt}}{\text{GDP}}\) are the FC corporate debt, FC sovereign debt, and LC sovereign debt in country \(i\), normalized by the GDP and all converted to same currency. \(G_{C_t}\) denotes a vector of global control variables, including the VIX index, the BBB-Treasury spread, the 10-Year Treasury yield, the TED spread, and the US Federal Funds Rate. Note that these variables are not country \(i\)-specific. \(\varepsilon_{i,t}, v_{i,t}, u_{i,t}\) denote the regression residuals.\(^{20}\) The regression specification is inspired by Du and Schreger (2017), which employed the same set of regressors.

Table 1 reports the coefficient estimates for eq (2, 3, 4). The debt to GDP variables enter the regression in percentage term and the CDS quotes enter the regression in basis points. Therefore, the regression estimate of \(\beta_1\) can be interpreted as indicating that a one percent increase in corporate debt to GDP is associated with a \(\beta_1\) basis point increase in sovereign CDS premium. As a reference, the average CDS spreads over the sample countries are 155 basis points.

We first compare our result with Du and Schreger (2017) (reproduced in column (1a)). Column (1b) of Table 1 shows that a one percent increase in FC corporate debt to GDP is significantly associated with 5.66 basis points increase in 5-year USD-denominated sovereign CDS spreads. Similarly, a one percent increase in FC sovereign debt to GDP is significantly associated with 11.12 basis points increase in 5-year USD-denominated sovereign CDS spreads. While Du and Schreger (2017) use local currency sovereign spreads as the dependent variable,\(^{21}\) the estimated effect we find here is consistent with what Du and Schreger (2017) reported.

To focus now on the sub-components of CDS spreads, columns (2a) and (2b) report the coefficient estimates of eq (3) using term structure and credit rating based decompositions respectively, while columns (3a) and (3b) report the coefficient estimates of eq (4). Columns (2a) and (2b) show that a one percent increase in FC sovereign debt to GDP is associated with a 2-3 basis point increase in the sovereign default premium. Columns (3a) and (3b), show that FC sovereign debt to GDP is also positively and significantly associated with the sovereign risk premium. These regression estimates are consistent with predictions from sovereign default models, reaffirming that the regression findings on sovereign debt are consistent with the literature.

\(^{19}\)5-year maturity is the most heavily traded maturity in the market and the most commonly used measure in the literature.

\(^{20}\)One might worry about the error terms \(v_{i,t}\) and \(u_{i,t}\) are correlated. Since the independent variables are the same in the two regressions, seemingly unrelated regression and standard OLS deliver equivalent estimates.

\(^{21}\)Local currency credit spreads are defined as the difference between an emerging country’s local currency bond yield and an US-Treasury bond yield that is converted to the emerging country’s currency by using FX swaps to eliminate exchange rate risk.
Table 1: Association between FC corporate debt to GDP and components of CDS premium

<table>
<thead>
<tr>
<th>Local currency sovereign spreads (bps)</th>
<th>Sovereign CDS premium (bps)</th>
<th>Sovereign CDS default premium (bps)</th>
<th>Sovereign CDS risk premium (bps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(%) Du and Schreger (2017)</td>
<td>(1a) Term</td>
<td>(2a) Rating</td>
<td>(3a) Term</td>
</tr>
<tr>
<td>FC Corporate debt</td>
<td>5.34***</td>
<td>5.66***</td>
<td>0.43</td>
</tr>
<tr>
<td>GDP</td>
<td>(1.13)</td>
<td>(1.20)</td>
<td>(0.28)</td>
</tr>
<tr>
<td>FC Sovereign debt</td>
<td>9.53*</td>
<td>11.12***</td>
<td>2.41***</td>
</tr>
<tr>
<td>GDP</td>
<td>(5.08)</td>
<td>(2.31)</td>
<td>(0.50)</td>
</tr>
<tr>
<td>LC Sovereign debt</td>
<td>6.78***</td>
<td>2.27</td>
<td>0.70</td>
</tr>
<tr>
<td>GDP</td>
<td>(2.00)</td>
<td>(2.01)</td>
<td>(0.51)</td>
</tr>
<tr>
<td>Observations</td>
<td>355</td>
<td>761</td>
<td>761</td>
</tr>
<tr>
<td>$R^2$ adjusted</td>
<td>0.69</td>
<td>0.64</td>
<td>0.72</td>
</tr>
<tr>
<td>Period</td>
<td>2005Q1-2012Q4</td>
<td></td>
<td>2004Q1-2016Q4</td>
</tr>
<tr>
<td>Countries</td>
<td>13</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Global Controls</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Country FE</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay (1998)) with a 4-quarter lag. * p<0.1, ** p<0.05, *** p<0.01. All the spread measure of the independent variables are 5-year tenor. The CDS are USD-denominated. Decomposition in column (2a) and column (3a) uses the affine term structure model by Longstaff et al. (2011). Decomposition in column (2a) and column (3a) applies the credit rating method by Remolona et al. (2008).

Main empirical findings:

More interestingly, column (2a) and column (2b) show that an increase in FC corporate debt to GDP has a small and insignificant effect on the sovereign CDS default premium. Regardless of the method of decomposition, the results indicate an insignificant relationship between FC corporate debt to GDP and the sovereign CDS default premium, a sharp contrast to the effect of FC sovereign debt to GDP to the default premium. This also notably contrasts with column (1b), which shows that the FC corporate debt to GDP has a significant correlation with the sovereign CDS.

Column (3) focuses on sovereign CDS risk premium spreads and shows that, regardless of the decomposition method, a one percent increase in FC corporate debt to GDP is significant and is associated with an increase of 5-6 basis points in the risk premium component. In fact, the adjusted $R^2$ decreases by twelve percentage points if we exclude FC corporate debt to GDP as an explanatory variable. The results show that almost all correlation of FC corporate debt to GDP with sovereign CDS spreads comes from co-movement with risk premium. We find this intriguing, as many papers in the empirical sovereign debt pricing literature have documented a large risk premium component in international asset prices and find that the risk premium is largely driven by global factors such as the VIX Index, US stock market returns, or monetary policy in advanced economies (among many others, see Longstaff et al. (2011) or Rey (2015)). The fact that FC corporate debt to GDP, a local factor, is also significant in explaining risk premium after controlling for all the global controls ($GC_t$) is important for understanding the mechanism and policy analysis. The positive and

\footnote{Coefficients in column (2a) and column (3a) adds up to column (1b), up to rounding errors. So as column (2b) and column (3b).}
significant correlation of FC corporate debt to GDP and sovereign risk premium spreads indicates a potential spillover from the corporate sector to the sovereign sector.

In summary, the empirical results show that an increase in FC corporate debt to GDP is significantly associated with an increase in the sovereign risk premium and a small and insignificant change of the sovereign default premium. Both the insignificance for the default premium and significance for the risk premium are interesting findings that the model section attempts to explain. Appendix A4 provides robustness checks that control for additional factors motivated by the existing literature (including GDP growth, trade balance to GDP, and reserve to GDP). The main findings of this section are robust to various specifications.

2.2.1 CDS spreads response on extreme dates conditional on FC corporate debt

We now turn the analysis to an extreme value event study approach.\(^{23}\) We show that the sovereign CDS spreads change on the event dates depends on the FC corporate external debt to GDP. Specifically, we identify event dates when the daily change of the VIX Index is at the top 1% of the sample distribution (a daily VIX change of 22%).\(^{24}\) We think of a dramatic change of VIX as a sudden increase in investor risk appetite, which is exogenous to emerging countries. The interest is in seeing how the CDS spreads change on these event dates conditional on existing debt; we do this by estimating the following daily panel local linear projections (Jordà (2005)):

\[
\Delta_t \text{Sovereign CDS}_{i,t} = \alpha_t + \gamma_{1,h}(\frac{\text{FC Corp debt}}{\text{GDP}})_{i,t-1q} + \gamma_{2,h}(\frac{\text{FC Sovereign debt}}{\text{GDP}})_{i,t-1q} + \gamma_{3,h}(\frac{\text{LC Sovereign debt}}{\text{GDP}})_{i,t-1q} + \omega_h F E_t + \nu_{i,t+h}
\] (5)

where \(\Delta_t \text{Sovereign CDS}_{i,t} \equiv \text{Sovereign CDS}_{i,t+h} - \text{Sovereign CDS}_{i,t-2}\) is the difference in CDS spreads between \(t - 2\) and \(h^{th}\)-day after the event date \(t\). \(FE_t\) are time fixed effects. The right-hand-side variables are values of the latest quarter prior to the event date \((t - 1q)\).

We identify 47 event dates over the sample period. We plot the coefficient estimates \(\gamma_{1,h}, \gamma_{2,h}, \gamma_{3,h}\) for \(h = 0\) to \(h = 10\) (two business weeks) in Figure 3. The top panel illustrates that the \(\gamma_{1,h}\) are consistently positive and significant, with the average estimate being 0.77 basis points, indicating that when investor risk aversion increases, a higher pre-existing FC corporate debt causes an increase in sovereign CDS spreads. The middle panel gives the estimates of \(\gamma_{2,h}\). FC sovereign debt also has a significant positive effect on sovereign CDS spreads, the average estimate is 0.67 basis points. Finally, the bottom panel plots coefficient estimates of \(\gamma_{3,h}\). Consistent with the regression reported in Table 1, the estimated coefficients are not significant for all \(h\). This provides evidence that the foreign currency nature of the debt is important for the underlying mechanism.

Overall, we find that a country with a higher \(\frac{\text{FC Corp debt}}{\text{GDP}}\) suffers from a larger sovereign CDS increase when investor risk aversion increases.\(^{25}\) We interpret this as evidence of FC corporate debt is a pricing factor for sovereign CDS. Investors ask for more compensation to take sovereign risk

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\(^{23}\)See Forbes (2012) for a recent example that uses the same approach.

\(^{24}\)For example, these dates include Lehman collapse, US being downgraded by S&P and Brexit referendum.

\(^{25}\)In Appendix A5, we show a scatterplot of \(\frac{\text{FC Corp debt}}{\text{GDP}}\) and \(\Delta_t \text{Sovereign CDS}_{i,t}\) on the Brexit referendum to visualize the positive relationship.
when \( \frac{FC \text{ Corp debt}}{GDP} \) is higher.

Figure 3: Local projection estimates of sovereign CDS change on debt to GDP (equation (5))

Notes: Dash lines are 95% confidence interval based on robust standard errors.
2.3 Supportive empirical evidence

In this subsection, we provide empirical evidence that guides the model direction. In particular, we first provide empirical evidence that emerging market sovereigns rely heavily on tax revenue. Secondly, we show that FC corporate debt could affect tax revenue when the exchange rate fluctuates, and therefore affects the default decision of a sovereign.

Figure 3:
Tax revenue to total fiscal revenue ratio (%) in the sample countries

Notes: This table reports the average tax revenue to total fiscal revenue from 2004-2014; standard deviation in parentheses. Data source: Author’s calculations of the IMF World Revenue Longitudinal dataset.

2.3.1 Tax revenue structure in emerging countries

Emerging market sovereigns rely on tax revenue as an important source of income. Figure 3 shows the 2004-2014 average of tax revenue to fiscal revenue ratio for the sample countries. We obtain the data from the IMF World Revenue Longitudinal Dataset (IMF WRL), which ends in 2014. Compared to the developed economies, emerging markets have a higher share of fiscal revenue that is attributable to tax revenue. The sample country average of tax revenue to total fiscal revenue ratio is 73%, which is 13% higher than the G7 average of 60%. The high reliance on tax revenue suggests fluctuation in tax revenues could affect the sovereign’s debt repayment ability.

2.3.2 Corporate debt, exchange rate and tax revenue in emerging countries

Motivated by the literature that studies the trade channel and financial channel of exchange rates,\(^{26}\) we provide evidence that FC corporate debt and exchange rates could affect tax revenue. We focus

\(^{26}\)For recent examples, see Kim et al. (2015), Kearns and Patel (2016), and Hofmann et al. (2017).
on two definitions of tax revenue: the revenue from corporate profit tax and total tax revenue. FC corporate debt and exchange rate movements could have a direct impact on corporate profits. Since corporate performance also affects the rest of the economy and therefore other tax sources such as labor income tax and production tax, we also examine the impact on total tax revenue.

We perform the following panel fixed effect regression to examine the relation between USD corporate debt and tax revenue in emerging countries:

$$\Delta \% (\text{tax revenue})_{i,t} = \alpha_i + \beta_1 \Delta S_{t-1} + \beta_2 (\frac{\text{USD Corp debt}}{\text{GDP}})_{i,t-1} \Delta S_{t-1} + \beta_3 (\frac{\text{USD Corp debt}}{\text{GDP}})_{i,t-1} \delta_1 \text{GDP growth}_{i,t-1} + \delta_2 \text{FE}_t + \epsilon_{i,t}$$

(6)

where FE$_t$ is the time fixed effect, and $\Delta S_t$ is the percentage change of bilateral local currency per USD exchange rate. The data frequency is annual.

The trade and financial channels of exchange rates posit that if trade-related exchange rates depreciate, this aids export expansion and therefore increases corporate profits. However, if the financial exchange rate depreciates, the financial burden of firms increases and leads to a reduction in corporate profits. In this regression, the unconditional change in the exchange rate could capture the trade channel, therefore, we expect a positive $\beta_1$. The exchange rate interaction with USD corporate debt to GDP captures the extent to which an increase in corporate USD debt changes the impact of the exchange rate to tax revenue. We hypothesize that a larger debt to GDP strengthens the financial channel, and thus expect a negative value of $\beta_2$.

Table 2 displays the regression estimates of eq (6), with the first two columns showing the year-on-year change of exchange rates on the RHS. To ease the concern about the endogeneity of exchange rates and tax revenue, in columns 3 and 4 we instrument the exchange rate change by exchange rate shocks that are identified through high frequency identification on the Federal Reserve FOMC meeting dates. The estimates of $\beta_1$ and $\beta_2$ have the expected signs. In all cases, the estimates of $\beta_2$ are significant and negative, and they show that the reduction of a country’s tax revenue caused by a depreciation of its currency is more dramatic when its corporate sector has high USD corporate debt. To interpret these estimates, a coefficient of -0.033 indicates that if the corporate USD debt to GDP is 10% and the local currency depreciates by 1%, then the corporate tax revenue is changed by $10 \times 1 \times (-0.033) = -0.33\%$ on average.

In summary, emerging market sovereigns rely heavily on tax revenue, especially corporate tax revenue, as a source of income. The tax revenue fluctuates with exchange rates, and a local currency depreciation lowers tax revenue especially when the corporate sector has high FC debt. The

---

27Emerging countries tend to have a higher share of corporate income tax than advanced economies. For example, Mexico and Chile are characterized by the OECD as “substantially higher revenues from taxes on corporate income & gains.”

28Rather than looking at FC corporate debt as in the earlier section, we focus on USD corporate debt so that the relevant exchange rate is simply the bilateral dollar-local currency exchange rate. To the extent that USD is the dominant currency in financing, which is what we observed in the data, $\frac{\text{USD Corp debt}}{\text{GDP}}$ and $\frac{\text{FC Corp debt}}{\text{GDP}}$ capture very similar variations. Moreover, we can instrument the exchange rate change by external US shocks that are identified through high-frequency identification.

29The high frequency identified shocks look at the one-day US-local currency exchange rate change during the FOMC meeting dates. This is known in the macroeconomics literature as the FOMC shocks. See for example, Kuttner (2001) and Gertler and Karadi (2015).

30As a reference, the mean change for Korea is 6% and for Brazil is 12%. Summary statistics are provided in Appendix A3.
connections between sovereign and corporations through tax revenue will serve as the main linkage in the model.

Table 2: Regression of tax revenue change on corporate debt and exchange rates (eq (6))

<table>
<thead>
<tr>
<th></th>
<th>YoY change of measures of tax revenue</th>
<th>YoY change of measures of tax revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OLS: change of exchange rates</td>
<td>IV: change of exchange rates instrumented by FOMC shocks</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>(\Delta S_{t-1})</td>
<td>0.416*</td>
<td>0.186**</td>
</tr>
<tr>
<td></td>
<td>(0.224)</td>
<td>(0.076)</td>
</tr>
<tr>
<td>(\left(\frac{\text{USD Corp debt}}{\text{GDP}}\right)<em>{i,t-1} \times \Delta S</em>{t-1})</td>
<td>-0.033**</td>
<td>-0.018***</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>(\frac{\text{USD Corp debt}}{\text{GDP}})_{i,t-1}</td>
<td>0.249</td>
<td>-0.079</td>
</tr>
<tr>
<td></td>
<td>(0.359)</td>
<td>(0.174)</td>
</tr>
<tr>
<td>GDP growth</td>
<td>1.073***</td>
<td>0.311**</td>
</tr>
<tr>
<td></td>
<td>(0.303)</td>
<td>(0.105)</td>
</tr>
<tr>
<td>Observations</td>
<td>199</td>
<td>218</td>
</tr>
<tr>
<td>(R^2) adjusted</td>
<td>0.27</td>
<td>0.48</td>
</tr>
<tr>
<td>Countries</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Country/Time FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes: The dependent variable of Column (1) and (3) is the year-on-year change of corporate tax revenue. The dependent variable of Column (2) and (4) is year-on-year change of total tax revenue. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust (Driscoll and Kraay (1998)) standard errors with a 3-year lag.* p<0.1, ** p<0.05, *** p<0.01.

3 An endogenous sovereign default model with a corporate sector

In this section, we build a small open economy sovereign default model with a corporate sector and risk-averse foreign lenders. We use this model to explain the empirical evidence we find in the baseline regression that FC corporate debt has a significant effect on the sovereign risk premium but an insignificant effect on the sovereign default premium. We first lay out the infinite-horizon dynamic stochastic model, then we reformulate it into a recursive model and define the equilibrium.

3.1 A infinite-horizon dynamic stochastic model

3.1.1 Environment:

Time is discrete and indexed by \(t \in \{0, 1, \ldots\}\). There are three types of agent. Two types of agents live indefinitely in the small open economy: entrepreneurs, who represent the corporate sector in the data, and a sovereign. The last agent type consists of foreign lenders who live outside the small open economy.
**Exogenous processes.** The small open economy experiences three persistent exogenous processes: productivity \((z_t)\), government default disutility cost \((V_t)\), and exchange rate \((S_t)\). The government default disutility cost is a utility cost that the sovereign bears when defaults occur.\(^{31}\)

The productivity process follows:

\[
\log(z_t) = \mu_z + \rho_z \log(z_{t-1}) + \epsilon_{z,t},
\]

with \(|\rho_z| < 1\) and \(\epsilon_{z,t} \sim N(0, \sigma_z^2)\).

The shock to default cost serves as a shock that drives sovereign default that is independent from the rest of the world condition. The default disutility cost process follows:

\[
V_t = \mu_V + \rho_V V_{t-1} + \epsilon_{V,t},
\]

with \(|\rho_V| < 1\) and \(\epsilon_{V,t} \sim N(0, \sigma_V^2)\).

The exchange rate changes the effective borrowing cost of corporate and sovereign debt, and is related to the conditions of the rest of the world. The exchange rate \((S_t)\) is defined as local currency per foreign currency (peso per dollar). An increase in \((S_t)\) represents a depreciation of the local currency. The exchange rate process follows:\(^{32}\)

\[
\log(S_t) = \mu_S + \rho_S \log(S_{t-1}) + \epsilon_{S,t},
\]

with \(|\rho_S| < 1\) and \(\epsilon_{S,t} \sim N(0, \sigma_S^2)\).

**Entrepreneur sector:**

**Preferences.** A unit continuum of representative risk-averse entrepreneurs, each indexed by \(i\), live in the small open economy.\(^{33}\) The entrepreneurs value present discounted consumption goods \((c)\) and government spending \((G)\). They have the following preference:

\[
U_t = E_t \sum_{j=t}^{\infty} \beta^{j-t} u(c_j, G_j), \tag{7}
\]

where \(\beta\) is the discount factor. The utility function \(u : \mathbb{R}_+ \to \mathbb{R}\) is strictly increasing and strictly concave.

**Production Technology.** The entrepreneurs are endowed with production technology that pro-

---

\(^{31}\)See below on the discussion of modeling default cost.

\(^{32}\)In the model, we take the domestic final goods as the numeraire. We denote the price of the final goods in local currency as \(P_t\); the price of the final goods in foreign currency is \(P_t^*\). If law of one price holds, then \(S_t P_t^* = P_t = 1\). Therefore \(S_t = \frac{1}{P_t^*}\), which is reasonable to assume to be exogenous to the small open economy.

\(^{33}\)When stating the entrepreneur problem, the \(i\) subscript is suppressed when it is not necessary.
duces final goods \((y_t)\) with capital \((k_t)\). The production technology is:
\[
y_t = z_t k_t^{\alpha_t}
\]

**Budget constraint.** The entrepreneur has access to a one-period FC external bond market and can accumulate capital. They face the following budget constraint:
\[
c_t + k_{t+1} \leq (1 - \tau)[z_t k_t^{\alpha_t} - (\Delta S_t) b_t] - S_t b_t + S_t q_t b_{t+1} + (1 - \delta) k_t
\]  
(8)

Here \(b_t\) denotes the amount of corporate bond in foreign currency maturing at time \(t\); \(\tau\) is a constant tax rate; \(\Delta S_t = \log(S_t) - \log(S_{t-1})\); \(\delta\) is the capital depreciation rate; and \(q_t\) is the corporate bond price in foreign currency. The entrepreneurs spend their income on consumption \((c_t)\), capital accumulation \((k_{t+1})\), and repayment of debt \((b_t\), on the RHS). The tax structure, which is consistent with accounting standards, taxes production revenue (1st term in the square brackets) minus exchange rate gains and losses (2nd term). The sources of income for entrepreneurs are the after-tax profit earned this period (the term in square brackets), bond proceeds from new bond issuance \((S_t q_t b_{t+1})\), and undepreciated capital \(((1 - \delta) k_t)\). The budget constraint converts all terms to local currency. The numeraire is the final goods.

**Default.** As the major focus of the paper is sovereign default, we model the default of the entrepreneur in a simple way.\(^{35}\) We assume a utility cost of default \((\epsilon)\) which follows an iid across time logistic distribution with a mean of \(\mu_\epsilon\) and a scale of \(\sigma_\epsilon\).\(^{36}\) Each period, after the shocks and production, the entrepreneur chooses either to repay their debt or default on it. If he/she chooses to default on the debt, they walk away from all debts with zero recovery \((b_t = 0)\) and tax obligation, and suffer the cost of default \((\epsilon)\). The period budget constraint in the default state is:
\[
c_t + k_{t+1} \leq z_t k_t^{\alpha_t} + S_t q_t b_{t+1} + (1 - \delta) k_t
\]  
(9)

**Sovereign sector:**

**Preferences.** The sovereign is benevolent, so it has the same preference as the entrepreneurs:
\[
U_t = E_t \sum_{j=t}^\infty \beta^{j-t} u(c_j, G_j),
\]  
(10)

---

\(^{34}\)Optimal taxation in sovereign default model is an interesting research question but is not the focus of this paper. The constant tax rate parsimoniously captures the fact that tax rate is usually not able to be changed quickly for institutional and political reasons.\(^{35}\) Entrepreneur default is not necessary for the tax revenue channel, which is the main mechanism in the model, to operate. The possibility of entrepreneur default allows the model to have two realistic features: corporate debt is defaultable and sovereign spreads and corporate spreads are positively correlated. See Bevilaqua et al. (2019) and Kaas et al. (2016) for recent evidence on the positive correlation.

\(^{36}\)This cost is commonly used in the discrete choice econometrics literature (McFadden (1973)) and recently used in sovereign default literature. For example, see Arellano et al. (2018). One could think of this as a non-monetary effort cost the entrepreneurs incur to abscond from the debt.
**Budget constraint.** The sovereign has access to a one-period FC external bond market. When the sovereign is not in the default state, the sovereign is subject to the following period-by-period budget constraint:

\[ G_t + S_t B_t \leq TR_t + S_t Q_t B_{t+1} + L \]  

(11)

Here \( B_t \) denotes the amount of sovereign bond in foreign currency maturing at time \( t \). The sovereign finances government spending \((G_t)\) and bond repayment \((S_t B_t)\) with tax revenue \((TR_t)\), new bond issuance \((S_t Q_t B_{t+1})\), and a constant endowment \( L \). The constant endowment is meant to capture the part of sovereign resources in the data that are not contributed to by corporate activities.

**Tax revenue.** The tax revenue formulation is important for understanding the spillover from corporate to sovereign. Total tax revenue is an aggregation across all entrepreneurs:

\[ TR_t \equiv \tau \left[ \int_0^1 (1 - d_{i,t})(z_{t,k_{i,t}^{\alpha}} - \Delta S_{t,b_{i,t}})d\bar{i} \right] = \tau(1 - \bar{d}_t)(z_{t,k_{t}^{\alpha}} - \Delta S_{t,b_{t}}) \]  

(12)

where \( k_t \) and \( b_t \) denote aggregate capital and corporate debt in the economy, which are independent from individual entrepreneur \( i \)'s actions. When each individual entrepreneur chooses capital and bond to maximize their lifetime utility, they do not take into account their individual effect on total tax revenue. Therefore, individual entrepreneurs do not account for their effect on the sovereign provision of government spending and sovereign debt prices.

**Default.** When the government defaults, we assume it does so on all the debt obligations. This standard assumption in the literature is consistent with the historical behavior of defaulting governments. As in most previous studies, we also assume zero recovery of the debt in default. We follow Arellano et al. (2017) in modeling the cost of default. Each period, after the shocks, the sovereign chooses to repay or default on the debt. In the period that the sovereign chooses to default, it suffers a one-time disutility cost \((V_t)\), which is stochastic and known at time \( t \) before the default decision is made. The cost \((V_t)\) can be thought of as a cost derived from a change of government office, reputation, sanctions, etc. The time variation of this cost can be understood as the change in the enforcement commitment of the government. Modeling default cost in this way, rather than through income/productivity loss, allows for the possibility that default could happen in good as well as bad productivity states. The default utility cost approach also facilitates analytical discussion in the next section and computation in the quantitative section. A few recent sovereign default papers introduce this approach to modeling sovereign default cost, including Aguiar and

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37 As standard in the literature, the discount rate \((\beta)\) in the small open economy is assumed to be lower than the risk free rate. Therefore the sovereign always want to borrow to front-load \( G_t \). Borrowing is used also for smoothing \( G_t \) across periods.

38 Mathematically, from a private point of view, \( \frac{\partial c_{k_{t+1}}}{\partial c_{b_{t+1}}} = \frac{\partial c_{b_{t+1}}}{\partial c_{b_{t+1}}} = 0 \).

39 Sovereigns do not only default in bad times. Tomz and Wright (2007) document that there are one-third of the sovereign defaults happen when the country’s GDP is above the trend.
Amador (2013), Arellano et al. (2017), Arellano et al. (2018), and Bianchi et al. (2018). The period budget constraint in the default state is:

$$G_t \leq TR_t + S_t Q_t B_{t+1} + L$$  \hspace{1cm} (13)

**Foreign lenders pricing:**

Risk-averse foreign lenders provide funding to both the sovereign and entrepreneurs. They price both sovereign and corporate bonds competitively according to their stochastic discount factor ($m_t, t+1$ or SDF). Since investors are outside of the small open economy, we need to specify the lenders’ pricing behavior. We adopt a reduced form approach as in Arellano and Ramanarayanan (2012) and Bianchi et al. (2018) to specify the SDF. While Arellano and Ramanarayanan (2012) and Bianchi et al. (2018) assume the shock to the income of the small open economy is included in the SDF formulation, we assume the shock to the exchange rate is included instead:

$$m_{t,t+1} = e^{(-r + \gamma \varepsilon S_{t+1} - 0.5 \gamma^2 \sigma^2_S)}$$  \hspace{1cm} (14)

Here $\varepsilon_S$ is the shock to the exchange rate, and $\sigma^2_S$ is the variance of exchange rate shocks. $\gamma \geq 0$ is the market price of risk, a parameter that governs the size of the risk premium. The reduced form SDF says the investors value payoffs more when the foreign currency appreciates.

Sovereign and corporate bond prices must satisfy the following asset pricing conditions:

$$q_t = E_t [m_{t,t+1}(1 - d_{t+1})]$$  \hspace{1cm} (15)

$$Q_t = E_t [m_{t,t+1}(1 - D_{t+1})]$$  \hspace{1cm} (16)

where $d_t$ and $D_t$ are the entrepreneur default and sovereign default indicator respectively. These indicators are equal to one if defaults happen and zero otherwise.

**Discussion of model assumptions:**

Before moving forward, we discuss three assumptions we have made in the model.

First, we assume that both entrepreneurs and the sovereign borrow solely in foreign currency. The assumption that no borrowing in local currency is mainly for computational reasons, as it results in one less dimension to consider. Otherwise, we need to keep track of two state variables. This assumption is reasonable for the corporate sector, as almost all external corporate debt

---

40 In their formulation, $m_{t,t+1} = e^{(-r - \kappa \varepsilon_t - 0.5 \kappa^2 \sigma^2_t)}$, where $\kappa$ is the time-varying price of risk, $\varepsilon_{t+1}$ is the shock to endowment and $\sigma^2_t$ is the variance of the endowment shock.

41 $\gamma$ is a parameter that captures both the risk aversion of investor and the correlation of SDF and exchange rate shock. For example, even if investors are risk averse but the correlation is zero, then $\gamma$ will be zero.

42 See the discussion below on the assumption of this particular relationship. See also Appendix A6 for the empirical support.
is denominated in FC for emerging countries. Our focus on the spillover from corporates to the sovereign controls for the level of the sovereign debt and the currency mix, as was done in the baseline regression. Therefore, the mechanism should work independently of the sovereign currency composition.

Second, we assume that the exchange rate and lender SDF are correlated such that the lender SDF is high when FC appreciates. In many small open economy models with a risk-averse investor, the rest of the world variables, such as lender SDF, are exogenous. Therefore, we need to make assumptions on how these exogenous variables behave. We assume the lender SDF is linked to the exchange rate of the small open economy rather than being directly linked to the endowment process of the small open economy. The particular correlation in mind could be generated from some banking/asset manager constraints such as the Value-at-Risk constraint in Bruno and Shin (2017) or the abscond constraint in Morelli et al. (2019). Caballero et al. (2016), Maggiori (2017) think of this as a safety property of reserve currency: a currency that appreciates in bad times (i.e., high lender SDF).

Maggiori (2013) provides empirical evidence for this relationship \( \text{cov}(m_{t+1}, \Delta S_{t+1}) > 0 \) for USD against a basket of currency, and terms this relationship the “USD Safety Premium.” In Appendix A6, we document the positive USD Safety Premium for each of our sample currencies.

Third, we assume sovereign default has no effect on the entrepreneur sector besides the disutility cost. We make this assumption mainly for emphasizing the spillover from entrepreneur to sovereign, but it also helps improve the tractability of the model. We emphasize the spillover from entrepreneur to sovereign, as the private sector does not take account into its aggregate effect. On the other hand, a benevolent sovereign internalizes its spillover to private sector, if there is any.

### 3.1.2 Recursive problem and equilibrium

We now describe the recursive optimization problems of the sovereign and entrepreneurs, and define the equilibrium. As is standard in the sovereign default literature, we focus on Markov perfect equilibrium. That is, we assume that in each period the agents’ decisions depend only on payoff-relevant state variables.

At the beginning of each period, the four exogenous shocks \((z, \epsilon, S, V)\) are realized. We also need \(S_{-1}\) for tax revenue accounting. We condense the exogenous shock notation to \(X \equiv (z, \epsilon, S_{-1}, S, V)\). Given these variables, the entrepreneurs repay their debt, pay taxes, and choose how much to consume, invest, and borrow. Simultaneously, the sovereign chooses its default decision on the

---

43 The is true across time. See the Appendix in Du and Schreger (2017) for the data evidence.
44 Engel and Park (2018), Ottonello and Perez (2018), and Du et al. (2016) provide more analysis on optimal sovereign debt currency composition.
45 A notable exception is Lizarazo (2013), which directly models the foreign investor portfolio problem.
46 This correlation is consistent with many views in the exchange rate determination literature such as disaster risk (Burnside et al. (2011), Farhi and Gabaix (2016)), countercyclical risk compensation (Lustig et al. (2014)), liquidity motive (Engel and Wu (2018), Jiang et al. (2018)), and big country size of the lender country (Hassan (2013)).
47 Two simple extensions of this model with sovereign default has an effect on TFP or entrepreneur cost of default will complete the feedback loop.
existing debt, issuance amount of the new debt, and the amount of government spending to provide.

**Recursive entrepreneur problem:**

We denote the option value of default for the entrepreneur as \( W^E(k,b;X) \) and the value of repaying for the entrepreneur as \( U^E(k,b,d;X) \). \( d \) is a default indicator and is equal to one if entrepreneur defaults and zero otherwise. Given exogenous state variables \((z,s,s_{-1})\), endogenous state variables \((k,b,d)\), and bond price schedule \( q(k',b',X) \), the entrepreneur solves the following problems each period:

\[
W^E(k,b;X) = \max_{d \in \{0,1\}} \{(1-d)U^E(k,b,0;X) + (d)[U^E(k,0,1;X) - c]\} \\
U^E(k,b,d;X) = \max_{c>0,k'\geq 0,b'} u(c,G) + \beta E_{X'}W^E(k',b';X')
\]

subject to

\[c + k' \leq [1 - \tau(1-d)][zk^\alpha - (\Delta S)\delta b] - Sb + Sq(k',b',X)b' + (1 - \delta)k\]

**Recursive sovereign problem:**

We denote the option value of default for the government as \( W^G(B,k,b,d;X) \) and the value of repaying for the government as \( V^G(B,k,b,d;X) \). Given exogenous state variables \((z,e,s_{-1},s,v)\), endogenous state variables \((B,k,b,d)\), bond price schedule \( Q(B',k',b';X) \), and tax revenue schedule \( TR(k,b,d;X) \), the sovereign solves the following problems each period:

\[
W^G(B,k,b,d;X) = \max_{D \in \{0,1\}} \{(1-D)V^G(B,k,b,d;X) + (D)[V^G(0,k,b,d;X) - V]\} ,
\]

where \( D \) is a default indicator and is equal to one if default occurs and zero otherwise.

The value of repaying of the government, \( V^G \), is given by:

\[
V^G(B,k,b,d;X) = \max_{G>0,b'} \{u(c,G) + \beta E_{X'}W^G(k',b';X')\} ,
\]

subject to

\[G + SB \leq TR(k,b,d;X) + SQ(B',k',b',X)B' + L.\]

where \( TR(k,b,d;X) = (1-d)\tau[zk^\alpha - \Delta S\delta] \).

**Foreign lenders’ bond price schedule:**

The equilibrium bond prices are consistent with lender asset pricing conditions:

\[
q(k',b';X) = E [m'(s')(1-d'(k',b';X'))] \tag{21}
\]

\[
Q(B',k',b';X) = E [m'(s')(1-D'(B',k',b';X'))] \tag{22}
\]
Recursive equilibrium definition

The recursive Markov equilibrium consists of two main blocks: the sovereign block and the entrepreneur block.

The entrepreneur block consists of policy functions for entrepreneur default, $d(k,b;d,X)$, capital accumulation, $k'(k,b,d;X)$, corporate borrowing, $b'(k,b,d;X)$, entrepreneur consumption, $c(k,b,d;X)$, value functions $W^E(k,b;X)$, $U^E(k,b,d;X)$, and bond price schedule $q(k',b';X)$. The policy and value functions solve the entrepreneur problem in eq (17, 18) and the bond price satisfies pricing equation (21). These policy functions result in a tax revenue function $TR(k,b,d;X)$ for the sovereign block.

The sovereign block has policy functions for default, $D(B,k,b,d;X)$, sovereign borrowing, $B'(B,k,b,d;X)$, provision of government goods $G(B,k,b,d;X)$, value function $W^G(B,k,b,d;X)$ and $V^G(B,k,b,d;X)$, and bond price schedule $Q(B',k',b';X)$. The policy and value functions solve the sovereign’s problem in eq (19, 20), and the bond price satisfies pricing equation (22).

In the model, we can think of the spread between the sovereign bond and risk-free bond as $Q_{\text{RiskFree}} - Q$. We can directly decompose the sovereign spread into the default premium and risk premium:

\[
Q_{\text{RiskFree}} - Q = E[m'] - E[m'(1-D')]
\]
\[
= E[m'] - E[m']E(1-D') - \text{cov}(m',1-D')
\]
\[
= E(m' | D') + \text{cov}(m',1-D') \equiv Q^{DP}
\]
\[
= Q^{RP} \equiv \text{default premium + risk premium}
\]

4 Quantitative Analysis

In this section, we first discuss the calibration strategy in subsection 4.1.\textsuperscript{48} We calibrate the model to target the pre-2008 moments. In subsection 4.2, we present some graphs from the policy function that illustrate the model mechanism. We evaluate the model performance in subsection 4.3 by comparing the untargeted model simulated moments with an unexpected reduction in the risk-free rate, which mimics the low world risk-free rate environment in the post-2008 period.

4.1 Calibration

We calibrate the model to Mexico, a standard emerging country in the sovereign default literature, using a model frequency of one year. We calibrate the model to target pre-2008 moments. The pre-2008 period is associated with a high risk-free interest rate of 2.5% (which is the 2003-2008 average of the real 5-year US Treasury rate).

**Functional form.** We assume a constant relative risk aversion (CRRA) utility function in which

\textsuperscript{48} The model is solved by value function iteration. Details of the numerical computation are described in Appendix A7.
the entrepreneurs derive utility from consumption goods and government goods separately. The period utility function is:

\[ u(c, G) = \frac{(c)^{1-\sigma} - 1}{1 - \sigma} + \frac{(G)^{1-\sigma} - 1}{1 - \sigma} \]

where \( \sigma \) is the coefficient of risk aversion.

### Table 3: Calibration

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Description</th>
<th>Values</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \tau )</td>
<td>Corporate tax rate</td>
<td>28%</td>
<td>Mexico data</td>
</tr>
<tr>
<td>( \rho_Z )</td>
<td>Persistence of TFP shock</td>
<td>0.93</td>
<td>AR(1), Mexico data</td>
</tr>
<tr>
<td>( \sigma_Z )</td>
<td>s.d. of TFP shock</td>
<td>0.02</td>
<td>AR(1), Mexico data</td>
</tr>
<tr>
<td>( \rho_S )</td>
<td>Persistence of exchange rate shock</td>
<td>0.95</td>
<td>AR(1), Mexico data</td>
</tr>
<tr>
<td>( \sigma_S )</td>
<td>s.d. of exchange rate shock</td>
<td>0.06</td>
<td>AR(1), Mexico data</td>
</tr>
<tr>
<td>( r )</td>
<td>Risk free rate</td>
<td>2.5%</td>
<td>2003-2007 5Y US Treasury average</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>Capital share</td>
<td>0.33</td>
<td>standard literature value</td>
</tr>
<tr>
<td>( \delta )</td>
<td>Capital depreciation</td>
<td>0.05</td>
<td>standard literature value</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>CRRA coefficient</td>
<td>2</td>
<td>standard literature value</td>
</tr>
<tr>
<td>( \beta )</td>
<td>Discount factor of the SOE</td>
<td>0.95</td>
<td>standard literature value</td>
</tr>
<tr>
<td>( \rho_V )</td>
<td>Persistence of sovereign default cost</td>
<td>0.5</td>
<td>Arellano et al. (2017)</td>
</tr>
<tr>
<td>( \mu_e )</td>
<td>Mean entrepreneur default cost</td>
<td>1.3</td>
<td>mean FC corporate debt to GDP (7.6%)</td>
</tr>
<tr>
<td>( \sigma_e )</td>
<td>Scale of logistic distribution</td>
<td>0.22</td>
<td>mean corporate default probability (1.8%)</td>
</tr>
<tr>
<td>( \mu_V )</td>
<td>Mean sovereign default cost</td>
<td>0.5</td>
<td>mean FC sovereign debt to GDP (4.2%)</td>
</tr>
<tr>
<td>( \sigma_V )</td>
<td>s.d. sovereign default cost</td>
<td>0.12</td>
<td>mean sovereign default premium (37bps)</td>
</tr>
<tr>
<td>( L )</td>
<td>Value of constant endowment</td>
<td>0.35</td>
<td>share of exchange rate sensitive fiscal revenue (60%)</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>Lender SDF parameter</td>
<td>41</td>
<td>mean sovereign risk premium (57bps)</td>
</tr>
</tbody>
</table>

**Parameter values.** We first choose a subset of parameters values that can be directly pinned down from the data or that have standard values from the literature. We then choose the second subset of parameter values so that model simulations match key aspects of the data. We estimate the TFP process using 1950-2014 data from Penn World Table where quadratic detrending is applied.\(^{49}\) This results in an estimation of \( \rho_Z \) of 0.93 and \( \sigma_Z \) of 0.02. We set the corporate tax rate to be 28%, as observed in Mexico. We estimate the exchange rate process using 2003Q1-2017Q4 data,\(^{50}\) which results in an estimate of \( \rho_S \) of 0.95 and \( \sigma_S \) of 0.06. We choose capital share \( (\alpha) \) to be 0.33 and capital depreciation rate \( (\delta) \) to be 0.05. The persistence of sovereign default disutility \( (\rho_V) \) is chosen to be 0.5, following Arellano et al. (2017).

---

\(^{49}\) We use a longer series than our empirical sample period, as we only have annual data for TFP.

\(^{50}\) The exchange rate we estimate is the nominal exchange rate divided by Mexico’s consumer price index, which reflects that the exchange rate is normalized by the final goods price in the model. The estimates are very close if we use Mexico’s tradable goods price index.
We choose the rest of the parameters by simulated method of moments, targeting six key pre-2008 moments of interest. These moments are 1) mean corporate default probability (1.8%), 2) mean corporate debt to GDP (7.6%), 3) mean sovereign default premium (37 bps), 4) mean sovereign risk premium (57 bps), 5) mean sovereign debt to GDP (4.2%), and 6) mean share of fiscal revenue that is exchange rate sensitive (60%). We choose six parameters \((\mu_e, \sigma_e, \mu_V, \sigma_V, L, \gamma)\) to match these six moments. Although the parameters are calibrated jointly, we can give a heuristic description of how the empirical moments inform specific parameters. First, the corporate default probability is useful for inferring the firm default cost \((\sigma_e)\). We infer \(\mu_e\) from the corporate debt to GDP ratio. The sovereign debt to GDP and sovereign default premium jointly gauge the parameter values of \(\mu_V\) and \(\sigma_V\). \(L\) is highly related to the equilibrium long run share of exchange rate sensitive fiscal revenue. Finally, we infer the risk premium parameter \(\gamma\) from the size of the sovereign risk premium. Table 3 reports the parameter values.

Table 4 reports long-run moments in the data versus those in the model simulations. The targeted moments section (Panel (A)) shows that the simulated data matches the calibration target well. The risk-free interest rate is 2.5% in this case. The mean output in this economy is 1.8.

<table>
<thead>
<tr>
<th></th>
<th>Panel (A)</th>
<th>Pre-2008 period</th>
<th>Targeted moments</th>
<th>Data (Mexico)</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corporate Sector</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>corporate FC debt to GDP</td>
<td>7.6%</td>
<td>7.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>corporate default rate*</td>
<td>1.8%</td>
<td>1.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sovereign Sector</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sovereign FC debt to GDP</td>
<td>4.2%</td>
<td>4.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sovereign default premium</td>
<td>37 basis points</td>
<td>37 basis points</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sovereign risk premium</td>
<td>57 basis points</td>
<td>56 basis points</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Panel (A) is simulated with the parameters reported in Table 3 (with 2.5% risk-free rate). Moments are computed by generating 600 simulation samples of 400 periods each and discarding the first 300 periods. Default and the year after default are excluded.

Due to the lack of country-specific data, we use the Latin America corporate default rate reported by M&G investments.

4.2 Model mechanism

We first examine how the sovereign bond price changes when entrepreneurs’ decisions change. Figure 4 demonstrates how the sovereign bond price varies with next period capital, \(k'\), holding all other variables constant. The figures are generated from the calibrated model. The calibration strategy is discussed below.

---

51 We conduct regressions of eq (6) for each subcomponent of tax revenue in Mexico. If the coefficient on the interaction term is significant, we count these as the exchange rate sensitive and as the data counterpart of the model tax revenue.

52 The figures are generated from the calibrated model. The calibration strategy is discussed below.
other variables, including sovereign debt, at a constant level. In the left panel, we plot the expected tax revenue against \( k' \). We see that as \( k' \) increases, the sovereign expects to obtain more tax revenue. This is because the expected future production increases. As we show in the middle panel, this increase in expected tax revenue is associated with a decrease in the sovereign default probability because the sovereign is more likely to repay with a higher tax revenue. Finally, in the right panel, we see that as \( k' \) increases, the sovereign bond price increases and eventually reaches the risk-free rate region. Overall, the increase in \( k' \) increases expected tax revenue, which supports sovereign bond repayment, lowers the sovereign default probability, and thus supports the sovereign bond price.

![Figure 4: Effect of a change in next period capital \( k' \)](image)

Notes: The figures plot the expected tax revenue, sovereign default probability, and sovereign bond price as next period capital \( k' \) varies. The state variables are held at their mean level and the other choice variables are held at their simulated mean level.

Figure 5 displays how the sovereign bond price varies with bond issuance, \( b' \). Recall that the tax revenue is \( \tau[z^{\alpha} - \Delta Sb] \). Because the exogenous variables are held at the mean level in this illustration, \( E(\Delta S) = 0 \), an increase in \( b' \) does not change the expected tax revenue in the next period. However, a change in \( b' \) still has an effect on sovereign bond price. In the left panel, we plot the variance of tax revenue against \( b' \). Since the exchange rate is stochastic, an increase in \( b' \) increases the volatility of tax revenue next period. As we show in the middle panel, an increase in \( b' \) leads to an increase in the sovereign default probability. This is because the increase in volatility increases the probability of getting very low tax revenues in the next period (greater left tail risk), and therefore leads to a higher default probability. In the right panel, the increase in the volatility of...
tax revenue and sovereign default probability translate to lower sovereign bond price as $b'$ increases.

Figure 5: Effect of a change in bond issuance $b'$

![Graph showing the effect of bond issuance on variance of tax revenue, sovereign default probability, and sovereign bond price.]

Notes: The figures plot the variance of tax revenue, sovereign default probability, and sovereign bond price as bond issuance $b'$ varies. The state variables are held at their mean level and the other choice variables are held at their simulated mean level.

Besides its effect on the default probability, an increase in $b'$ also has an effect on the risk premium. Figure 6 shows how the sovereign bond risk premium varies with $b'$. The left panel plots the covariance of tax revenue and the SDF against $b'$. The covariance becomes more negative as $b'$ increases. Since the debt is denominated in FC, a FC appreciation reduces the profit of the entrepreneur, which leads to lower tax revenues. The higher $b'$ amplifies the tax revenue contraction for the same unit of FC appreciation. SDF increases when FC appreciates, therefore the covariance of the SDF and tax revenue becomes more negative. This affects the sovereign risk premium as tax revenues shrink more and default is more likely at the states when foreign lenders have a high valuation on cash-flow. The higher $b'$ increases the sovereign risk premium.

**Iso-default probability**

The set of figures above show the two entrepreneur decisions individually and their relationship to the sovereign bond price. In Figure 7, we plot a contour map (iso-default probability curve) of the sovereign default probability as $k'$ and $b'$ vary, holding the exogenous variables at their mean values. Each of the contour lines represents a set of ($k', b'$) pairs such that sovereign default probability is the same. The contour lines are upward sloping because the two variables have opposite effects on the sovereign bond price, as was shown above. An increase in bond issuance increases the sovereign default probability and an increase in next period capital decreases the sovereign default probability. When entrepreneurs increase their bond issuance, the sovereign default probability can
be maintained at the same level if they invest a sufficiently large amount of the bond proceeds to accumulate capital.

Figure 6: Relationship of sovereign risk premium and bond issuance $b'$

![Diagram](image)

Notes: The figures plot the covariance of tax revenue and stochastic discount factor ($m$), and sovereign risk premium as bond issuance $b'$ varies. The state variables are held at their mean level and the choice variables are held at their simulated mean level.

Figure 7: Iso-sovereign default probability contour when entrepreneur bond and capital varies

![Diagram](image)

Notes: The figures plot the iso-default probability curve for the sovereign when next period capital $k'$ and bond issuance $b'$ vary. The state variables are held at their mean level and the other choice variables are held at their simulated mean level.
Experiment: A reduction in the risk-free interest rate

In the model, both corporate bond issuance and capital are endogenous variables, and the optimal choices of both respond to shocks. The fact that the increase in FC corporate debt is a common phenomenon for many emerging countries suggests it is more plausible that there is a common shock that drives this behavior. Consistent with many empirical findings, we hypothesize a credit supply-side story in which a reduction of the world risk-free interest rate acts as the exogenous driver of the observed increase in FC corporate debt.\footnote{For example, the contemporaneous correlation between FC corporate debt to GDP and the 5-year US Treasury rate ranges from -0.42 to -0.67 for the countries we show in Figure 1. Papers by Alter and Elekdag (2017), Bruno and Shin (2017), and Bräuning and Ivashina (2019) provide empirical support that the low US interest rate is an important factor for the increase in both bonds and loans to emerging markets.} We examine how a change in the risk-free rate changes the optimal bond level and capital accumulation and therefore the sovereign bond price.

Figure 8 shows the conditional sovereign default probability, conditioning on the exchange rate in the next period (\(\log(S')\)) for two different interest rates (2.5% and 0.1%). Conditional on a particular exchange rate level next period,\footnote{Note that we are not assuming the sovereign knows the exchange rate next period. The exercise analyzes what would happen if the exchange rate happens to be at a particular point next period.} there is some probability of default for the sovereign because of the uncertainty about other stochastic variables such as TFP and sovereign cost of default next period. The figure in the upper panel plots the conditional sovereign default probability when the interest rate is high (2.5%). Given the state variables,\footnote{For this illustration, we hold exogenous variables at their mean. Endogenous state variables are held at the simulated mean. We also hold the sovereign debt level constant, just to focus on the effect of the entrepreneurs’ response.} the equilibrium decisions pin down the optimal capital accumulation and bond issuance (\(k'^*\) and \(b'^*\)), which deliver the shape of the conditional sovereign default probability line. The conditional sovereign default probability is upward sloping. The positive slope is due to a local currency depreciation increases the debt burden of the economy and reduces tax revenue, which causes a high marginal utility gain from default. In this case, repayment only happens if TFP or the cost of default are at higher levels. Therefore, the conditional default probability goes up as \(S'\) increases.

In the lower panel, we superimpose the conditional sovereign default probability line for high and low interest rate regimes. Upon a reduction in the risk-free interest rate, entrepreneurs take advantage of the cheap financing by increasing \(k'\) and \(b'\). We denote the optimal \(k'\) and \(b'\) at the low risk-free rate as \(k'^{**}\) and \(b'^{**}\), where \(k'^{**} > k'^{*}\) and \(b'^{**} > b'^{*}\). These optimal choices change the shape of the conditional sovereign default probability, which is the red line in the lower panel. We describe the changes in three steps. First, the increase in bond issuance (\(b'\)) makes the conditional probability line steeper, increasing default probability when the local currency depreciates (right-hand side of the figure) and decreasing the default probability when the local currency appreciates. Overall, this effect increases the default probability, as the utility curvature makes the loss from a local currency depreciation more painful than the gain from a local currency appreciation. This is the “exchange rate effect” of the corporate debt.

Second, because part of the increase in bond issuance is used to finance more next period capital
the additional capital pulls down the conditional sovereign default probability line for all \( S' \). This can be seen at the point when \( \log(S') = 0 \). As we hold the exchange rate at the mean level for this illustration (i.e. \( \log(S) = 0 \)), \( \log(S') = 0 \) means there is no exchange rate change next period and the corporate bond has no effect on the tax revenue. The conditional sovereign default probability at this point is below the one when the interest rate is high, indicating that the additional capital lowers the default probability. This is the “investment effect” of corporate debt. The exchange rate effect and investment effect counteract each other. Graphically, the low interest rate equilibrium (red line) has a larger conditional default probability on the right-hand side of the intersection point but a smaller conditional default probability on the left-hand side. Mathematically, denote \( P(D' = 1 | S') \) as the conditional sovereign default probability. The default probability is an unweighted integral of the area below the line: \( \int [P(D' = 1 | S')] dF(\log(S')) \). In this particular example, the unconditional sovereign default probability of the high interest rate case is 33 basis points, and is 32 basis points for the low interest rate case.\(^57\) The combination of the two effects leads to an insignificant change in sovereign default premium.

Third, in the low interest rate case, because of the higher debt level, the conditional sovereign default probability is tilted towards the region where the local currency depreciates. This means that sovereign default is more likely to happen when the foreign currency appreciates, which is the state when foreign lenders value the repayment more. This is the “state switching effect” of the corporate debt. The increase in corporate debt alters the region where sovereign default is more likely to happen, and it increases the likelihood of sovereign default in the state that the foreign lenders don’t prefer. It increases the risk premium that is charged to compensate for taking the risk. Mathematically, the risk premium is a SDF weighted integral of the conditional sovereign default probability: \( \int [m' - E(m')] P(D' = 1 | S') dF(\log(S')) \), where the foreign lenders put more weight on the region where the foreign currency appreciates. In this particular example, the risk premium goes up from 37 basis points to 54 basis points.

To summarize, when there is a reduction in the risk-free interest rate, the entrepreneurs’ optimal behavior increases corporate debt and capital accumulation, which has opposite effects on sovereign default probability. However, the increase in FC corporate debt causes the sovereign to default more often in the region in which foreign lenders value more the repayment (FC appreciates), leading to a higher premium.

\(^{57}\)The default premium is \( E(m') \{ \int [P(D' = 1 | S')] dF(\log(S')) \} \), which is the default probability weighted by a constant.
Notes: The figure shows sovereign default probability conditioning on \( \log(S') \). In this illustration, exogenous variables at their mean (e.g. \( \log(S) = 0 \)). Endogenous state variables are held at the simulated mean. Sovereign debt level is held constant to focus on the effect from entrepreneurs’ response.
**Predictions**

The model has two testable predictions. First, upon an exchange rate change, a country with a higher corporate FC debt to GDP has a larger change in default premium. Second, holding the debt level constant, an increase in capital stock or investment decreases default premium. Similarly, holding capital stock or investment constant, an increase in corporate debt is associated with an increase in default premium. We test these predictions by augmenting the baseline regression in eq (3) in two ways. First, we add exchange shocks identified through high frequency FOMC surprise and interact these exchange rate stocks with corporate FC debt to GDP. Second, we control for investment to GDP and capital stock to GDP. These predictions are verified and reported in Appendix A8.

4.3 Business cycle moments and model performance

In this subsection, we evaluate the model performance by giving the model an unexpected risk-free rate reduction. This reduction in interest rate mimics the low risk-free rate environment post-2008 and incentivizes the increase in FC corporate debt in the model. We then compare the untargeted post-2008 moments with the model moments generated from the low risk-free rate case.

In Table 5, we reproduce the long-run moments in Table 4 in Panel (A). Panel (B), reports the model simulated moments that are generated under the low-interest rate scenario (0.01%), showing that the model also mimics the post-crisis period well. First, the FC corporate debt to GDP ratio goes up to 11.4%, which is close to the post-crisis mean of 12.2%. There is a small change in the corporate default rate. This is consistent with some recent empirical findings that an increase in corporate leverage doesn’t generate a significant change in corporate default risk. Second, when we look at the moments of interest in the government sector, our model also predicts the untargeted post-2008 period well. This period features a small increase in sovereign FC debt to GDP and default premium, but a large increase in risk premium. Interestingly, in the simulated data, FC corporate debt increases 3.8% across the two regimes and the sovereign risk premium increases by 27 basis points. This gives an average effect of 1% change in corporate debt to 7 basis points change in sovereign risk premium, which is close to our panel regression results in Table 1 (5.2 and 5.9 basis points). Overall, given a reduction in the world interest rate, the model predicts both corporate and government sector moments of interest well.

---

58 This is consistent with Chang et al. (2017) who find that, with the world interest rate shock as the prime driving force, their calibrated model can account for the dynamics of growth in foreign debt in the emerging markets well.

59 For example, Salomao and Varela (2018) find that Hungarian firms which borrow more in FC do not exit the market more often. Alfaro et al. (2019) also find an insignificant relationship between corporate leverage and default risk, measured by Altman’s Z score.
Table 5: Model generated moments and data

<table>
<thead>
<tr>
<th>Panel (A)</th>
<th>Panel (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-2008 period</td>
<td>Post-2008 period</td>
</tr>
<tr>
<td>Targeted moments</td>
<td>Untargeted moments</td>
</tr>
<tr>
<td>Data (Mexico)</td>
<td>Model</td>
</tr>
<tr>
<td><strong>Corporate Sector</strong></td>
<td></td>
</tr>
<tr>
<td>corporate FC debt to GDP</td>
<td>7.6%</td>
</tr>
<tr>
<td>corporate default rate*</td>
<td>1.8%</td>
</tr>
<tr>
<td><strong>Sovereign Sector</strong></td>
<td></td>
</tr>
<tr>
<td>sovereign FC debt to GDP</td>
<td>4.2%</td>
</tr>
<tr>
<td>sovereign default premium</td>
<td>37 basis points</td>
</tr>
<tr>
<td>sovereign risk premium</td>
<td>57 basis points</td>
</tr>
</tbody>
</table>

Notes: Panel (A) is simulated with the parameters reported in Table 3 (with 2.5% risk-free rate). Panel (B) is simulated with the same set of parameters with the risk-free rate changed to 0.1%, matching the post-2008 average. Moments are computed by generating 600 simulation samples of 400 periods each and discarding the first 300 periods. Default and the year after default are excluded.

*Due to the lack of country-specific data, we use Latin America corporate default rate reported by M&G investments.

5 Social planner

This section focuses on the spillover from the entrepreneurs to the sovereign, which generates an externality to the sovereign and affects sovereign debt pricing. We discuss the key trade-off in 5.1 and the social planner solution in 5.2.

5.1 Trade-offs:

We analyze the effect of increasing FC corporate debt by investigating the Euler equation. For expositional purposes, we assume that the bond price schedule and value functions are differentiable and normalize $S = 1$. The first order condition of the entrepreneur debt decision is:

$$u_c'(c, G)[q + \frac{\partial q}{\partial b'}b'] = \beta E(u_c'(c', G')[S' - (\tau)\Delta S']|d' = 0)$$

(24)

The above Euler equation arises in typical default models as in Arellano (2008) and Arellano and Ramanarayanan (2012), except for the new term $[S' - (1 - \tau)\Delta S]$, which is equal to 1 in those models. Entrepreneurs face a trade-off between the marginal benefits (MB) today of having one additional unit of debt and the marginal costs from repaying the debt tomorrow. On the marginal benefit (MB) side, the trade-off takes into account the extensive margin cost of an extra unit of bond ($q$) and the intensive margin of an extra unit of bond affecting the price of the whole issuance ($\frac{\partial q}{\partial b'}b'$). On the marginal cost side, the trade-off takes into account that bond repayment is relevant only in the states where the entrepreneur repays. The new term $S' - (\tau)\Delta S'$ arises as exchange rate affect the entrepreneurs’ income. The constant tax rate serves as an automatic stabilizer, as the tax...
duty goes down when repayment is high.

Private decisions also influence the sovereign bond price schedule. From the social planner’s standpoint, the optimal trade-off takes into account the equilibrium effect that if everyone increases \( b' \) by \( \Delta b \), the aggregate corporate debt \( \bar{b}' \) also increases by \( \Delta b \). In other words, \( \partial \bar{b}' = \partial b' \). The first-order condition of choosing the debt level from the social standpoint is thus:

\[
\begin{align*}
\left. u'_c(c, G)[q + \frac{\partial q}{\partial b'}] + u'_G(c, G)[\frac{\partial \bar{b}'}{\partial b'} \frac{\partial Q}{\partial b'} B'] = \beta E \left( u'_c(c', G') \left[ S' - (\tau) \Delta S' \right] | d' = 0 \right) + \beta E \left( u'_G(c', G') \tau \Delta S' | d' = 0 \right) \right) = 0
\end{align*}
\]

(25)

The second term on the right-hand side represents an additional trade-off because an additional unit of corporate bond also translates into a bigger change in corporate tax revenue when the exchange rate fluctuates. Because this effect alters the future period resources of the sovereign, it changes the sovereign bond price in the current period, which is the second term on the left-hand side.

Figure 9 plots the trade-off numerically from the quantitative model. The private MB always slopes downward, as more debt lowers the price of the corporate bond.\(^{60}\) The private MC first slopes upward but later slopes downward when the private default probability increases far enough.\(^{61}\) We also take the term \( u'_G(c, G)[\frac{\partial \bar{b}'}{\partial b'} \frac{\partial Q}{\partial b'} B'] \) to the right-hand side of eq (25) to combine the private MC and public MC as the social MC. The social MC is always above the private MC, which means the public MC is positive. The entrepreneur always exerts a negative externality on the sovereign.

---

\(^{60}\)Private MB could be negative (not shown) when the debt reaches the right-hand side of the Laffer curve.

\(^{61}\)This is a common property of sovereign default models. See discussion in Kim and Zhang (2012).
5.2 Social planner solution

In this subsection, we analyze the social planner’s solution, which internalizes the externality from the corporate sector to the sovereign sector.

Specifically, we consider a constrained social planner’s solution where the social planner chooses both the entrepreneurs’ choice variables \((k', b')\) and the sovereign choice variable \((B')\).\(^{62}\) It is also subject to the same set of frictions and technology as in the decentralized solution. For example, the social planner cannot commit to repay, thus the bonds are still subject to default risk and the corporate tax rate is fixed.

Mathematically, the social planner problem is:

\[
V^S(B, k, b; X) = \max_{B', k', b'} \{u(c, G) + \beta E_{X'} U(k', b'; X')\},
\]

subject to

\[
G + (1 - D)SB \leq \tau [zk^\alpha - \Delta Sb] + SQ(B', k', b', X)B'
\]

\[
c + k' \leq (1 - \tau)[zk^\alpha - (\Delta S)b] - (1 - d)Sb + Sq(k', b', X)b' + (1 - \delta)k
\]

and default and pricing condition eq (17, 19, 21, 22) as in the decentralized equilibrium.

Table 6 compares the decentralized solution to the social planner’s solution. The decentralized solution is the same as the model prediction in Table 5. In Panel (A), the social planner’s solution has a lower FC corporate debt to GDP and a higher FC sovereign debt to GDP than the decentralized solution. The FC corporate debt to GDP is lower because the social planner internalizes the spillover from the corporate sector to the sovereign sector. This thus leads to a lower sovereign risk premium in equilibrium. The reduction in risk premium improves sovereign financing conditions, increasing the equilibrium FC sovereign debt to GDP.\(^{63}\) All these patterns hold true in the low-interest rate case (post-2008) as well. Compared to the decentralized equilibrium, the transition from a high- to low-interest rate in the social planner’s case has a smaller increment in FC corporate debt to GDP, a higher increment in FC sovereign debt to GDP, and a smaller increment in sovereign risk premium.

\(^{62}\)Another way to interpret this is that the sovereign in the decentralized problem also chooses the entrepreneurs’ variables on their behalf.

\(^{63}\)Conditional on the same amount of sovereign debt, the risk premium is reduced in the social planner solution. The higher FC sovereign debt actually increases the risk premium, but the simulated risk premium is still lower than the decentralized case.
Table 6: Model generated moments: decentralized and social planner solution.

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<th>Post-2008 period</th>
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<tr>
<td></td>
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<td>corporate default rate</td>
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<td>sovereign FC debt to GDP</td>
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<td>4.6%</td>
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<tr>
<td>sovereign default premium</td>
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<td>35 basis points</td>
</tr>
<tr>
<td>sovereign risk premium</td>
<td>56 basis points</td>
<td>49 basis points</td>
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</table>

Notes: Panel (A) is simulated with the parameters reported in Table 3 (with 2.5% risk-free rate). Panel (B) is simulated with the same set of parameters with the risk-free rate changed to 0.1%, matching the post-2008 average. Moments are computed by generating 600 simulation samples of 400 periods each and discarding the first 300 periods. Default and the year after default are excluded.

6 Conclusion

This paper investigates the spillover from corporate external debt to sovereign debt pricing. We argue that the recent surge in FC corporate debt in many emerging countries has an unintended consequence in increasing sovereign credit spread. In making this argument, we first show empirically that an increase in FC corporate debt has a significant positive association with a higher sovereign risk premium but no significant association with the sovereign default premium. The empirical findings pose a challenge to standard sovereign default models, which put more focus on risk-neutral foreign investors and an endowment economy setup.

To reconcile the empirical findings, we build a sovereign default model with a corporate sector and risk-averse foreign investor. We calibrate the model quantitatively to Mexico and find that it can replicate the targeted pre-2008 crisis moments and untargeted post-2008 moments well. The model’s main mechanism goes through corporate tax revenue to the sovereign. Entrepreneurs in the model borrow from abroad in FC and accumulate capital for production. The extra borrowing facilitates productive investment and production, which translates to lower sovereign default probability. The foreign currency nature of the corporate debt increases the exchange rate risk of profit and tax revenue, which translates to a higher sovereign default probability. These two opposite forces result in an insignificant effect on sovereign default premium (default probability). The increase in FC exposure, however, leads to profit reduction and makes it more likely for the sovereign to default when FC appreciates, which often coincides with bad times in foreign investor economy. This leads to a higher risk premium in sovereign debt pricing.

The paper provides counterfactual analysis by studying the social planner problem that internalizes the externality from corporate to sovereign debt pricing. The analysis finds excessive borrowing in FC corporate debt when compared to the decentralized economy. The social planner solution
has on average a 1.5 percentage point lower corporate debt to GDP, a 0.5 percentage point higher sovereign debt to GDP, and a 10 basis point lower sovereign risk premium. This calls for a policy intervention such as a Pigovian tax or capital control to reduce the external FC corporate debt level and implement the social planner allocation.
References


Kearns, J. and Patel, N. (2016). Does the financial channel of exchange rates offset the trade channel? BIS Quarterly Review.


Appendix

Appendix A1 Equivalence between CDS and sovereign bond

Figure 10: Cashflow chart of buying a CDS and shorting a sovereign bond with investing in risk free bond

Strategy 1, buying a CDS generates cashflow exactly the same as strategy 2, short selling a face value risky bond and buying a face value risk-free bond, regardless of repay or default. By no-arbitrage, $P=$(c2-c1), which says that the CDS premium is equal to the risky bond rate over the risk-free rate.

Appendix A2 Construction of variables

Construction of default premium and risk premium variables

In this appendix, we describe in detail the decomposition of CDS premia and construction of each variable. Theoretically, risk premium is the additional return required by a risk-averse investor (or a constrained investor) compared to a risk-neutral investor. In this paper, we adopt two well-defined methods from the finance literature to measure the risk premium. Both methods infer the default probability from CDS spreads. There are a few advantages in using CDS spreads rather than the actual bond yield. First, the CDS market are often more liquid than the underlying bond market of the emerging countries. Second, the CDS spreads are not directly subject to interest rate risk, while the underlying fixed-rate bonds are. Finally, CDS are available in constant maturities (standard 1, 3, 5, 10 year). Both estimation methods rely on the assumption that risk-neutral investors only ask for a return that compensate the expected default probability. However, they are different in terms...
of how to infer the expected default probability.

**Affine term structure decomposition.** The first method relies on the term structure of sovereign CDS spreads to infer the expected default probability. The method and notation we discuss here follow closely Longstaff et al. (2011). We will be relying on taking expectations over the risk-neutral measure (related variables are denoted with superscript $Q$) and over the objective process (related variables are denoted with superscript $P$). Theoretically, the CDS spread of a CDS contract at time $t$ with $M$-year maturity can be written as follows:

$$CDS_t(M) = \frac{2(1 - R^Q) \int_t^{t+M} D(t, u) E_t^Q [\lambda_u e^{-\int_u^t (\lambda_v)dv}] du}{\sum_{j=1}^{2M} D(t, t + j/2) [E_t^P e^{-\int_t^{t+j/2} \lambda_s ds}]},$$

where $R^Q$ is the constant recovery rate (risk-neutral fractional recovery of the bond if there is a credit event), $E^Q$ is the expectation under risk-neutral measure, $r_t$ is the risk-free rate, $\lambda_t$ denotes the risk-neutral arrival rate of a credit event, and $D(t, u)$ is the price of a default free zero coupon bond (issued at date $t$ and maturing at date $u$). Intuitively, the numerator is the present value of the contingent payment by the protection seller upon a credit event. The denominator is the present value of a $M$-year semiannual annuity, which is the “insurance premium” that is paid by the protection buyer upon a credit event not having occurred.

Under the objective process, we assume the arrival rate of a credit event follows a log normal process:

$$d\ln \lambda_t = \kappa^P (\theta^P - \ln \lambda_t) dt + \sigma^P dB_t^P.$$

Similarly, under the risk-neutral process, we assume:

$$d\ln \lambda_t = \kappa^Q (\theta^Q - \ln \lambda_t) dt + \sigma^Q dB_t^Q.$$

The two process are linked through the “market price of risk” in the following form:

$$\eta_t = \delta_0 + \delta_1 \ln \lambda_t$$

This governs the change of probability distribution from $P$ to $Q$. Specifically, the parameters are bridged by the following relationships: $\kappa^Q = \kappa^P + \delta_1 \sigma_\lambda$ and $\kappa^Q \theta^Q = \kappa^P \theta^P - \delta_0 \sigma_\lambda$. Therefore, when $\delta_0 = 0$ and $\delta_1 = 0$, there is no market price of risk and the two processes will be the same.

Analogously, we can compute the same CDS pricing with the expectation taking over the probability distribution $P$ implied by the objective process:

$$CDS_t^P(M) = \frac{2(1 - R^Q) \int_t^{t+M} D(t, u) E_t^P [\lambda_u e^{-\int_u^t (\lambda_v)dv}] du}{\sum_{j=1}^{2M} D(t, t + j/2) [E_t^P e^{-\int_t^{t+j/2} \lambda_s ds}]},$$

This term, $CDS_t^P(M)$, is the hypothetical CDS spreads that an investor would require when they compute expectation using the objective process. That is, this is the CDS spread that corresponds to
the physical default probability of the underlying asset, which is the default premium. To compute the risk premium, we take the difference between the market observed spread and the estimated hypothetical default premium. That is, $CDS_t(M) - CDS_t^P(M)$.

We estimate the $CDS_t^P(M)$ term by a maximum likelihood approach. We need to estimate $\kappa^Q$, $\kappa^P$, $\kappa^Q \theta^Q$, $\kappa^P \theta^P$ and $\sigma_\lambda$. $\delta_0$ and $\delta_1$ can be calculated through $\kappa^Q = \kappa^P + \delta_1 \sigma_\lambda$ and $\kappa^Q \theta^Q = \kappa^P \theta^P - \delta_0 \sigma_\lambda$. We make use of the term structure of CDS prices and the time series of the term structure to identify $\lambda_t$ and the parameters ($\kappa^Q$, $\kappa^P$, $\kappa^Q \theta^Q$, $\kappa^P \theta^P$, $\sigma_\lambda$). Specifically, we have a term structure of one-year, three-year and five year CDS contracts. We assume the three-year CDS contract is priced perfectly and one-year and five-year are priced with mean zero normally distributed errors with standard deviation $\sigma_\varepsilon(1)$ and $\sigma_\varepsilon(5)$ respectively. The three-year CDS spreads is then inverted to infer $\lambda_t$. The recovery rate is assumed to be 0.25.

Computationally, we use Longstaff et al. (2011) programming code to conduct the maximum likelihood estimation and the decomposition. The data input for the code is the one-year, three-year, five year CDS spreads and the zero-coupon discount rate.

Credit rating decomposition. The second method relies on credit ratings to infer the expected default probability. The method and notation we discuss here follow closely Remolona et al. (2008). Credit rating agencies assign ratings to sovereigns. At the same time, they publish regularly average sovereign cumulative default rates by rating for various investment horizons $T$ (denoted as $PD_t(T)$ for each time $t$). For example, in 2016, the 5-year default rate for a Moody’s A rated sovereign is 1.16%. Assuming a hazard rate, we compute a Rating Implied Expected Loss for investment horizon $T$ ($RIEL_t(T)$), which is defined as the recovery rate ($RR$) adjusted default intensity:

$$(1 - Pr_t(\text{default} < T) \times (1 - RR)) = (1 - PD_t(T) \times (1 - RR)) = e^{-T \times RIEL_t(T)}$$

Consistent with the assumption above, we assume a constant recovery rate of 25% throughout the exercise. For the example of observing a default rate of 1.16%, the formula above gives $(1 - 0.0116 \times (1 - 0.25)) = e^{-5 \times RIEL_t(5)} \Rightarrow RIEL_t(5) = 0.00175$. The $RIEL$ is then used as the default premium from credit rating decomposition, which is 17.5 basis points in this case. The risk premium is then computed as $CDS_t(T) - RIEL_t(T)$.

Throughout the exercise, we use Moody’s credit rating and default rates from Moody’s Investors Service reports to infer the $RIEL$. The reports are released annually (with some irregular semi-annual updates) and credit ratings can be changed in any given quarter. These give the time variation of the estimated $RIEL$. 
Construction of external debt by currency type by sector

We construct the FC corporate external debt, the FC sovereign external debt, and the LC sovereign external debt data in two ways and the results are robust to the construct method. First, we follow Du and Schreger (2017) cleaning procedure closely, which rely on BIS International Debt Statistics (IDS), Locational Banking Statistics (LBS) and commercial data source. Second, BIS provide more transparent data than before so we also construct the data based on BIS data only with some mild assumptions.

**Du and Schreger procedure.** The procedure in brief is as follows:

1. Obtain country aggregate outstanding bond and cross-border loan data from the BIS
2. Obtain transaction level bond and loan data from Bloomberg (Du and Schreger (2017) use Thomson One instead)
3. Identify the external loans and bonds in transaction level
   - (3a) A loan deal is counted as external if at least one bookrunner of the deal is a foreign bank
   - (3b) All bond issuances in international market are counted towards external debt
4. Aggregate the Bloomberg data to country-level aggregate
5. Split the aggregate level bond and loan data in (1) by the share by each sector (public, private) and by each currency from the aggregated Bloomberg data
6. Obtain the sovereign debt held by foreign lenders in domestic market by national data source and Arslanalp and Tsuda (2014)
7. Combine bond and loan values to construct the external debt variables

The aggregated Bloomberg data covers on average 80% of the BIS numbers. The BIS statistics take into account of adjustments such as additional offerings and buying back debts before maturity. It also combines information from a few other commercial databases so the aggregate numbers are more accurate. Therefore, splitting the BIS numbers with disaggregated data from Bloomberg gives a good measure of the share of debt by sector and by currency.

**Using BIS data only.** BIS actively improves the transparency of IDS and LBS. The recent version has more sectoral and currency split information. We construct the variables as follows.

For IDS:

1a) IDS provides international bond amount denominated in USD and EUR; We count these debts towards FC
1b) We count the debt from "Central bank," "General government," "Public banks," and "Public other financial institutions" as public debt. The rest are counted as private debt.

For LBS:

2a) LBS provides loan amount denominated in USD, EUR, GBP, JPY, and CHF; We count these loans towards FC
2b) LBS provides sectoral split by financial and non-financial breakdown, but not sovereign and corporate breakdown. We count all loans toward the private sector, which is consistent with the
confidential version of LBS that the loan to public sector is negligible.\(^{64}\)

(3) We obtain the sovereign debt held by foreign lenders in domestic market by national data source and Arslanalp and Tsuda (2014).

(4) We combine bond and loan values to construct the external debt variables

\(^{64}\)BIS starts to report more detailed sectoral breakdown since 2013 but the detailed breakdown is restricted for central banks access only.
## Appendix A3 Summary statistics

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Appendix A4 Robustness of baseline regression

We run regression (2, 3, 4) with additional country-specific controls to show the key findings are robust across specifications.

\[
\text{Sovereign CDS}_{i,t} = \alpha_i + \beta_1 \left( \frac{\text{FC Corp debt}}{\text{GDP}} \right)_{i,t-1} + \beta_2 \left( \frac{\text{FC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \beta_3 \left( \frac{\text{LC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \beta_4 \text{CC}_{j,t-1} + \mu_{Gt} + \epsilon_{i,t}
\]

\[
\text{Sovereign CDS}_{i,t}^{\text{Default premium}} = \eta_i + \gamma_1 \left( \frac{\text{FC Corp debt}}{\text{GDP}} \right)_{i,t-1} + \gamma_2 \left( \frac{\text{FC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \gamma_3 \left( \frac{\text{LC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \gamma_4 \text{CC}_{j,t-1} + \omega_{Gt} + \nu_{i,t}
\]

\[
\text{Sovereign CDS}_{i,t}^{\text{Risk premium}} = \chi_i + \delta_1 \left( \frac{\text{FC Corp debt}}{\text{GDP}} \right)_{i,t-1} + \delta_2 \left( \frac{\text{FC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \delta_3 \left( \frac{\text{LC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \delta_4 \text{CC}_{j,t-1} + \theta_{Gt} + u_{i,t}
\]

where the three additional controls, CC_4, CC_5, CC_6 are year-on-year GDP growth, reserve to GDP and trade balance to GDP.

Appendix Table 1: Panel regression with components of USD sovereign CDS as dependent variables, robustness check

<table>
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<th>USD sovereign CDS premium (bps)</th>
<th>USD sovereign CDS default premium (bps)</th>
<th>USD sovereign CDS risk premium (bps)</th>
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<tr>
<td>(%) (1) (2a) (2b) (3a) (3b)</td>
<td>Term Rating Observations R^2 adjusted Period Countries Global Controls Country FE</td>
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<tr>
<td>(5.606*** 0.454 -0.274 5.152*** 5.881***)</td>
<td>(0.938) (0.303) (0.237) (0.785) (0.965)</td>
<td>(11.078*** 2.486*** 2.258*** 8.592*** 8.820***)</td>
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</table>

Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay (1998)) with a 4-quarter lag. * p<0.1, ** p<0.05, *** p<0.01. All the spread measure of the independent variables are 5-year tenor. Decomposition in column (2a) and column (3a) uses affine term structure model by Longstaff et al. (2011). Decomposition in column (2a) and column (3a) applies credit rating method by Remolona et al. (2008).
Appendix A5 Scatterplot for a representative event date

We plot the unconditional relationship of FC corporate debt to GDP against a three-day change in sovereign CDS over the Brexit referendum on June 23rd, 2016 (one day before and two days after). On this date, the VIX index increased by 50%. The CDS spreads increase by an average of 10 basis points with the country with more FC corporate debt to GDP tending to have a larger increase. We think of the dramatic increase in VIX as a proxy of an increase in investor risk appetite and investors evaluate the riskiness of a country by looking at the FC corporate debt to GDP as a pricing factor.

Figure 2: Positive relationship of change of sovereign CDS and FC corporate debt to GDP on Brexit referendum day

Appendix A6 USD Safety Premium

In this section, we provide empirical evidence that USD, the major FC in our sample emerging countries debt profile, appreciates when lender SDF is high, supporting the relationship assumed in the model section. We follow the approach developed by Maggiori (2013) to document this “USD Safety Premium” for each of our sample country.

Consider a two country world: a EM country (home) and the US (foreign). We denote the foreign variable with *. By no-arbitrage condition, there exist two SDF, one for each country, such that:

\[ 1 = E_t[M_{t+1}R_{t+1}] \]

\[ 1 = E_t[M^*_tR^*_t] \]
where $\Lambda_{t+1}$ is the home SDF and $R_{t+1}$ is the home asset return. Exchange rate $S_t$ is denoted as home currency per USD.

If assets are traded internationally and no arbitrage condition holds. Then there exist two SDFs such that:

$$M_{t+1} = M_{t+1}^* \frac{S_t}{S_{t+1}}$$

Assuming the variables are all jointly log-normally distributed, then the expected excess return of US investment converted to home currency and home investment is:

$$0 = E_t M_{t+1}^* (R_{t+1}^* - R_{t+1} \frac{S_t}{S_{t+1}})$$

$$E_t (r_{t+1}^* - \Delta S_{t+1} - r_{t+1}) + \frac{1}{2} \text{var}_t (r_{t+1}^*) - \frac{1}{2} \text{var}_t (\Delta S_{t+1} + r_{t+1}) = -\text{cov}_t (m_{t+1}^*, r_{t+1}^*) - \text{cov}_t (m_{t+1}^*, \Delta S_{t+1}) + \text{cov}_t (m_{t+1}^*, r_{t+1})$$

In the case when $r_{t+1}$ and $r_{t+1}^*$ are risk free rates that are known at time $t$, we have:

$$r_{t+1} - r_{t+1}^* + E_t (\Delta S_{t+1}) + \frac{1}{2} \text{var}_t (\Delta S_{t+1}) = \text{cov}_t (m_{t+1}^*, \Delta S_{t+1}) \equiv SP_t.$$  

The USD is safe if it appreciates in bad times. Those scenarios are characterized by high marginal utility growth (i.e., a high SDF case). Therefore, a positive $\text{cov}_t (m_{t+1}^*, \Delta S_{t+1})$ is evidence of the safety property of USD. Maggiori (2013) documents a positive $\text{cov}_t (m_{t+1}^*, \Delta S_{t+1})$ both conditionally and unconditionally for the US against a basket of rest of the world countries. In this paper, $\text{cov}_t (m_{t+1}^*, \Delta S_{t+1}) > 0$ will be consistent with our reduced form SDF with a positive $\gamma$.

We estimate the USD safety premium ($SP_t$) in two ways. First, we document an ex-ante $SP_t$. Second, following an approach developed in Maggiori (2013), we compute an ex-post $\tilde{SP}_t$ with a two-stage estimation, based on the realized value. We use the data at quarterly frequency with one-year investment horizon. Following Du et al. (2018) and Engel and Wu (2018), the (one-year) interest rate swap rates are treated as the risk free rate. We obtain the one-year exchange rate expectation from survey forecast from Bloomberg. The sample period is 2001Q2-2017Q4 where the starting date is constrained by the availability of exchange rate forecast data.

For the ex ante $SP_t$, notice that if we want to show $SP_t > 0$, it is sufficient to show that $DUIP_t \equiv r_{t+1} - r_{t+1}^* + E_t (\Delta S_{t+1}) > 0$ because $\frac{1}{2} \text{var}_t (\Delta S_{t+1})$ is always positive by the definition of variance. Therefore, without estimating the conditional variance of exchange rate, we provide evidence of an ex-ante UIP deviation that biased towards an excess return if investing in home currency.

---

65 Home and US agents agree on the prices of all assets that they can trade. Under complete markets, the span of assets covers the entire state space so that agents agree on all possible prices. Under this condition, the SDF of each country is unique and obeys the relationship. However, if markets are not complete agents need only agree on the prices of assets that can actually be traded. For each country there exists an infinite set of valid SDFs. The relationship does not need to hold between any two arbitrary SDFs. However, the equation can be considered a denition for SDFs in one country given a choice of SDF in the other country. To simplify the exposition, we assume here that markets are complete.

66 We take the median forecast as the expectation.
Table 7 below reports the mean value of the term $DUIP_t \equiv r_{t+1} - r^*_{t+1} + E_t(\Delta s_{t+1})$ where the home country is one of the sample countries and the foreign country is the US. We can see that all countries exhibit a UIP deviation that is biased toward an excess return of investing in EM countries. The simple cross-country average is around 0.038 (3.8%). This provides evidence that there is a positive USD safety premium.

<table>
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<tr>
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<th>Country</th>
<th>mean $DUIP_t$</th>
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<td>NA</td>
<td>Russia</td>
<td>0.061</td>
</tr>
<tr>
<td>Hungary</td>
<td>0.010</td>
<td>South Africa</td>
<td>0.026</td>
</tr>
<tr>
<td>India</td>
<td>0.074</td>
<td>Thailand</td>
<td>0.018</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.072</td>
<td>Turkey</td>
<td>0.073</td>
</tr>
<tr>
<td>Korea</td>
<td>0.035</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For the ex-post $\tilde{SP}_t$, we follow one of the approaches by Maggiori (2013) with a two-stage estimation. Formally, define $\tilde{SP}_t \equiv r_{t+1} - r^*_{t+1} + \Delta s_{t+1} + \frac{1}{2} \bar{\text{var}}_t(\Delta s_{t+1})$, where $\Delta s_{t+1}$ is the observed ex-post realization. The term $\bar{\text{var}}_t(\Delta s_{t+1})$ is an estimate of the conditional variance from the following first stage regression using ex-post data:

$$\Delta s_{t+1} = \alpha_t Y_t^e + \epsilon_t^{e+1}$$

where $Y_t^e = [1, r^*_{t+1} - r_{t+1}, \Delta s_t]$.

The estimated residuals, $\hat{\epsilon}_t^{e+1}$, are used to compute $\bar{\text{var}}_t(\Delta s_{t+1}) = (\hat{\epsilon}_t^{e+1})^2$. Table 8 below reports the mean value of $\tilde{SP}_t$ where the home country is one of the sample countries and the foreign country is the US. Again we see that all countries exhibit a positive USD safety premium.

<table>
<thead>
<tr>
<th>Country</th>
<th>mean $\tilde{SP}_t$</th>
<th>Country</th>
<th>mean $\tilde{SP}_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>0.096</td>
<td>Malaysia</td>
<td>0.001</td>
</tr>
<tr>
<td>Chile</td>
<td>0.026</td>
<td>Mexico</td>
<td>0.006</td>
</tr>
<tr>
<td>China</td>
<td>0.004</td>
<td>Philippines</td>
<td>0.034</td>
</tr>
<tr>
<td>Colombia</td>
<td>0.025</td>
<td>Poland</td>
<td>0.041</td>
</tr>
<tr>
<td>Croatia</td>
<td>0.002</td>
<td>Russia</td>
<td>0.003</td>
</tr>
<tr>
<td>Hungary</td>
<td>0.053</td>
<td>South Africa</td>
<td>0.049</td>
</tr>
<tr>
<td>India</td>
<td>0.015</td>
<td>Thailand</td>
<td>0.016</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.044</td>
<td>Turkey</td>
<td>0.014</td>
</tr>
<tr>
<td>Korea</td>
<td>0.021</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[^{67}\text{See equation (11) of Maggiori (2013)}\]
To conclude, from both ex-ante and ex-post aspects, we find that there is a positive USD safety premium. This supports the reduced form relationship in the modeling section which assumes that the FC appreciates when lender’s SDF is high.

Appendix A7 Numerical Algorithm

Recursive equilibrium definition

To compute the model solution, we first discretize the shock processes \((z,S,V)\) and choice variables \((B,k,b)\). The three exogenous shocks are “tauchenize” to 11, 21 and 31 grid points respectively. The choice variables are discretized to 41 grid points each. We then solve the model by using a two loop algorithm for each of the two sector. For each sector, we first iterate the value function in an inner loop and iterate the bond price schedule in an outer loop. Convergence in each sector is defined as both value function difference and bond price difference are smaller their the tolerance level of \(1 \times 10^{-5}\). The algorithm is common in the literature but we extend it to a two sector setup.

The model is solved with the following algorithm:

1) Start with initial guesses for corporate bond price \(q_0(k',b';X)\) and enter \(U_0^E(k,b;X)\), we iterate until \(U^E(k,b;X)\) converges.

2) Once the value function \(U^E(k,b;X)\) converges, compute the default set by comparing \(U^E(k,b;X)\) to \(U^E(k,0;X) - \epsilon\)

3) Update the corporate bond price schedule using the default set according the pricing equation and the old bond price schedule with a \((0.5,0.5)\) weight.

4) Iterate step 1) to 3) until value function and bond price schedule converge.

5) Compute a tax revenue schedule for the sovereign from the converged entrepreneur policy function.

6) Given the tax revenue schedule, start with initial guesses for sovereign bond price \(Q_0(k',b';X)\) and enter \(W_0^G(k,b;X)\); We iterate until \(W^G(k,b;X)\) converges.

7) Once the value functions converge \(W^G(B,k,b;X)\), compute the default set by comparing \(W^G(B,k,b;X)\) to \(U^E(0,k,b;X) - V\)

8) Update the sovereign bond price schedule using the default set according the pricing equation and the old bond price schedule with a \((0.5,0.5)\) weight.

9) Iterate step 6) to 8) until value function and bond price schedule converge.
Appendix A8 Testable predictions

In this section, we verify two testable predictions from the model.

**Prediction 1.** Upon an exchange rate change, a country with a higher corporate FC debt to GDP has a larger change in default premium.

**Prediction 2.** Holding debt level constant, an increase in capital stock or investment decreases default premium. Similarly, holding capital stock or investment constant, an increase in corporate debt is associated with an increase in default premium.

We test these predictions by augmenting the baseline regression in eq (3) in two ways. First, we add exchange shocks identified through high frequency FOMC surprise and interact exchange rate shocks with corporate FC debt to GDP. Second, we control for investment to GDP and capital stock to GDP. We perform the following regressions:

\[
Sovereign CDS_{i,t}^{Default\ premium} = \alpha_i + \beta_1 \Delta S_{t-1} + \beta_2 \Delta S_{t-1} \left( \frac{\text{FC Corp debt}}{\text{GDP}} \right)_{i,t-1} + \beta_3 \left( \frac{\text{LC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \mu G_{it} + \epsilon_{i,t}
\]

\[
Sovereign CDS_{i,t}^{Default\ premium} = \eta_i + \gamma_1 \left( \frac{\text{Investment}}{\text{GDP}} \right)_{i,t-1} + \gamma_2 \left( \frac{\text{FC Corp debt}}{\text{GDP}} \right)_{i,t-1} + \gamma_3 \left( \frac{\text{FC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \omega G_{it} + \nu_{i,t}
\]

\[
Sovereign CDS_{i,t}^{Default\ premium} = \chi_i + \delta_1 \left( \frac{\text{Capital stock}}{\text{GDP}} \right)_{i,t-1} + \delta_2 \left( \frac{\text{FC Corp debt}}{\text{GDP}} \right)_{i,t-1} + \delta_3 \left( \frac{\text{LC Sovereign debt}}{\text{GDP}} \right)_{i,t-1} + \theta G_{it} + \upsilon_{i,t}
\]

To ease endogenity between default risk and exchange rate, we identified the exchange rate shock as LC per USD exchange rate change over one day window of FOMC meeting dates. Because, there are no capital stock data available in quarterly frequency, we use the cumulative sum of investment as a related series to interpolate the annual capital stock to quarterly frequency.

---

68 When multiple meetings occur in the same quarter, we aggregate the shock to quarter frequency, as in Gertler and Karadi (2015).
69 Cubic spline interpolation is applied.
Figure 12: Testing model predictions with modified baseline regression

<table>
<thead>
<tr>
<th>Term</th>
<th>Default premium</th>
<th>Default premium</th>
<th>Default premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta S_{t-1}$</td>
<td>-1.2643**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.6079)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta S_{t-1}(\frac{\text{FC Corp debt}}{\text{GDP}})_{i,t-1}$</td>
<td>0.0418*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0235)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$(\frac{\text{Investment}}{\text{GDP}})_{i,t-1}$</td>
<td></td>
<td>-1.5825**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.7618)</td>
<td></td>
</tr>
<tr>
<td>$(\frac{\text{Capital stock}}{\text{GDP}})_{i,t-1}$</td>
<td>-8.3391**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.4326)</td>
<td></td>
</tr>
<tr>
<td>FC Corp debt GDP</td>
<td>-0.0756</td>
<td>0.5562**</td>
<td>0.4418*</td>
</tr>
<tr>
<td></td>
<td>(0.2938)</td>
<td>(0.2560)</td>
<td>(0.2599)</td>
</tr>
<tr>
<td>FC Sovereign debt GDP</td>
<td>4.0306***</td>
<td>2.9119***</td>
<td>2.5224***</td>
</tr>
<tr>
<td></td>
<td>(0.6834)</td>
<td>(0.5685)</td>
<td>(0.4863)</td>
</tr>
<tr>
<td>LC Sovereign debt GDP</td>
<td>0.6981*</td>
<td>0.4059</td>
<td>0.6768</td>
</tr>
<tr>
<td></td>
<td>(0.3779)</td>
<td>(0.4035)</td>
<td>(0.4265)</td>
</tr>
</tbody>
</table>

Observations: 713 769 769
Period: 2004Q1-2016Q4
Countries: 17
Global Controls: Yes
Country FE: Yes

Notes: Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay (1998)) with a 4-quarter lag. * p<0.1, ** p<0.05, *** p<0.01.