Why Do Emerging Economies Borrow in Foreign Currency? The Role of Exchange Rate Risk*

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Abstract

Borrowing in foreign currency has historically induced a large currency mismatch on emerging economies' balance sheets, leading to financial instability and economic crises. Nonetheless, emerging market sovereigns still borrow a substantial amount in foreign currency. Moreover, we find empirically that emerging market sovereigns borrow even more in foreign currency when exchange rate volatility is higher, precisely when it is riskier for them to do so. This paper builds a quantitative sovereign default model with a risk-averse sovereign and risk-averse international investors, where the optimal currency composition of external sovereign borrowing is the outcome of a risk-sharing problem between the borrower and lenders. Emerging economies choose to bear exchange rate risk and borrow in foreign currency because international investors charge a high exchange rate risk premium on emerging market local currency debt. Moreover, the required premium on local currency debt is higher when exchange rate volatility increases, further dissuading emerging economies from borrowing in local currency. The estimated model with high risk aversion of lenders quantitatively matches well the foreign exchange risk premium, the relative borrowing cost in local currency over foreign currency, and the currency composition of external public debt. The model also performs well quantitatively in accounting for positive comovements between the foreign currency share of external public debt and exchange rate volatility, and the relative borrowing cost in local currency over foreign currency and exchange rate volatility. A counter-factual exercise shows that exchange rate stabilization results in a welfare gain to the emerging market sovereign of 0.35% measured in consumption equivalents.

JEL classification: F30, F31, F34

Keywords: Emerging Market Debt, Currency Composition, Foreign Exchange Risk Premium

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1 Introduction

"Emerging markets aren't out of woods yet. Original sin, then, may not have been vanquished after all. It may merely have shifted from borrowers to lenders."
– Agustin Carstens and Hyun Song Shin from the BIS (2019)

Historically, many emerging market governments were not able to borrow from abroad in their own currencies. Eichengreen and Hausmann (1999) described this pervasive phenomenon as "original sin", highlighting how incompleteness in financial markets confined these economies to borrowing externally only in foreign currency, mostly in dollars. Typically, assets of emerging economies were denominated in their own local currency, and consequently, dollar liabilities of emerging economies induced currency mismatch on their balance sheets. This currency mismatch was a source of financial instability when their local currencies depreciated, leading to subsequent economic crisis. The most notable example is the Asian Financial Crisis in the late 1990s, during which several emerging economies experienced a sudden and large depreciation of their domestic currencies precisely when their liabilities were highly dollarized. The risks associated with foreign currency borrowing have induced many researchers to urge that emerging economies lower their financial vulnerability by borrowing in their own currencies (Krugman, 1999; Jeanne and Zettelmeyer, 2002; Schneider and Tornell, 2004; and Aghion, Bacchetta, and Banerjee, 2004).

Over the last two decades, emerging economies have started borrowing in local currency, overcoming their "original sin".[1] Not only have domestic capital markets deepened, global investors have also started tapping into emerging market local currency denominated sovereign debt.[2] Nonetheless, on average, emerging market sovereigns still borrow substantially in foreign currency, exposing their balance sheet to exchange rate risk: the average foreign currency share of external public debt in 2004–2018 is around 80%.

In fact, emerging economies tilt their currency composition of external borrowing more towards foreign currency when exchange rate volatility increases. Figure 1 depicts the cross-sectional median of option-implied exchange rate volatility over a one-year horizon and the detrended foreign currency (FC) share of external public debt across 18 emerging economies.[3] Figure 1 shows a strong positive correlation between the foreign currency share of external public debt and exchange

[1]As will be discussed in details later when reviewing related literature, many papers have associated this trend with more disciplined monetary policy in emerging economies, for instance, Engel and Park (2021, forthcoming) and Ottonello and Perez (2019). A number of earlier works link the predominance of foreign currency borrowing in emerging market to the lack of monetary policy credibility (e.g. Jeanne (2005)).

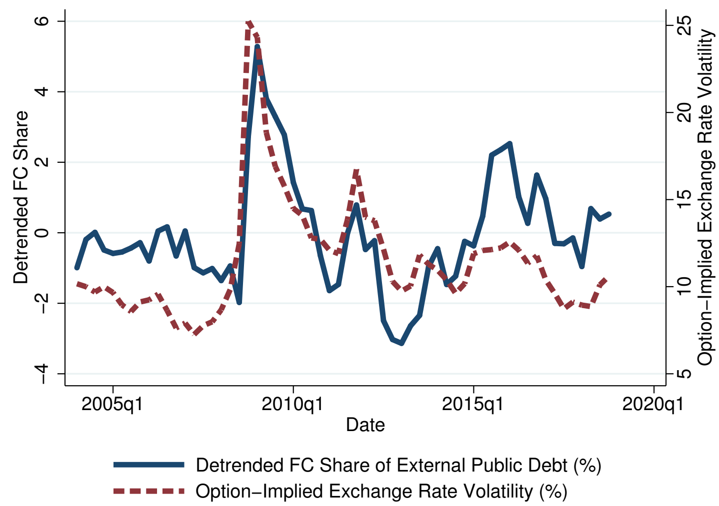
[2]This is a general trend across emerging markets documented by Du and Schreger (2016) and Arslanalp and Tsuda (2014).

[3]The foreign currency share is detrended using HP-filter but the positive correlation is robust to linear de-trending. Moreover, as shown in Figure A2, the valuation effect coming from exchange rate changes is not the driver of this positive comovement.

rate volatility. The correlation of the two series is 0.65. Emerging economies borrow *even more* in foreign currency when exchange rate volatility is higher, precisely the time when it is riskier for emerging market sovereigns to do so.[4]

Given that the currency denomination of sovereign debt is now a more relevant margin of debt management, why do emerging economies still borrow substantially in foreign currency? Moreover, why do they borrow even more in foreign currency when exchange rate volatility is higher, i.e., when it is riskier for them to do so? Lastly, how large is the welfare gain from stabilizing the exchange rate to an emerging economy, considering that exchange rate risk has to be borne either by the emerging economy or international lenders?

Figure 1: FC Share of External Public Debt and Exchange Rate Volatility



Notes: The source of the data is the author's calculations based on Bloomberg and Arslanalp and Tsuda (2014, updated 2020). The figure shows the cross-sectional medians across 18 emerging economies. The foreign currency share of external public debt is detrended using HP filter. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options.

This paper argues that international investors require a high exchange rate risk premium when they lend in emerging market local currency, discouraging emerging economies from borrowing in their own currency. Moreover, the exchange rate risk premium is especially high when the exchange rate is more volatile, as it exposes lenders' balance sheets to higher risk, which further shifts the currency composition away from local currency toward foreign currency.

For emerging economies, borrowing in foreign currency exposes their balance sheet to exchange rate risk, while, for international investors, lending in emerging market currency exposes their investment to exchange rate risk. When emerging economies borrow from abroad in foreign currency,

[4]The correlation is robust to using an alternative measure of exchange rate volatility, as shown in Figure A1.

they can enjoy a lower borrowing cost whilst exposing their balance sheet to exchange rate risk. On the other hand, when borrowing from abroad in local currency, emerging economies do not bear the exchange rate risk but face a higher interest rate due to the exchange rate risk premium charged by foreign investors as a compensation for their risk taking. The optimal currency composition is, therefore, the outcome of the optimal sharing of exchange rate risk between the sovereign and international lenders.

The core idea of this paper captures how an asset can be risky to one agent but not to the other as their preferences concern their consumption evaluated in different units. Rather surprisingly, this is not a common feature of open macroeconomic models as they assume there is either a single good in the economy or that purchasing power parity holds. Both assumptions cause the real exchange rate to be equal to a constant, and therefore, it does not matter in which currency agents evaluate their returns.[5]

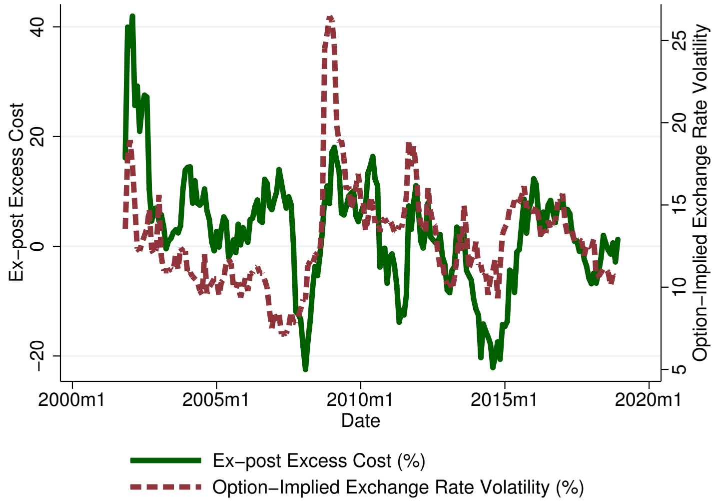
We show empirically that the relative cost of borrowing in local currency to that in foreign currency indeed rises as exchange rate volatility increases, supporting our key argument that lenders require a risk premium when lending in local currency as a compensation for the exchange rate risk. Figure 2 shows the time series of the cross-sectional median of the ex-post excess cost of borrowing in local currency over foreign currency and that of option-implied exchange rate volatility. The correlation between the two time-series is 0.4. Figure 2 illustrates how the relative cost of borrowing in local currency over foreign currency increases with higher exchange rate volatility.[6] When the exchange rate is more volatile, the risk that lenders need to bear when lending in emerging market local currency increases. Therefore, lenders require more compensation, which increases the exchange rate risk premium and subsequently the relative cost of borrowing in local currency over foreign currency. The very effect from the increase in the exchange rate risk premium on the borrowing cost in local currency is strong enough that emerging economies shift their portfolio away from local currency to foreign currency when their exchange rates are more volatile as we have seen in Figure 1.

To account for these newly documented empirical relationships, we introduce endogenous currency choice in debt issuance and risk-averse global investors to an otherwise standard quantitative sovereign default model (Eaton and Gersovitz, 1981; Aguiar and Gopinath, 2006; and Arellano, 2008). The model has three key components. First, a sovereign can issue defaultable debt in local and foreign currency and borrows externally. Second, foreign lenders are risk averse and can invest in risk-free US treasuries (denominated in foreign currency), emerging market debt denominated in local currency, and that in foreign currency. Lenders are risk averse and require compensation

[5]Nominal and real returns are the same in the model described in Section 3 as the aggregate price level is stable.

[6]Figure A3 shows that the positive correlation is present with an alternative measure of exchange rate volatility, the annualized standard deviation of past daily exchange rate returns over the past one year.

Figure 2: Ex-post Excess Cost of Borrowing in LC over FC and Exchange Rate Volatility



Notes: The excess cost of borrowing in local currency over foreign currency is defined as $y_{i,t}^{LC} - \left(y_{i,t}^{FC} + s_{i,t+12} - s_{i,t}\right)$ where $y_{i,t}^{LC}$, $y_{i,t}^{FC}$ and $s_{i,t}$ are the one-year local currency debt interest rate, the one-year foreign currency debt interest rate, and the log of the exchange rate – the local currency price of US dollar for a country i at monthly date t. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options.

for the risk that they take. Lastly, the sovereign is concerned about their consumption in local currency (in units of a local consumption basket with a stable aggregate price of a local consumption basket) while foreign lenders evaluate their returns in foreign currency (in units of a foreign consumption basket with a stable aggregate price of a foreign consumption basket). Thus, borrowing in foreign currency creates a currency mismatch on the sovereign's balance sheet, while lending in local currency creates a currency mismatch on lenders' balance sheets.

In the model, when exchange rate volatility increases, it is *riskier* for the emerging market sovereign to borrow in foreign currency. Debt repayment fluctuates more with exchange rate returns, exposing the emerging market sovereign to more risk. Moreover, the default probability for a given level of foreign currency debt increases. *Ceteris paribus*, the emerging market sovereign wants to borrow less in foreign currency and more in local currency. On the other side, it is *riskier* for foreign lenders to lend in emerging market local currency. The currency mismatch induced by lending in a local currency exposes lenders to exchange rate risk; higher exchange rate volatility exposes lenders' balance sheet to higher risk when lending in local currency. *Ceteris paribus*, foreign lenders want to lend less in local currency and more in foreign currency. The quantitative sizes of the two will determine the currency composition of external sovereign borrowing in equilibrium. In this paper, we show that the size of the risk aversion of lenders is a key determinant of the exchange rate risk premium, relative borrowing cost in local currency over foreign currency, and currency composition of emerging market external borrowing and its fluctuation with exchange rate volatility.

We calibrate our model to match four key moments of Colombia – a median emerging economy in our sample – from 2004–2008: (1) the average external public debt to GDP, (2) the average local currency bond interest rate spread, (3) the average foreign currency bond interest rate spread and (4) the standard deviation of foreign currency bond interest rate spread.[7] We calibrate to Colombia because it exhibits output and exchange rate processes similar to the median in our sample of 18 countries employed in the empirical section, and its mean foreign currency share of external borrowing in 2004–2018 is close to the median value across emerging economies in the same period. The model matches well the key targeted moments, and moreover, it matches well quantitatively the foreign currency share of external borrowing. When the model is calibrated to match the average interest rate spread of local currency and foreign currency debt, which results in a high level of risk aversion of international lenders, the average currency composition of external public debt from the model – an untargeted moment – is aligned with what we see in the data.[8]

Two experiments are conducted with the estimated model. First, we see how the model moments change when there is an unexpected increase in exchange rate volatility. The estimated model with high risk aversion of lenders performs well in accounting for an increase in the foreign currency share of external public debt and for a rise in the relative cost of borrowing in local currency over foreign currency, qualitatively and quantitatively close to what we see in the empirical analyses. Secondly, the welfare gain for the emerging economy from stabilizing the exchange rate is computed by shutting down the exchange rate volatility and setting it equal to zero. The welfare gain is sizable at 0.35% in units of consumption equivalents. The welfare cost of exchange rate volatility comes from direct and indirect effects. First, it is a direct consequence of the high foreign exchange rate risk premium charged by foreign lenders on emerging market local currency debt. Second, it is indirectly due to shifting their currency composition of external borrowing more to foreign currency, exposing emerging economies' balance sheets to more risk.

This paper highlights the role of currency mismatch on lenders' balance sheets in determining the currency composition of external borrowing. The policy recommendations are different from the past literature which focuses on the borrowers' lack of commitment in their monetary policy. This paper highlights the need to stabilize exchange rate volatility and to develop a strong domestic investor base.

Related Literature

This paper contributes to three strands of the literature in international macroeconomics. First,

[7] An interest rate spread refers to the difference between the real rate of Colombian government bonds and the US treasury real rate of one-year maturity. Since we compute the average spread with monthly data in 2004–2018, we use *realized* inflation to compute the real rates due to data limitations.

[8] The model also closely matches another untargeted moment: the standard deviation of the local currency spreads.

this paper is broadly related to the quantitative sovereign debt literature (for instance, Eaton and Gersovitz, 1981; Aguiar and Gopinath, 2006; and Arellano, 2008). Several papers in the literature have examined certain aspects of debt management such as its maturity composition and post-default renegotiation.[9] Most of these papers assume that emerging economies borrow in foreign currency and abstract away from optimal currency composition. Closely related to this paper, Broner, Lorenzoni, and Schmukler (2013) present a stylized two-period model to argue that maturity choice is an outcome of a risk-sharing problem between an emerging market sovereign and risk-averse international investors, where the sovereign borrows short-term as international investors charge high term-premia on the long-term bonds. While borrowing in short-term increases the probability of suffering a liquidity crisis, long-term debt is more expensive. Our optimal currency composition problem captures an analogous trade-off. In our paper, borrowing in foreign currency exposes emerging economies to exchange rate risk, but borrowing in local currency is more expensive due to the high exchange rate risk premium charged by risk-averse international investors.[10]

Secondly, this paper bridges two strands of literature in open macroeconomics: optimal currency composition of sovereign debt and the foreign exchange rate risk premium. This paper jointly explains the currency composition of external sovereign debt and the foreign exchange risk premium. Exploring the role of currency mismatch on lenders, this paper contributes to studies on the optimal currency composition of external sovereign debt. All the papers in the literature have focused on the lack of monetary policy commitment in emerging economies. Ottonello and Perez (2019) and Engel and Park (2021, forthcoming) study the joint determination of the currency denomination of sovereign defaultable debt and inflation when they borrow from risk-neutral foreign lenders.[11] They argue that the original sin dissipation is linked to the gain of monetary policy credibility in emerging economies.[12] These papers explain the currency composition of external sovereign borrowing but fall short of generating realistic interest rate spreads as they assume risk-neutral investors.[13] Moreover, the baseline models of Engel and Park (2021, forthcoming) and Ottonello and Perez (2019) would predict higher local currency share of sovereign debt if there were an exogenous increase in volatility of output; borrowing in local currency is more valuable

[9]For instance, Broner, Lorenzoni, and Schmukler (2013) and Aguiar, Amador, Hopenhayn, and Werning (2019) examine optimal maturity structure. Yue (2010) and Pitchford and Wright (2012) introduce post-default renegotiation to defaultable debt models, and Asonuma and Trebesch (2016) incorporate preemptive and post-default renegotiation.

[10]Relatedly, Salomao and Varela (2021) and Liao (2020) document how firms reap the benefit of issuing debt in lower-interest-rate currencies (such as US dollar) while it exposes their balance sheet to currency risk.

[11]The baseline model of Ottonello and Perez (2019) does not have a strategic default.

[12]In the early 2000s, many emerging economies adopted inflation targeting.

[13]With risk-neutral lenders, we need to see a substantial level of exchange rate depreciation on average to justify the interest rate spread. However, year-over-year real exchange rate returns (against US dollar) in 2004–2018 are small and positive, i.e. on average we see a small exchange rate *appreciation*.

for the sovereign as the hedging benefit of local currency debt is higher.[14] Their models would not capture the positive comovement between foreign currency share and exchange rate volatility. Also, focusing on the sovereign's monetary policy commitment, Du, Pflueger, and Schreger (2020) build a two-period model and argue that the degree of credibility in their monetary policy and risk-averse investors may help explain the cross-sectional correlation between the currency composition of debt and hedging benefits of local currency debt. As is standard in the literature, Du, Pflueger, and Schreger (2020) assume an exogenous stochastic discount factor of lenders, correlated with the sovereign's income shock.[15]

We are the first to introduce risk-averse lenders and lenders' portfolio choices between risk-free foreign currency assets (US treasuries), and emerging market government debt denominated in both foreign currency and in local currency.[16] The key feature of the paper is that the riskiness of assets depends on the unit in which one's consumption is evaluated, which is not captured by many macro models due to their assumptions that imply a constant real exchange rate. The optimal currency composition is the outcome of a risk-sharing problem between a risk-averse emerging market sovereign and risk-averse foreign lenders.[17]

This paper contributes to a vast literature on the foreign exchange rate risk premium which explains the failures of uncovered interest rate parity, the expected excess return on foreign assets over domestic assets. Earlier papers include Solnik (1974), Kouri (1976), and Stulz (1981). Many of the theoretical papers are devoted to explaining the Fama (1984) puzzle, which documents a positive correlation between the expected excess return and the interest rate differential.[18] Most closely related to our paper are recent developments in the literature focusing on risk-averse investors and habitat or noise traders whose supply of assets is exogenous, i.e., not driven by the risk and return profiles of assets. These studies include Koijen and Yogo (2020), Gourinchas, Ray, and Vayanos (2021), Greenwood, Hanson, Stein, and Sunderam (2020) and Itskhoki and Mukhin (2021a,b). In contrast, our paper, the foreign exchange risk premium is determined in equilibrium where both risk-averse foreign lenders and the risk-averse borrower make their optimal portfolio choices between emerging market debt denominated in different currencies.

Empirically, it is closely related to recent papers focusing on the global risk sentiment in accounting for the foreign exchange risk premium. They document a positive co-movement between

[14]The stochastic process of output or tradable goods is the only stochastic process in their models.

[15]There is no default risk in the model.

[16]To our knowledge, Lizarazo (2013) is the only paper in the sovereign debt literature that feature risk-averse lenders and their portfolio choice problems. Lizarazo (2013) does not have emerging market debt denominated in different currencies.

[17]Our paper also captures the hedging benefit of local currency debt exogenously where the model features a negative correlation between exchange rate and output stochastic processes, i.e. the emerging market currency depreciates when output is low.

[18]Empirical papers in this literature employ the realized exchange rates measuring the UIP condition, relying on the assumption of rational expectations and full information. Engel (1996, 2014) surveys empirical and theoretical models.

the deviation from the uncovered interest parity (UIP) and global risk perception measure, VIX (for instance, Di Giovanni, Kalemli-Özcan, Ulu, and Baskaya, 2017 and Kalemli-Özcan and Varela, 2021). This paper focuses on a country-level risk measure, exchange rate volatility, the quantity of risk that investors bear when investing in local currency.[19]

Lastly, this paper provides a rationale why emerging economies have “fear of floating" their exchange rates, pioneered by Calvo and Reinhart (2002). Many of papers have focused on “original sin" as a source of fear of floating their exchange rates, where they analyze empirically and explore theoretically the negative balance sheet effect of foreign currency liabilities (Krugman, 1999; Céspedes, Chang, and Velasco, 2004; and Kim, Tesar, and Zhang, 2015). We show that even when emerging market sovereigns can optimally choose their currency composition of external borrowing, exchange rate volatility incurs a high welfare cost to emerging economies. A sizable welfare cost of exchange rate volatility may explain why many countries would like to stabilize their currency relative to the hard currency, such as the US dollar, as documented by Ilzetzki, Reinhart, and Rogoff (2019). Hassan, Mertens, and Zhang (2021) builds a theoretical model, where countries want to stabilize its exchange rate relative to a hard currency, which appreciates in investors' bad times, rationalizing the emergence of an anchor currency.

Organization. The paper is organized as follows. In Section 2, we discuss the data and two key empirical findings. Section 3 describes the model. Section 4 presents the key quantitative results that corroborate empirical relationships and the welfare cost of having currency mismatch. Section 5 concludes.

2 Empirical Evidence

In this section, we present two new empirical relationships between (i) the currency composition of external sovereign debt and exchange rate volatility, and (ii) the cost of borrowing in its local currency (LC) relative to that in foreign currency (FC) and exchange rate volatility. We first investigate how the share of their external public debt in foreign currency fluctuates with exchange rate volatility. We show that emerging economies borrow more in foreign currency when their exchange rates are more volatile. When borrowing in foreign currency exposes emerging economies to greater risk, governments actually borrow more in foreign currency and less in their own currency. We rationalize the empirical pattern with a strong positive co-movement between the excess cost of borrowing in local currency over foreign currency and exchange rate volatility. International investors require higher compensation when lending in emerging market local currency as exchange rate volatility increases. When exchange rate volatility increases, the local-currency debt becomes

[19] In Section 2, we show that a positive co-movement between the relative cost of borrowing in local currency over foreign currency and exchange rate volatility is still present when we control for time fixed effects or VIX.

too expensive for emerging economies and discourages them from borrowing its own currency.

Subsection 2.1 describes the data that we employ for the empirical analyses. Subsection 2.2 presents the two main empirical findings.

2.1 Description of Data

The key variable of interest is the share of foreign currency debt in total external sovereign debt. We employ the quarterly data of 2004Q1–2018Q4 from Arslanalp and Tsuda (2014, updated 2020). The stock of debt is at book value, and hence it is not affected by the changes in the market prices of bonds. Our sample includes 18 countries, which are a subset of the 24 countries in Arslanalp and Tsuda (2014, updated 2020). Among those 24 countries, we exclude Latvia and Lithuania since their euro-denominated debt is included as foreign currency even after they adopt the euro during our sample period. We also drop Egypt as its data only contain treasury bills. Uruguay is excluded in the sample as the information on local currency denominated debt held by foreign investors is missing. Argentina and Ukraine are excluded as their data on local currency interest rates are not available. Therefore, the 18 countries in our sample are: Brazil, Bulgaria, Chile, China, Colombia, Hungary, India, Indonesia, Malaysia, Mexico, Peru, Philippines, Poland, Romania, Russia, South Africa, Thailand and Turkey.[20]

To measure the cost of borrowing in local currency for each emerging market sovereign, we use one-year zero-coupon local currency yields y_{it}^{LC}, where most of which are the estimates from the Bloomberg Fair Value Curve. The data are from Du and Schreger (2016) and Bloomberg.[21] For the cost of borrowing in foreign currency (FC), we use one-year sovereign US dollar-denominated CDS spreads and the US one-year treasury rates to construct one-year zero-coupon FC yields y_{it}^{FC}, following Du, Pflueger, and Schreger (2020). Both CDS spreads and treasury rates are from Bloomberg. We measure the cost of borrowing in foreign currency as:

$$y_{it}^{FC} = CDS_{\$,it} + y_{it}^{US}$$

Two measures of exchange rate volatility are used: option-implied exchange rate volatility from money market options and the annualized standard deviation of daily exchange rate returns over the past 12 months (from now on, option-implied exchange rate volatility and realized exchange

[20] All the countries are inflation targeting except Bulgaria, Romani and China. Bulgaria and Romania are committed to joining the euro area and so we did not drop them in the sample. Excluding China in the sample does not change any of the results qualitatively.

[21] In the dataset of Du and Schreger (2016), only the spread between the LC yield and the US treasury rate of the same maturity is included. Therefore, we add back the US treasury rates to recover local currency yields. The US treasury rates are from Bloomberg. For Bulgaria and Romania, local currency government bond yields are not in the dataset of Du and Schreger (2016), and so they are fetched from Bloomberg.

rate volatility, respectively).[22] Following Bruno and Shin (2017), we employ the option-implied exchange rate volatility, derived from one-year at-the-money exchange rate options. Exchange rate volatility computed from exchange rate options is useful not only because it is available at high frequency but also since it is forward-looking. It captures market participants' expectations of exchange rate volatility for one year from the date that the price is quoted. The option-implied exchange rate volatility is computed under the assumption of risk-neutral investors. The fluctuations in option-implied exchange rate volatility may contain information about changes in the market sentiments. For robustness, we also use realized exchange rate volatility, measured using the annualized standard deviation of exchange rate returns over the past year.

The key control variable is expected depreciation. The survey data from Consensus Economics are used to compute the expected depreciation.[23] Since a higher second moment of exchange rates may be accompanied by exchange rate depreciation, the effect of first moment changes of exchange rates are controlled for in the empirical analyses. We argue that the empirical patterns are not the result of a spurious correlation between the expected exchange rate depreciation and the variables of our interest. A number of other macro variables are included in the regressions: year-over-year inflation, year-over-year real GDP growth, private credit to GDP, external public debt to GDP, capital openness and default probability.[24] The data are from the IMF IFS dataset, FRED, World Bank WDI dataset, Chinn and Ito (2006), and Standard and Poor's.

The empirical analysis with the foreign currency share of external sovereign debt is conducted at a quarterly frequency due to data availability. The analysis with the relative cost of borrowing in local currency over foreign currency is done at a monthly frequency but the finding does not depend on whether we use monthly or quarterly data. The sample period is from 2004 to 2018.

2.2 Currency Composition and Borrowing Costs in Emerging Economies

We first look at how the cyclical component of the share of external sovereign debt in foreign currency is correlated with exchange rate volatility.[25] The foreign currency share of external sovereign debt is,

$$\lambda_{FC} = \frac{S_{it}F_{it}}{D_{it} + S_{it}F_{it}},$$

[22] We use the exchange rate against the dollar when computing exchange rate volatility.

[23] The data are proprietary and can be purchased through FX4casts: https://fx4casts.com/

[24] We use the maximum of credit ratings of local currency and foreign currency bonds at a given point of time period when those two ratings are different. The mapping from rating to default probability is from the rating reports from Standard and Poor's. Even when ratings are the same, default probability may change when credit rating agencies' estimates of default probabilities for the same credit rating changes.

[25] In the last decade, the ability to borrow in their own currency has improved, a general trend across emerging economies. Many papers in the literature argue that the "original sin dissipation" is associated with the gain of monetary policy credibility across emerging economies. Therefore, we take out the trend and focus on the cyclical component of the currency composition of external public debt.

where λ_{FC} is the foreign currency share of external public debt, S_{it} is the domestic price of a dollar, F_{it} is the total stock of external public debt denominated in foreign currency, and D_{it} is the total stock of external public debt denominated in local currency. The series is detrended using an HP filter.[26]

We then formally show that the relationship is statistically significant and present even after controlling for some of the relevant channels that the literature has documented and other potential confounding variables. We estimate the following panel fixed effect regressions:

$$\tilde{\lambda}_{FC,it} = \beta_1 \sigma_{FX,it} + \Gamma' X_{it} + \beta_i + \epsilon_{it} \tag{1}$$

The dependent variable, $\tilde{\lambda}_{FC,it}$, is the cyclical component of the share of external public debt in foreign currency λ_{FC}. The main regressor $\sigma_{FX,it}$ is exchange rate volatility. The country fixed effects are included in the regression. We employ two measures of exchange rate volatility as aforementioned: option-implied exchange rate volatility and realized exchange rate volatility computed using daily exchange rate returns over the past one year. The control variables X_{it} include expected depreciation computed with the survey data, year-over-year inflation, year-over-year real GDP growth, Chinn and Ito's measure of capital openness, private credit to GDP, external public debt to GDP and one-year default probability.

The result of the regression (1) summarized in Table 1 affirms the empirical pattern that we have seen in Figure 1, where emerging economies on average borrow more in foreign currency when their exchange rates are more volatile. A one percentage point increase in exchange rate volatility is associated with 0.31 – 0.33 percentage points higher foreign currency share of external public debt. The size of the estimates does not change much across different measures of exchange rate volatility. Controlling for expected depreciation and other macro variables also does not change the results qualitatively nor quantitatively.[27]

The positive estimates are robust to various other specifications. Table A1 summarizes the regressions results when we use linear de-trending instead of HP filtering. The estimates do not change much quantitatively, and the estimates are all statistically significant. We also look at the sample period after the global financial crisis (2009–2018) and the results are summarized in Table A2. A positive correlation is not driven by the global financial crisis in 2007–2008. Lastly, including time fixed effects or global control variables in the estimation does not change the results qualitatively. The results with time fixed effects and global control variables are summarized in Tables A3 and A4, respectively. Global control variables are the log of VIX, the US 10-year

[26] The smoothing parameter is 1600. The results do not change when we use a linear de-trending.

[27] In Section 4, we will conduct a counter-factual exercise where the exchange rate volatility increases by 1 percentage point, and we compare the changes in the foreign currency share computed with model simulated data to the regression estimate of 0.33%.

Table 1: FC Share of External Public Debt and Exchange Rate Volatility

	FC Share of External Public Debt (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma_{\text{FX, IMPLIED}}$	0.321***	0.312***	0.324***			
	(0.054)	(0.053)	(0.058)			
$\sigma_{\text{FX, REALIZED}}$				0.310***	0.300***	0.331***
				(0.057)	(0.061)	(0.061)
Expected Depreciation		0.108*	0.149**		0.091*	0.152**
		(0.056)	(0.069)		(0.048)	(0.063)
Inflation			-0.058			-0.023
			(0.124)			(0.084)
Real GDP growth			-0.111			-0.036
			(0.089)			(0.072)
Capital Openness			-1.100			-1.468
			(2.916)			(2.801)
Private Credit to GDP			-0.057*			-0.068**
			(0.032)			(0.029)
External Public Debt to GDP			-0.064			-0.021
			(0.051)			(0.034)
Default Probability			-0.223			-0.321*
			(0.209)			(0.191)
R-squared	0.095	0.101	0.128	0.102	0.107	0.140
N. of cases	909	909	793	982	982	862

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay, 1998) with a 4-quarter lag. All specifications include country fixed effects. The dependent variable is the HP filtered FC share of external public debt. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past one year.

treasury rate, the federal fund rate, and the TED spread. The positive co-movement between the foreign currency share of external public debt and exchange rate volatility is intact after controlling for these global factors. We have not included quarterly time fixed effects in the baseline model since we already take out the time trend from the foreign currency share of external public debt, the dependent variable.

Since the data on debt stocks are measured at their face values, the valuation change can only come from exchange rate movements. When the domestic price of a dollar (S_{it}) goes up , i.e. domestic currency depreciates, then mechanically foreign currency share may increase. We compute the foreign currency share at the constant exchange rate over time as a robustness check, using the 2006Q1 exchange rate against the US dollar. The amount of external public debt outstanding denominated in foreign currency is divided by the end of quarter exchange rate against the US dollar and multiplied by the 2006Q1 exchange rate. The underlying assumption of this conversion is that foreign currency debt is all denominated in US dollars.[28]

$$\lambda_{FC,it}^{\text{FX–Adj}} = \frac{S_{i,2006Q1}F_{it}}{D_{it} + S_{i,2006Q1}F_{it}}$$

Figure A2 in the Appendix shows a positive comovement between the cyclical component of FX-adjusted foreign currency share fluctuates and exchange rate volatility. A strong positive correlation in Figure 1 is not a result of the mechanical changes in the foreign currency share due to exchange rate depreciation when exchange rate volatility increases. The correlation computed between detrended FX-adjusted foreign currency share and the option-implied exchange rate volatility is 0.65. With the realized exchange rate volatility, the correlation is 0.68.

Table 2: FX-Adjusted FC Share in External Public Debt and Exchange Rate Volatility

	FX-Adjusted FC Share (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma_{\text{FX, IMPLIED}}$	0.162***	0.153***	0.166***			
	(0.045)	(0.045)	(0.045)			
$\sigma_{\text{FX, REALIZED}}$				0.156**	0.146**	0.167**
				(0.067)	(0.070)	(0.065)
Expected Depreciation		0.102**	0.145**		0.098**	0.146**
		(0.045)	(0.063)		(0.040)	(0.063)
Inflation			-0.061			-0.055
			(0.093)			(0.084)
Real GDP growth			-0.083			-0.054
			(0.085)			(0.074)
Capital Openness			-1.308			-1.528
			(2.415)			(2.488)
Private Credit to GDP			-0.047			-0.055*
			(0.029)			(0.029)
External Public Debt to GDP			-0.102**			-0.063**
			(0.039)			(0.031)
Default Probability			-0.076			-0.147
			(0.181)			(0.176)
R-squared	0.031	0.038	0.069	0.032	0.039	0.070
N. of cases	909	909	793	929	929	813

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay, 1998) with a 4-quarter lag. All specifications include country fixed effects. The dependent variable is the HP filtered FX-adjusted FC share of external public debt. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past one year.

We use the cyclical component of the FX-adjusted foreign currency share of external public debt as a dependent variable to run the regression (1). Table 2 summarizes the regression results.

[28]The strong positive correlation between the cyclical component of foreign currency share and exchange rate volatility does not depend on which quarterly date is used as a base date.

The estimates of the coefficient of interest are smaller quantitatively but are still sizeable at around 0.17 and statistically significantly different from zero. In sum, emerging economies borrow more in foreign currency when their exchange rate volatility increases – that is, emerging economies have larger currency mismatch on their balance sheets when it entails more risk.

We then investigate how the relative cost of borrowing in local currency over foreign currency is correlated with exchange rate volatility. The ex-post excess cost of borrowing in local currency over foreign currency is defined as:

$$y_{i,t}^{LC} - \underbrace{\left(y_{i,t}^{FC} + s_{i,t} - s_{i,t+12}\right)}_{\text{Cost of Borrowing in FC in units of LC}}$$

where $y_{i,t}^{LC}$ is the one-year zero-coupon local currency yield and $y_{i,t}^{FC}$ is the one-year zero-coupon foreign currency yield, constructed from sovereign CDS spreads.[29]

We then estimate the following panel fixed effect regressions:

$$y_{i,t}^{LC} - \left(y_{i,t}^{FC} + s_{i,t} - s_{i,t+12}\right) = \beta_1 \sigma_{FX,it} + \gamma' X_{it} + \beta_t + \beta_i + \epsilon_{it} \tag{2}$$

$$y_{it}^{j} = \beta_1 \sigma_{EXR,it} + \gamma' X_{it} + \beta_t + \beta_i + \epsilon_{it}, \text{ where } j = \{LC, FC\} \tag{3}$$

The dependent variable in the regression (2) is the ex-post excess cost of borrowing in local currency over foreign currency (in units of local currency). In regression (3), we separately run two regressions, one with local currency yields and the other with foreign currency yields as dependent variables and compare the quantitative size difference in the elasticity estimates, β_1. All specifications include country and monthly date fixed effects.[30] The expected depreciation computed with the survey data is included. Also, we control for macro variables as aforementioned.

Table 3 summarizes the results of regression (2). The relative cost of borrowing in local currency to that in foreign currency increases significantly as exchange rates are more volatile. A one percentage point increase in implied exchange rate volatility leads to 0.66 – 0.89 percentage points increase in the excess cost of borrowing in local currency over foreign currency. The findings are robust to controlling for expected depreciation and other macro variables, such as inflation, real GDP growth, capital openness, private credit to GDP, external public debt to GDP and default probability. The last three columns show the regression result with an alternative exchange rate volatility measure – realized exchange rate volatility. A one percentage point increase in realized exchange

[29] The empirical literature has measured the UIP condition using realized exchange rates on the assumption of rational expectations and full information, i.e. it justifies on the grounds that the error of measurement $s_{t+12} - E_t s_{t+12}$ is not correlated with things known at time t. In the regression below, $\text{Cov}_t(s_{t+12} - E_t s_{t+12}, \sigma_{FX,it}) = 0$, where $\sigma_{FX,it} = E_t \sigma_{t+12}$.

[30] We include time fixed effects here rather than global factors since most of the global variables are only available at lower frequency, for instance, at quarterly or annual.

Table 3: Relative Cost of Borrowing in LC over FC and Exchange Rate Volatility

	Expost Excess Cost of Borrowing in LC over FC (%): $y_{i,t}^{LC} - (y_{i,t}^{FC} + s_{i,t+12} - s_{i,t})$					
	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma_{\text{FX, IMPLIED}}$	0.894***	0.936***	0.659***			
	(0.178)	(0.181)	(0.192)			
$\sigma_{\text{FX, REALIZED}}$				0.664***	0.685***	0.450**
				(0.196)	(0.196)	(0.222)
Expected Depreciation		-0.341**	-0.393**		-0.259	-0.329**
		(0.157)	(0.160)		(0.165)	(0.160)
Inflation			0.946***			0.918***
			(0.235)			(0.201)
Real GDP growth			-0.168			-0.205
			(0.182)			(0.188)
Capital Openness			-7.373			-8.317
			(7.939)			(7.028)
Private Credit to GDP			-0.337***			-0.307***
			(0.091)			(0.089)
External Public Debt to GDP			-0.035			0.045
			(0.103)			(0.103)
Default Probability			0.587			0.498
			(0.704)			(0.665)
R-squared	0.613	0.618	0.655	0.603	0.606	0.647
N. of cases	1768	1768	1587	1866	1866	1680

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay, 1998) with a 4-month lag. All specifications include country and monthly date fixed effects. The dependent variable is the expost excess cost of borrowing in LC over FC. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past one year.

rate volatility leads to 0.45 – 0.66 percentage points increase in the excess cost of borrowing in local currency over foreign currency.[31] We also show that the positive association remains when we replace the realized exchange rate returns with the expected exchange rate depreciation using the survey data. The result is summarized in Table A6 in the Appendix.

Recent empirical works document a positive co-movement between the deviation from the uncovered interest parity (UIP) and global risk perception measure, VIX (Di Giovanni, Kalemli-Özcan, Ulu, and Baskaya, 2017 and Kalemli-Özcan and Varela, 2021).[32] Moreover, Kalemli-Özcan

[31] In Section 4, we will conduct a counter-factual exercise where the exchange rate volatility increases by 1 percentage point, and we compare the change in the relative cost of borrowing in local currency over foreign currency computed with model simulated data to the regression estimate of 0.45 percentage points.

[32] We control for time fixed effects in the regression. As in the literature, we see a positive co-movement between the deviation from the UIP and VIX shown in Table A5 in the Appendix, when we include global control variables including VIX, instead of time fixed effects.

Table 4: Cost of Borrowing in LC and in FC and Exchange Rate Volatility (%)

	One-year Interest Rates			
	$y_{i,t}^{LC}$	$y_{i,t}^{FC}$	$y_{i,t}^{LC}$	$y_{i,t}^{FC}$
	(1)	(2)	(3)	(4)
$\sigma_{\text{FX, IMPLIED}}$	0.224***	0.080***		
	(0.024)	(0.022)		
$\sigma_{\text{FX, REALIZED}}$			0.147***	0.009
			(0.025)	(0.009)
Expected Depreciation	0.065***	0.014**	0.056***	0.024***
	(0.016)	(0.005)	(0.016)	(0.006)
Inflation	0.167***	0.031**	0.177***	0.013
	(0.035)	(0.014)	(0.043)	(0.016)
Real GDP growth	-0.183***	-0.035***	-0.161***	-0.065***
	(0.033)	(0.010)	(0.032)	(0.011)
Capital Openness	1.297***	-0.506	0.891	0.652**
	(0.449)	(0.427)	(0.543)	(0.267)
Private Credit to GDP	0.045***	-0.005	0.050***	0.009**
	(0.004)	(0.004)	(0.005)	(0.004)
External Public Debt to GDP	0.001	0.033***	0.007	0.037***
	(0.016)	(0.011)	(0.015)	(0.006)
Default Probability	0.041	-0.001	0.095	0.069
	(0.115)	(0.041)	(0.113)	(0.044)
R-squared	0.631	0.871	0.627	0.846
N. of cases	2437	1745	2575	1980

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay, 1998) with a 4-month lag. All specifications include country and monthly date fixed effects. In columns (1) and (3), the dependent variable is the one-year LC interest rate. In columns (2) and (4), the dependent variable is the one-year FC interest rate. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past one year.

and Varela (2021) also document the comovement between the UIP deviation and a measure of policy uncertainty from Baker, Bloom, and Davis (2016). Closely related to this paper, Hassan, Mertens, and Zhang (2021) document a positive comovement between *allowed* annual standard deviation of nominal exchange rate relative to US dollar and excess return on the currency. Complementing their work focusing on the global and country risk factor, this paper shows that exchange rate volatility is an important factor explaining the deviation from the uncovered interest parity in emerging economies and showing that investors on average earn higher excess returns on local currency debt over foreign currency debt when the exchange rate is more volatile.

We then analyze how local currency and foreign currency one-year borrowing rates have different levels of elasticity to exchange rate volatility. Table 4 summarizes the results of regression (3) with different measures of exchange rate volatility. In Table 4, the estimated elasticity is around three times larger for the local currency interest rate compared to that for the foreign currency interest rate with the implied exchange rate volatility. With the realized exchange rate volatility, the elasticity is around an order of magnitude larger for the local currency interest rate than for the foreign currency interest rate, and the elasticity for the foreign currency interest rate is no longer significantly different from zero.

The empirical pattern documented can help explain why emerging economies borrow more in foreign currency when exchange rate volatility increases. When exchange rate volatility increases, local-currency debt becomes too expensive from the government's perspective and discourages them from borrowing its own currency. Therefore, the sovereign chooses to bear more exchange rate risk and borrow more in foreign currency.

3 Model

In this section, we build a small open economy sovereign default model with risk-averse foreign lenders. The sovereign can issue debt in two currencies, local currency (LC) and foreign currency (FC). The government is benevolent, maximizing the utility of its households. The government borrows on behalf of households. This assumption implies that the stock of external public debt is equal to the stock of external debt in the model.[33]

We first present the environment of the infinite-horizon dynamic stochastic model and define the equilibrium. The key mechanism of the model is then highlighted.

3.1 Environment

3.1.1 Exogenous Processes

There are three exogenous processes in the model: endowment, exchange rate and the default disutility cost that the sovereign suffers when deciding to default on their debt obligations. The endowment (y_t) and exchange rate (S_t) processes follow:

$$\begin{pmatrix} \log(y_t) \\ \log(S_t) \end{pmatrix} = \begin{pmatrix} \mu_y \\ \mu_s \end{pmatrix} + \begin{pmatrix} \rho_y & 0 \\ 0 & \rho_s \end{pmatrix} \begin{pmatrix} \log(y_{t-1}) \\ \log(S_{t-1}) \end{pmatrix} + \begin{pmatrix} \epsilon_t^y \\ \epsilon_t^s \end{pmatrix} \quad \text{where} \quad \begin{pmatrix} \epsilon_t^y \\ \epsilon_t^s \end{pmatrix} \sim N \begin{pmatrix} \sigma_y^2 & \rho_{y,s}\sigma_y\sigma_s \\ \rho_{y,s}\sigma_y\sigma_s & \sigma_s^2 \end{pmatrix}.$$

$\rho_{y,s}$ captures the correlation between endowment and exchange rate shocks. In the data, for emerging economies, $\rho_{y,s}$ is typically estimated to be negative. S_t is the price of foreign currency in units of local currency. An increase in S_t is a depreciation of local currency. The exchange rate is exogenous in the model, and in the Appendix A.3, a simple general equilibrium open economy

[33]We can think of the formulation as if the government transfers the proceedings of net borrowing to households in a lump-sum and households are hand-to-mouth. This assumption is imposed so that the problem is computationally tractable.

model with two countries is described, where the exchange rate is endogenously determined while its process is governed by the exogenous productivity processes of the two countries.

The shock to default disutility cost is independent from the endowment and exchange rate shocks.[34]

$$\nu_t = \mu_\nu + \rho_\nu \nu_{t-1} + \epsilon_t^\nu, \quad \text{where} \quad \epsilon_t^\nu \sim N(0, \sigma_\nu^2).$$

3.1.2 Benevolent Sovereign

There is a sovereign who lives indefinitely and time is discrete and indexed by t. The sovereign is benevolent, maximizing the utility of its households.[35]

Preferences are defined over an infinite stream of consumption and default decisions,

$$U_t = \mathbb{E}_t \sum_{j=t}^{\infty} \beta^{j-t} \big(u(c_j) - D_j \nu_j \big).$$

$u(\cdot)$ has a functional form such that it exhibits a constant relative risk aversion, where risk aversion is parameterized by γ. $D_t = 1$ when the sovereign defaults on its debt at time t. Following Arellano, Bai, and Bocola (2017), we model the default cost ν_t as stochastic disutility cost known at time t before the sovereign decides to default on its debt.

The sovereign can issue one-period debt in two currencies – local and foreign – in the external bond market.[36] b_{t+1}^{LC} denotes the amount of debt issued in LC in units of LC and b_{t+1}^{FC} denotes the amount of debt issued in FC in units of FC.[37] The period budget constraint when the sovereign does not default at time t is:

$$c_t + b_t^{LC} + b_t^{FC} S_t = q_t^{LC} b_{t+1}^{LC} + q_t^{FC} b_{t+1}^{FC} S_t + y_t.$$

The sovereign pays back its debt in both currencies, b_t^{LC} and b_t^{FC} and consumes c_t with the new debt, b_{t+1}^{LC} and b_{t+1}^{FC} issued at prices q_t^{LC} and q_t^{FC}, respectively, and its endowment, y_t.

When the sovereign defaults, the period budget constraint is:

$$c_t = q_t^{LC} b_{t+1}^{LC} S_t + q_t^{FC} b_{t+1}^{FC} S_t + y_t.$$

[34] In the quantitative section, we assume that the shock to the default cost is not persistent.

[35] The interaction of the private sector's external borrowing and the government's currency choice in its debt issuance is an interesting area to explore but we abstract away from this interaction. Du and Schreger (2021) and Wu (2021) explore the role of corporate debt in sovereign borrowing costs.

[36] The discount factor is lower than the risk free rate and so households want to front-load their consumption.

[37] We assume the monetary authority sets $P_t = \bar{P}$. Without loss of generality we assume $\bar{P} = 1$. Alternatively, we can think of it as exogenous real exchange rate, and LC and FC debt are denominated in domestic and foreign consumption baskets, respectively.

When the government defaults, we assume that it does so on all of its debt obligations and for both currencies. Selective defaults are not allowed in this model.[38] Also, note that there is no financial exclusion after the sovereign defaults on their debt.

When the sovereign defaults on its debt obligations, it incurs default disutility cost, ν_t as aforementioned. This stochastic process captures time-varying enforcement cost due to reputation, trade costs and others.[39]

The correlation between output and the exchange rate stochastic processes is typically negative for an emerging economy, and it is indeed what we see from the parameter estimation in Section 4. The negative correlation between output and exchange rate shocks implies that this model also has the feature that debt in local currency provides hedging against income risk. For foreign currency debt, the sovereign needs to pay back more when their output is low but the repayment value of local currency debt does not fluctuate with the exchange rate.

3.1.3 Risk-averse Foreign Lenders

There is a continuum of competitive risk-averse foreign lenders, indexed by i, lending to the sovereign.[40] They are endowed with one unit of foreign currency in every period.[41] Every period, they choose how much to invest in risk-free FC assets, emerging market FC bonds, and emerging market LC bonds. They maximize their expected utility from their wealth in the next period, $\tilde{W}_{t+1}$, in units of FC,

$$E_t u(\tilde{W}_{t+1}),$$

where u is increasing and concave and exhibits constant relative risk aversion with the risk aversion parameter α. We approximate the utility function with the second-order Taylor expansion, which gives us the mean-variance utility over its one-period gross return, $\tilde{R}_{t+1}$.[42] The maximization problem is choosing the portfolio mix between EM FC debt B^{FC}_{t+1}, EM LC debt B^{LC}_{t+1} and the rest in the US treasury $\left(1 - B^{FC}_{t+1} - B^{LC}_{t+1}\right)$. B^{FC}_{t+1} and B^{LC}_{t+1} are in units of FC,

$$\max_{B^{FC}_{t+1} \geq 0, B^{LC}_{t+1} \geq 0} \mathbb{E}_t(\tilde{R}_{t+1}) - \frac{\alpha}{2}\mathrm{Var}_t(\tilde{R}_{t+1}).$$

[38] This is optimal under the set-up where the default disutility cost is not a function of the currency of debt the sovereign defaults on.

[39] This modeling of the sovereign default costs is in line with Aguiar and Amador (2013), Arellano, Bai, and Bocola (2017), Arellano, Bai, and Mihalache (2018) and Arellano, Bai, and Mihalache (2018).

[40] The i subscript is suppressed when it is not necessary.

[41] We assume that the final good price of the foreign consumption basket, P^*_t, does not change over time.

[42] The assumption of short-lived intermediaries avoids the need to carry the level of wealth of the intermediaries as another state variable.

The gross return from the portfolio is,

$$\tilde{R}_{t+1} = \underbrace{(1 - B^{FC}_{t+1} - B^{LC}_{t+1})(1 + r_f)}_{\text{US treasury}} + \underbrace{\frac{B^{FC}_{t+1}}{q^{FC}_t}\big(1 - D_{t+1}\big)}_{\text{EM FC debt}} + \underbrace{\frac{B^{LC}_{t+1}}{q^{LC}_t}\big(\frac{S_t}{S_{t+1}}(1 - D_{t+1})\big)}_{\text{EM LC debt}}.$$

The investors choose optimally between three different assets to maximize their mean-variance utility, and the F.O.C.s for choosing EM LC and FC debt are, respectively:

$$\begin{aligned} &\frac{1}{q^{LC}_t}\,\mathbb{E}_t\big(\frac{S_t}{S_{t+1}}(1 - D_{t+1})\big) - (1 + r_f) \\ &= \alpha\frac{B^{FC}_{t+1}}{q^{FC}_t}\frac{1}{q^{LC}_t}\,\mathbb{E}_t\left(\frac{S_t}{S_{t+1}}(1 - D_{t+1})\right)\mathbb{E}_t\, D_{t+1} + \alpha\frac{B^{LC}_{t+1}}{(q^{LC}_t)^2}\text{Var}_t\big(\frac{S_t}{S_{t+1}}(1 - D_{t+1})\big); \end{aligned} \tag{4}$$

$$\begin{aligned} &\frac{1}{q^{FC}_t}\,\mathbb{E}_t\big((1 - D_{t+1})\big) - (1 + r_f) \\ &= \alpha\frac{B^{LC}_{t+1}}{q^{LC}_t}\frac{1}{q^{FC}_t}\,\mathbb{E}_t\left(\frac{S_t}{S_{t+1}}(1 - D_{t+1})\right)\mathbb{E}_t\, D_{t+1} + \alpha\frac{B^{FC}_{t+1}}{(q^{FC}_t)^2}\text{Var}_t\big((1 - D_{t+1})\big). \end{aligned} \tag{5}$$

With the two above FOCs, we can solve the bond price schedules numerically.[43]

3.1.4 Discussion of Assumptions

We assume lenders are myopic. They maximize their utility derived from the one-period gross return of their portfolios. This assumption captures how institutional investors, such as mutual funds, have quarterly and annual regulatory requirements. The internal compliance and external regulations would limit the risk taking capacity of these investors. Moreover, computationally, this simplifies the problem as we do not need to carry the wealth of lenders as an additional state variable. Itskhoki and Mukhin (2021a), Itskhoki and Mukhin (2021b), Gourinchas, Ray, and Vayanos (2021), Greenwood, Hanson, Stein, and Sunderam (2020), and Coimbra and Rey (2017) also make an analogous assumption of a short-lived financial intermediary.

In the model, the sovereign optimally chooses not to selectively default on either LC or FC debt as the default disutility costs are not a function of the currency denomination of debt. First, selective defaults are rare events in recent history. It is not clear whether the sovereign defaults more on one than the other as the recent historical incidence of LC and FC sovereign debt defaults are quite comparable (Du and Schreger, 2016). Second, the credit ratings of LC and FC debt are the same

[43] $\text{Cov}_t\left((1 - D_{t+1}), \frac{S_t}{S_{t+1}}(1 - D_{t+1})\right) = \mathbb{E}_t\left(\frac{S_t}{S_{t+1}}(1 - D_{t+1})\right)\mathbb{E}_t\, D_{t+1}$.

or have a one notch difference for most of the countries in our sample.[44] Theoretical works in the literature do not feature selective defaults between LC and FC external debt.[45]

Moreover, the exchange rate is exogenous in the model. Essentially, the sources of structural shocks that govern the exchange rate and its volatility are not important in the model as long as exchange rate risk can not be diversified away. The exchange rate risk, therefore, has to be either borne by the borrower or lenders. The currency composition is therefore an outcome of the risk-sharing problem between them. As aforementioned, in the Appendix A.3, we present a simple general equilibrium model analogous to a Balassa-Samuelson model, where the exchange rate is endogenously determined while its process is governed by the exogenous output processes of the emerging economy and the advanced economy. In the model, the portfolio choices nor the consumption of the emerging economy or the advance economy do not affect the real exchange rate determination.

3.1.5 Recursive Problem and Equilibrium

In this subsection, we describe the recursive problem that the sovereign solves and define the equilibrium. We focus on the Markov Perfect Equilibrium.

At the beginning of each period, the three exogenous shocks, (y, S, ν) are realized. We denote these exogenous states as $X \equiv \{y, S, \nu\}$. The sovereign chooses its default decision on the debt due this period, issuance amount of new debt in the two currencies and consumption. $W(b^{LC}, b^{FC}; X)$ is the option value of default and $V(b^{LC}, b^{FC}; X)$ is the the value of repaying their debt. Given exogenous and endogenous state variables (b^{LC}, b^{FC}, X), and bond price schedules for LC and FC bonds, $q^{LC}(b'^{LC}, b'^{FC}, X)$ and $q^{FC}(b'^{LC}, b'^{FC}, X)$, the sovereign solves the below problem every period:

$$W(b^{LC}, b^{FC}; X) = \max_{D=\{0,1\}} \{(1-D)V(b^{LC}, b^{FC}; X) + D\big[V(0,0;X) - \underbrace{\nu}_{\text{Default Disutility Costs}}\big]\}$$

D is an indicator equal to one when sovereign defaults on its debt obligations and zero otherwise.

$$V(b^{LC}, b^{FC}; X) = \max_{c \geq 0, b'^{LC}, b'^{FC}} \{u(c) + \beta E_{X'|X} W(b'_{LC}, b'_{FC}; X')\}$$

$$c + b^{LC} + b^{FC}S = q^{LC}(b'^{LC}, b'^{FC}, X)b'^{LC} + q^{FC}(b'^{LC}, b'^{FC}, X)b'^{FC}S + y$$

[44] In fact, Amstad, Packer, and Shek (2020) investigate a broad sample of 73 emerging economies and found that the rating difference between LC and FC bonds is almost zero by 2015.

[45] To highlight the role of exchange rate risk in the currency composition of external sovereign borrowing, this paper abstracts away from jurisdiction differences between LC and FC debt. More discussions on the effect of jurisdictions on sovereign defaults can be found in Erce and Mallucci (2018).

The bond markets clear:

$$b'^{LC} = B'^{LC}S, \;\; b'^{FC} = B'^{FC}.$$

The equilibrium bond prices are consistent with lender's asset pricing conditions, satisfying first order conditions of risk-averse lenders, (4) and (5):

$$q^{LC}(b'^{LC}, b'^{FC}; X) = \frac{\Psi^{LC}(b'^{LC}, b'^{FC}; X) + \sqrt{(\Psi^{LC}(b'^{LC}, b'^{FC}; X))^2 - 4(1+r_f)\alpha\frac{b'^{LC}}{S}\Omega^{LC}(b'^{LC}, b'^{FC}; X)}}{2(1+r_f)},$$

$$q^{FC}(b'^{LC}, b'^{FC}; X) = \frac{\Psi^{FC}(b'^{LC}, b'^{FC}; X) + \sqrt{(\Psi^{FC}(b'^{LC}, b'^{FC}; X))^2 - 4(1+r_f)\alpha b'^{FC}\Omega^{FC}(b'^{LC}, b'^{FC}; X)}}{2(1+r_f)},$$

where $\Psi^{LC}(\cdot)$, $\Psi^{FC}(\cdot)$, $\Omega^{LC}(\cdot)$, and $\Omega^{LC}(\cdot)$ are:

$$\Psi^{LC}(b'^{LC}, b'^{FC}; X) = \mathbb{E}\left(\frac{S}{S'}(1 - D'(b'^{LC}, b'^{FC}; X'))\right) - \alpha\frac{b'^{FC}}{q_{FC}(b'^{LC}, b'^{FC}; X)}\mathbb{E}\left(\frac{S}{S'}(1 - D'(b'^{LC}, b'^{FC}; X'))\right),$$

$$\Psi^{FC}(b'^{LC}, b'^{FC}; X) = \mathbb{E}\left(1 - D'(b'^{LC}, b'^{FC}; X')\right) - \alpha\frac{b'^{LC}}{q^{LC}(b'^{LC}, b'^{FC}; X)}\mathbb{E}\left(\frac{S}{S'}\left(1 - D'(b'^{LC}, b'^{FC}; X'\right)\right),$$

$$\Omega^{LC}(b'^{LC}, b'^{FC}; X) = \text{Var}\left(\frac{S}{S'}\left(1 - D'(b'^{LC}, b'^{FC}; X')\right)\right), \;\; \Omega^{FC}(b'^{LC}, b'^{FC}; X) = \text{Var}\left(1 - D'(b'^{LC}, b'^{FC}; X')\right).$$

Note that each equation contains both q^{LC} and q^{FC} and so a system of two equations given b'^{LC}, b'^{FC}, X is solved numerically.[46]

The recursive Markov equilibrium is defined as a set of policy functions for the emerging market sovereign's consumption $c(b^{LC}, b^{FC}; X)$; default $D(b^{LC}, b^{FC}; X)$; sovereign borrowing in local currency $b'_{LC}(b^{LC}, b^{FC}; X)$ and that in foreign currency $b'_{FC}(b^{LC}, b^{FC}; X)$; value functions $W(b^{LC}, b^{FC}; X)$ and $V(b^{LC}, b^{FC}; X)$; and bond price schedules, $q^{LC}(b'^{LC}, b'^{FC}, X)$ and $q^{FC}(b'^{LC}, b'^{FC}, X)$.

3.2 Mechanism

To highlight the key mechanism, we derive analytically the price schedules assuming that default dis-utility cost is equal to infinity, i.e. there is no default risk, $D_{t+1} = 0$. We highlight how lenders require compensation for exchange rate volatility as it creates the currency mismatch on lenders when lending in local currency. Therefore, the relative cost of borrowing in local currency over foreign currency increases with exchange rate volatility, rendering local currency borrowing more expensive.

[46]There is another root to the quadratic equations but the other solutions imply zero bond prices for both currencies when lenders are risk-neutral – these solutions are off the equilibrium path.

When we assume that there is no default risk, the relative price of FC debt over LC debt is:[47]

$$q_t^{FC} - q_t^{LC} = \frac{1}{1+r_f} - \underbrace{\frac{\mathbb{E}_t\left(\frac{S_t}{S_{t+1}}\right)}{1+r_f}}_{q^{LC}_{RN,t}\ :\ \textbf{Risk Neutral LC Bond Price}} \times \underbrace{\left(\frac{1}{2}+\frac{1}{2}\sqrt{1-4B'^{LC}(1+r_f)\alpha\underbrace{\mathrm{Var}_t\Big(\frac{S_t}{S_{t+1}}\Big)}_{\propto\sigma_S^2}}\right)}_{\Lambda_t^{LC}\ :\ \textbf{Risk Premium on LC Bond}\ \leq 1}$$

The price of FC debt is equal to the inverse of the gross risk free rate,

$$q_t^{FC} = \frac{1}{1+r_f},$$

by a no arbitrage condition as there is no risk from holding FC debt to international investors; hence, the rate of return is the same as the risk-free rate.

The price of LC debt has two components: risk-neutral $q^{LC}_{RN,t}$ and risk premium components Λ_t^{LC}. The risk-neutral LC debt price is equal to the exchange rate return discounted by the risk-free rate by a no arbitrage condition,

$$q^{LC}_{RN,t} = \frac{\mathbb{E}_t\left(\frac{S_t}{S_{t+1}}\right)}{1+r_f}.$$

The price of LC debt is the product of $q^{LC}_{RN,t}$ and Λ_t^{LC},

$$q_t^{LC} = q^{LC}_{RN,t} \times \Lambda_t^{LC} \leq q^{LC}_{RN,t}.$$

The risk-premium lowers the price of LC debt and increases the interest rate on LC debt. When $\alpha = 0$, $\Lambda_t^{LC} = 1$. Λ_t^{LC} captures the deviation from the uncovered interest parity (UIP). The relative price of FC over LC debt increases with σ_S^2 , i.e. the interest rate on LC over FC debt is higher with σ_S^2:

$$\frac{\partial(q^{FC} - q^{LC})}{\partial\sigma_S^2} > 0.$$

Moreover, the increase is larger as the risk aversion of lender, α, is larger.

$$\frac{\partial\partial(q^{FC} - q^{LC})}{\partial\alpha\partial\sigma_S^2} > 0.$$

[47]When $\rho_s \approx 1$, then $\mathrm{Var}_t\big(\frac{S_t}{S_{t+1}}\big) \approx \big(\exp(\sigma_S^2) - 1\big)\exp(\sigma_S^2)$. As shown in the calibration section, the value of ρ_s estimated outside the model is 0.99.

Specifically, when $\alpha = 0$,

$$q_t^{FC} - q_t^{LC} = \frac{1}{1+r_f} - \frac{\mathbb{E}_t\left(\frac{S_t}{S_{t+1}}\right)}{1+r_f} \Longrightarrow \frac{\partial(q^{FC} - q^{LC})}{\partial \sigma_S^2} = 0,$$

whereas in the data we see a strong positive correlation between the relative price of FC over LC bonds and exchange rate volatility.

We can clearly see that the size of the FX risk premium channel depends on the risk-aversion of the lender. In the quantitative analysis, the parameter of the risk aversion of lenders α will be disciplined by the average real interest rate of LC debt that we see in the data, and we will show that estimated α is high enough that the model simulations are aligned with the two empirical patterns that we have documented in Section 2.

Let us now assume further $E_t\left(\frac{S_{t+1}}{S_t}\right) = 1$ and see how the optimal currency composition of emerging market sovereign changes when there is an increase in exchange rate volatility. Say we have $b'^{*FC} > 0$ and $b'^{*LC} > 0$, satisfying the first order conditions of choosing b'^{FC} and b'^{LC}:

$$u'(c_t)\left[q_t^{FC} - \left(q_t^{LC} + \frac{\partial q_t^{LC}}{\partial b_{t+1}^{LC}}\right)\right] = \beta \text{Cov}_t\left(u'(c_{t+1}), \frac{S_{t+1}}{S_t}\right). \tag{6}$$

The left hand side of (6) represents the marginal benefit today for the sovereign of issuing one more unit of FC debt and one less unit of LC debt, which is equated to the marginal cost tomorrow of one more unit of FC debt and one less unit of LC debt, exposing its balance sheet to more exchange rate risk. We can rewrite it as

$$u'(c_t)\left(\frac{1}{1+r_f}(1-\Lambda_t^{LC}) + \left|\frac{\partial q_t^{LC}}{\partial b_{t+1}^{LC}}\right|\right) = \beta \text{Cov}_t\left(u'(c_{t+1}), \frac{S_{t+1}}{S_t}\right). \tag{7}$$

Notice that Λ_t^{LC} is less than one; so both sides of the equation are positive. When exchange rate volatility increases, holding the portfolio fixed at their current optimum, i.e. at $b'^{\star FC}$ and $b'^{\star LC}$, the risk premium part of the price Λ_t^{LC} decreases, and the slope of the LC debt price schedule $\left|\frac{\partial q_t^{LC}}{\partial b_{t+1}^{LC}}\right|$ increases. That means the marginal benefit of issuing one more unit of FC debt and one less unit of LC debt is higher:

$$\underbrace{u'(c_t)\left[q_t^{FC} - \left(q_t^{LC} + \frac{\partial q_t^{LC}}{\partial b_{t+1}^{LC}}\right)\right]}_{\textbf{FC DEBT CHEAPER} \ \Uparrow} = \underbrace{\beta \text{Cov}_t\left(u'(c_{t+1}), \frac{S_{t+1}}{S_t}\right)}_{\text{FC DEBT RISKIER} \ \Uparrow}.$$

The marginal cost of issuing one more unit of FC debt and one less unit of LC debt increases too, due to higher exchange rate volatility. When the risk aversion of lenders is high enough, an increase in the marginal benefit is larger than the marginal cost. Consequently, the emerging market sovereign borrows more in foreign currency and less in local currency. Whether an increase in the marginal benefit of issuing FC debt would be larger than that of the marginal cost with higher exchange rate volatility is a quantitative question, which largely depends on the risk aversion of lenders. In Section 5, we will show that our model, with the estimated parameters, matches the comovement of the currency composition of emerging market external borrowing and exchange rate volatility.

4 Quantitative Analysis

Subsection 4.1 discusses how we calibrate the parameters of the model. The parameters are calibrated to match the key moments of Colombia, a median emerging economy, in 2004 – 2018. Subsection 4.2 depicts a selection of policy functions to highlight the key mechanism. In subsection 4.3, we evaluate the model performance upon an increase in the exchange rate volatility. In subsection 4.4, the exchange rate volatility is shut down to zero to quantify how costly the currency mismatch on the borrower and lenders is when borrowing externally in both currencies.

4.1 Calibration

We calibrate the model to Colombia, a median emerging economy: (i) its income and exchange rate processes are close to the median in our sample of 18 emerging economies and (ii) the average of the fraction of external public debt denominated in foreign currency is 82%, close to the mean of 80% in our sample. One period in the model is one year.

Parameter Values: The risk-aversion of the sovereign γ is set to one which is in the range of standard values used in the literature. The output and exchange rate processes are estimated outside the model. We estimate the output process using annual real GDP data from WDI in 2000–2018 where log-linear detrending is applied. The real exchange rate is computed using the nominal exchange rate against the dollar and the consumer price indices of US and Colombia, where all the data are from the IMF IFS. We estimate the exchange rate process using the annual real exchange rate against the dollar in 2000 – 2018.[48] The correlation between the output and exchange rate shocks is estimated to be -0.11. The risk-free rate is the average of the 5-year inflation linked US-treasury rate in 2004 – 2018.

[48]The estimated parameters hardly change when we use the nominal exchange rate instead.

The rest of the parameter values are estimated by the simulated method of moments. We target four moments. The first moment is the average of the annual external public debt to GDP in 2004Q1–2018Q4 from Arslanalp and Tsuda (2014, updated 2020) dataset. Secondly, we target the mean of the LC spread in 2004M1–2018M12, which we measure as the below:

$$(y_{COL,t}^{LC} - \pi_{COL,t+12}) - (y_{US,t}^{USD} - \pi_{US,t+12})$$

where y_t^{LC} is the one-year LC interest rate, $y_{US,t}^{USD}$ is the one-year treasury rate, and $\pi_{j,t+12}$ is the inflation from monthly date t to 12 months after for country j. Lastly, we target the mean and the standard deviation of the FC spread, which we take as the average of one-year CDS spread in 2004M1 – 2018M12. In sum, the four targeted moments are: (i) the mean external debt to GDP (14.8%), (ii) the mean LC spread (1.63%), (iii) the mean FC spread (0.66%), and (iv) the standard deviation of FC spread (0.54%). We calibrate time discount factor β, risk aversion of global investors α, mean default dis-utility cost shock μ_ν and its standard deviation σ_ν to match moments (i) – (iv).

Although the four parameters are jointly determined to match four moments, we can still offer a heuristic description of how each parameter is mostly inferred from an empirical moment. The time discount factor β governs how much households want to front-load their consumption and hence the amount of borrowing, i.e., external debt to GDP. Moreover, the risk aversion of global investors α governs the size of the exchange rate risk premium and hence the local currency interest rate spread. Lastly, the FC spread is capturing the default probability and the risk premium associated with the default probability. Therefore, the mean and the standard deviation of the FC spread disciplines the mean and standard deviation of default disutility cost shocks. Table 5 summarizes the parameter values.

The risk-aversion α for international lenders is a key parameter governing the size of the foreign exchange rate risk premium, which is estimated to be 51. The level of risk aversion is high, as seen in the literature explaining the equity premium (Campbell and Cochrane (1999); Lustig and Verdelhan (2007)). The risk aversion parameter employed in the sovereign default model with risk averse lenders is similar in magnitude; for instance, in Hatchondo, Martinez, and Padilla (2014), their estimated relative risk aversion of government and lenders are 2 and 59, respectively.[49]

The mean share of external public debt in foreign currency from 2004Q1 – 2018Q4 is the key untargeted moment. We also look at the standard deviation of the LC spread, which is another untargeted moment, to see if the model can explain the means and standard deviations of both LC and FC spreads.

Table 6 reports the long-run moments in the model vis-a-vis those in the data. The targeted

[49]In their paper, investors' preference is described by the recursive utility model proposed by Epstein and Zin (1991).

Table 5: Parameter Values

Parameters	Description	Values	Notes
Parameters from the literature			
γ	Risk aversion of the sovereign	1.0	Literature
Parameters from the data			
ρ_y	Persistence of output shock	0.9	AR(1), Colombia
σ_y	Std of output shock	0.03	AR(1), Colombia
ρ_s	Persistence of exchange rate shock	0.99	AR(1), Colombia
σ_s	Std of exchange rate shock	0.13	AR(1), Colombia
$\rho_{y,s}$	Correlation of output and exchange rate shocks	-0.11	AR(1), Colombia
r_f	Risk-free rate	0.5%	mean 5-year US real rate
Parameters from moment matching			
β	Time discount factor	0.93	External Debt to GDP (14.8%)
α	Risk aversion of the global investors	51	mean LC spread (1.63%)
μ_ν	Mean sovereign default cost	0.59	mean FC spread (0.66%)
σ_ν	Std sovereign default cost	0.16	std FC spread (0.54%)

Table 6: Targeted and Untargeted Moments

	Data %	Panel (A) **Model** %
Targeted moments		
Mean LC Spread	1.63	1.63
Mean FC Spread	0.66	0.64
Std of FC Spread	0.54	0.53
Mean External Debt to GDP	14.8	13.2
Untargeted moments		
Mean FC Share	82.0	86.7
Std of LC Spread	2.30	2.00

Panel (A) is simulated with the parameters reported in Table 5. The model moments are computed by generating $100,000$ periods of simulate data and discarding the first $1,000$ periods. Default year and the year after default are excluded when calculating the long-run average.

moments closely match the data. Both of the untargeted moments also match the data well: the mean FC share of external public debt from the model simulations is 86.7%, close to the mean FC share at 82% in the data. Also, the standard deviation of LC spread is close to the data counterpart.

The model is able to match the average FC share of external public debt where the key determinant of the currency composition is the foreign exchange rate risk premium charged by foreign lenders as a compensation for exchange rate risk when they lend in local currency. The estimated model *jointly* explains the currency composition of external sovereign debt and the cost of borrowing in local and foreign currency.

4.2 Policy Functions

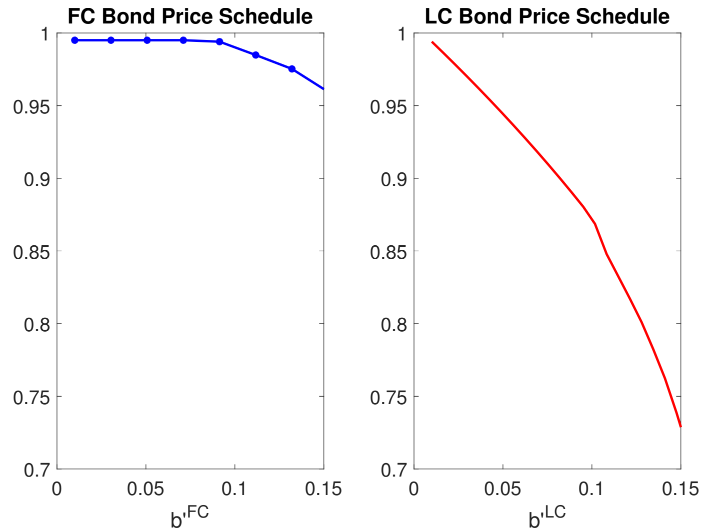
4.2.1 Policy Functions in the Baseline Model

We first examine the bond price schedules to highlight the relative benefit of borrowing in FC over LC: it is cheaper to borrow in foreign currency. In Figure 3, the blue line is the FC debt price plotted against FC debt and the red line is the LC debt price plotted against LC debt, while holding the other choice variable fixed at zero. The exogenous variables are set at their mean values. For instance, $S = 1$.[50] In Figure 3, the price of FC debt is equal to the inverse of the gross risk free rate when FC borrowing is below a threshold. Above this threshold, the default probability becomes positive and the FC debt interest rate is higher than the risk free rate. For LC debt, since investors bear the exchange rate risk, they require compensation for the exchange risk that they are taking even in the absence of the default risk. Hence, the price of LC debt falls as the sovereign borrows more in local currency. The default risk is “tail risk", and hence, for a low level of borrowing, it does not affect the price; however, the exchange rate risk, when borrowing in LC, is reflected in the the LC interest rate even at a low level of LC borrowing as lenders charge the exchange rate risk premium.

We then examine how the default probability varies with the level of borrowing in both currencies. In Figure 4, the blue line plots the default probability against FC debt b'^{FC}. The red line, in Figure 4, plots the default probability against LC debt b'^{LC}. For both policy functions, we set the other choice variable fixed at zero. The default probability is higher when the sovereign issues the same amount in FC than in LC. When the sovereign borrows in FC, it may default on its debt upon a large depreciation as the repayment value of FC debt in units of LC goes up, even when its output is not low and its default cost is not low. Moreover, when borrowing in foreign currency, the sovereign tends to face a higher debt burden when its output is low due to the negative correlation between output and exchange rate shocks. Therefore, default probability is higher for FC debt for a given level of borrowing, which captures the additional expected default utility cost of borrowing in FC over LC. Currency composition is determined by balancing out the riskiness of FC borrowing and the costliness of LC borrowing.

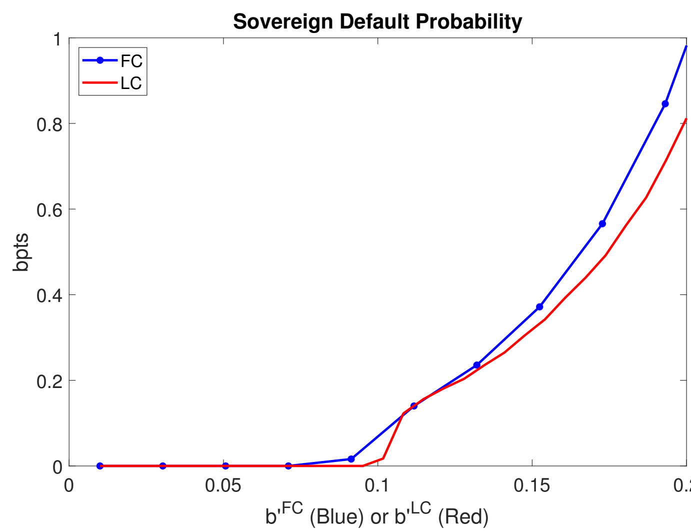
[50] Note that the units of b'^{LC} and b'^{FC} are the same as $S = 1$.

Figure 3: LC and FC Debt Prices



Notes: The LHS figure plots the price schedule of FC debt b'^{FC} as b'^{FC} varies. The RHS figure plots the price schedule of LC debt b'^{LC} as b'^{LC} varies. We fix the other choice variable at zero, i.e. $b'^{LC} = 0$ (LHS), and $b'^{FC} = 0$ (RHS).

Figure 4: Default Probability



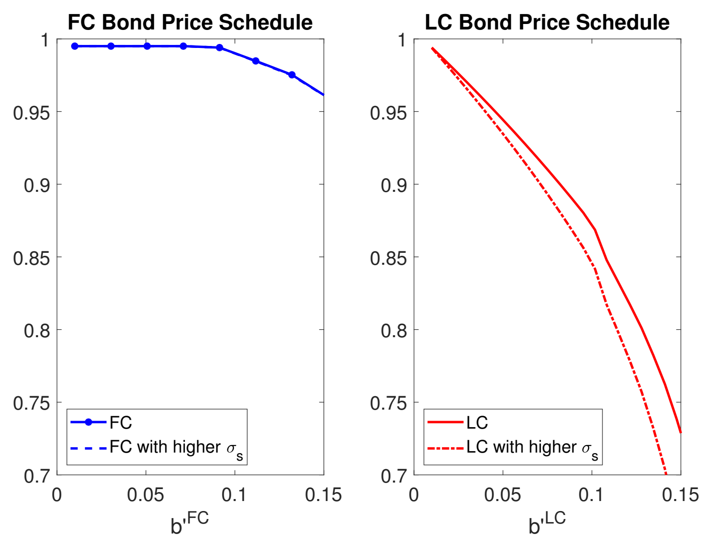
Notes: The blue line with dots plots the default probability as FC debt b'^{FC} varies. The red solid line plots the default probability as LC debt b'^{LC} varies. We fix the other choice variable at zero, i.e. $b'^{LC} = 0$ (blue line), and $b'^{FC} = 0$ (red line).

4.2.2 Policy Functions with Higher Exchange Rate Volatility

We analyze how the policy functions change when exchange rate volatility increases by one percentage point from 13% to 14%. The policy functions with higher exchange rate volatility are plotted as dashed lines. All exogenous state variables are set at their mean values.

Figure 5 shows the price schedules of FC and LC debt against amount of debt in FC and in LC, respectively. The other choice variable is set at zero. With higher exchange rate volatility, the default probability increases slightly for a given level of FC debt, and hence the price of FC debt falls; but the quantitative size is so small that FC debt price schedules against the FC debt hardly change quantitatively with higher exchange rate volatility. However, the LC debt price schedule shifts down and becomes steeper as lenders bear more exchange rate risk per its investment in LC debt.

Figure 5: LC and FC Bond Prices with Higher Exchange Rate Volatility σ_s

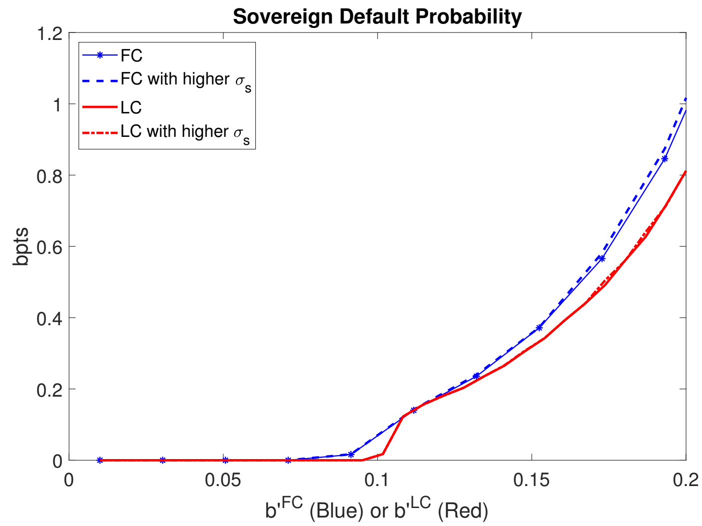


Notes: The LHS figure plots the price schedules of FC debt b'^{FC} as b'^{FC} varies. The RHS figure plots the price schedules of LC debt b'^{LC} as b'^{LC} varies. We compare the one with the baseline exchange rate volatility to the other with 1 percentage point higher exchange rate volatility. We fix the other choice variable at zero, i.e. $b'^{LC} = 0$ (LHS), $b'^{FC} = 0$ (RHS)

Figure 6 shows the default probability. The policy functions with higher exchange rate volatility are plotted as dashed lines. The other choice variable is fixed at zero. With higher exchange rate volatility, the default probability for FC debt (while not borrowing at all in LC) increases for a given level of FC borrowing, b'^{FC}; however, the default probability for LC debt (while not borrowing at all in FC) does not change as exchange rate volatility increases.

The quantitative size of an increase in default probability when borrowing in FC is small but the interest rate increase of local currency borrowing is sizeable. As we see in the next subsection, the sovereign, with higher exchange rate volatility, shifts their portfolio towards more FC borrowing and less LC borrowing.

Figure 6: Default Probability with Higher Exchange Rate Volatility σ_s



Notes: The blue lines plot the default probabilities as FC debt b'^{FC} varies. The red lines plot the default probabilities as LC debt b'^{LC} varies. We compare the one with the baseline exchange rate volatility to the other with 1 percentage point higher exchange rate volatility, depicted in dashed lines. We fix the other choice variable at zero, i.e. $b'^{LC} = 0$ (blue lines), $b'^{FC} = 0$ (red lines).

4.3 Experiment: Higher Exchange Rate Volatility

In this subsection, we examine how the model performs when there is an unexpected increase in the exchange rate volatility from 13% to 14%.[51] The model long-run moments with higher exchange rate volatility are compared with their regression counterparts. Specifically, we examine how the model moments, (i) the relative borrowing cost of LC over FC debt and (ii) the FC share of external public debt, change and see if we can match the empirical relationships documented in Section 2.

In Table 7, the same long-run moments in Table 6 are computed with the higher exchange rate volatility of 14% and we compare them with the moments that we have computed in the baseline model. We see that with higher exchange rate volatility, the relative cost of borrowing in LC over FC, $y^{LC}_{i,t} - \left(y^{FC}_{i,t} + s_{i,t} - s_{i,t+12}\right)$, increases and the FC share rises. Both changes in the relative interest rates and the FC share of external public debt are very much quantitatively aligned with what we see in the data. The model performs well in matching the empirical relationships that we see in the data.

For robustness, we investigate the results with (1) a larger increase in exchange rate volatility, and (2) a larger decrease in exchange rate volatility summarized in Tables A7 and A8.[52] Tables A7

[51] The 75th percentile of the realized exchange rate volatility from 2004–2018 for Colombia is 14.2%. We also examine how the model moments change with a larger increase and a larger decrease in the exchange rate volatility.

[52] We look at a 2 percentage-point increase and decrease in exchange rate volatility. Given that the baseline exchange rate volatility is 13%, that's around 15% increase and decrease from the baseline value.

Table 7: Untargeted Moments: Higher Exchange Rate Volatility

	Panel (A) Baseline $\sigma_s = 13\%$	Panel (B) Counterfactual Higher $\sigma_s = 14\%$	Higher FX Volatility $\Delta\sigma_s = +1\%$	
			Δ in Model	Δ in Data
Relative cost: $y_t^{LC} - \left(y_t^{FC} + s_t - s_{t+12}\right)$	0.99%	1.30%	$+0.31\%$	$+0.45\%$
FC Share	86.70%	87.07%	$+0.37\%$	$+0.33\%$

Panel (A) is simulated with the parameters reported in Table 5. Panel (B) is simulated with the same parameter set but with a higher exchange rate volatility of 14%. The model moments are computed by generating $100,000$ periods of simulated data and discarding the first $1,000$ periods. Default year and the year after default are excluded when calculating the long-run average.

and A8 show that the results still hold for larger changes in exchange rate volatility.

4.4 Quantifying the Welfare Cost of Exchange Rate Volatility

In this last subsection, we quantify the welfare cost of the volatile exchange rate by shutting down to zero.[53] With no exchange rate volatility, LC and FC debt become perfect substitutes. The long-run average $V(\cdot)$ is computed with the simulated data from the baseline model where the exchange rate volatility is 13% and from the experiment where there is no exchange rate risk. Then, we compute the welfare gain of removing the exchange rate risk.

Table 8: Welfare Cost of Currency Mismatch

	Panel (A) Baseline	Panel (C) $\sigma_s = 0$
Relative cost: $y_t^{LC} - \left(y_t^{FC} + s_t - s_{t+12}\right)$	0.99%	0%
$y^{LC} - r_f$	1.63%	0.57%
$y^{FC} - r_f$	0.66%	0.57%
Welfare gain		+0.35% c.e.

Panel (A) is simulated with the parameters reported in Table 5. Panel (C) is simulated with the same parameter set but with zero exchange rate volatility. The model moments are computed by generating 100,000 periods of simulated data and discarding the first 1,000 periods. Default year and the year after default are excluded when calculating the long-run average.

Table 8 summarizes how the moments change when exchange rate volatility is set to zero. The interest rate spread goes down to 0.57%, which captures expected default probability and the risk-premium associated with the default probability. The welfare gain, measured in units of consumption equivalents, is 0.35%.

[53] $S = 1$ in all periods.

The welfare gain of removing the currency mismatch on both borrower and lenders' balance sheets rationalizes the fear of floating that is prevalent across emerging economies even when emerging economies can issue debt in their own currencies. This finding highlights that the fear of floating may arise not just because they suffer from the "original sin" and have dollarized liabilities, but more fundamentally, due to the unit of account difference between emerging economies and global investors. The currency risk has to be borne either by the borrower or lenders, and therefore, even when the sovereign can remove its risk from its balance sheet by borrowing in local currency, it needs to pay a higher interest rate on local currency debt due to the migration of currency risk to lenders' balance sheets. Hence, the welfare gain of stabilizing the exchange rate to the sovereign is sizeable even when it can optimally choose its currency composition. This trade-off present in the model and the welfare implication shed light on the optimal exchange rate policy.

5 Conclusion

This paper documents two new empirical relationships: (i) emerging market sovereigns borrow more in foreign currency when the risk of holding foreign currency debt is higher, i.e., when exchange rate volatility is higher, and (ii) the relative cost of borrowing in local currency to that in foreign currency increases with exchange rate volatility. We rationalize these two new facts with a model of risk-averse global investors who charge a high foreign exchange rate risk premium when lending in local currency. The emerging market sovereign optimally chooses how much risk it bears by borrowing in foreign currency and how much risk it shifts to lenders by borrowing in local currency. The currency composition is determined by balancing out the riskiness of foreign currency borrowing and the costliness of local currency borrowing.

Higher exchange rate volatility increases compensation required by lenders, translating into even higher risk premium charged on local currency debt. A higher relative cost of borrowing in local currency over foreign currency shifts the currency composition even further away from local currency to foreign currency, exposing the sovereign's balance sheet to more exchange rate risk. When exchange rate volatility is driven down to zero, the welfare gain of the sovereign is sizeable, rationalizing the fear of floating their exchange rates, prevalent across emerging economies. A fairly large welfare cost calls for importance of developing a domestic investor base. Future work can investigate possible policy instruments which may stabilize exchange rate fluctuations, such as foreign exchange reserves and foreign exchange swap agreements.

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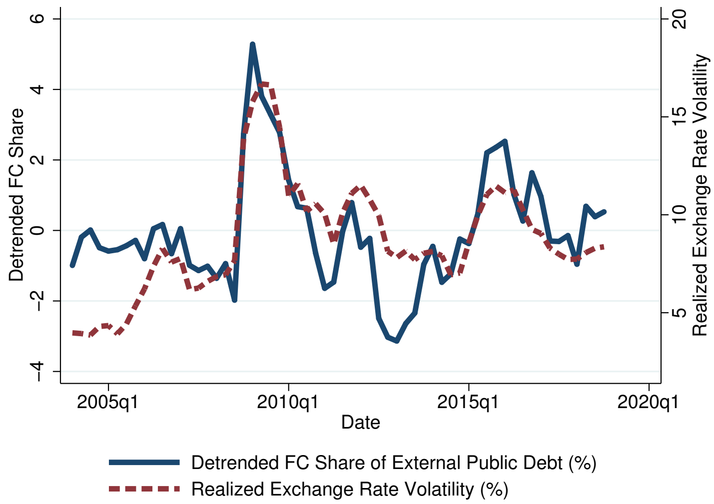
A Appendix

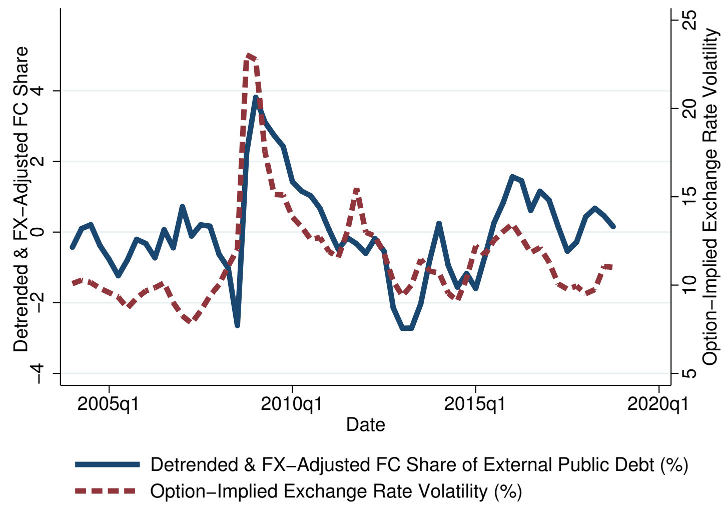
A.1 Additional Figures

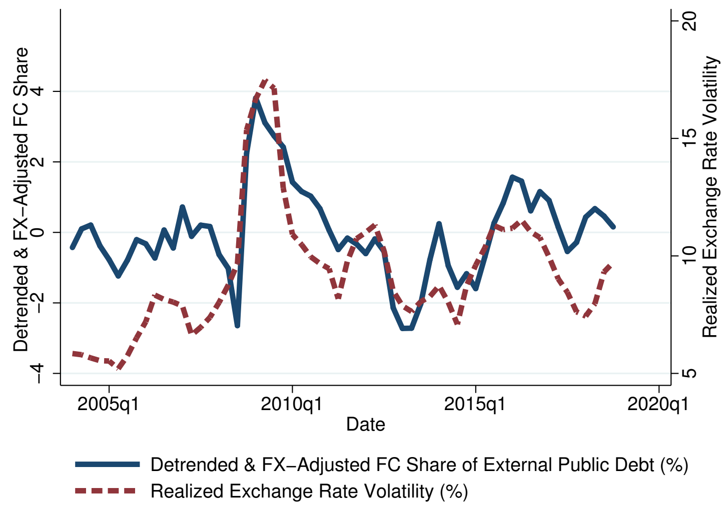
Figure A1: FC Share of External Public Debt and Realized Exchange Rate Volatility



Notes: The source of the data is the author's calculations based on Bloomberg and Arslanalp and Tsuda (2014, updated 2020). The figure shows the cross-sectional medians across 18 emerging economies. The foreign currency share of external public debt is detrended using HP filter. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past year.

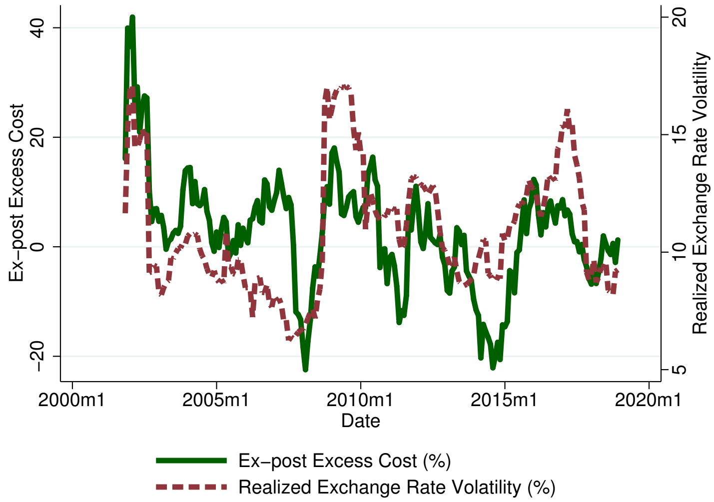
Figure A2: FX-adjusted FC Share of External Public Debt and Exchange Rate Volatility





Notes: The source of the data is the author's calculations based on Bloomberg and Arslanalp and Tsuda (2014, updated 2020). The figure shows the cross-sectional medians across 18 emerging economies. The foreign currency share of external public debt is FX-adjusted and detrended using HP filter. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past year.

Figure A3: Ex-post Excess Cost of Borrowing in LC over FC and Realized Exchange Rate Volatility



Notes: The excess cost of borrowing in local currency over foreign currency is defined as $y_{i,t}^{LC} - \left(y_{i,t}^{FC} + s_{i,t+12} - s_{i,t}\right)$ where $y_{i,t}^{LC}$, $y_{i,t}^{FC}$ and $s_{i,t}$ are the one-year local currency debt interest rate, the one-year foreign currency debt interest rate, and the log of the exchange rate – the local currency price of US dollar for a country i at monthly date t. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past year.

A.2 Additional Tables

Table A1: FC Share of External Public Debt and Exchange Rate Volatility with Linear Detrending

	FC Share of External Public Debt (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma_{\text{FX, IMPLIED}}$	0.343***	0.310***	0.278***			
	(0.082)	(0.089)	(0.083)			
$\sigma_{\text{FX, REALIZED}}$				0.304***	0.259***	0.227**
				(0.079)	(0.096)	(0.107)
Expected Depreciation		0.339**	0.568***		0.366***	0.582***
		(0.142)	(0.155)		(0.136)	(0.143)
Inflation			0.184			0.175
			(0.165)			(0.123)
Real GDP growth			-0.092			-0.105
			(0.150)			(0.155)
Capital Openness			3.944			4.566
			(5.442)			(5.247)
Private Credit to GDP			-0.098			-0.088
			(0.069)			(0.070)
External Public Debt to GDP			-0.060			-0.055
			(0.142)			(0.094)
Default Probability			0.608			0.753*
			(0.436)			(0.412)
R-squared	0.028	0.043	0.088	0.023	0.042	0.089
N. of cases	857	857	745	930	930	814

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay, 1998) with a 4-quarter lag. All specifications include country fixed effects. The dependent variable is linearly detrended FC share of external public debt. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past year.

Table A2: FC Share of External Public Debt and Exchange Rate Volatility in the Post-GFC

	FC Share of External Public Debt (%)					
Sample: Post-GFC	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma_{\text{FX, IMPLIED}}$	0.433***	0.423***	0.428***			
	(0.085)	(0.083)	(0.059)			
$\sigma_{\text{FX, REALIZED}}$				0.340***	0.330***	0.333***
				(0.060)	(0.065)	(0.044)
Expected Depreciation		0.135*	0.175**		0.116	0.168**
		(0.070)	(0.065)		(0.072)	(0.071)
Inflation			0.055			0.048
			(0.083)			(0.078)
Real GDP growth			-0.150*			-0.108
			(0.079)			(0.082)
Capital Openness			2.638			1.680
			(1.940)			(2.086)
Private Credit to GDP			-0.043*			-0.056*
			(0.025)			(0.029)
External Public Debt to GDP			-0.115			-0.070
			(0.072)			(0.066)
Default Probability			-1.120***			-1.172***
			(0.385)			(0.402)
R-squared	0.140	0.150	0.204	0.136	0.143	0.187
N. of cases	661	661	593	701	701	629

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay, 1998) with a 4-quarter lag. All specifications include country fixed effects. The dependent variable is HP filtered FC share of external public debt. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past year. The sample period is 2009–2018.

Table A3: FC Share of External Public Debt and Exchange Rate Volatility with Time FE

	FC Share of External Public Debt (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma_{\text{FX, IMPLIED}}$	0.221***	0.215***	0.256**			
	(0.079)	(0.079)	(0.123)			
$\sigma_{\text{FX, REALIZED}}$				0.168***	0.162***	0.184**
				(0.050)	(0.050)	(0.085)
Expected Depreciation		0.029	0.047		0.064	0.089
		(0.053)	(0.065)		(0.044)	(0.070)
Inflation			0.155			0.112
			(0.103)			(0.086)
Real GDP growth			-0.020			-0.022
			(0.077)			(0.074)
Capital Openness			-0.637			-0.552
			(2.285)			(2.134)
Private Credit to GDP			-0.044			-0.037
			(0.039)			(0.034)
External Public Debt to GDP			-0.033			-0.008
			(0.043)			(0.034)
Default Probability			-0.598**			-0.561**
			(0.290)			(0.272)
R-squared	0.249	0.249	0.297	0.233	0.234	0.276
N. of cases	909	909	793	982	982	862

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay, 1998) with a 4-quarter lag. All specifications include country and quarterly time fixed effects. The dependent variable is HP filtered FC share of external public debt. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past year.

Table A4: FC Share of External Public Debt and Exchange Rate Volatility with Global Control Variables

	FC Share of External Public Debt (%)	
	(1)	(2)
$\sigma_{\text{FX, IMPLIED}}$	0.405***	
	(0.079)	
$\sigma_{\text{FX, REALIZED}}$		0.334***
		(0.064)
Expected Depreciation	0.164**	0.172***
	(0.062)	(0.058)
Inflation	-0.055	-0.052
	(0.096)	(0.067)
Real GDP growth	-0.146*	-0.067
	(0.076)	(0.059)
Capital Openness	-0.670	-1.353
	(2.624)	(2.463)
Private Credit to GDP	-0.043	-0.045
	(0.032)	(0.029)
External Public Debt to GDP	-0.053	0.004
	(0.038)	(0.028)
Default Probability	-0.583**	-0.675***
	(0.225)	(0.217)
VIX	0.370	0.665***
	(0.322)	(0.197)
US 10-year treasury	-0.191	-0.123
	(0.453)	(0.392)
Federal Fund Rate	0.804***	0.643***
	(0.253)	(0.186)
TED spread	-1.838***	-1.202**
	(0.663)	(0.539)
R-squared	0.162	0.164
N. of cases	793	862

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay, 1998) with a 4-quarter lag. All specifications include country fixed effects. The dependent variable is HP filtered FC share of external public debt. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past year. Global control variables are included.

Table A5: Relative Cost of Borrowing in LC over FC and Exchange Rate Volatility With Global Control Variables

	Expost Excess Cost of Borrowing in LC over FC (%): $y^{LC}_{i,t} - (y^{FC}_{i,t} + s_{i,t+12} - s_{i,t})$	
	(1)	(2)
$\sigma_{\text{FX, IMPLIED}}$	1.502***	
	(0.276)	
$\sigma_{\text{FX, REALIZED}}$		1.024***
		(0.280)
Expected Depreciation	-0.533***	-0.517**
	(0.201)	(0.209)
Inflation	-0.024	0.106
	(0.284)	(0.293)
Real GDP growth	-0.486**	-0.272
	(0.221)	(0.252)
Capital Openness	-26.487***	-29.897***
	(9.924)	(8.907)
Private Credit to GDP	-0.341***	-0.343***
	(0.094)	(0.095)
External Public Debt to GDP	0.119	0.210
	(0.136)	(0.146)
Default Probability	-1.022	-1.281
	(0.898)	(0.916)
VIX	1.795	3.034**
	(1.348)	(1.196)
US 10-year treasury	0.588	0.285
	(1.419)	(1.484)
Federal Fund Rate	2.571**	1.929*
	(1.093)	(1.125)
TED spread	-7.885***	-5.660*
	(2.844)	(3.263)
R-squared	0.309	0.270
N. of cases	1587	1680

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay, 1998) with a 4-month lag. All specifications include country and monthly date fixed effects. The dependent variable is the expost excess cost of borrowing in LC over FC. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past year. Global control variables are included.

Table A6: Ex-ante Relative Cost of Borrowing in LC over FC and Exchange Rate Volatility

	Ex-ante Excess Cost of Borrowing in LC over FC (%): $y_{i,t}^{LC} - (y_{i,t}^{FC} + \mathbb{E}_t\, s_{i,t+12} - s_{i,t})$	
	(1)	(2)
$\sigma_{\text{FX, IMPLIED}}$	0.113**	
	(0.048)	
$\sigma_{\text{FX, REALIZED}}$		0.087***
		(0.033)
Expected Depreciation	-0.924***	-0.939***
	(0.022)	(0.023)
Inflation	0.107*	0.115**
	(0.062)	(0.056)
Real GDP growth	-0.145***	-0.131***
	(0.048)	(0.040)
Capital Openness	1.447*	0.944
	(0.861)	(0.881)
Private Credit to GDP	0.013	0.016
	(0.013)	(0.013)
External Public Debt to GDP	-0.046**	-0.062***
	(0.021)	(0.017)
Default Probability	-0.078	-0.019
	(0.139)	(0.131)
R-squared	0.869	0.870
N. of cases	1587	1680

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay, 1998) with a 4-month lag. All specifications include country and monthly date fixed effects. The dependent variable is the ex-ante cost of borrowing in LC over FC, computed using the survey forecast data from Consensus Economics. Option-implied exchange rate volatility is the volatility derived from one-year at-the-money exchange rate options. Realized exchange rate volatility is the annualized standard deviation of daily exchange rate returns over the past year.

Table A7: Untargeted Moments: Larger Increase in Exchange Rate Volatility

	Panel (A) Baseline $\sigma_s = 13\%$	Panel (D) Counterfactual Higher $\sigma_s = 15\%$	Higher FX Volatility $\Delta\sigma_s = +2\%$	
			Δ in Model	Δ in Data
Relative cost: $y_{i,t}^{LC} - \left(y_{i,t}^{FC} + s_{i,t} - s_{i,t+12}\right)$	0.99%	1.73%	$+0.74\%$	$+0.90\%$
FC Share	86.70%	87.3%	$+0.60\%$	$+0.66\%$

Panel (A) is simulated with the parameters reported in Table 5. Panel (D) is simulated with the same parameter set except with a higher exchange rate volatility of 15%. The model moments are computed by generating $100,000$ periods of simulated data and discarding the first $1,000$ periods. Default year and the year after default are excluded when calculating the long-run average.

Table A8: Untargeted Moments: Larger Decrease in Exchange Rate Volatility

	Panel (A) Baseline $\sigma_s = 13\%$	Panel (E) Counterfactual Lower $\sigma_s = 11\%$	Lower FX Volatility $\Delta\sigma_s = -2\%$	
			Δ in Model	Δ in Data
Relative cost: $y_{i,t}^{LC} - \left(y_{i,t}^{FC} + s_{i,t} - s_{i,t+12}\right)$	0.99%	0.73%	-0.27%	-0.90%
FC Share	86.70%	85.63%	-1.07%	-0.66%

Panel (A) is simulated with the parameters reported in Table 5. Panel (E) is simulated with the same parameter set except with a lower exchange rate volatility of 13%. The model moments are computed by generating $100,000$ periods of simulated data and discarding the first $1,000$ periods. Default year and the year after default are excluded when calculating the long-run average.

A.3 General Equilibrium Model: Exogenous Real Exchange Rate

This subsection summarizes a general equilibrium model, similar to the Balassa-Samuelson model, where the exchange rate is determined by exogenous TFP processes of the two countries.[54] There are two countries, an emerging economy (EM) and an advanced economy (AE). Assume that monetary policy makers in the EM and in the AE use their monetary instrument to completely stabilize nominal prices in their own currency. The nominal exchange rate S_t is defined as the price of AE currency in units of EM currency. The nominal exchange rate is just the real exchange rate as in the baseline model in Section 3.

Let's assume that EM is endowed with a fixed amount of labor $\bar{L}$, and labor is not mobile across borders. The EM can produce non-tradable and tradable goods, where the productions functions are:

$$Y_t^T = A_t L_t^T, \text{ and } Y_t^N = L_t^N.$$

Then, the wage should be equal to:

$$\frac{W_t}{P_t^T} = A_t \text{ and } \frac{W_t}{P_t^N} = 1.$$

Therefore, it follows:

$$\frac{P_t^N}{P_t^T} = A_t.$$

The consumption basket c_t is a Cobb-Douglas aggregator that combines nontradable goods c_t^N and tradables c_t^T.

$$c_t = \left(c_t^N\right)^\alpha \left(c_t^T\right)^{1-\alpha}, \quad \alpha \in (0,1).$$

Then, the aggregate price P_t is,

$$P_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} \left(P_t^N\right)^\alpha \left(P_t^T\right)^{1-\alpha}.$$

As the monetary authority stabilizes the price level to be constant $P_t = \bar{P}$, and, without loss of generality, let us normalize $\bar{P} = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}$. Then, it follows that

$$\left(P_t^N\right)^\alpha \left(P_t^T\right)^{1-\alpha} = 1,$$

$$A_t^\alpha P_t^T = 1,$$

$$P_t^T = A_t^{-\alpha}.$$

[54] Balassa (1964) and Samuelson (1964).

The AE solves the analogous problem and the tradable goods price P_t^{*T} is given by:

$$P_t^{*T} = (A_t^*)^{-\alpha}.$$

Assume that the law of one price holds:

$$S_t P_t^{*T} = P_t^T.$$

Then, the nominal exchange rate is:

$$S_t = \left(\frac{A_t}{A_t^*}\right)^{-\alpha}.$$

In this general equilibrium model, the exchange rate is determined by the productivity differences between the EM and the AE.

In the model, EM income Y_t is given as

$$\begin{aligned} Y_t &= P_t^T A_t L_t^T + P_t^N L_t^N \\ &= A_t^{-\alpha} A_t L_t^T + \alpha C_t \\ &= A_t^{1-\alpha}(\bar{L} - L_t^N) + \alpha C_t \\ &= A_t^{1-\alpha}\bar{L} - A_t^{1-\alpha}\frac{\alpha C_t}{P_t^N} + \alpha C_t. \end{aligned}$$

Since $P_t^N = P_t^T A_t = A_t^{-\alpha} A_t = A_t^{1-\alpha}$, the aggregate output is,

$$Y_t = A_t^{1-\alpha}\bar{L}.$$

When EM tradable sector productivity A_t increases, the EM income goes up, and its currency appreciates. The negative correlation between the EM income Y_t and the exchange rate S_t can be weakened when the tradable sector productivity shocks in the EM and in the AE are positively correlated.