NBER WORKING PAPER SERIES

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Working Paper 30418
http://www.nber.org/papers/w30418

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
September 2022

We appreciate comments from Paul Bergin, Javier Bianchi, David Cook, Jens Christensen, Wenxin Du, Charles Engel, Sylvain Leduc, Zheng Liu, Hidehiko Matsumoto, Thomas Mertens, JungJae Park, Diego Perez, Jing Zhang, Tony Zhang and seminar participants at U Wisconsin, HKUST, UC Davis, UC Irvine, UC Santa Barbara, WEAI 2021, the NBER IFM Spring meeting 2022, the Reserve Bank of Chicago, the Reserve Bank of San Francisco, the Board of Governors of the Federal Reserve, VEAMS, the SED 2022 and the CICF 2022. Devereux gratefully acknowledges financial support from the Social Sciences and Humanities Council of Canada. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 30418
September 2022
JEL No. F30,F40

ABSTRACT

This paper studies the interaction between foreign exchange reserves and the currency composition of sovereign debt in emerging countries. Focusing on inflation targeting countries, we find that holdings of foreign reserves are associated with higher local currency sovereign debt, an exchange rate which is less sensitive to global shocks, and a lower exchange rate risk premium in local currency sovereign spreads. We rationalize these findings within a financially constrained model of a small open economy. The Sovereign values local currency debt as a hedge against endowment risk, but since the exchange rate tends to depreciate in times of global downturns, risk averse international investors charge an additional currency risk premium on this debt. When a country optimally uses foreign reserves to lean against the wind in response to global shocks, this dampens the response of the exchange rate, providing insurance for the global investor. By reducing the risk premium on local currency debt, foreign exchange reserves therefore facilitate a higher share of local currency debt in the sovereign portfolio. Quantitatively, we find the welfare benefits for the sovereign from optimal foreign reserves management can be very large.

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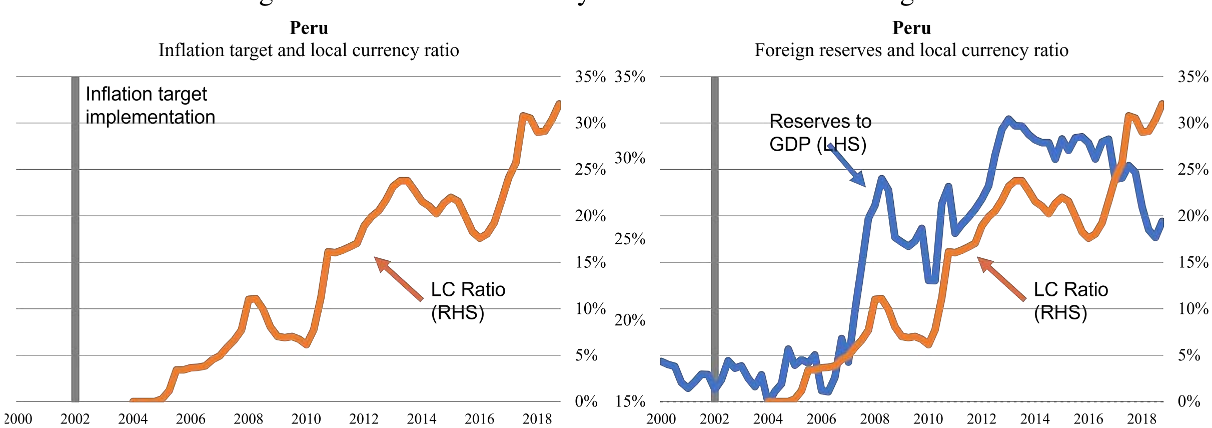
1 Introduction

It is widely acknowledged that government borrowing in local currency is advantageous due to the state contingent nature of domestically denominated debt. In a closed economy, a sovereign can inflate away the debt burden in bad times. In an open economy, endogenous exchange rate depreciation can further reduce the real value of the debt in bad times. However, for long periods many emerging country (EM) sovereigns could only borrow externally in foreign currency (FC), a phenomenon dubbed as "original sin" (Eichengreen and Hausmann (1999)). The constraints of "original sin" have been associated with many painful economic crises, such as the Latin American crisis in the 1980s and the Asian Financial crisis in 1997-1998. Surprisingly however, this pattern has changed more recently since the early 2000s. Based on our empirical sample, the local currency (LC) share of the external EM sovereign debt has been increased from a median of 5% in 2005 to 38% in 2018.

How did some EMs manage to escape from "original sin"? Several papers (Du et al. (2020), Engel and Park (2022) and Ottonello and Perez (2019)) have pointed to the importance of a credible monetary policy, such as the adoption of an inflation targeting regime, as contributing to the LC rise. The logic is that if a country commits to forego inflating away the LC denominated debt, it helps to attract external investors, since their investment is more protected from inflation-induced depreciation. Figure 1(a) plots the LC share of Peru's sovereign debt. The Central Bank of Peru has implemented inflation targeting based monetary policy since 2002, and as we see, the LC share of sovereign borrowing started to pick up in 2004 and eventually reached about 30% at the end of 2019.

Figure 1: Peru Local Currency Share and Reserves Management



We take a complementary tack in this paper. We argue that the enormous foreign exchange reserves accumulation and foreign exchange management during the same period also contributed to the rise in LC share. Some evidence for this can be seen in Figure 1(b) , which plots the empirical association between reserves accumulation and LC share for Peru. There is a strong positive relationship between the two, especially since the large ramp up of reserves in 2006.

Why would the presence of foreign reserves be important in fostering local currency sovereign borrowing? Suppose there are two countries, A and B. There is a global economic downturn which is associated with a sudden stop crisis and a large depreciation in country A but not country B because country B defended the sudden stop crisis with ample of foreign reserves. These behaviors have very different implications for foreign exchange risk premia and therefore local currency debt pricing. The extreme example can be generalized as follows. Risk averse international investors are subject to global economic fluctuations. Lending to a sovereign in LC introduces an additional exchange rate risk to the investment returns. In particular, currencies that depreciate in investor bad times are risky from investors point of view. This results in a risk premium being charged on LC debt. But if a country uses reserves to smooth out the exchange rate response to global fluctuations, referred to as "leaning against the global wind", this can reduce the risk premium embedded in LC interest rate. From the sovereign's standpoint, this makes the LC debt more attractive and tilts the currency portfolio to LC.

To be more concrete, suppose a risk-averse international investor is indifferent between lending to the same EM sovereign in FC and LC, then no-arbitrage would imply the following log return condition:

$$i_t = i_t^* + E_t(S_{t+1} - S_t) + cov_t(m_{t+1}^*, S_{t+1} - S_t)$$

where i_t is the LC interest rate for a EM sovereign, i_t^* is the FC interest rate for the same EM sovereign,[1] S_t is the nominal exchange rate, $E_t(S_{t+1} - S_t)$ is the expected nominal exchange rate change, m_{t+1}^* is the international investor's stochastic discount factor. The LC interest rate (i_t) is a mark up over the FC interest rate (i_t^*), which consists of the expected exchange rate change ($E_t(S_{t+1} - S_t)$) and the exchange rate risk premium ($cov_t(m_{t+1}^*, S_{t+1} - S_t)$). In the extreme case where the EM sovereign faces no cost of ex-post inflation, $E_t(S_{t+1} - S_t) \to \infty$ because the sovereign is expected to inflate everything away. This rationalizes the case of "original sin" as $i_t \to \infty$. Engel and Park (2022) and Ottonello and Perez (2019) provide explanations of how EM countries reduced this expectation term to a small number. While this mechanism is present in our model, our analysis focuses more on the $cov_t(m_{t+1}^*, S_{t+1} - S_t)$ term, which is measured to be empirically large. A "lean against the global wind" reserves management policy that dampens the exchange rate depreciation in states when m_{t+1}^* is high can reduce the $cov_t(m_{t+1}^*, S_{t+1} - S_t)$ and therefore the risk premium being charged in the local currency rate.

We begin by documenting some novel empirical facts and then complement the empirical section with a quantitative model of optimal sovereign currency portfolio and reserves management. Empirically, we study the interrelationship of the sovereign currency portfolio, inflation targeting and reserves management. First, exclusively among inflation targeters, an increase in foreign reserves to GDP is associated with an increase in the LC share. Second, inflation targeting EMs that hold substantial reserves tend to have exchange rates which are less sensitive to global factors. Third, inflation targeters decumulate (accumulate) reserves upon a globally driven exchange rate

[1] Note that these are interest rates for the same government. This is not the same as the uncovered interest party condition.

depreciation (appreciation). Finally, an increase in reserves to GDP is associated with lower local currency sovereign spreads and moreover, sovereign spreads are lower not due to lower credit risk but rather due to a lower exchange rate risk component. Interestingly, these findings do not hold for non-inflation targeters. In sum, these empirical patterns are consistent with our hypothesis: inflation targeting emerging economies who actively manage their reserves tend to “lean against the global wind”, experience a lower exchange rate risk premium in sovereign spreads and display a higher LC share.

To account for the empirical findings, we build a small open economy model with tradable and non-tradable goods. The model features an endogenous currency composition of sovereign debt, endogenous foreign reserves management, and risk averse international investors. The small open economy consists of a public sector and a private sector. To understand the sovereign currency portfolio and reserves management, we introduce two agents in the public sector. First, a sovereign chooses how much debt to issue in FC or LC, and then, ex-post, how much debt to inflate away. Secondly, a central bank conducts foreign reserves management by buying and selling reserves and domestic bonds. To motivate reserves management, we introduce representative households who are subject to occasionally binding collateral constraint and a pecuniary externality (Bianchi (2011)) and a banking sector that that is constrained by moral hazard (Gabaix and Maggiori (2015)). The pecuniary externality provides a rationale for foreign reserves management. The constrained banking sector allows for effective foreign reserves management[2].

The economy is subjected to a domestic tradable endowment shock and a global risk premium shock. Ceteris paribus, the sovereign prefers LC debt over FC debt because it is a good hedge for domestic endowment shocks. Upon a bad endowment shock, the exchange rate endogenously depreciates because of a lower tradable consumption and also debt inflation directly pursued by the sovereign. However, the LC interest rate is higher because international investors charge a premium on local currency debt, due to exchange rate risk. The exchange rate also tends to depreciate due to endogenous deleveraging in response to negative global shocks, making local currency EM debt riskier for risk averse international investors.

We show that the optimal foreign exchange management that maximizes the domestic welfare is to “lean against the global wind”. Because of the collateral constraint on borrowing and pecuniary externality, households overborrow in normal times and underborrow upon negative shocks. In particular, in response to a global negative shock, households cut back on borrowing, which can result in real exchange rate depreciation that tightens the collateral constraint too much. This can precipitate a “sudden stop” (a binding collateral constraint) and results in even sharper exchange rate depreciation. Ex-ante, the central bank accumulates reserves to undo the overborrowing. The economy is less leveraged and it lowers the probability of a sudden stop. Ex-post, upon a global negative shock, the central bank decumulates reserves to avoid a sudden stop. The optimal foreign exchange intervention policy is to “lean against the global wind” and by doing so mitigates the

[2] This approach to foreign reserves management is similar to that in Davis et al. (2020).

impact of global shocks on the real exchange rate.

The optimal "lean against the global wind" foreign reserves policy explains the second and third empirical facts that reserves holding countries have a lower sensitivity to global factors. The lower sensitivity to global factors results in less exchange rate premium on LC interest rate, which explains the fourth empirical fact. The lower LC interest rate leads the sovereign to endogenously issue more debt in LC, which explains the first empirical fact. Intuitively, by providing insurance to global investors via a more stable exchange rate during global bad times, the Sovereign enjoys a lower insurance premium (risk premium) in the issuance of instruments (local currency debt) that insure against domestic shocks.

We calibrate the quantitative model to Brazil, one of the success stories in overcoming the original sin. The model is able to accurately match the average LC share in Brazil (50% in the data vs 53% in model). We then use the same parameterization but shut down different channels. We find that inflation targeting explains roughly two thirds of the LC share and reserves management explains the other one third. However, we show that the gain in the LC share by further inflation commitment (full price stabilization) is very limited. Therefore, reserves management makes possible a level of LC share that is not attainable solely by strict inflation targeting, and in fact allows for some inflation flexibility. We validate our model by using simulated data obtained from our model. Our model simulation can generate regression estimates that are quantitatively close to the empirical counterpart.

Our quantitative model allows us to compute the welfare benefits from optimal foreign reserves intervention (FXI) separately for private households and for the sovereign. For private households, the welfare benefits are positive but modest, in line with the benefits of macroprudential policy as in Bianchi (2011), for instance. But for the sovereign, we find very large welfare benefits. The sovereign benefits in two ways from optimal FXI. First, there is the benefit of a better smoothing of public goods spending from the use of local currency debt. But also there is the benefit of being able to borrow at a lower world interest rate. The combination of these two effects of optimal FXI imply big welfare effects for the sovereign in the production of public goods.

Literature review. Our paper is related to recent literature on overcoming "original sin", including Du et al. (2020), Engel and Park (2022) and Ottonello and Perez (2019). These papers study the optimal currency composition and its interplay with monetary credibility (inflation policy).[3] Sunder-Plassmann (2020) and Hurtado et al. (2022) also study the interplay of inflation/monetary policy and local currency debt while taking the currency portfolio as given. Ogrokhina and Rodriguez (2018) provides empirical evidence of the relationship between inflation targeting and sovereign debt denomination. Our paper advances the literature by linking up the relationship between currency composition and foreign reserves.[4] We argue that foreign reserves management changes the risk profile of the currency, therefore influencing the pricing of sovereign debt, and the

[3]Relatedly, Drenik et al. (2022) and Liu et al. (2021) study the liability currency choice for the private sector.

[4]In addition, Engel and Park (2022), Ottonello and Perez (2019) and Sunder-Plassmann (2020) considers only a risk-neutral investor.

sovereign currency portfolio.

The paper is also related to the literature of reserves management. Papers by Bianchi et al. (2018), Bianchi and Sosa-Padilla (2020) and Hur and Kondo (2016) focus on the role of foreign reserves in reducing sovereign default risk. We show both empirically and theoretically the relevance of reserves on the currency composition of sovereign debt. A closely related paper is Alfaro and Kanczuk (2019), which study local currency debt and reserves management to hedge income risk.[5] Reserves management is also motivated as a tool to correct for different forms of externality, as studied in Arce et al. (2019), Benigno et al. (2022), Davis et al. (2020), Fanelli and Straub (2021) and Kim and Zhang (2020). Finally, reserves management is also viewed as a form of risk management. Hassan et al. (2022) proposes a risk-based theory of stabilizing currency movements, in which the currency that stabilizes its return to the anchor country enjoy a lower interest rate. Bocola and Lorenzoni (2020) argues that foreign reserves are useful to stabilize the exchange rate in a crisis and reduce liability dollarization. Amador et al. (2020) studies exchange rate managment at the zero lower bound.

The model of sudden stops in the paper is closely related to Schmitt-Grohe and Uribe (2020), who show the existence of "under-borrowing" equilibria in Bianchi (2011) framework, where investor's deleveraging can generate large real exchange rate depreciation and current account reversals. We show that the use of foreign reserves to lean against the wind, following the reserves management policy as in Davis et al. (2020), can improve interest rate terms of LC interest rate faced by a sovereign government.

This paper also contributes to the literature on "original sin redux" (Carstens and Shin (2019)), which documents the rise of local currency sovereign debt and studies implications for the international investor currency mismatch problem.[6] We provide a theoretical setup to these empirical findings and study the role of reserves management in dampening the response to global factors (Bruno et al. (2021)).

The paper is organized as follows. Section 2 presents the empirical analysis of LC share, foreign reserves and inflation targeting. The model is presented in Section 3. Section 4 discusses the results from the quantitative version of the model, including policy functions, simulated moments, simulated regressions and a welfare analysis. Section 5 concludes.

2 Empirical findings

In this section, we describe our data (subsection 2.1) and document a number of novel empirical findings. We first show a positive relationship between foreign reserves and LC debt among inflation targeting EMs in subsection 2.2. We then provide evidence that the exchange rates in EMs with higher foreign reserves display lower sensitivity to global factors (proxied by the VIX) in subsection 2.3. Furthermore, countries decumulate their reserves upon global factor-driven exchange rate

[5] In contrast to our paper Alfaro and Kanczuk (2019) do not consider inflation and currency choice in their framework.

[6] See for example, Bertaut et al. (2021), Hofmann et al. (2020) and Hofmann et al. (2022) for more detailed empirical support.

movement, supporting the “lean against the wind” behavior (subsection 2.4). Finally, in subsection 2.5, we show the higher foreign reserves are associated with lower LC sovereign spreads which is driven by a lower exchange rate premium in the spreads. Putting all this together, foreign reserves management results in lower exchange rate sensitivity to global shocks and this is reflected in bond pricing by investors. This results in lower LC spreads and a higher LC share.

2.1 Data description

We focus on 24 emerging countries as in Arslanalp and Tsuda (2014). Arslanalp and Tsuda (2014) build and maintain a panel dataset of currency composition of EM sovereign debt using various data sources. It allows us to systemically construct the LC share of EM sovereign.[7] The dataset covers all the large and commonly studied emerging countries. Our quarterly sample starts from 2004Q1 and ends at 2019Q2. The countries are listed in the Table 1.

We use an inflation targeting definition from Ogrokhina and Rodriguez (2018),[8] who follow the definition from Mishkin (2004).[9] Whether a country is an inflation targeter is reflected as a time-varying dummy in the empirical analysis. We label the countries who remain non inflation targeters throughout the sample as (IT=0) in Table 1.

We also use the covered interest parity dataset from Du et al. (2018) to obtain a measure of LC spreads and the decomposition. The countries that have data available from Du et al. (2018) are labeled with (DS) in Table 1.

The rest of the datasources are standard and are listed in Appendix Table 10.

Table 1: Sample countries

Asia	Latin America	European Union	Europe, Middle East, Africa
China (DS) (IT=0)	Argentina (IT=0)	Bulgaria (IT=0)	Egypt (IT=0)
India (DS)	Brazil (DS)	Hungary (DS)	Russia (DS)
Indonesia (DS)	Chile (DS)	Latvia (IT=0)	South Africa (DS)
Malaysia (DS) (IT=0)	Colombia (DS)	Lithuania (IT=0)	Turkey (DS)
Philippines (DS)	Mexico (DS)	Poland (DS)	Ukraine
Thailand (DS)	Peru (DS)	Romania	
	Uruguay		

Notes: DS denotes countries that are available in the Du and Schreger dataset for pricing data. IT=0 denotes countries that are not inflation targeters in our entire sample period. Note that Latvia and Lithuania joined the Eurozone in the later part of the sample period, but all the empirical results are not affected if we exclude these two.

[7] Engel and Park (2022), Ottonello and Perez (2019), Du et al. (2020) and Sunder-Plassmann (2020) use this dataset as well.

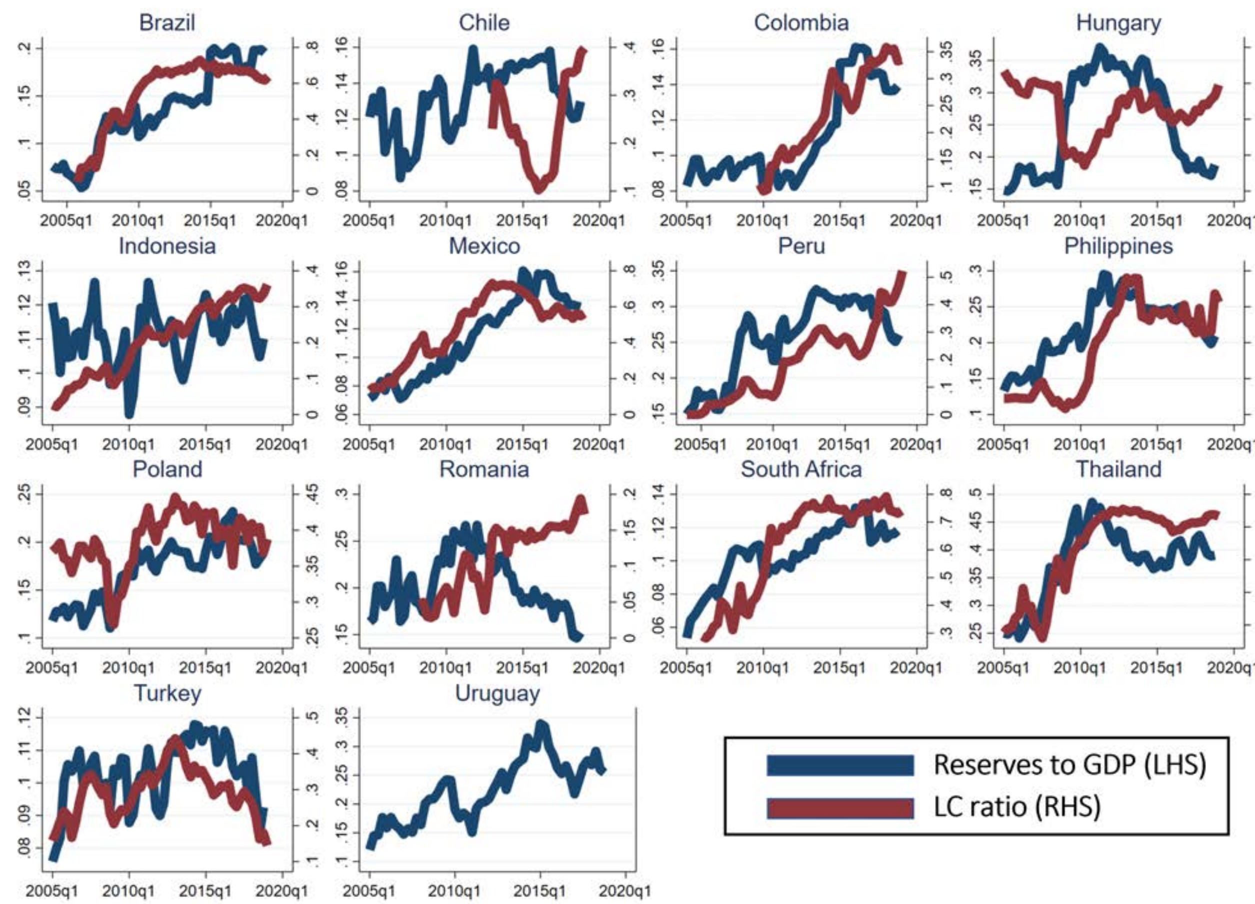
[8] We updated India, Russia and Ukraine as inflation targeter since their paper. The detail list and year of inflation targeting is provided in Appendix Table 11.

[9] There are a number of essential elements to an inflation targeting regime: (i) an explicit central bank mandate to pursue price stability as the primary objective of monetary policy; (ii) an explicit quantitative target for inflation; (iii) a high degree of transparency in monetary policy strategy and implementation; and (iv) monetary policy based on a wide set of information, including an inflation forecast.

2.2 Foreign reserves and local currency debt

Figure 2 illustrates the unconditional relationship between the local currency share of sovereign debt and the ratio of reserves to GDP for a sub-sample of our countries who adopted inflation targeting before 2010. It seems apparent that there is a positive relationship for most countries. In order to explore this in more detail however, we estimate a panel regression.

Figure 2: Time series plot of reserves to GDP and LC ratio for inflation targeters



Notes: Blue lines represent reserves to GDP ratio (LHS) and red lines represent LC share of sovereign debt (RHS).

For each country i and time t, we define the variable *LC share* as $LCshare_{i,t} = \frac{\text{foreign held local currency sovereign debt}_{i,t}}{\text{foreign held total sovereign debt}_{i,t}}$. We follow most of the literature in focusing on external debt. Inspired by the studies cited above that focus on inflation commitment, we control for whether a country is an inflation targeter. We use the definition by Ogrokhina and Rodriguez (2018) that documents the explicit inflation targeting dates for these countries. The annual panel fixed effect regression takes the form:

$$LCshare_{i,t} = \alpha_i + \beta_1 IT_{i,t} + \beta_2 (IT_{i,t} = 0) \times ln(\frac{reserves}{GDP}) + \beta_3 (IT_{i,t} = 1) \times ln(\frac{reserves}{GDP}) + \gamma GC_t + \delta DC_{i,t} + \varepsilon_{i,t} \tag{1}$$

where $IT_{i,t}$ is a time-varying dummy for whether the country is an inflation targeter, GC is a vector of global factor controls (VIX, US Treasury 5Y, US GDP growth) and DC is a vector of domestic variable controls (Domestic GDP growth, World Bank govt effectiveness index, World Bank policy stability index, the Chinn-Ito Index, domestic credit to GDP). These control variables follow Engel and Park (2022). Since many of these variables are only available at annual frequency, we restrict our regression to an annual frequency (end of year data).[10]

The regression estimates are displayed in Table 2. The first column shows estimates without controls. Column (2) to column (4) reports estimates with global controls alone, domestic controls alone and both global and domestic controls. These estimates largely confirm the existing literature that finds a relationship between LC share and inflation targeting. The IT coefficient of all four specifications are significantly positive. Inflation targeting countries tend to have a significantly higher LC ratio. For example, in the first column, the coefficient indicates inflation targeting countries tend to have 49.2% higher LC share than non-inflation targeter. In the sample, countries that adopt inflation targets never return to non inflation targeting. The positive relationship therefore captures a low frequency difference induced by changing from a non-inflation targeter to an inflation targeter within a country.[11]

More interestingly, in addition to whether a country is an inflation targeter, we see that the coefficient estimates for $(IT_{i,t} = 1) \times ln(\frac{reserves}{GDP})$ are significantly positive in all specifications. This indicates that an inflation targeter with a higher reserves to GDP ratio tends to have a higher LC share of sovereign debt. This differs for non inflation targeters, who appear to have insignificant estimates across different specifications. The empirical results here suggests that in addition to being an inflation targeter, which is a long-term institution change for some EMs, the management of foreign reserves seems to have an interesting correlation with the sovereign currency portfolio at a higher frequency.[12]

2.3 Foreign reserves and exchange rate sensitivity

International investors who hold sovereign debt in local currency bear exchange rate risk. But exchange rate risk is important only insofar as it is correlated with the investor's own stochastic discount factor. This suggests that well diversified international investors would be indifferent to exchange rate movements attributable solely to local factors within an individual emerging economy. We next provide some empirical evidence on the relationship between foreign reserves and

[10] Regressions in quarterly frequency give qualitatively the same results.

[11] A time invariant difference between inflation targeters and non-inflation targeters is captured by a country fixed effect.

[12] Note that the effect is not mechanically driven by exchange rate valuation. An depreciation of LC will lower the LC share but increase the reserves to GDP ratio, leading to a negative relationship.

Table 2: Local currency debt ratio and foreign reserves

$$LCratio_{i,t} = \alpha_i + \beta_1 IT_{i,t} + \beta_2 (IT=0) \times ln\frac{reserves}{GDP}_{i,t} + \beta_3 (IT=1) \times ln\frac{reserves}{GDP}_{i,t} + controls_{i,t} + \varepsilon_{i,t}$$

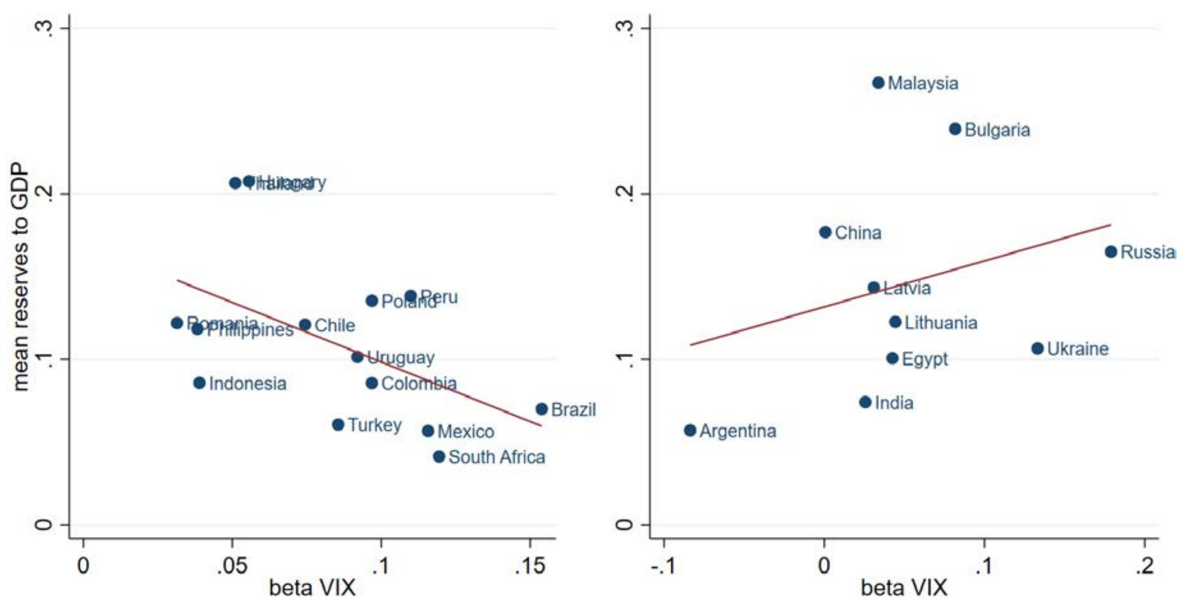
	no control	global controls	domestic controls	all controls
	(1)	(2)	(3)	(4)
IT dummy	0.492***	0.220**	0.340***	0.114**
	(0.136)	(0.091)	(0.065)	(0.041)
$(IT=0) \times ln\frac{reserves}{GDP}$	-0.017	0.018	-0.033**	-0.003
	(0.020)	(0.020)	(0.015)	(0.008)
$(IT=1) \times ln\frac{reserves}{GDP}$	**0.179*** **	**0.094*** **	**0.108*** **	**0.042** **
	(0.046)	**(0.026)**	**(0.018)**	**(0.015)**
VIX		-0.000		-0.002**
		(0.001)		(0.001)
US Treasury 5Y		-0.030***		-0.027***
		(0.007)		(0.002)
US GDP growth		1.124		-0.691
		(1.083)		(0.832)
Domestic GDP growth			0.205	0.283*
			(0.141)	(0.149)
Chinn-Ito Index			-0.050	-0.015
			(0.037)	(0.046)
Govt Effectiveness			0.148***	0.129***
			(0.023)	(0.027)
Political Stability			0.009	0.015
			(0.010)	(0.015)
$\frac{Domestic\ credit}{GDP}$			0.003***	0.002***
			(0.000)	(0.000)
N	311	311	270	270
Within R^2	0.14	0.28	0.39	0.47

Discroll Kraay (1998) standard errors with 5 lags in parentheses

* p<0.1, ** p<0.05, *** p<0.01

exchange rate movements in EMs that is attributable to global factors.

Figure 3: mean reserves to GDP and sensitivity of exchange rate to VIX index (β^{VIX})



Notes: p-value of the regression slope for the left and right figure are 0.04 and 0.28 respectively. R^2 for the left and right figure are 0.26 and 0.06 respectively

We first look at cross-sectional evidence. To capture the exchange rate movements that are relevant for investors, we regress the log change of EM exchange rates on the log change of the VIX index country by country at quarterly frequency:

$$\Delta s_t = \alpha + \beta^{VIX} \Delta lnVIX_t + \varepsilon_t \tag{2}$$

where s_t is the log of the exchange rate of EM currency per USD.

In this quarterly regression, we obtain a β^{VIX} for each emerging country. This can be interpreted as a measure of how sensitive the EM currency is to changes of global shocks as measured by the VIX index, an often-used measure of foreign investor risk appetite/stochastic discount factor/state.

Figure 3 below plots separately the time series mean of reserves to GDP v.s. the beta obtained from eq (2) for each country for inflation targeters and non inflation targeters.[13] On the left hand panel, we see a negative slope that indicates a country with a higher mean reserves to GDP tends

[13]Strictly speaking, inflation targeters in this cross-sectional picture are countries that become inflation targeter during first half of the sample period. India, Russia and Ukraine become inflation targeters at almost the end of the sample.

to have a lower β^{VIX} for inflation targeting countries. The regression line of this scatter plot has a p-value of 0.04. In contrast, we see an insignificantly positive relationship on the right hand side for non-inflation targeters. Taken together, this empirical evidence indicates that inflation targeting countries with high reserves have their exchange rate less sensitive to global movements.

2.4 Lean against the global wind

Now we turn our focus to some panel regression evidence. We look at how changes of reserves to GDP are associated with changes of globally and locally driven exchange rates. To do so, we first conduct a panel regression at quarterly frequency:

$$\Delta s_{i,t} = \alpha_i + \beta_i^{VIX} \Delta lnVIX_t + \sum_{t=0}^{T} \delta_t T_t + \varepsilon_{i,t} \tag{3}$$

where T_t is a time dummy.

Note that we allow for country-dependent coefficients on the VIX as well as time fixed effects, so the regression can capture the most aggregate related exchange rate movements. We produce fitted values for the dependent variable $\Delta\hat{s}_{i,t}$ and fitted values for the residual $\hat{\varepsilon}_{i,t}$. $\Delta\hat{s}_{i,t}$ can be interpreted as the exchange rate movements that are related to global factors and the residual will be country specific exchange rate movements.

After decomposing the exchange rate into two components, we investigate how a country's foreign reserves co-move with different components with the follow panel regression at quarterly frequency:

$$\Delta ln(\frac{reserves}{GDP})_{i,t} = \alpha_i + \beta_1 IT_{i,t} + \beta_2(IT_{i,t}=0)\Delta\hat{s}_{i,t} + \beta_3(IT_{i,t}=1)\Delta\hat{s}_{i,t} + \beta_4(IT_{i,t}=0)\hat{\varepsilon}_{i,t} + \beta_5(IT_{i,t}=1)\hat{\varepsilon}_{i,t} + \varepsilon_{i,t} \tag{4}$$

In table 3, we report the regression estimates of eq (4). The coefficient on $IT_{i,t}$ is negative, meaning that inflation targeting countries decumulate reserves more than non-inflation targeter on average. The more interesting result is that only the coefficient on $(IT_{i,t} = 1)\Delta\hat{s}_{i,t}$ is significant and the estimate is negative. This means that for inflation targeting countries, there is decumulation of reserves when the currency depreciates due to its global component. This is not the case for currency depreciation that is due to country specific factors, as the coefficient estimate of $(IT_{i,t} = 1)\hat{\varepsilon}_{i,t}$ is small and insignificant. This foreign reserves management behaviour is consistent with a "lean against the wind" story for inflation targeters, in which Central Banks use their existing reserves to intervene in face of pressure on the currency coming from global shocks.[14]

[14] The effect is not mechanical. Mechanically, a depreciation of the local currency (an increase Δs_t) will increase $\frac{reserves}{GDP}$ because the reserves are in foreign currency and GDP is measured in local currency. Therefore, the mechanical relationship should result in a positive coefficient.

Table 3: Global factor exchange rates and change of reserves

	$\Delta ln(\frac{reserves}{GDP})_{i,t}$
IT dummy	-0.030***
	(0.009)
$(IT=0)\times$ global exchange rate change	-0.129
	(0.190)
$(IT=1)\times$ global exchange rate change	**-0.241****
	(0.105)
$(IT=0)\times$ local exchange rate change	0.103
	(0.088)
$(IT=1)\times$ local exchange rate change	-0.042
	(0.108)
N	2647
Within R^2	0.01

Discroll Kraay standard errors with 5 lags in parentheses.

* p<0.1, ** p<0.05, *** p<0.01

2.5 Foreign reserves and local currency sovereign spreads

We now provide some evidence directly from the pricing data. For a global investor who invests in EM local currency sovereign bonds, the sovereign spread is defined as the yield over the US treasury of the same maturity:

$$\text{local currency sovereign spread} \equiv \text{local currency sovereign yield} - \text{US Treasury yield} \tag{5}$$

Since the local currency sovereign yield is in a different currency denomination than the US Treasury, investing in local currency sovereign bonds involve two risks: pure credit risk and exchange rate risk. As in Du and Schreger (2017), one can use the cross currency swap to eliminate the currency risk. This could be thought of as swapping the US Treasury yield to the EM currency and treat it a risk-free benchmark in EM currency. So we add and subtract the cross currency swap (CCS) to equation (5) and result in:

$$\begin{aligned}\text{local currency sovereign spread} \equiv & \underbrace{\text{local currency sovereign yield} - \text{US Treasury yield} - \text{CCS}}_{\text{local currency sovereign risk (LCCS, pure credit risk)}} \\ & + \underbrace{\text{CCS}}_{\text{exchange rate risk}}\end{aligned} \tag{6}$$

We directly obtain these sovereign spreads and the decomposition from the Du and Schreger database. Note that because of a non-nesting sample with Arslanalp and Tsuda (2014), we are left with just 16 countries in this exercise (see Table 1). With a quarterly panel fixed effect setting, we regress the local currency sovereign spread and each of its component with the reserves to GDP:

$$y_{i,t} = \alpha_i + \beta_1 ln(\frac{reserves}{GDP})_{i,t} + \beta_2 ln(\frac{Govt\ LC\ debt}{GDP})_{i,t} + \beta_3 ln(\frac{Govt\ FC\ debt}{GDP})_{i,t} + \beta_4 ln(\frac{Privdebt}{GDP})_{i,t} + \beta_5(E_t \Delta S_{t+1}) + \beta_6 GDPgrowth_{i,t} + \beta_7 ln\frac{Domestic\ credit}{GDP} + \beta_8 lnVIX_t + \varepsilon_{i,t} \quad (7)$$

where $y_{i,t} = \{$local currency sovereign spread, exchange rate risk, pure credit risk$\}$ defined in eq (6) and we control for govt external debt to GDP, private external debt to GDP, domestic GDP growth, domestic credit to GDP and the VIX index, all of which are known to be important in explaining sovereign risk. $E_t \Delta S_{t+1}$ is a measure of expected exchange rate using survey forecasted exchange rate expected from Bloomberg.

The regression estimates are reported in Table 4 below. The first column reports the regression with the local currency sovereign spread as the dependent variable. The coefficient estimate of $ln(\frac{reserves}{GDP})$ is negative and significant, indicating an increase in reserves is associated with a reduction in the sovereign spread. When we look at the component that is associated with this reduction, we find that the reduction in the sovereign spread is primarily associated with a change in the exchange rate premium component in column (2), while there is no significant change attributable to the credit risk component in column (3).[15]

Table 4: Sovereign Spreads and Foreign Reserves

	LC spreads (%)	Exchange rate premium (%)	Local currency credit risk (%)
	(1)	(2)	(3)
$ln\frac{reserves}{GDP}$	-1.797**	-1.840***	0.043
	(0.709)	(0.445)	(0.520)
$ln\frac{govt\ debt}{GDP}$	0.843**	0.951***	-0.108
	(0.329)	(0.216)	(0.277)
$ln\frac{private\ debt}{GDP}$	2.117***	1.748***	0.369
	(0.464)	(0.239)	(0.325)
Survey expected	-0.549	-7.503***	6.955***
appreciation	(2.134)	(1.740)	(1.265)
GDP growth	-0.529	-0.181	-0.348
	(0.733)	(0.779)	(0.431)
Domestic credit to GDP	0.004	0.012	-0.008
	(0.013)	(0.008)	(0.008)
ln VIX	2.591***	1.773***	0.818***
	(0.257)	(0.154)	(0.211)
N	565	565	565
R^2	0.31	0.33	0.22

Discroll Kraay standard errors with 5 lags in parentheses

* p<0.1, ** p<0.05, *** p<0.01

[15] We control for survey forecast-based expected exchange rate appreciation as a proxy of controlling for first-moment exchange rate movement. It is the forecast value of the end of quarter exchange rate 1 year from the current quarter. We construct the value such that a positive value is an expected appreciation.

3 A model of currency composition and foreign reserves

So far, we have shown that the share of local currency sovereign debt is significantly positively related to foreign exchange reserve holdings and more so for inflation targeting countries, while at the same time, for inflation targeting countries, reserves tend to be reduced in response to a depreciation in nominal exchange rates that is driven by global risk factors. Finally, we showed that reserve holdings are significantly associated with lower sovereign spreads, and in particular the component of sovereign spreads that is driven by currency risk. How can we account for these different phenomena with a single model, and furthermore, show how each all these findings are interrelated?

In this section, we lay out a small open economy tradable-nontradable model to reconcile the empirical findings and study the interaction between sovereign debt currency composition and foreign reserves. Local currency debt for the sovereign is a good hedge for domestic shocks, since the local currency depreciates in domestic bad times. Inflation targeting makes local currency debt possible, because investors understand the sovereign will not completely inflate away the debt. However, risk averse international investors charge a risk premium on local currency bonds because of exchange rate risk, since global bad shocks are associated with depreciation of local currency and bad times for investors. The risk premium makes local currency debt less attractive for the sovereign. Reserves management dampens the sensitivity of the exchange rate to global shocks. This acts so as to reduce the local currency risk premium. The presence of financial frictions in the domestic economy, as described more fully below, leads the Central Bank to accumulate reserves in placid periods, and deploy reserves in response to downturns in the global economy. This acts so as to stabilize the domestic real exchange rate. Intuitively, by providing insurance to global investors via a more stable exchange rate during global bad times, the Sovereign enjoys a lower insurance premium (risk premium) in the issuance of instruments (local currency debt) that insure against domestic shocks.

Figure 4 displays a graphical illustration of the connections of the agents. The small open economy has five types of agents:

1. Representative households who borrow subject to a collateral constraint as in Bianchi (2011); Davis et al. (2020). This constraint gives rise to a pecuniary externality and a role for reserves accumulation.[16]

2. Domestic financial intermediaries who purchase bonds from private households, financed by borrowing in international financial markets. This supports the effectiveness of foreign exchange rate intervention, as in Gabaix and Maggiori (2015).

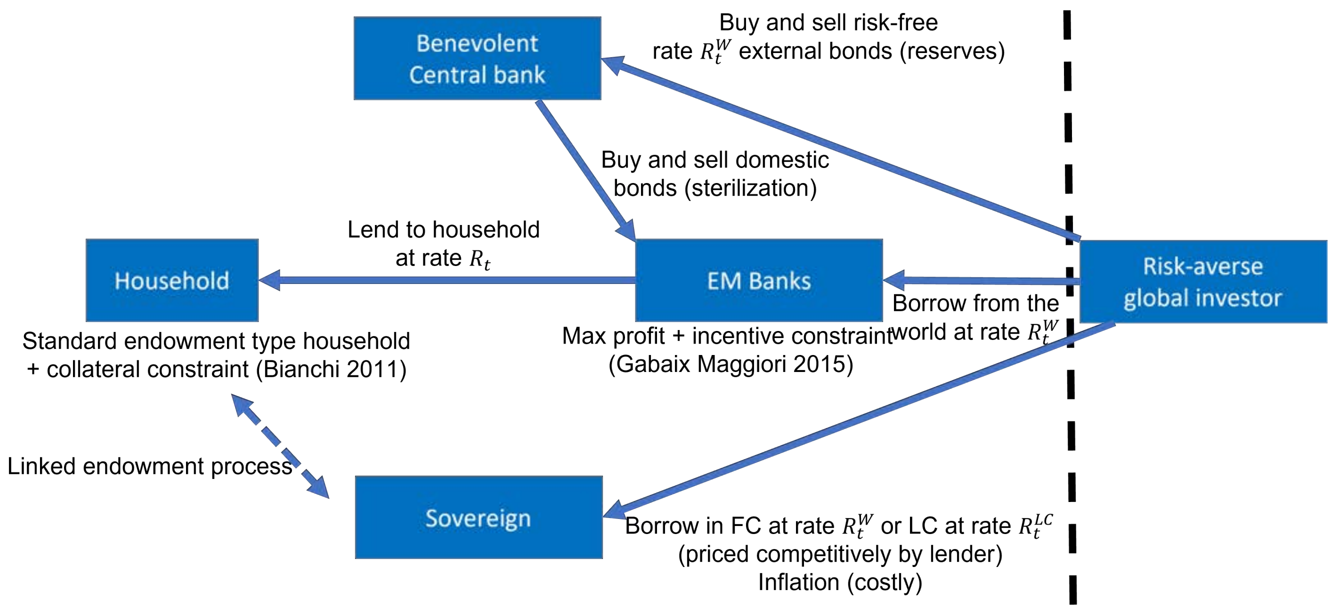
3. A benevolent Central Bank that chooses an optimal reserve management policy.

[16] Foreign reserves accumulation as a tool to correct for pecuniary externality is studied in Arce et al. (2019) and Kim and Zhang (2020)

4. A Sovereign that issues debt in foreign and local currency to smooth and front-load government spending.

5. Risk averse international investors who provide funding to the small open economy.

Figure 4:



3.1 Exogenous processes and the law of one price

We assume there are two exogenous processes in the model. The first one is tradable endowment y_t^T of the small open economy. The second one is the world interest rate (R_t^W) charged to the country's foreign currency debt. The two shocks are assumed to be uncorrelated and represent different aspects of the world. The endowment shock represents country-specific movements and the world interest rate shock present global economic fluctuations.

The tradable endowment process is

$$y_t^T = \rho^y y_{t-1}^T + \sigma^y \varepsilon_t^y$$

The world interest rate process is

$$R_t^W = \rho^R R_{t-1}^W + \sigma^R \varepsilon_t^R$$

Denote p_t^T as the tradable goods price at home, P_t^{T*} as the tradable goods price in the foreign country. S_t as the home currency price of a foreign currency (e.g. Peso per USD), we assume that the law of one price is satisfied for traded goods, so that $p_t^T = S_t P_t^{T*}$. Without loss of generality, we normalize $P_t^{T*} \equiv 1$.

3.2 The Sovereign problem

We begin by describing the problem of the Sovereign. The Sovereign must provide public goods to citizens, where we assume for simplicity that public goods are produced by government spending on the internationally traded goods. The Sovereign desires to front-load government spending and borrow from international investors.[17] In addition to total borrowing, the Sovereign can choose in which currency to issue debt. We assume that in the absence of monetary policy commitment, the Sovereign can choose the overall inflation rate of the economy, subject to a disutility cost of inflation ($l(\frac{P_t}{P_{t-1}})$), as in Engel and Park (2022), Ottonello and Perez (2019) and Du et al. (2020).[18]

The households value consumption (c_t), government spending (G_t) and dislike inflation ($\frac{P_t}{P_{t-1}}$). ω_g is the pareto weight on government spending. The Sovereign maximizes the total discounted sum of the household utility by providing government spending and choosing inflation. There are four choice variables for the Sovereign: government spending (G_t), debt in foreign currency (B_t^{FC}), debt in local currency (B_t^{LC}) and the aggregate price index (P_t).

$$W = \max_{G_t, B_t^{FC}, B_t^{LC}, P_t} E_0 \sum_{t=0}^{\infty} \beta^t \left[(1-\omega_g) u(c_t) + \omega_g [v(G_t) - l(\frac{P_t}{P_{t-1}})] \right] \tag{8}$$

The Sovereign receives tax revenue from the private households which is proportional to the country's tradable endowment. We assume the sovereign receives a constant share τ of the tradable endowment.[19] If we let the total tradable endowment be $(1+\tau)y_t^T$, we assume that the Sovereign receives τy_t^T per period, and and the private economy gets y_t^T. To simplify notation, denote $\tau y_t^T \equiv y_t^G$.

Given this discussion, the Sovereign budget constraint is:

$$\text{Budget constraint in LC: } p_t^T G_t + \frac{S_t}{R_t^{FC}} B_t^{FC} + \frac{1}{R_t^{LC}} B_t^{LC} \leq p_t^T y_t^G + S_t B_{t-1}^{FC} + B_{t-1}^{LC}$$

where p_t^T is the nominal price of the traded goods, S_t is the nominal exchange rate, R_t^{FC} and R_t^{LC} are respectively the rate of return on foreign and local currency debt. Also, from above, we have $p_t^T = S_t$. Now write this equation in real terms as

$$\text{Real budget constraint: } G_t + \frac{1}{R_t^{FC}} B_t^{FC} + \frac{1}{R_t^{LC} p_t^T} B_t^{LC} \leq y_t^G + B_{t-1}^{FC} + \frac{B_{t-1}^{LC}}{p_t^T} \tag{9}$$

[17] We assume that the Sovereign does not borrow directly from private households. This allows us to separate the problem of currency denomination of Sovereign debt cleanly from that of optimal FX intervention. Relaxing this assumption would not materially affect the benefits of intervention for the Sovereign portfolio choice, but would make the analysis more complicated.

[18] As will be shown in subsection 3.6, the Central Bank is benevolent and maximizes the same objective as the sovereign. Allowing the Central Bank to choose the inflation rate yields the same allocations as the Sovereign choosing the inflation rate. We follow the convention in the literature in having the same entity choose the currency portfolio and inflation rate.

[19] We assume constant tax rate for simplicity but it is in fact the optimal tax rate for this class of utility (See Fernandez et al. (2020)). Tax revenue could be proportional to GDP without changing any of the qualitative results, so long as real GDP and the tradable endowment are positively correlated. Assuming revenue as proportional to the tradable endowment simplifies the analysis.

As we will show later, the price index can be expressed in the following form.

$$
\begin{aligned}
P_t &= [\alpha(p_t^T)^{1-\xi} + (1-\alpha)(p_t^N)^{1-\xi}]^{\frac{1}{1-\xi}} \\
&= \quad p_t^T[\alpha + (1-\alpha)(\tfrac{p_t^N}{p_t^T})^{1-\xi}]^{\frac{1}{1-\xi}}
\end{aligned}
\tag{10}
$$

Because prices are fully flexible, changing P_t has no consequences for the the relative price $\frac{p_t^N}{p_t^T}$. The inflation setter can therefore pick a P_t which determines p_t^T and changes the real value of local currency debt.

First order conditions with respect to government spending and foreign currency debt are:

$$
\text{FOC } G_t^T: \; \lambda_t = v_{T,t} = \frac{1}{G_t^\sigma} \tag{11}
$$

where the last equality follows from a CRRA utility we assume in the quantitative section.

$$
\text{FOC } B_t^{FC}\text{:} \; \underbrace{v_{T,t}}_{MBFC} = \underbrace{\beta R_t^W[E_t u_{T,t+1}]}_{MCFC} \tag{12}
$$

MBFC and *MCFC* stand for marginal benefit and cost of FC debt.

The choice of local currency debt is determined by the first order condition:

$$
\begin{aligned}
\text{FOC } B_t^{LC}\text{: } \underbrace{v_{T,t}(1 + \frac{\partial 1/R_t^{LC}}{\partial B_t^{LC}})}_{MBLC} &= \underbrace{\beta R_t^{LC}[E_t v_{T,t+1}\frac{p_t^T}{p_{t+1}^T}]}_{MCLC} \\
&= \beta R_t^{LC}[E_t(v_{T,t+1})E_t(\tfrac{p_t^T}{p_{t+1}^T}) + cov_t(v_{T,t+1}, \tfrac{p_t^T}{p_{t+1}^T})] \\
&= \beta R_t^{LC}[E_t(v_{T,t+1})E_t(\tfrac{S_t}{S_{t+1}}) + cov_t(v_{T,t+1}, \tfrac{S_t}{S_{t+1}})]
\end{aligned}
\tag{13}
$$

where *MBLC* and *MCLC* represent the marginal benefit and cost of LC debt. This condition illustrates that the Sovereign has a possible risk hedging benefit of issuing debt in local currency due to the possibility that the nominal exchange rate depreciates ($\frac{S_t}{S_{t+1}} \downarrow$) in bad times for the Sovereign - i.e. when the marginal utility of government spending ($v_{T,t+1}$) is high.

The FOC for the price index (inflation) is:

$$
\begin{aligned}
\text{FOC } P_t: \; \underbrace{l'(\tfrac{P_t}{P_{t-1}})\tfrac{1}{P_{t-1}}}_{\text{MC of inflation}} &= v'(G_t)\tfrac{\partial (p_t^T)^{-1}}{\partial P_t}B_{t-1}^{LC} \\
&= \underbrace{-v'(G_t)\frac{B_{t-1}^{LC}}{P_t^T}\frac{1}{P_t}}_{\text{MB of inflation}}
\end{aligned}
\tag{14}
$$

Since $B_{t-1}^{LC} < 0$ for borrowing, the marginal benefit of inflation is positive when there is some local currency borrowing. The marginal benefit of inflation is also higher when the marginal utility of G_t is high. In the extreme case where the Sovereign has no disutility of inflation at all, the

Sovereign would always inflate away any existing debt with an arbitrarily high inflation rate. i.e. arbitrary high P_t, p_t^T and S_t.

3.3 International investors.

Unlike the conventional analysis of sovereign borrowing we assume that international investors are risk averse. From the investors point of view, they price the assets according to their asset pricing equation.

$$E_t[\Gamma^*_{t+1} R_t^W] = 1 \text{ and } E_t[\Gamma^*_{t+1} R_t^{LC} \frac{S_t}{S_{t+1}}] = 1$$

where Γ^*_{t+1} is the stochastic discount used by the international investor. We assume Γ^*_{t+1} is a function of the world interest rate, $\Gamma^*_{t+1} = f(R^W_{t+1})$ with $f' > 0$ (parameterized in section 4). The idea is to capture the fact that when the international investors are in bad times, they charged a higher premium on assets. Therefore, a high interest rate state is associated with high marginal utility of the investors.

The investor's no arbitrage condition implies:

$$\begin{aligned} E_t[\Gamma^*_{t+1} R_t^W] &= E_t[\Gamma^*_{t+1} R_t^{LC} \tfrac{S_t}{S_{t+1}}] \\ &= R_t^{LC}[E_t(\Gamma^*_{t+1}) E_t(\tfrac{S_t}{S_{t+1}}) + cov_t(\Gamma^*_{t+1}, \tfrac{S_t}{S_{t+1}})] \end{aligned} \tag{15}$$

Equation (15) implies that investors will require a premium on local currency debt over foreign currency debt t in the case where $cov_t(\Gamma^*_{t+1}, \frac{S_t}{S_{t+1}}) < 0$, since in this case, the local currency will depreciate when investors have high marginal utility of funds - i.e. in bad times for investors.

With risk averse investor - Local currency premium

We plug in (15) into the Sovereign's first order condition for local currency debt eq(13). This yields:

$$u_{T,t}(1 + \frac{\partial 1/R_t^{LC}}{\partial B_t^{LC}}) = \beta \frac{E_t(\Gamma^*_{t+1} R_t^W)}{[E_t(\Gamma^*_{t+1}) E_t(\frac{S_t}{S_{t+1}}) + cov_t(\Gamma^*_{t+1}, \frac{S_t}{S_{t+1}})]} [E_t(u_{T,t+1}) E_t(\frac{S_t}{S_{t+1}}) + cov_t(u_{T,t+1}, \frac{S_t}{S_{t+1}})]$$

$$u_{T,t}(1 + \frac{\partial 1/R_t^{LC}}{\partial B_t^{LC}})[E_t(\Gamma^*_{t+1}) E_t(\frac{S_t}{S_{t+1}}) + cov_t(\Gamma^*_{t+1}, \frac{S_t}{S_{t+1}})]$$

$$= \beta R_t^W E_t(\Gamma^*_{t+1})[E_t(u_{T,t+1}) E_t(\frac{S_t}{S_{t+1}}) + cov_t(u_{T,t+1}, \frac{S_t}{S_{t+1}})]$$

Divide the whole equation by $E_t(\Gamma^*_{t+1}) E_t(\frac{S_t}{S_{t+1}})$, to get:

$$\underbrace{u_{T,t}}_{MBFC} \underbrace{[1 + \frac{cov_t(\Gamma^*_{t+1}, \frac{S_t}{S_{t+1}})}{E_t(\Gamma^*_{t+1}) E_t(\frac{S_t}{S_{t+1}})}](1 + \frac{\partial 1/R_t^{LC}}{\partial B_t^{LC}})}_{\text{local currency risk premium}} = \underbrace{\beta R_t^W [E_t u_{T,t+1}]}_{MCFC} + \underbrace{\beta R_t^W \frac{cov_t(u_{T,t+1}, (\frac{S_t}{S_{t+1}}))}{E_t(\frac{S_t}{S_{t+1}})})}_{\text{hedging benefit}} \tag{16}$$

Compared to the first order condition of foreign currency debt, in additional to the hedging benefit, local currency debt is more expensive because of the local currency risk premium. The optimal portfolio choice between foreign currency debt and local currency debt boils down to how much the hedging benefit of local currency debt is worth relative to the higher interest cost compared to the foreign currency debt. But both the hedging benefit and the local currency premium are critically dependent on the stochastic process for the nominal exchange rate. These will depend not just on the monetary policy rule (the behaviour of the price level), but also the process for the real exchange rate. In section (3.6) below, we show how foreign exchange reserves management influences the real exchange rate. In order to explain this, we turn to the household problem, then the role of intermediary financiers, and finally the optimal reserve management policy of the central bank.

3.4 Household problem

The household sector is same as Bianchi (2011), but using the calibration of Schmitt-Grohe and Uribe (2020) to allow for an exacerbated role for pecuniary externalities.[20]

A continuum of identical households receive tradable (y_t^T) and non-tradable endowments (y^N, a constant). They choose the consumption of tradable goods (c_t^T) and non-tradable goods (c_t^N) within each period. Households can sell one period maturity foreign currency denominated bonds to financial intermediaries at a gross rate R_t. By assumption, households and financial intermediaries do not trade in local currency bonds, perhaps due to "orginal sin" at the private level. This is empirically realistic, since it is widely recognized that most corporate EM borrowing is in foreign currency. [21]

Household problem is described as:

$$V = \max_{c_t^T, c_t^{NT}, b_t^{FC}} E_0 \sum_{t=0}^{\infty} \beta^t \left[(1-\omega_g) u(c_t) + \omega_g [v(G_t) - l(\frac{P_t}{P_{t-1}})] \right] \tag{17}$$

subject to

$$c_t = [\alpha^{1/\xi} (c_t^T)^{(\xi-1)/\xi} + (1-\alpha)^{1/\xi} (c_t^N)^{(\xi-1)/\xi}]^{\xi/(\xi-1)}$$

where c_t is aggregate consumption. The period budget constraint, written in units of the domestic currency, is given by

$$p_t^T c_t^T + p_t^N c_t^N + S_t \frac{b_t^{FC}}{R_t} \leq p_t^T (1+\tau) y_t^T + p_t^N y^N + S_t b_{t-1}^{FC} - T_t + TR_t^{CB} + \Pi_t \tag{18}$$

where $b_t^{FC} < 0$ denotes new foreign currency borrowing at time t. p_t^T, and p_t^N are the prices for tradable and non-tradable goods and S_t is the nominal exchange rate. $T_t = \tau y_t^T$ represents a tax paid

[20] This is critical, since as shown in Davis et al. (2020), it gives rise to a role for countercyclical foreign exchange rate intervention.
[21] See Du and Schreger (2017), Wu (2022) for evidence.

to the government, and TR_t^{CB} is a transfer from the Central Bank. Finally, Π_t represents profits of financial intermediaries, which are described below.

Households face a borrowing constraint that depends on the value of GDP, given by:

$$\text{credit constraint: } -S_t\frac{b_t^{FC}}{R_t} \leq \kappa(p_t^T y_t^T + p_t^N y^N) \tag{19}$$

where κ is a parameter that determines the tightness of the borrowing constraint.

Household equilibrium conditions

The market clearing condition for tradable and non-tradable goods are:

$$y^N = c_t^N$$

$$p_t^T c_t^T + S_t\frac{b_t^{FC}}{R_t} \leq p_t^T(1+\tau)y_t^T + S_t b_{t-1}^{FC} - T_t + TR_t^{CB} + \Pi_t$$

Households first order conditions lead to the equilibrium relative price of non-tradables given by:

$$\frac{p_t^N}{p_t^T} = \frac{1-\alpha}{\alpha}\left(\frac{c_t^T}{y^N}\right)^{\frac{1}{\xi}} \tag{20}$$

The household's Euler equation is:

$$u_{T,t} - \mu_t = \beta R_t[E_t u_{T,t+1}] \tag{21}$$

where $u_{T,t}$ is the derivative w.r.t to c_t^T and μ_t is the multiplier on the borrowing constraint.

The complementary slackness condition of the borrowing constraint is:

$$S_t\frac{b_t^{FC}}{R_t} + \kappa(p_t^T y_t^T + p_t^N y^N) \geq 0 \text{ and with equality if } \mu_t > 0$$

3.5 Financial sector

As in Gabaix and Maggiori (2015), households cannot directly access international financial markets. In order to borrow, they sell bonds denominated in foreign currency to a set of competitive one-period lived financial intermediaries. Financial intermediaries borrow from international investors, in foreign currency, and lend to households. Financial intermediaries begin each period with zero net worth, and satisfy a balance sheet condition;

$$\left(\frac{b_t^{fs}}{R_t} + \frac{F_t^{fs}}{R_t^W}\right) = 0$$

where b_t^{fs} represents bonds purchased from domestic households at price $\frac{1}{R_t}$, and F_t^{fs} represent bonds purchased from international investors at price $\frac{1}{R_t^W}$. Intermediary profits are then $(b_t^{fs} + F_t^{fs})$.

To prevent intermediaries absconding with receipts from foreign lenders (which equal $-\frac{F_t^{fs}}{R_t^W}$ in real terms, intermediaries are limited by the incentive constraint that discounted profits must be at least equal to $\Gamma \mid \frac{F_t^{fs}}{R_t^W} \mid$ times receipts at the beginning of period $t+1$, which are $-\frac{F_t^{fs}}{R_t^W}$. This leads to a wedge between domestic and world returns on foreign currency bonds, given by

$$R_t = R_t^W - \frac{\Gamma}{\beta}\frac{F_t^{fs}}{R_t^W} \tag{22}$$

where $F_t^{fs} < 0$ is the financial sector borrowing from abroad, which, in equilibrium will equal the household's borrowing from financial intermediaries. Higher household borrowing will increase the trading activity of financiers, increasing the wedge between domestic and world rates of return.

3.6 The Central Bank and reserves management

The private sector can also hold bonds issued by the Central Bank. Given the Central Bank's constraint on reserves, as described below, the private sector must have a non-negative position in Central Bank bonds.

Notation. By bond market clearing we have:

$$b_t^{FC} + b_t^{fs} + b_t^{cb} = 0 \text{ , } F_t = F_t^{fs} + F_t^{cb} \tag{23}$$

Here, the first equality is the domestic bond market clearing condition, which says that bonds traded within the domestic market must sum to zero, where b_t^{fs} and b_t^{cb} respectively represent bonds issues by the financial intermediaries and the Central Bank. The second equation defines net foreign assets, which is the sum of the claims of the financial intermediaries F^{fs} and the Central Bank F^{cb} on the rest of the world.[22]

In addition, the balance sheets of the financial intermediaries and the Central Bank must be satisfied, as follows:

$$\frac{b_t^{fs}}{R_t} + \frac{F_t^{fs}}{R_t^W} = 0 \text{ , } \frac{b_t^{cb}}{R_t} + \frac{F_t^{cb}}{R_t^W} = 0$$

Noting that taxes paid to the Sovereign are given by $T_t = \tau y_t^T$, it follows that the households balance of payments condition may be written as

$$p_t^T c_t^T - S_t \frac{F_t}{R_t^W} \leq p_t^T y_t^T - S_t F_{t-1} \tag{24}$$

[22] We note that the net foreign asset definition here represents the net claims that the private sector holds indirectly through the asset holdings of the Central Bank and the financial intermediaries. It excludes the debt of the Sovereign, as described above.

and the condition (22) becomes

$$R_t = R_t^W + \frac{\Gamma}{\beta}\left(\frac{-F_t + F_t^{cb}}{R_t^W}\right) \tag{25}$$

Equation (24) indicates that despite the presence of financial intermediaries, households effectively borrow at the world interest rate, since intermediary profits are rebated to households in a lump-sum transfer. But despite that, (25) implies that Central Bank sterilized intervention will have non-neutral effects on the economy. When the central bank increases its reserve holdings, it must borrow from the private sector. The private sector in turn will attempt to maintain its total borrowing $-F_t$ by selling more bonds to the intermediaries. But this will tend to push up domestic interest rates above foreign interest rates, and as a result, leads to a fall in total private sector borrowing.

So far however we have not explained the motivation between Central Bank foreign reserves management. We now turn to this.

3.6.1 The Central Bank optimization

The Central Bank manages reserves through sterilized intervention, buying reserves with bonds issued to the private sector, while also depleting reserves by retiring bonds. As discussed above, sterilized intervention has real effects in this model due to the frictions in financial markets associated with financial intermediaries.[23] Since the Central Bank can buy or sell reserves on the world market without going through the financial intermediaries, its intervention policy can affect the domestic rate of return faced by households and thereby affecting the total external position of households. Without full commitment, we assume that the Sovereign (the fiscal authority) chooses the inflation rate as part of its fiscal decision making. The Central Bank maximizes a weighted sum of the welfare of the domestic household and the sovereign taking into account the first order conditions and collateral constraints of the household and the sovereign. In addition, we assume that optimal reserves are chosen under discretion, so the Central Bank chooses reserves in each period taking the actions of the future policy maker as given. Finally, as in Davis et al. (2020), we assume that reserves are constrained to be non-negative. Therefore, the Central Bank problem is:

$$\underset{F_t^{cb}}{max} E_0 \sum_{t=0}^{\infty} \beta^t \left\{(1-\omega_g)u(c_t) + \omega_g(v(g_t))\right\} \tag{26}$$

subject to

$$\text{CES aggregator: } c_t = \frac{\{[\alpha^{1/\xi}(c_t^T)^{(\xi-1)/\xi} + (1-\alpha)^{1/\xi}(c_t^N)^{(\xi-1)/\xi}]^{\xi/(\xi-1)}\}^{1-\sigma}}{1-\sigma}$$

$$\text{Household Euler equation: } u_{T,t} - \mu_t = \beta[E_t u_{T,t+1}(R_t^W - \frac{\Gamma}{\beta}(F_t - F_t^{cb})] \tag{27}$$

[23]See Davis et al. (2020) for a detailed discussion of the mechanics of intervention in a similar model.

$$\text{Eqm relative price:} \quad \frac{p_t^N}{p_t^T} = \frac{1-\alpha}{\alpha}\left(\frac{c_t^T}{y^N}\right)^{\frac{1}{\xi}} \tag{28}$$

$$\text{Borrowing constraint:} \quad -\frac{F_t}{R_t^W} \leq \kappa\left(y_t^T + \frac{1-\alpha}{\alpha}\left(\frac{c_t^T}{y^N}\right)^{\frac{1}{\xi}} y^N\right) \tag{29}$$

$$F_t^{cb} \geq 0$$

and sovereign FOCs (11), (12), (14), (16).

The optimal Central Bank reserve policy in this model is based on the analysis of Davis et al. (2020). The critical feature of the model is that the collateral constraint depends on the real exchange rate, which in turn depends on the consumption of traded goods and total private sector borrowing. Since the presence of the real exchange rate in the collateral constraint represents a pecuniary externality, private agents do not explicitly take account of the effect of their borrowing on the real exchange rate and the probability of a sudden stop. The key difference between Central Bank optimization and the household optimization hinges on the Central Bank internalizing the pecuniary externality to respond via reserves management (F_t^{cb}). By changing the reserves level, the Central Bank alters the interest rate the households are facing (equation (27)). It therefore change the consumption path of households and the real exchange rate (via equation (28)). This in turn has an effect on the tightness of the borrowing constraint (equation (29)).

As shown by Schmitt-Grohe and Uribe (2020), if there is sufficient complementarity in consumption between traded and non-traded goods, a fall in private sector borrowing may give rise to a self-fulfilling deleveraging driven sudden stop. For high levels of initial debt, there may be multiple equilibrium levels of private consumption and borrowing - in one equilibrium the collateral constraint is slack and borrowing and traded goods consumption is high with a high real exchange rate, while another equilibrium involves low borrowing, consumption and a much lower real exchange rate. In our paper we follow the analysis of Davis et al. (2020) by assuming that agents select the unconstrained equilibrium when it exists. But this still leaves the possibility of a sudden collapse in capital inflows and a discrete real exchange rate depreciation if a rise in the world interest rate leads households to delever beyond a critical threshold (where the good equilibrium vanishes). As a result, there is a role for the Central Bank in using foreign reserves intervention to avoid a sudden stop. In particular, as is shown below, the Central Bank will wish to accumulate reserves in normal times in order to reduce the probability of sudden stops, and run down reserves in response to a rise in global interest rates, to limit the deleveraging of the private sector. The detailed mechanics of foreign exchange intervention are described more fully in Appendix A and in Davis et al. (2020).

3.7 Price index and exchange rate

We have already noted that the link between the Sovereign's problem and foreign reserve management of the Central Bank is the behaviour of the nominal exchange rate. To be more precise, we can define the consumer price index for this economy as P_t, which given the form of consumer preferences is:

$$\begin{aligned} P_t &= [\alpha(p_t^T)^{1-\xi} + (1-\alpha)(p_t^N)^{1-\xi}]^{\frac{1}{1-\xi}} \\ &= [\alpha(p_t^T)^{1-\xi} + (1-\alpha)(\frac{p_t^N}{p_t^T})^{1-\xi}(p_t^T)^{1-\xi})]^{\frac{1}{1-\xi}} \\ &= \{[(p_t^T)^{1-\xi}][\alpha + (1-\alpha)(\frac{p_t^N}{p_t^T})^{1-\xi}]\}^{\frac{1}{1-\xi}} \\ &= p_t^T[\alpha + (1-\alpha)(\frac{p_t^N}{p_t^T})^{1-\xi}]^{\frac{1}{1-\xi}} \\ &= S_t^T[\alpha + (1-\alpha)(\frac{p_t^N}{p_t^T})^{1-\xi}]^{\frac{1}{1-\xi}} \end{aligned} \tag{30}$$

where the last equality follows from the law of one price in traded goods and the normalization of the foreign price level.

Rearranging the CPI definition (30) gives the conditions for the nominal exchange rate:

$$S_t = \underbrace{P_t}_{\text{price index factor}} \times \underbrace{[\alpha + (1-\alpha)(\frac{p_t^N}{p_t^T})^{1-\xi}]^{-\frac{1}{1-\xi}}}_{\text{real exchange rate factor}} \tag{31}$$

Two forces drive the nominal exchange rate in this model, a nominal price index factor that depends on monetary policy and a domestic factor that is related to the relative price of tradable and non-tradable goods. Foreign reserves management can stabilize the second factor, while inflation policy can influence the nominal price index. In both cases, the reduction in the sensitivity of the nominal exchange rate to global shocks can reduce the currency risk premium imposed by international investors, thereby fostering the issue of local currency debt on the part of the Sovereign.

As eq(20) indicates, real exchange rate depends on the relative consumption of goods, $\frac{p_t^N}{p_t^T} = \frac{1-\alpha}{\alpha}(\frac{c_t^T}{y^N})^{\frac{1}{\xi}}$. Without any government intervention, a lower tradable endowment, or a higher R_t^W which results in endogenous deleveraging of the households, lower c_t^T. Therefore, the real exchange rate endogenously depreciates in bad times for the local economy, which give rise to the hedging benefit of local currency debt. The real exchange rate also endogenously depreciates in times when R_t^W is high, which is the bad times for global investors.

3.8 Competitive equilibrium definition

The competitive equilibrium consist of three blocks. The private block, the sovereign block and the central bank block.

Given the exogenous states (y^T and R^W), reserves policy $F^{cb}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$ and the pricing function $\frac{p^N}{p^T}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$, the financial intermediary operates according to equation (25) and gives $R(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$. The household optimization consists of consumption policy function $c^T(B^{FC}, B^{LC}, b^{FC}, y^T, R^W), c^N(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$ and debt policy $b^{FC'}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$ such that it solves for (17) with a value function $V(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$, subjects to the household budget constraint (18) and credit constraint (19). Bond markets clear as in (23) and non-tradable goods market clear such that $c^N = y^N$.

Given the private and reserves policy F^{cb} and the price schedule $R^{LC}(B^{FC'}, B^{LC'}, b^{FC}, y^T, R^W)$ from investor's no arbitrage condition (15), the sovereign chooses $P(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$, $G(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$, $B^{FC'}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$ and $B^{LC'}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$ such that it maximizes (8) with a value function $W(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$, subject to budget constraint (9). $P(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$ and $\frac{p^N}{p^T}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$ deliver S (or p^T) according to (31).

Given the private block and the soverign block, the central bank chooses a reserves policy function $F^{cb}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$ subject to the negative constraint ($F^{cb} \geq 0$) such that it solves Problem (26).

3.9 An analytical example

Section 4 below constructs a full quantitative analysis of the model. Here we provide some further intuition with the help of analytical approximation to the optimal local currency bond portfolio. We make use of the portfolio approximation techniques in Devereux and Sutherland (2011). Using this, we may obtain an analytical expression for the optimal share of local currency bonds issued by the Sovereign. To keep things simple, we focus here only on the case with full inflation targeting, which highlights the link between foreign reserves management and local currency sovereign debt. To begin, we rewrite the Sovereign's budget constraint as:

$$G_t + D_{t-1} R^W_{t-1} + D^L_{t-1} R^x_{t-1} = y^G_t + D_t \tag{32}$$

where $D_t \equiv -\left(\frac{B^{FC}_t}{R^W_t} + \frac{B^{LC}_t}{R^{LC}_t p^T_t}\right)$ represents the value of new debt issued by the Sovereign in time t, $D^L_t \equiv -\frac{B^{LC}_t}{R^{LC}_t p^T_t}$ is the value of local currency debt, and $R^x_{t-1} \equiv R^W_{t-1} - R^{LC}_{t-1} \frac{p^T_{t-1}}{p^T_t}$ is the ex-post (time t) excess return on foreign currency debt over local currency debt. For simplicity in what follows, we further define $\tilde{R}^{LC}_{t-1} = R^{LC}_{t-1} \frac{p^T_{t-1}}{p^T_t}$.

We may then rewrite the portfolio optimization conditions for the Sovereign and the international investors as

$$E_{t-1} R^x_{t-1} G_t^{-\sigma} = 0 \tag{33}$$

$$E_{t-1} R^x_{t-1} \Gamma^*_t = 0 \tag{34}$$

We then combine eq(33) and eq(34) with the Euler equation for optimal provision of government spending.

$$G_t^{-\sigma} = \tilde{\beta} E_t R_t^W G_{t+1}^{-\sigma} \tag{35}$$

Following Devereux and Sutherland (2011), we take a 2nd order approximation of eq(33) and eq(34) around a non-stochastic steady state , combined with a first order approximation of eq(32), and eq(35). Here we make a slight change in the model so as to ensure the existence of a non-stochastic steady state by re-defining the time discount factor to be endogenous to the size of government consumption, so that $\tilde{\beta} = \omega G_t^{-\eta}$. It is also assumed that in steady state, the Sovereign is a net debtor. [24]

For this example we make the additional assumptions about the shocks to Y_t^G and R_t^W;

$$\log(Y_t^G) = \bar{Y}_t^G + \varepsilon_y$$

$$\log(R_t^W) = \bar{R}_t^W + \varepsilon_R$$

where ε_y and ε_R are mean zero i.i.d. random variables.

For a variable z, we define $\hat{z}$ as the log deviation from steady state, except for $\hat{D}$ and $\hat{R}_t^x$, which is defined below. Then the 2nd order approximation of eq(33) can be written as

$$E_t\left(\hat{R}_t^x + \frac{1}{2}(\hat{R}_t^{2W} - \hat{\hat{R}}_t^{2LC}) - \sigma \hat{G}_t \hat{R}_t^x\right) = \mathscr{O}(\varepsilon^3) \tag{36}$$

$$E_t\left(\hat{R}_t^x + \frac{1}{2}(\hat{R}_t^{2W} - \hat{\hat{R}}_t^{2LC}) - \hat{\Gamma}_t^* \hat{R}_t^x\right) = \mathscr{O}(\varepsilon^3) \tag{37}$$

where $\hat{R}_t^x \equiv \hat{R}_t^W - \hat{\hat{R}}_t^{LC}$, and $\mathscr{O}(\varepsilon^3)$ denotes that the approximation is up to the second order.

We may approximate eq(32), and eq(35) up to the first order. [25] This gives:

$$\hat{G}_t + \frac{1}{\beta}\hat{D}_{t-1} + \frac{\bar{D}}{\beta \bar{G}}\hat{R}_{t-1}^W - \frac{\bar{D}}{\beta \bar{G}}^L \hat{R}_{t-1}^x = y_g \hat{y}_t^G + \hat{D}_t + \mathscr{O}(\varepsilon^2) \tag{38}$$

$$E_t \sigma \hat{G}_{t+1} = (\sigma - \eta)\hat{G}_t + \hat{R}_t^W + \mathscr{O}(\varepsilon^2) \tag{39}$$

where $\hat{D}_{t-1} = \frac{D_{t-1} - \bar{D}_t}{\bar{G}}$, $\bar{\beta} = \frac{1}{\bar{R}^W}$ is the reciprocal of the steady state world interest rate, and $y_g = \frac{\bar{Y}^G}{\bar{G}}$.

Equation (38) reflects the fact that up to a first order, the steady state value of R_t^x is zero, so the first order response of D_t^L does not enter eq(38). Moreover, from the definition of R_{t-1}^x, we may

[24] In a steady state, we must have $\omega \bar{G}^{-\eta} R^W = 1$. We could alternatively introduce portfolio adjustment costs, which would serve the same purpose as an endogenous time discount factor, following the arguments of Schmitt-Grohé and Uribe (2003). Note to simplify the exposition, we assume that the Sovereign does not take into account the effect of spending on the time discount factor. This doesn't affect the qualitative results of this section. Moreover, the value of η can be very small while still ensuring the existence of a steady state.

[25] Note that because eq(36) and eq(37) are accurate only up to second order, in order to determine the optimal portfolio, the other equations can be approximated up to first order.

write

$$\hat{R}^x_{t-1} = \hat{R}^W_{t-1} - \hat{R}^{LC}_{t-1} + \hat{S}_t - \hat{S}_{t-1} \tag{40}$$

where we have used the fact that $p^T_t = S_t$ from above.

Finally, we make the assumption that the stochastic discount factor of international investors is a function of the global interest rate R^w_t, and moreover, up to a first order approximation, we have

$$\hat{\Gamma}^*_t = -\gamma \hat{R}^W_t + \mathscr{O}(\varepsilon^2) \tag{41}$$

We wish to obtain the optimal response of government spending $\hat{G}_t$ in order to obtain the equilibrium local currency portfolio from eq(36) and eq(37). Using eq(38) and iterating forward, we obtain the approximate inter-temporal budget constraint condition as:

$$E_t \sum_{i=0}^{\infty} \beta^i \left(y_g Y^G_{t+i} - G_{t+i} - \frac{\bar{D}}{\beta \bar{G}} \hat{R}^W_{t+i-1} \right) + \frac{\bar{D}}{\beta \bar{G}}^L \hat{R}^x_{t-1} + \frac{1}{\beta} \hat{D}_{t-1} = \mathscr{O}(\varepsilon^2) \tag{42}$$

where we have used the fact that $E_t R^x_t = 0$ up to the first order.

Now substituting in eq(39) and summing, using the assumptions on $\hat{Y}^G_t$ and $\hat{R}^W_t$ we obtain (ignoring the order notation hereafter)

$$\hat{G}_t = (1 - \beta\vartheta) \left(y_g Y^G_t - \frac{\bar{D}}{\beta \bar{G}} \hat{R}^W_{t-1} - \beta \left(\frac{\bar{D}}{\beta \bar{G}} + \frac{1}{\sigma}\right) \hat{R}^W_t + \frac{\bar{D}}{\beta \bar{G}}^L \hat{R}^x_{t-1} + \frac{1}{\beta} \hat{D}_{t-1} \right) \tag{43}$$

where $\vartheta = \frac{\sigma - \eta}{\sigma} < 1$.

Now, equating eq(36) with eq(37), and using eq(41) and eq(43), dropping the time notation since this describes a constant portfolio, we may derive the optimal local currency portfolio

$$\frac{\bar{D}}{\beta \bar{G}}^L = \frac{1}{Var(\hat{S})} \left(\underbrace{\underbrace{-y_g Cov(\hat{Y}^g, \hat{S})}_{\text{hedging domestic shock}} + \underbrace{\beta\left(\frac{\bar{D}}{\beta} + \frac{1}{\sigma}\right) Cov(\hat{R}^W, \hat{S})}_{\text{hedging global shock}}}_{\text{hedging benefit}} - \underbrace{\frac{\gamma}{1 - \beta\vartheta} Cov(\hat{R}^W \hat{S})}_{\text{local currency risk premium}} \right) \tag{44}$$

Expression (44) captures the intuition discussed in the more general model above. The sovereign would like to have a positive local currency debt in order to hedge both income (tax revenue) risk and world interest rate risk, so long as the covariance between revenue and the nominal exchange rate is negative, and so long as the nominal exchange rate depreciates in response to positive world interest rate shocks, given that the sovereign is a debtor, and interest rate shocks tend to depress current fiscal spending. On the other hand, the final term in eq(44) indicates that a positive covariance between world interest rate shocks and the nominal exchange rate tends to increase the cost of local currency debt, given risk averse lenders, and ceteris paribus, would reduce the sovereign's optimal local currency portfolio.

This expression takes the process for the nominal exchange rate as given. But given condition (30) above, we know that nominal exchange rate process is driven partly by foreign exchange reserve management and the real exchange rate. Foreign reserve intervention can reduce the covariance between the world interest rate and the nominal exchange rate.[26] In principle, this could reduce or increases the sovereign's issue of local currency debt since the lower direct hedging benefit of a reduced covariance between world interest rates and the nominal exchange rate goes against the fall in costs of issuing local currency debt when this covariance falls. In the quantitative analysis below we find that the second channel clearly dominates, and foreign reserves management unambiguously leads to an increase in local currency debt issue.[27]

4 Calibration and quantitative evaluation

4.1 Calibration strategy

We calibrate our model to Brazil, a typical and widely studied emerging economy. The model frequency is annual. We separate our parameters into three blocks. The first block contains parameters that are standard and are directly taken from the literature. The second block is estimated from the data and the last block is calibrated to match data moments.

For the first block, we take the CRRA coefficient (σ) of 5 for both households and the government. We take the elasticity of substitution between tradable and non-tradable goods (ξ) of 0.45, very close to estimate from Schmitt-Grohe and Uribe (2020), and Akinci (2017). As discussed at length in their paper, this is the empirically relevant value.[28] We take the weight on tradable goods (α) of 0.30, which is commonly used in the literature. The weight on government utility function is set at 0.02 from Bianchi et al. (2019).[29]

The second block is comprised of parameters directly estimated from the Brazilian data. We use the one year CDS rate to measure the r^W ($r^W \equiv R^W - 1$). To get the exogenous component of the country's funding cost, we first run a regression of $CDS_t^{1y} = \alpha_0 + \beta_0 VIX_t + \varepsilon_t$. We use the fitted value from this regression $C\hat{D}S_t^{1y}$ as r^W. We then estimate the AR(1) coefficient of r^W. The estimated persistent coefficient is 0.4 and the standard deviation of the innovation is 0.038.

[26] The endogenous stochastic process for the nominal exchange rate implied by foreign reserve management cannot be described by first order approximation, since it is discontinuous at the point where the collateral constraint binds. This is described in Appendix A. Despite this, optimal foreign reserve management always reduces $(\hat{R}_t^W, \hat{S}_t)$

[27] This example can be extended to allow for lack of inflation commitment on the part of the Sovereign. In that case, we must add eq(14) to eq(36) and eq(37) in the approximation. The approximation becomes more cumbersome however, due to the fact that the first order approximation of eq(14) involves a first order portfolio term $\hat{D}_{t-1}^L$, and requires a higher order (3rd order) approximation of the optimal portfolio equations, as in Devereux and Sutherland (2010).

[28] A low elasticity of substitution is critical for the link between world real interest rates, the real exchange rate, and the need for FX interventions as discussed above (see also the Appendix).

[29] Technically, we can calibrate this utility weight from the data. However, calibrating this value is computationally challenging given the rich structure of our model. We take this input from the literature and postpone a full calibration for future work.

Symbols	Description	Values	Notes
Parameters from the literature			
σ	CRRA coefficient	5	Standard literature value
ξ	Elasticity of substitution between T and NT goods	0.45	Schmitt-Grohe and Uribe (2020),Akinci (2017)
α	weight on tradable goods	0.3	Standard literature value
w_g	weight on government spending	0.02	Bianchi et al. (2019)
Parameters from the data			
ρ^{r^W}	Persistence of r^W	0.4	Estimated AR(1) of 1yr Brazilian CDS
σ^{r^W}	sd of innovation of r^W	0.038	Same
Er^W	Mean of r^W	0.02	Same
σ	Persistence of y^T	0.65	Estimated AR(1) on Brazil GDP[30]
β	sd of innovation of y^T	0.03	Same
π^{target}	Target inflation rate	4.5%	Central Bank of Brazil target
Parameters from moment matching			
β	Discount factor	0.9	External private debt to GDP (17.5%)
Γ	Financial friction parameter	0.056	Matching regression β in table 3
κ	Credit constraint parameter	0.203	Crisis probability (7%)
γ	Investor SDF $m = \exp^{-r+\gamma\varepsilon_\tau - 0.5\gamma^2\sigma_\tau^2}$	$\gamma = 44.055$	Foreign exchange premium (6.9%)
k	Sovereign inflation disutility cost and functional form	δ=8170	Inflation rate of 6.3% Quadratic cost $\delta(\pi - \pi^{target})^2$
τ	Share of endowment to the government	0.053	Total government debt to GDP (9.8%)

The mean value of r^W is 0.02. For the endowment process, we estimate the AR(1) process after a quadratic detrending. The estimated persistent coefficient is 0.65 and the standard deviation of innovation is 0.03.

For the last block, we use a set of parameters to match the data moments in the Brazilian data. Although the parameters are calibrated jointly, we can give a heuristic description of how the empirical moments inform specific parameters. The discount factor (β) and the parameter on the collateral constraint (κ) are calibrated jointly to match the total private debt to GDP and implied crisis probability of 5-8% in the literature. The parameter on the financial friction (Γ) is useful for matching reserves sensitive to exchange rate movements (β_3 in table 3). The calibrated value is $\beta = 0.9$, $\kappa = 0.203$ and $\Gamma = 0.056$. We then parameterize the investor stochastic discount factor as $\Gamma^*_{t+1} = e^{(-r_t^W + \gamma\varepsilon^r_{t+1} - 0.5\gamma^2\sigma_r^2)}$, where ε^r_{t+1} is the innovation of r^W and σ_r^2 is the unconditional variance of r_t^W. We calibrate the parameter γ to 44.055 to match the average forward exchange premium of 6.9% in the data. We parameterize the inflation disutility cost using a quadratic cost function: $\delta(\pi_t - \pi^{target})^2$ where $\pi_t \equiv \frac{P_t}{P_{t-1}}$ and π^{target} is the inflation target by the Central Bank of Brazil (4.5%). The parameter δ is set to 8170 to match to realized inflation in Brazil (6.3%).

[30]The GDP process is quadratic detrended.

4.2 Policy functions

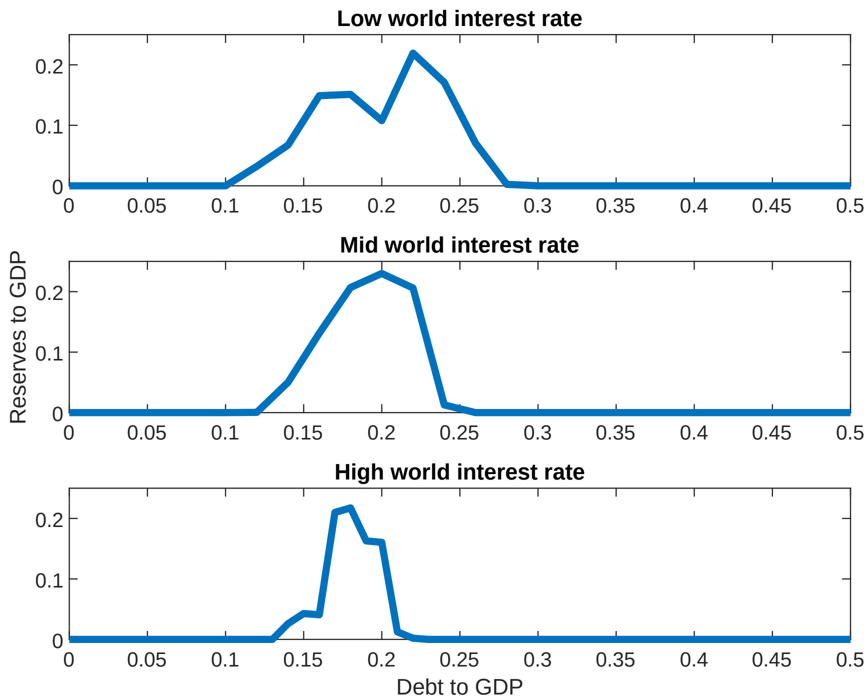
To understand the mechanism of foreign reserves management (FXI), Figure 5 shows the optimal reserves to GDP (y-axis) as a function of existing private debt to GDP (x-axis). We set the existing private debt at an arbitrary level from low to high and plot the optimal reserves to GDP accordingly. The next period debt is chosen optimally. The three panels correspond to the case when the world interest rate is at a low, middle and high level.[31] Each of the figures demonstrates four phases of reserves management. First, when the private debt to GDP is low, there is no need to accumulate reserves. This is because the economy is very far from a sudden stop crisis. Second, as the private debt to GDP rises, there is an accumulation of reserves. This is because the economy enters a region where there is a positive probability that the collateral constraint is binding in the next period. The economy as a whole is overborrowing due to the pecuniary externality that households do not internalize. Therefore, the Central Bank accumulates reserves to save and to correct for the pecuniary externality. Third, when the debt to GDP is sufficiently high, the constraint binds and the households are underborrowing in the sense of Schmitt-Grohe and Uribe (2020). The central bank then finds it optimal to decumulate reserves to support private consumption. In this sense, the severity of the crisis is dampened. Finally, as private debt to GDP goes even higher, the central bank hits the non-negative reserves constraint. The reserves to GDP ratio then goes to zero.

This figure illustrates the lean against the global wind property of the optimal reserves policy. As the interest rate goes up (from the upper to the lower panel), the central bank decumulates reserves earlier as the economy hits the binding region quicker. The peak of the reserves to GDP ratio is located at more towards to left-hand-side of the figure at higher realizations of the interest rate. The central bank also sells down its reserves more aggressively in this case, as shown by the fact that it reaches the zero reserves region earlier at the right-hand side of the figure.

Figure 6 shows the equilibrium price schedule offered by for the local currency debt price as a function of local currency debt derived from the simulated model. As local currency debt increases, risk averse investors increase the interest rate required on debt, so the price sinks. The red line illustrates the debt price in the absence of FXI, while the blue line shows the same policy function in the case of optimal FXI. It is apparent that FXI leads to an increase in the price at which the sovereign can issue local currency debt across the full range of debt issue.

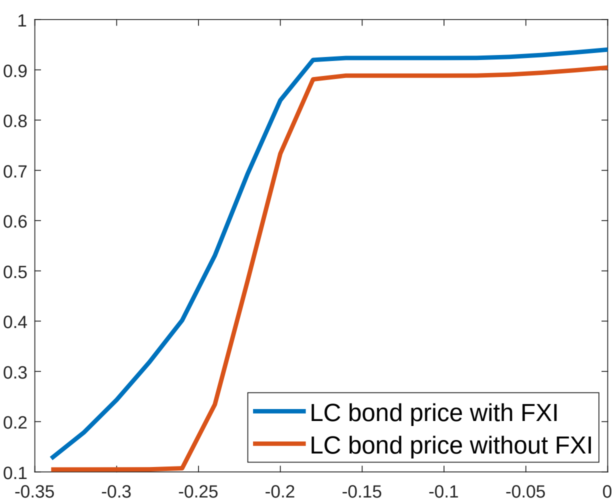
[31] The three cases correspond to second to the lowest interest rate, median and second to the highest interest rate.

Figure 5: Policy function of optimal foreign reserves management



Notes: Y axis refers to reserves to GDP ratio and x axis is the existing private debt (b^{FC}_{t-1}) to GDP ratio. Existing private debt is set at an arbitrary level from low to high. The next period debt is chosen optimally. The three cases correspond to second to the lowest interest rate, median and second to the highest interest rate.

Figure 6: Price schedule of local currency debt



Notes: the X axis is the local currency sovereign debt ($B^{LC\prime}$) and the Y axis is the corresponding local currency bond price. The endowment level is held at one grid point below the mean and all other choice variables are at the mean level. The blue line refers to the case with foreign exchange intervention (FXI) and the red line refers to the case without FXI.

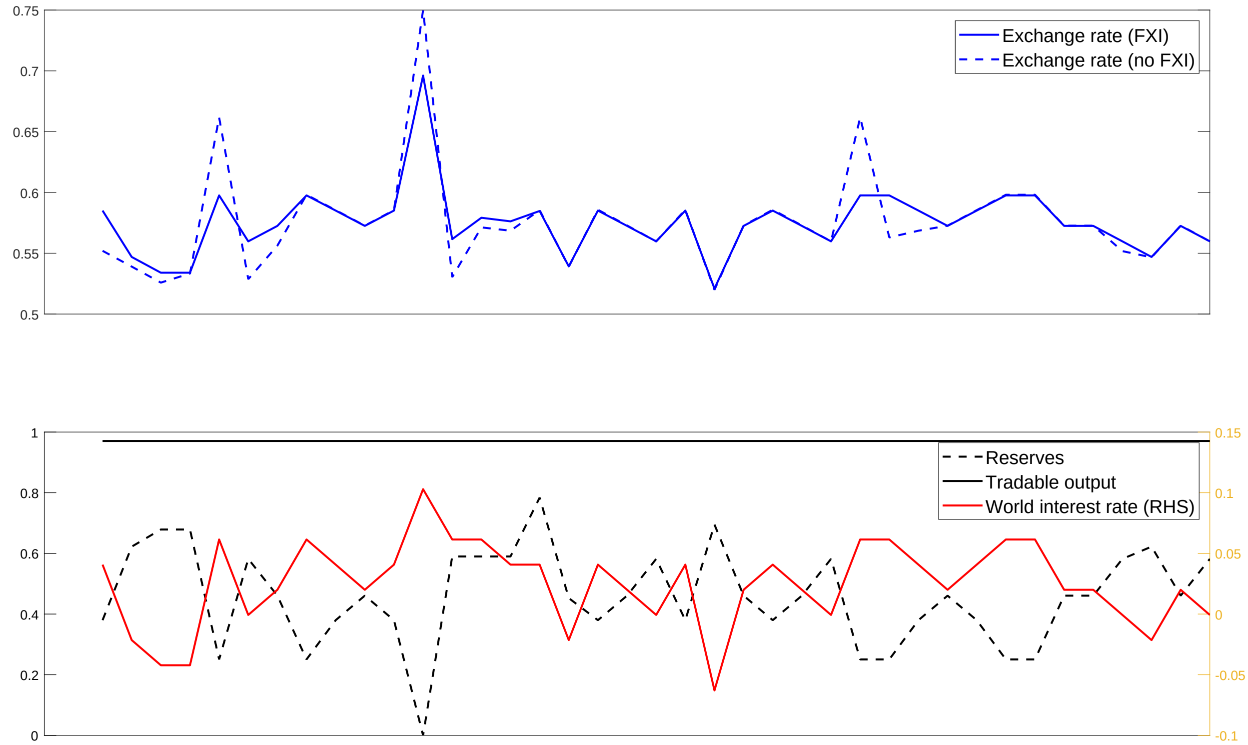
4.3 The dynamics of the exchange rate and foreign exchange reserves

Figure 7 below illustrates the workings of the part of the model that governs the dynamics of foreign reserves and the exchange rate. For a better illustration, this figure is generated using the parameterization discussed above, but the realized path of endowment of traded goods is always at one grid below the mean and allows for a stochastic world interest rate. So we focus on the response to global shocks. The two panels show a simulated path of the exchange rate, reserves and world interest rate. The top panel of the figure shows the behaviour of the nominal exchange rate with and without optimal foreign exchange intervention. The figure also assumes full inflation targeting, so the nominal exchange rate is driven only by movements in the relative price of non-traded to traded goods. The bottom panel of the figure shows an exogenous stochastic process for the world interest rate and the optimal foreign exchange reserve policy followed by the Central Bank, subject to a non-negativity constraint on reserves.

It is clear from the figure that the optimal foreign exchange management policy dampens the volatility of the nominal exchange rate. During normal times (in the middle of the time series), the exchange rate with FXI is less volatile (blue solid line) and is always further from the mean than the one without FXI (dashed blue line). There are three crises in the simulated path, which are all caused by a spike in the foreign interest rate (note that the endowment is assumed to be constant in this simulation). At the left and right of the time series, a sudden stop crisis is prevented by FXI, leading to a substantially less depreciated exchange rate. In the middle of the figure a sudden stop crisis still occurs regardless of the FXI. But even so, the case with FXI has a less depreciated exchange rate due to a decumulation of reserves (the bottom panel). In this manner, the FXI policy makes local currency debt safer from the perspective of international investors. Ex-ante, investors understand that FXI leads to a more stable (less depreciated) exchange rate when global shocks hit (when the risk premium and marginal utility of the investor is high). The investor pricing therefore results in the higher price schedule as shown in Figure 6.

The bottom panel of the figure shows that foreign exchange reserves are strongly negatively correlated with world interest rates - reserves increase in times of low interest rates and are then depleted in face of interest rate spikes. For some large and persistent increases in interest rates, reserves hit their lower bound.

Figure 7: Simulations for reserves and exchange rates under optimal FXI



Notes: For a better illustration, the model is solved under the assumed stochastic process but the realized simulation path of the tradable endowment is held at one grid below the mean. All the choice variables are chosen optimally according to the policy functions.

4.4 Quantitative results

Table 5 shows the results of the simulated model moments. The model targeted moments are all close to those of Brazilian data. The spread between local and foreign currency rate for Brazil is measured at 6.9%. The mean spread of the simulations with optimal FXI (column (2)) get matches this almost exactly at 7.0%. Without FXI but with endogenous inflation policy (column (3)), the risk premium is 10%. The inflation rate is calibrated at the historical inflation rate of 6.3 percent over the sample. Government debt is estimated at roughly 10 percent of GDP.

The untargeted moments in the simulated model concern the level of FX reserves and the ratio of debt in local currency. In the model with optimal FX policy (column (2)), the mean reserves to GDP ratio is 13.4 percent, very close to the level of 14 percent observed in the data sample. The baseline model matches well the mean share of government debt in local currency - 50 percent in the data, 53 percent in the model with FXI and endogenous monetary policy. We note that in the absence of endogenous FX intervention, but with endogenous monetary policy local currency debt represents a smaller fraction of the total at 39.8%. This accords well with the empirical evidence presented in section 2 above where we showed a robust association between FX reserves and local currency debt. It is noteworthy that despite a higher share of local currency debt, the risk premium on local currency sovereign debt is 300 basis points lower in the case of optimal FXI compared to the model with optimal monetary policy but no FXI. This is because the exchange rate risk premium is much lower in the case of FXI than no FXI (0.7% vs 3.9%).[32] Intuitively, FXI leads to a more stable exchange rate response to global shocks, as described in the theoretical section and subsection 4.3 above. This is also reflected in the fact that the crisis probability with optimal FXI is much lower (3.3 percent, compared to 7.5 percent without FXI).

In column (4), we report the model moments for the case when we assume the inflation cost tends to infinity ($\delta \to \infty$), representing a full inflation targeting commitment, but assuming no FXI policy. Given the infinite inflation cost, the inflation rate is choosen at 4.5%, which is the central bank target. The infinite inflation cost case is associated with a LC share of 40.7%, slightly higher than the case in column (3). Comparing column (4) to FXI case in column (2), we can see that additional inflation commitment cannot achieve the same LC share as FXI. This is because a full inflation commitment policy cannot act countercyclically and therefore is not able to lower the risk premium on local currency debt. Further inflation commitment only lower the exchange rate risk premium from 3.9% to 3.8%.

By contrast, column (5) reports the extreme case when there is no inflation cost at all ($\delta = 0$), but the CB follows an optimal FXI policy. The LC interest rate is infinite and the LC share is always zero. This accords with our empirical evidence that foreign reserves is only correlated with LC share when the country is an inflation targeting country.

4.5 Model simulated regressions

We conduct a simulation analysis with the model that can be compared to the results of Tables 2-4 in Section 2 above. In Tables 6-8, using the calibration for Brazil, we simulate 14 separate economies, and then also simulate 10 economies with the same calibration except without a very low inflation cost (inflation disutility $\delta = 20$).[33] This mirrors the empirical results based on 14 inflation targeting countries and 10 countries without inflation targeting. We run each simulation for 520 periods, and drop the first 500 periods, giving us 20 years of data similar to the sample size of our empirical results above.[34] In the model, there is no time variation of inflation targeting, so we run the regressions separately for inflation targeters and non-targeters to prevent collinearity of the IT dummy with country fixed effects.

Table 6 corresponds to Table 2 in the empirical section above. We regress the model implied

[32] The simulated policy functions in Figure 6 confirm that the local currency spread is reduced by FXI for the same states of FC and LC holdings along each point of the interest rate grid.

[33] The average LC share for this low inflation cost calibration is 3%. We do not mimic the non-inflation targeter using $\delta = 0$ because that would imply a LC share of zero all the time and there will be no correlation with any variables by construction.

[34] While many of our empirical regressions above are at quarterly frequency, the results are unchanged if we switch to annual frequency.

Table 5: Moments from the model simulation

Variable	Brazil Data	Model with FXI	Model with no FXI	Model with full IT and no FXI	Model with no IT cost but with FXI
	(1)	(2)	(3)	(4)	(5)
Targeted					
Private Debt to GDP	17.5%	17.0%	17.4%	17.4%	17.0%
Crisis Probability	-	3.3%	7.5%	7.5%	0.33%
regression β_3 in table 3 of $\Delta reserves$ on $\Delta\hat{s}_{i,t}$	-0.34 for Brazil , -0.24 for Panel	-0.30	NA	NA	NA
Government LC spread $r_{LC} - r_{FC}$	6.9%	7.0%	10%	8.3%	NA (LC rate = ∞)
Realized Inflation Rate	6.3%	6.3%	6.1%	4.5%	NA
Total Gov Debt to GDP	5+4.8%=9.8% (FC+LC)	9.9%	10.1%	10.3%	7.23%
Untargeted					
Reserves to GDP	14%	13.4%	0%	0%	13.4%
Expected exchange rate change		6.3%	6.1%	4.5%	NA
Exchange rate risk premium		0.7%	3.9%	3.8%	NA
FC gov. debt to GDP	5%	5.1%	5.8%	5.9%	7.23%
LC gov. debt to GDP	4.9%	5.7%	4.1%	4.2%	0%
LC gov debt share	50%	53%	39.8%	40.7%	0%

Notes: The model is simulated for 11,000 periods and dropping the first 1,000 periods. Mean values are reported. IT standards for inflation taregeting. Column (2) is the full model calibrated with foreign exchange intervention (FXI). Column (3) is the calibrated model but shutting down FXI channel. Column (4) is the calibrated model but setting inflation cost to infinity and no FXI channel. Column (5) is the calibrated model but setting inflation cost to zero.

LC share on the model value of reserves to GDP and other controls. For the simulated 'inflation targeting' sample, the coefficient on reserves to GDP is significant at the 1 percent level, and very close in absolute size to that of Table 2. On the other hand, for the non-inflation targeters, the reserves to GDP variable has no significant affect on the LC ratio, similar to Table 2.

Table 6: Model simulated regression of local currency debt ratio and foreign reserves

$$LCratio_{i,t} = \alpha_i + ln\frac{reserves}{GDP}_{i,t} + controls_{i,t} + \varepsilon_{i,t}$$

	Inflation targeter	Non-inflation targeter
LHS:	$LCratio_{i,t}$	$LCratio_{i,t}$
	(1)	(2)
$ln\frac{reserves}{GDP}$	**0.120*** **	-0.005
	(0.020)	(0.016)
r^W	0.554	0.471*
	(0.566)	(0.243)
GDP growth	0.793***	0.009
	(0.129)	(0.032)
N	280	200

Notes: Discroll Kraay (1998) standard errors with 5 lags in parentheses
* p<0.1, ** p<0.05, *** p<0.01
Simulated sample of inflation targeter is based on simulations of the calibrated model 14 times. Simulated sample of non inflation target is based on simulations of the calibrated model 10 times. Each time we simulate 520 periods and dropping the first 500 periods.

Table 7 reports the results of the simulated regression corresponding to Table 3 of the empirical section. We take the global shock in the model as a proxy for VIX in the data to construct the fitted values of the model-simulated equivalent to eq(3), and regress this on the change in reserves to GDP from the simulated model. We see that the exchange rate response to the global interest rate shock in the model (the fitted value) is significant for the IT sample, but not for the non-IT sample. Just as in Table 3, the residual response of the exchange rate has no significant effect in either case. Finally Table 8 reports the model simulations for the local currency risk premium, and the relationship between the risk premium and FX reserves, along with other controls. For the IT sample, there is again a significant negative association between FX reserves and the risk premium, and the coefficient estimates are also very close to 4 at around 1.5%. The regression coefficient is insignificant for the non-IT sample.

To emphasize the contrast between IT and non-IT countries, Figure 8 shows a scatter plot from the model simulations, separating the IT simulations from the non-IT countries. For the IT countries, the scatter plot illustrates the negative relationship between the beta coefficient of the exchange rate regressed on the world interest rate (on the horizonal axis) and the level of FX reserves

Table 7: Model simulated foreign reserves and global factor of exchange rate regressions

$$\Delta ln(\frac{reserves}{GDP})_{i,t} = \alpha_i + \beta_1 \text{global exchange rate change}_{i,t} + \beta_2 \text{local exchange rate change}_{i,t} + \varepsilon_{i,t}$$

	Inflation targeter	Non-inflation targeter
LHS	$\Delta ln(\frac{reserves}{GDP})_{i,t}$	$\Delta ln(\frac{reserves}{GDP})_{i,t}$
	(1)	(2)
global exchange rate change	**-0.077***	0.002
	(0.041)	(0.002)
local exchange rate change	0.057	0.002
	(0.091)	(0.001)
N	280	200

Notes: Discroll Kraay (1998) standard errors with 5 lags in Lparentheses
* p<0.1, ** p<0.05, *** p<0.01
Simulated sample of inflation targeter is based on simulations of the calibrated model 14 times. Simulated sample of non inflation target is based on simulations of the calibrated model 10 times. Each time we simulate 520 periods and dropping the first 500 periods.

Table 8: Model simulated sovereign spreads and foreign reserves regressions

$$(r^{LC}_{i,t} - r^{W}_{i,t}) = \alpha_i + ln\frac{reserves}{GDP}_{i,t} + controls_{i,t} + \varepsilon_{i,t}$$

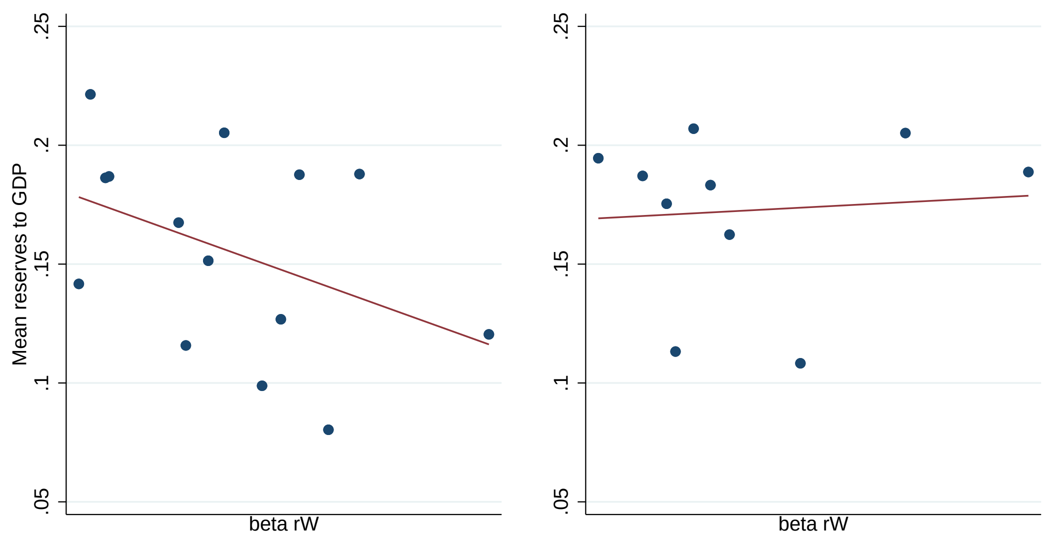
	Inflation targeter	Non-inflation targeter
LHS:	LC spreads (%)	LC spreads (%)
	(1)	(2)
$ln\frac{reserves}{GDP}$	**-1.5***	-50.7
	(0.3)	(150.1)
r^W	-28.8**	4126.8
	(11.0)	(2476.7)
$\frac{\text{public debt}}{GDP}$	38.4	3757.4
	(53.7)	(4203.4)
$\frac{\text{private debt}}{GDP}$	-22.7	-3278.0
	(21.8)	(4673.8)
GDP growth	-0.000	66.1
	(2.8)	(200.8)
N	280	200

Notes: Discroll Kraay (1998) standard errors with 5 lags in parentheses
* p<0.1, ** p<0.05, *** p<0.01
Simulated sample of inflation targeter is based on simulations of the calibrated model 14 times. Simulated sample of non inflation target is based on simulations of the calibrated model 10 times. Each time we simulate 520 periods and dropping the first 500 periods.

to GDP (on the vertical axis). Comparing this figure to figure 3 above, we see that the simulated model accurately represents the impact of FX reserves on the sensitivity of the exchange rate to global shocks. By contrast, the relationship is slightly positive for the non-IT simulations, again consistent with Figure 3.

In summary, these results from the model-based simulations provide strong quantitative support for the dual importance of inflation targeting and the holding and deployment of foreign exchange rate reserves in fostering the growth of local currency sovereign debt for emerging market economies.

Figure 8: Scatter plot of model simulated reserves to GDP and exchange rate sensitivity to global shock



Notes: The Y axis shows mean reserves to GDP and the X-axis is the regression beta of a country's exchange rate on r^W. The simulated sample of inflation targeters is based on simulations of the calibrated model 14 times. The simulated sample of non inflation targeters is based on simulations of the calibrated model 10 times. For each time we simulate 520 periods and drop the first 500 periods.

4.6 Welfare analysis

How beneficial is FXI in avoiding welfare-reducing sudden stops and fostering local currency borrowing for the sovereign? In this final section, we report estimates of the welfare benefits of FXI both for households and for the sovereign. We compute the welfare estimates in the following way. Both for the FXI and no FXI case, we take the simulated data of column (2) and column (3) of Table 5. That is, we simulate the model for 11,000 periods, drop the first 1,000 periods, and record the values for consumption and government spending. We use the discounted sum of the utility of household consumption and sovereign government spending for the whole path, and then compute a constant c and constant G that gives the same utility as these sum of utilities.

Table 9 reports the welfare results in terms of consumption equivalent (for both household and government consumption). First, for households, the welfare gain of FXI is consumption is 0.25% of consumption equivalent. This is quite consistent with Bianchi (2011)'s estimated number for the benefits of prudential capital taxes, where he finds a small welfare gain (0.135%).

The welfare gain for sovereign is much larger. It is 13.5%. In contrast to the welfare gains for households, the sovereign benefits in two ways from optimal FXI. First, the sovereign has smoother government consumption, since it is issuing local currency debt which is a hedge against endowment and global shocks. But it benefits also from being able to borrow at a lower interest rate. It is the combination of these two effects which make the FXI policy so valuable for the sovereign. Table 9 provides further insight into the welfare benefits of FXI by showing two intermediate cases. Intermediate case FXI1 computes the outcome where agents decisions are guided by optimal FXI but the sovereign borrows at the LC interest rate that would pertain without FXI. This captures the benefits from using LC debt, but not the benefits of a lower borrowing cost. We see that the welfare gain in this case is 6.3 percent. Intermediate case FXI2 shows the polar opposite case, where there is no FXI, but governments face the lower interest cost of borrowing that would be implied by optimal FXI. In this case, the welfare gain is 3.4 percent. In either case, Table 9 indicates that, given our calibrated model, the benefits of FXI and local currency borrowing for the sovereign can be substantial.

Table 9: Welfare analysis

	FXI	Intermediate FXI1	Intermediate FXI2	No FXI
Consumption equivalent	0.9872			0.9847
Welfare gain relative to no FXI	0.25%			
Government spending equivalent	0.0802	0.0751	0.0731	0.0707
Welfare gain relative to no FXI	13.5%	6.3%	3.4%	

Notes: The numbers are based on the model simulated data for 11,000 periods and dropping the first 1,000 periods. Intermediate FXI1 case allows the agents to make decisions based on optimal FXI, but government spending is computed based on the interest rate in the no FXI case.. Intermediate FXI2 case refers to a situation without FXI affecting agents behavior, but government spending is computed based on the interest rate in the FXI case.

5 Conclusion

The constraints faced by emerging market economies in the international financial system have been the subject of an enormous research effort over the last two decades. At the turn of the century, most emerging countries were constrained by original sin; the inability to borrow in domestic currency. As we discussed in the introduction, this limitation has been substantially relaxed for many emerging countries in the intervening decades. Many commentators have argued that the monetary stability brought by inflation targeting is a key explanation for this development. Our paper adds to this by arguing that, in addition to inflation targeting, the accumulation of foreign exchange reserves and active foreign exchange rate intervention to lean against the wind represents another important reason that sovereigns have been able to issue own currency debt. We show substantial empirical evidence in support of our claim, and we build a rich open economy macroeconomic model that explains the transition towards an increase in sovereign local currency debt issue and potentially large welfare gain. Each element in the model is an important link explaining how sovereigns have managed to shed off the curse of original sin. However, some questions remain. One feature we do not fully explain is why advanced economies can easily issue local currency debt without holding or deploying large stocks of foreign reserves. We leave this question of the inherent difference between emerging economies and advanced economies in the financial system for future research.

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Appendix

A Sudden stops and the collateral constraint

Following Schmitt-Grohe and Uribe (2020), we assume that the collateral constraint on household borrowing depends on the current value of GDP, and that the elasticity of substitution in preferences between traded and non-traded goods is sufficiently low that there can arise an underborrowing equilibrium driven by self-fulfilling expectations. Figure A, taken from Schmitt-Grohe and Uribe (2020), illustrates the relationship between net private sector borrowing and the collateral constraint. The figure illustrates the left and right hand side of the borrowing constraint, written first as a steady state condition

$$-F = \kappa(y_t^T + \frac{(1-\alpha)}{\alpha}(y^T + F(1-\frac{1}{R^W}))^{\frac{1}{\xi}}) \tag{45}$$

and secondly as a 'short-run' condition

$$-F_t = \kappa(y_t^T + \frac{(1-\alpha)}{\alpha}(y^T - \frac{F_t}{R_t^W} + F_{t-1})^{\frac{1}{\xi}}) \tag{46}$$

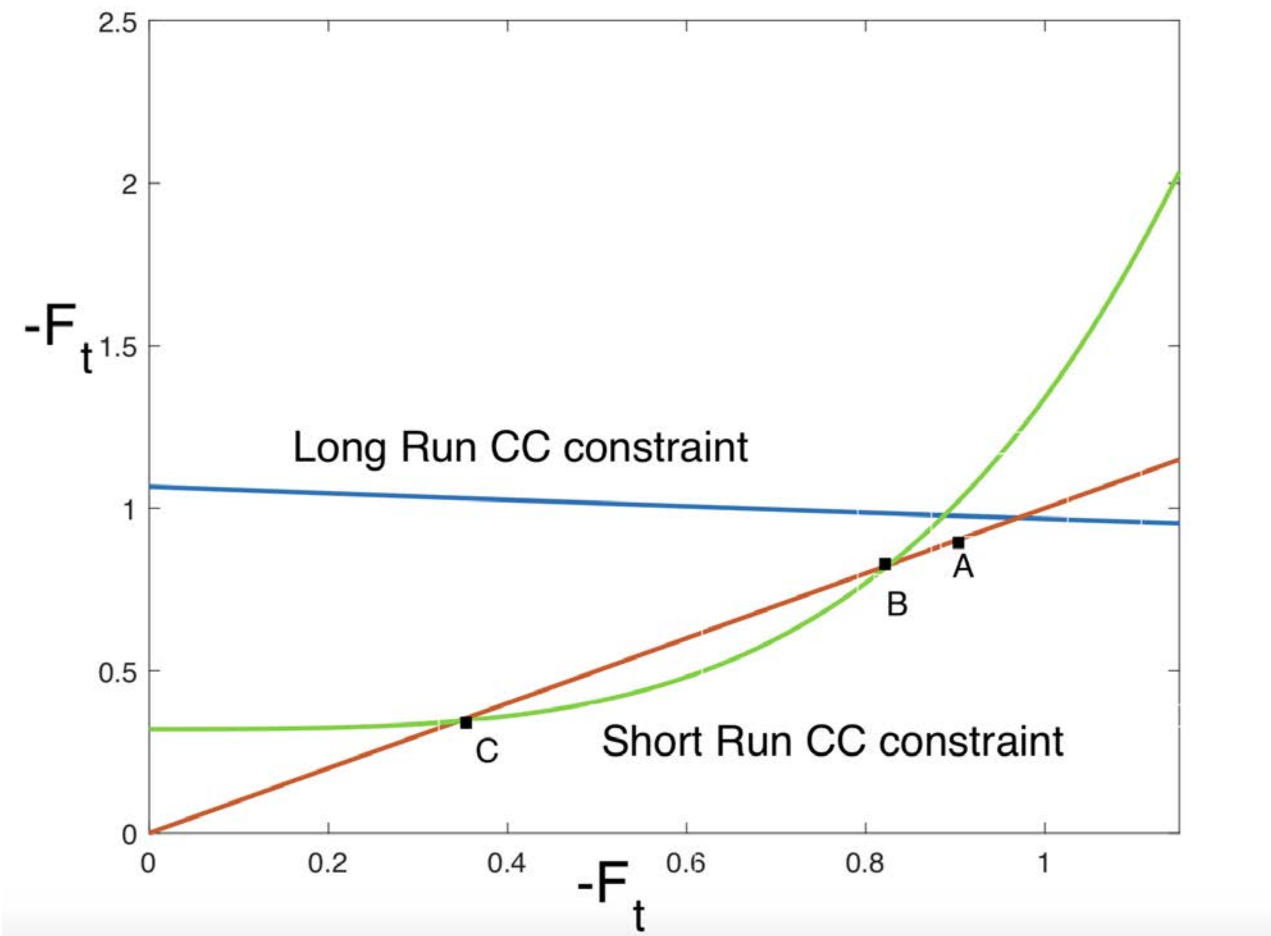
where for simplicity we have assumed that traded good output is constant at y^T, and non-traded good output is normalized to unity.

Equation (45) describes a downward sloping relationship on the left hand side, as a higher net foreign debt $-F$ tightens the borrowing constraint by reducing traded good consumption, depreciating the real exchange rate, and reducing the value of collateral. The intersection of this with the 45^0 line indicates the maximum possible long run level of net foreign debt. Point A in the graph could be a steady state debt level in which the collateral constraint is not binding.

However, note that, conditional on $-F_{t-1}$, the right hand side of (46) is increasing in $-F_t$. Then, in some cases, coinciding with point A, there may be other short run equilibria, where the collateral constraint binds if agents reduce their debt sufficiently, causing a fall in the right hand side of (46) more than the fall in the left hand side. This can occur if the elasticity of substitution between traded and non-traded goods is low, so a fall in current consumption of traded goods leads to a large fall in the relative price of non-traded goods, and the short run borrowing constraint intersects the 45^0 line with a slope greater than unity. Points B and C in the figure are both potential equilibria.

In the quantitative solution of the model, in the case of multiple equilibria, it is necessary to adopt an equilibrium selection mechanism. Schmitt-Grohe and Uribe (2020) discuss a number of alternative strategies for selecting an equilibrium in a quantitative evaluation of their model. We follow Davis et al. (2020) in assuming that if equilibrium A exists, agents coordinate on that equilibrium, but if not, then they coordinate on equilibrium C. The argument is that equilibrium B is unstable in a traditional sense. The implication of this equilibrium selection assumption is that small increases in the world interest rate can lead to precipitous declines in consumption of traded goods, depreciating real exchange rates, and reversals in the current account. This implies that a rising world interest rate can cause large 'sudden stops'. This link between world interest rates and sudden stops is present only due to the calibration of the model with low intra-temporal elasticity of demand and the potential for multiple equilibria as in figure A.

Figure 9: Long run and short run borrowing constraint



B Data appendix

Table 10: Data source

Sample period: 2004Q1-2019Q1

Variable	Data source
Reserves	IMF IFS
Local currency share	Arslanalp and Tsuda (2014)
Local currency sovereign spreads	Du and Schreger (2016)
VIX	FRED
US Treasury 5Y	FRED
US GDP	World Bank WDI, IMF IFS
Domestic GDP	World Bank WDI, IMF IFS
Chinn-Ito Index	Chinn Ito (2006)
Govt Effectiveness	World Bank WDI
Political Stability	World Bank WDI
Domestic credit to GDP	World Bank WDI
External public debt to GDP	BIS International Debt Statistics
External private debt to GDP	BIS International Debt Statistics, BIS locational bank statistics
Nominal exchange rates	IMF IFS
Inflation targeting	Ogrokhina and Rodriguez (2018)

Table 11: Inflation targeting year

Inflation Targeter	Inflation target year	Non Inflation Targeter
Brazil	1999	Argentina
Chile	1999	Bulgaria
Colombia	1999	China
Hungary	2001	Egypt
India	2016	Lithuania
Indonesia	2005	Lativa
Korea	2001	
Mexico	2001	
Peru	2002	
Philippines	2002	
Poland	2002	
Romania	2005	
Russia	2013	
South Africa	2000	
Thailand	2000	
Turkey	2006	
Uruguay	2002	
Ukraine	2015	

C Computation algorithm

The computation of the model is based on Schmitt-Grohe and Uribe (2020), Davis et al. (2020) and Ottonello and Perez (2019). The model is solved by value function iteration. We iterate until the maximum distance of any point in the value function is smaller than 1^{-5} (convergence). There are three big blocks in the model. The households problem, the sovereign problem and the central bank problem. There are two useful observations. First, the central bank reserves decision is not a state variable, the endogenous states are private debt (b^{FC}) and public debt (B^{FC},B^{LC}). Second, the central bank internalizes its effect on sovereign and private decision subject to the equilibrium conditions.

Households problem.

Let the household value function be $V(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$. However, sovereign decisions only matter in determining the reserves positions in a given state. Therefore, it is useful to rewrite the problem as $V(F^{cb}, b^{FC}, y^T, R^W)$. We solve the household problem given any reserves state and central bank picks the optimal reserves state when we solve the central bank problem. Specifically, given any F^{cb}, y^T and R^W, in iteration number n, the household chooses a policy $b^{FC'}_{temp,n}$ with an inital guess of $V_{temp,n}(F^{cb}, b^{FC}, y^T, R^W)$. We iterate until convergence of $V_{temp,n}$.

Sovereign problem.

Let the sovereign value function be $W(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$. Note that while the original in problem involves P_{t-1}, as in Ottonello and Perez (2019), we can detrend the problem and normalize the choice as choosing $P_t/P_{t-1} = \pi_t$ each period. Since the central bank decides the reserves policy given the private and sovereign decision. The reserves policy is unsolved in this stage. Therefore, we solve the sovereign problem given any reserves state and central bank picks the optimal reserves state when we solve the central bank problem. Specifically, given any F^{cb}, y^T,R^W, b^{FC}, B^{FC} and B^{LC}, the sovereign chooses policies $B^{FC'}_{temp,n}$, $B^{LC'}_{temp,n}$ $\pi_{temp,n}$ with an inital guess of $W_{temp,n}(F^{cb}, B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$. The foreign investors price the local currency sovereign bond $q^{LC}_{temp,n}(F^{cb}, B^{FC'}_{temp,n}, B^{LC'}_{temp,n}, b^{FC'}_{temp}, y^T, R^W)$ based on equation 15 given $B^{FC'}_{temp,n}$, $B^{LC'}_{temp,n}$ $\pi_{temp,n}$,$b^{FC'}_{temp}$.

Central bank problem.

Let the central bank value function be $U(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$. Given all temporary value function and policy function above, and state variables (B^{FC},B^{LC},b^{FC},y^T,R^W), the central bank choose the optimal reserves state $F^{cb}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$. And after solving $F^{cb}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$, we can plug this back to the temporary value function and policy function to obtain $V(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$, $W(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$, $b^{FC}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$, $q^{LC}(B^{FC'}, B^{LC'}, b^{FC'}, y^T, R^W)$, $B^{LC'}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$, $B^{FC'}(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$, $\pi(B^{FC}, B^{LC}, b^{FC}, y^T, R^W)$.

Computation.

We discretize the exogenous process using Tauchen method. The y^T and r^W are discretized with 5 grids and 9 grids. Grid points for F^{cb}, b^{FC}, B^{FC}, B^{LC}, π are 100, 100, 15, 15, 15 respectively. As in Ottonello and Perez (2019), once the maximum was choosen on the grid, we use a numerical optimizer routine to find the maximum in a continuous neighborhood around the initially identified point. We use Gaussian quadrature methods to compute all expectations and piecewise linear interpolation to interpolate policies outside the grids.