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SOVEREIGN FINANCE IN EMERGING MARKETS

FINANÇAS SOBERANAS EM MERCADOS EMERGENTES

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SOVEREIGN FINANCE IN EMERGING MARKETS

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“A Lannister always pays his debts.”

Tyrion Lannister, character from A Game of Thrones by George R. R. Martin

RESUMO

Cada ensaio desta tese trata de uma característica recente das finanças soberanas em economias de mercado emergentes. Em cada artigo, amplia-se um modelo macroeconômico quantitativo de dívida e *default* soberanos para responder a uma questão específica. No primeiro capítulo, investiga-se se é melhor para os países emergentes emitir dívida externa denominada em moeda local ou estrangeira usando um modelo com taxa de câmbio real e inflação. Mostra-se como as comparações de bem-estar entre as duas opções de denominação da dívida dependem da credibilidade da política monetária. No segundo ensaio, analisa-se a acumulação conjunta de dívida soberana e reservas internacionais pelos governos dos países emergentes. Nesse arcabouço teórico, as reservas internacionais são uma forma preventiva de poupança que pode ser usada para suavizar o consumo mesmo depois de um *default* soberano. As estatísticas calculadas com dados simulados de um modelo com *default* soberano parcial indicam que a aquisição simultânea de ativos e passivos é uma política ótima nesse tipo de modelo. No último capítulo, examina-se se as baixas taxas de juros livres de risco internacionais, observadas em países desenvolvidos desde a mais recente crise financeira global, levaram a uma busca por rentabilidade – identificada por meio de *spreads* menores mesmo sob maior risco de *default* – nos títulos soberanos de mercados emergentes. Verifica-se que a inclusão de investidores estrangeiros avessos a perdas, característica destacada pela literatura de finanças comportamentais, em um modelo padrão de *default* soberano gera esse resultado.

Palavras-chave: dívida externa, default soberano, denominação monetária de dívida, reservas internacionais, busca por rentabilidade.

ABSTRACT

Each essay in this doctoral dissertation relates to a recent feature of sovereign finance in emerging market economies. In each article, I extend a quantitative macroeconomic model of sovereign debt and default to answer a particular question. In the first chapter, I investigate whether it is better for emerging countries to issue external debt denominated in local or foreign currency using a model with real exchange rates and inflation. I show how the welfare comparisons between the two options of debt denomination depend on the credibility of the monetary policy. In the next essay, I analyze the joint accumulation of sovereign debt and international reserves by emerging countries' governments. In this theoretical framework, international reserves are a form of precautionary savings that can be used to smooth consumption even after a sovereign default. Statistics calculated with simulated data from a model with partial sovereign default indicate that the combined acquisition of assets and liabilities is an optimal policy in this type of model. In the last chapter, I examine whether low international risk-free interest rates, as observed in developed countries since the most recent global financial crisis, lead to a search for yield – identified via lower spreads even under higher default risk – in emerging markets sovereign bonds. I find that the inclusion of loss averse foreign lenders, a trait highlighted by the behavioral finance literature, in a standard model of sovereign default generates this result.

Keywords: external debt, sovereign default, currency denomination of debt,
international reserves, search for yield.

CONTENTS

1 GAINS FROM LOCAL CURRENCY EXTERNAL DEBT

1.1 Abstract

Is it better for emerging countries to issue external debt denominated in local (LC) or foreign currency (FC)? An economy issuing LC debt can avoid an explicit and costly default by inflating away its debt. However, in the hands of a discretionary policymaker, such tool might lead to excessive inflation and negative consequences for welfare. To investigate this question, I use a quantitative model of sovereign default extended to incorporate real exchange rates and inflation. I find that an economy issuing LC debt defaults less often, sustains slightly lower debt levels, and presents positive average inflation. The net effect is a modest welfare loss when compared to issuing debt in FC. However, if monetary policy is credible, the welfare change is positive, but also of limited size. In this case, the real exchange rate serves as a buffer to accommodate negative output shocks and to prevent defaults.

1.2 Introduction

Eichengreen and Hausmann (1999) named the inability of emerging markets to borrow from foreigners using instruments denominated in their own currencies the "original sin". In the last decade, however, emerging markets seem to have overcome, at least partially, this shortcoming. Lane and Shambaugh, (2010) and Bénétrix, Lane, and Shambaugh, (2015) show that emerging markets abandoned negative net external positions in foreign currency (FC) when debt, equity and foreign direct investments are considered. The change of the currency denomination of liabilities from foreign to local also happened when restricting the scope to debt markets. Such outcome occurred mostly through an increasing participation of non-resident lenders in local government debt markets (Burger, Warnock and Warnock, 2010, Arslanalp and Tsuda, 2014, Du and Schreger 2017, Alfaro and Kanczuk, 2017, and Maggiori, Neiman and Schreger, 2018)[1].

Contemporaneously to the shift in currency denomination of external debt, several emerging countries adhered to inflation targeting regimes (Hammond, 2012) and reduced inflation and

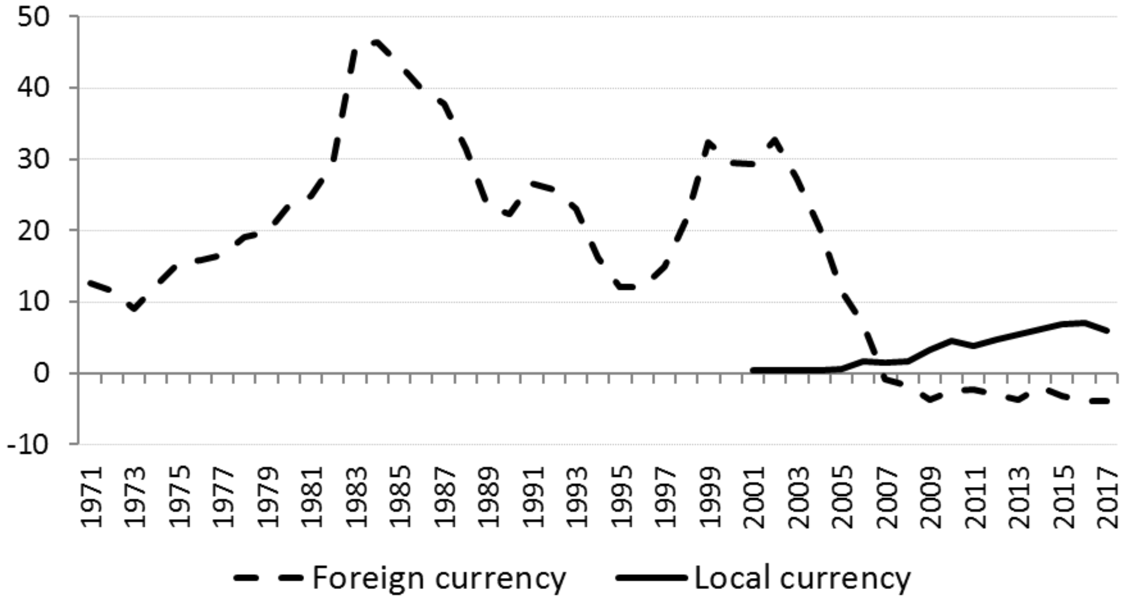
[1] In a sample of 22 emerging countries, Arslanalp and Tsuda (2014) show that the median share of foreign ownership of government debt denominated in local currency increased from 2.7% in the last quarter of 2004 to 17.7% in the second quarter of 2016.

its volatility (Vega and Winkelried, 2005, Gonçalves and Salles, 2008, Lin and Ye, 2009, Mendonça and Souza, 2012). Burger, Warnock, and Warnock (2010) show the importance of this development to attract foreign investors to local currency bonds. Nevertheless, inflation is not the only concern for an investor in local currency (LC) bonds in emerging markets. The empirical literature – using both recent and historical data – reveals that even sovereign debt denominated in local currency is not free from de jure defaults (Kohlscheen 2010, Rogoff and Reinhart 2011, Du and Schreger 2016, and Jeanneret and Souissi, 2016).

Inspired by the combination of increased foreign participation in local debt markets, improved monetary policy frameworks, and default risk, I investigate the consequences of changing the denomination of external debt from FC to LC using a small open economy model with endogenous default, real exchange rate and inflation. In such a framework, a discretionary sovereign chooses consumption and borrowing from foreign lenders, whether or not to default, and the inflation rate. Assuming that both default and inflation have negative consequences for the economy, I compare the two possibilities of debt denomination: FC and LC. In the former case, since inflation cannot erode debt, there is no benefit in increasing the price level. However, if debt is nominal, inflation is a tool available to smooth consumption and to avoid an explicit and costly default. I focus on the contingency in the repayment value of LC debt provided by variations in the exchange rate. This is achieved if the domestic currency depreciates and the value of debt measured in FC declines during bad times (subpar output). The loosening of the resource constraint of the domestic economy allows a less severe contraction in consumption than in the case of FC debt and turns the option to default on debt less attractive.

I calibrate the model with data from Brazil, an emerging market whose external debt denomination is shifting from FC to LC (Figure 1.1). It is also a country with a long history of defaults, and one of the first non-advanced economies to adopt an inflation target regime. Besides, Brazil is a representative case of the situation of other emerging countries. Values for Brazil and the median are similar in Table 1.1, which brings external debt information for 12 emerging countries. Considering net positions, data in column 3 reveal that most countries are creditors in foreign currency, in line with the results from Bénétrix, Lane and Shambaugh (2015) for a broader concept of liabilities. Evidence also shows that countries borrow significant amounts in local currency (column 4).

Figure 1.1 – Brazil net external debt by currency of denomination (% GDP)



Note: The figure plots net external debt positions by currency denomination in annual frequency. Data start in 1971 and 2001 for foreign and local currencies, respectively. Source: Author's computation based on data from the Central Bank of Brazil. More information about data construction in the appendix.

The policy functions obtained indicate that an economy with LC debt is more likely to default, inflate, and increase the real exchange rate during periods of low output and when the current debt stock is higher. In addition, the sovereign issues more debt during good times, when its cost is lower due to the reduced probability of default. These results remain in an economy with FC debt, except for inflation, that is always zero.

With simulated data, I find that the model with FC debt replicates features of the Brazilian economy (shared by emerging markets in general) during the period of external debt denominated in US dollars (1971-2006). It mirrors the average debt level and the default frequency, and exhibits counter-cyclical behavior for default risk premium, trade balance, and real exchange rate.

Table 1.1 – Net external debt by local and foreign currency, 2015

Country	Gross External Debt		Net Assets in Foreign Currency	Net Debt in Local Currency
	% GDP	% in Local Currency	% GDP	% GDP
	1	2	3	4
India	23.1	28.7	2.4	6.6
Brazil	**25.9**	**22.9**	**5.0**	**5.9**
Mexico	36.5	29.5	10.1	10.8
Russia	28.5	16.4	35.4	4.7
Poland	52.6	35.4	-4.8	18.6
Argentina	22.5	3.9	15.6	0.9
Thailand	29.0	24.8	40.2	7.2
Ukraine	121.7	0.8	6.2	1.0
Chile	43.0	3.7	0.0	1.6
South Africa	32.0	42.6	10.4	13.6
Hungary	74.0	23.0	-7.2	17.0
Romania	41.8	11.2	-5.6	4.7
Median	**34.3**	**22.9**	**5.6**	**6.3**

Note: The table reports gross external debt (public and private) as a share of GDP (column 1), the share of gross external debt denominated in local currency (column 2), the net position of debt instruments in foreign currency (column 3, where positive numbers mean creditor positions), and in local currency (column 4, where positive numbers mean debtor positions). Source: Author's computation based on data from the Quarterly External Debt Statistics Database (IMF/WB), and the Balance of Payments and International Investment Position Statistics (IMF). More information about data construction in the appendix.

Gains and losses appear when the currency denomination changes from FC to LC. The benefits are fewer defaults and less volatility in trade balance, real exchange rate, and default risk premium. Inflation and real exchange rate depreciation – achieved through a reduction in the consumption of traded goods – contribute to a relief of the debt burden in bad times. With the loosening of the resource constrain in such periods, the default frequency declines from 2.4% in the FC case to 1.4%. In the economy with FC debt, the contraction in the consumption of traded goods also increases the real exchange rate, but does not affect the debt burden, due to the currency of denomination of debt.

The disadvantages of LC debt are two: higher inflation and lower debt sustainability. The discretionary sovereign with the ability to use inflation to erode debt has an inflationary bias and creates excessive inflation, negatively affecting domestic welfare. Beyond that, the mean debt-to-GDP ratio falls 0.3pp (equivalent to 3.8%), because interest rate spreads increase on average. Despite a lower default premium, foreign lenders require a compensation for the possibility of expropriation via nominal exchange rate depreciation. Overall, I find a modest negative welfare change from switching from FC to LC debt issuance. The measured effect is a 0.05% fall in the certainty equivalent consumption.

From a descriptive perspective, the model with LC also performs well. As observed for Brazil from 2007 to 2017, the model exhibits counter-cyclical risk premium, trade balance, and real exchange rate, while inflation is pro-cyclical. This last feature, similar to a Phillips curve, occurs because during periods of high output the sovereign accumulates more debt and is more tempted to use inflation. The model also generates a sensible amount of inflation, 2.9%, in comparison to 4.3% in the data.

All the previous results are qualitatively robust to: i) the inclusion of risk-averse lenders, or ii) the use of a lower utility cost of inflation. In the latter robustness exercise, the lower utility cost of inflation can be interpreted as a decrease in the credibility of monetary policy (Onder and Sunel, 2016, Ottonello and Perez, 2018, Du, Pflueger and Schreger, 2017). If this parameter is set so that model's average inflation matches its observed counterpart, the main results remain the same. The average inflation increases from 2.9% to 4.2%, the mean debt-to-GDP ratio falls another 0.2pp, and the welfare loss from changing from FC to LC is 0.10%, instead of 0.05%, in terms of equivalent consumption.

However, if the monetary policy is fully credible and can commit to zero inflation (infinitely high inflation costs), there is a small welfare gain from issuing LC debt (0.07%). In this case, only real exchange rate fluctuations relieve the debt burden during bad times. Therefore, the default frequency falls less, from 2.4% to 1.8%. Nevertheless, since there is no inflation, debt sustainability increases in comparison to the FC case. The relation between monetary policy credibility and the welfare changes from LC debt issuance help us to understand the phenomenon of "original sin" in a different way. If the monetary policy credibility is very low, the government frequently creates inflation and does not borrow a relevant amount. This scenario might lead to meaningful welfare losses if the sovereign issues LC debt. Therefore, when the monetary policy regimes of emerging countries completely lack credibility, the optimal choice is to issue debt in FC. This prediction is in line with evidence of high inflation and low participation of foreigners in local debt markets in emerging countries before the adoption and the adherence to reliable monetary policy regimes. Thus, such absence of inflation credibility in emerging markets is an alternative explanation for the "original sin", opposed to hypothesis of an incompleteness in international financial markets presented by Eichengreen and Hausmann (1999).

This paper contributes to the literature on quantitative models of external debt and default in economies with incomplete markets based on the works of Eaton and Gersovitz (1981), Grossman and Van Huyck (1988), Alfaro and Kanczuk (2005), Aguiar and Gopinath (2006) , and Arellano (2008)[2]. The model presented here connects to two recent strands of this literature.

The first of them uses models with two sectors (traded and non-traded goods) to study real exchange rate determination in settings with credible monetary policy. In such scenarios, the sovereign does not inflate the debt away. Papers in this literature include Gumus (2013), Asonuma (2016), Alfaro and Kanczuk (2017), and Na et al (2018). The first – and more closely related to my work - finds that with LC debt the economy sustains higher quantities of debt and defaults less frequently. The ensuing welfare increase, nonetheless, has a limited magnitude. The second related literature focuses on nominal debt when monetary policy is discretionary and explicit default is possible[3]. Nuño and Thomas (2016) and Onder and Sunel (2016), inspired by the recent experience of countries in the periphery of the Euro area, find that welfare is higher when debt is issued in FC and there are no incentives to create inflation. These papers, however, use models with a single traded of good, neglecting, therefore, real exchange rate movements.

I link the two branches of the literature by asking if it is better for emerging countries to issue LC or FC debt using the model of Ottonello and Perez (2018) with default risk, discretionary monetary policy, and real exchange rate determination[4]. I show that the conclusion of Gumus

[2] Recent surveys of this approach are Stahler (2013), Aguiar and Amador (2014), and Aguiar et al. (2016).

[3] This framework has been extended in several directions and used to investigate various topics. Among others, examples are i) self-fulfilling debt crises in small economies and in monetary unions (Aguiar et al. 2013, 2015, and Araujo et al. 2013); ii) the origin of the default risk on LC sovereign debt coming from FC corporate borrowing and the consequent currency mismatch (Du and Schreger, 2017); iii) how the exogenous cyclicality of the inflation rate influences debt sustainability in a closed economy (Hur, Kondo and Perri, 2017); iv) the complementary role of seigniorage in economies with debt and money (Rottger, 2016, and Sunder-Plassmann, 2017, with cash-in-advance constraints, and Fried, 2017, with search frictions).

[4] Ottonello and Perez (2018) present an extension of their benchmark model including outright default in appendix D. I use a particular case in which governments issue LC or FC debt as Gumus (2013), Nuño and Thomas (2016), and Onder and Sunel (2016) do. Differently from the analysis of Ottonello and Perez (2018), I discuss the policy functions of the model, present calculations of the welfare change from issuing LC debt for different degrees of monetary policy credibility and show how the results persist in the presence of risk-averse lenders.

(2013) about welfare gains from issuing LC debt depends on the degree of monetary policy credibility[5].

1.3 Model

The model represents a small open economy that receives a stochastic endowment of traded goods and a fixed amount of non-traded goods every period. The central planner borrows from risk neutral foreign lenders using only debt (a non-contingent instrument). I compare the cases of debt denominated in foreign and local currencies. Since the sovereign cannot commit to repay, every period it chooses whether or not to default on the stock of debt. In case of default, the country is excluded from international markets by a random number of periods. If the government decides to continue participating in markets, it is able to borrow today due to the next period, when a decision between default and repayment is made again. Every period the sovereign also chooses its preferred inflation rate.

The preferences of the household appear in equations (1.1) and (1.2)[6]. In the expressions above, $\boldsymbol{E}$ is the expectation operator, and C_t is the aggregate household consumption, comprised of c_t^T and c_t^N, traded and non-traded goods, respectively. The household utility is negatively influenced by the inflation rate, π_t. The four parameters express the subjective discount rate, β, the constant coefficient of relative risk aversion, σ, the share of tradable goods in the utility function, α, and the inflation cost, γ.

$$U = \boldsymbol{E}_{t=0} \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{\gamma}{2} \pi_t^2 \right) \tag{1.1}$$

$$C_t(c^T, c^N) = (c_t^T)^{\alpha} (c_t^N)^{1-\alpha} \tag{1.2}$$

5 Du, Pflueger and Schreger (2017), Engel and Park (2018) and Ottonello and Perez (2018) investigate how monetary policy credibility influences sovereign debt currency composition, but not welfare changes. Du, Pflueger and Schreger (2017) use a two period model without possibility of default. Engel and Park (2018) use an optimal contract model in which default does not happen in equilibrium. Ottonello and Perez (2018) analyze the question using the model without default risk. Their models predict that countries with less disciplined monetary policies (or lower inflation costs) rely more on foreign currency debt.

6 Ottonello and Perez (2018) show that models with cash-in-advance constraints or with money in the utility function are a possible foundation of this functional form. Nuno and Thomas (2016) and Du, Pflueger and Schreger, (2017) also assume quadratic inflation costs in the utility function in models of sovereign debt. The former show that such functional form can also be justified on the grounds of costly price adjustment by firms.

The endowment of the traded good, y_t^T, follows the autoregressive process described in equation (1.3), with ε_t representing a white noise with standard normal distribution. In order to reduce the number of state variables in the problem, I normalize the fixed amount of non-traded goods to one, as Alfaro and Kanczuk (2017) and Ottonello and Perez (2018) do. Thus, in equilibrium we have that $c_t^N = y_t^N = 1$.

$$ln(y_t^T) = \rho ln(y_{t-1}^T) + \eta\varepsilon_t \tag{1.3}$$

The prices of traded and non-traded good are denoted by p_t^T and p_t^N, respectively. I assume that the price of the traded good in the international economy is stable and normalize it to one, $p^* = 1$. Using the law of one price, I find that $p_t^T = p^* e_t = e_t$, in which e_t is the nominal exchange rate. An increase in the nominal exchange rate represents a depreciation of the domestic currency. The aggregate price level is the solution to the minimization problem in equation (1.4) subject to $C_t = 1$.

$$P_t \equiv \min_{(c_t^T, c_t^N)} \; e_t c_t^T + p_t^N c_t^N \tag{1.4}$$

Given the functional forms, equation (1.5) presents the solution relating the aggregate price and the nominal exchange rate. Equation (1.6) defines the inflation rate.

$$P_t = e_t \frac{1}{\alpha}\left(\frac{c_t^T}{c_t^N}\right)^{1-\alpha} \tag{1.5}$$

$$\pi_t = \frac{P_t}{P_{t-1}} \tag{1.6}$$

If debt is denominated in FC and the sovereign opts for honoring its obligation, keeping its access to the international financial markets, equation (1.7) expresses the resource constraint of the economy. In this expression, d_t^* and q_t^* denote the amount of FC debt and its price, respectively. In an economy issuing LC debt, the resource constraint is equation (1.8), and the quantity of debt and its price are represented by d_t and q_t in the order given.

$$e_t c_t^T + p_t^N c_t^N = e_t y_t^T + p_t^N y_t^N + e_t q_t^* d_{t+1}^* - e_t d_t^* \qquad (1.7)$$

$$e_t c_t^T + p_t^N c_t^N = e_t y_t^T + p_t^N y_t^N + q_t d_{t+1} - d_t \qquad (1.8)$$

Using the equilibrium condition $c_t^N = y_t^N$, equation (1.9) shows the resource constraint, regardless of the currency of debt denomination, if the sovereign defaults. In this situation, the sovereign does not repay its debt, neither borrows more. As usual in this literature, the economy faces a direct output cost when it defaults. This assumption is required to sustain positive debt levels, because exclusion from markets is not a punishment harsh enough to do so.

I model this loss using the same specification as Arellano (2008), equation (1.10). It is frequently used in this literature, and consistent with the empirical observation[7]. This expression means that there are no direct costs of default for output levels up to a certain threshold (ψ). Above such point, the direct costs become positive and increase with output[8]. This functional form captures the idea that output cannot be high even under a good productivity shock. One interpretation, proposed by Arellano (2008), is that defaults are associated with disruptions in the domestic financial market and that credit is an essential input for production. Following Alfaro and Kanczuk (2017) and Ottonello and Perez (2018), I restrict the cost to the tradable sector of the economy, because it is the only one with a stochastic component.

$$c_t^T = y_t^{T,a} \qquad (1.9)$$

$$y_t^{T,a} = \begin{cases} y_t^T, if\ y_t^T \leq \psi \\ \psi.\ if\ y_t^T > \psi \end{cases} \qquad (1.10)$$

Foreign lenders, who have access to a risk-free asset with return r^*, price the debt, that reflects the sovereign's actions. They price the bond's payoff using the reduced form stochastic discount factor in equation (1.11). In this specification, already used in this type of model by Arellano and Ramanarayanan (2012) and Bianchi, Hatchondo and Martinez (2018), the parameter κ governs the risk premium and its correlation with the stochastic process for y_t^T. While $\kappa = 0$

[7] See Mendoza and Yue (2012) for a general equilibrium model of sovereign defaults and business cycles that generates non-linear output costs of default. The asymmetry happens due to working capital financing constraints for imported inputs that lack perfect domestic substitutes.

[8] According to Aguiar et al (2016), an asymmetric output cost of default is essential to replicate sensible values of average debt and default frequencies in this type of model.

leads to risk neutrality pricing, positive values imply that lenders value more returns in states with negative income shocks in the small open economy. These are exactly the times when default is more likely to happen.

$$m_{t+1} = exp(-r^* - \kappa\eta\varepsilon_{t+1} - 0.5\kappa^2\eta^2) \tag{1.11}$$

Equation (1.12) shows that the price of FC debt depends on the default decision that the sovereign makes in the next period ($f_t = 1$ means the government defaults and $f_t = 0$ means it repays). The default decision in period $t+1$, in its turn, is a function of the state variables y_{t+1}^T and d_{t+1}^*. Hence, the price of debt in period t hinges on the current endowment of traded goods and the amount borrowed in period t for repayment in $t+1$. The former variable is relevant because it brings information about its next realization due to the autocorrelation in the stochastic process for y_t^T. This justifies the use of the conditional expectations operator, $\boldsymbol{E_y}$, in the pricing equations. The price of LC debt, equation (1.13), also depends on the depreciation of the nominal exchange rate, because foreign investors are interested in the return measured in FC. Since the current and future nominal exchange rates appear in the right hand side of equation (13), the price of LC debt is a function of y^T, d_t, and d_{t+1}.

$$q_t^*(y^T, d_{t+1}^*) = \boldsymbol{E_y}[m_{t+1}(1 - f_{t+1})] \tag{1.12}$$

$$q_t(y^T, d_t, d_{t+1}) = \boldsymbol{E_y}\left[m_{t+1}(1 - f_{t+1})\frac{e_t}{e_{t+1}}\right] \tag{1.13}$$

Using, $c_t^N = y_t^N$, note that the resource constraint for the FC economy (7) can be reduced to (1.14). It makes clear that i) the problem can be interpreted as the single good canonical model rescaled, and ii) inflation cannot be used to decrease the real value of debt via nominal exchange rate depreciation. Since there are inflation costs, but no benefits, the sovereign chooses $\pi_t = 0$. In the LC case, inflation is not necessarily zero. Besides, equation (1.15), derived from (1.5) and (1.8) and using $c_t^N = y_t^N$, shows that P_{t-1} is a state variable, because $P_t = \pi_t P_{t-1}$.

$$c_t^T = y_t^T + q_t^* d_{t+1}^* - d_t^* \tag{1.14}$$

$$c_t^T = y_t^T + \frac{1}{P_t}\frac{1}{\alpha}\left(\frac{c_t^T}{c_t^N}\right)^{1-\alpha}(q_t d_{t+1} - d_t) \tag{1.15}$$

In order to reduce the dimension of the problem, and write it in a recursive manner, I present a de-trended version of this economy. First, I define ϵ_t, the real exchange rate, $\hat{d}_t$, a measure of debt scaled by the price level of the previous period, and $\tilde{q}_t$, an auxiliary price variable associated with LC debt, in equations (1.16) to (1.18)[9]. Then, equation (1.19) expresses the de-trended resource constraint for the LC economy, already plugged with equation (1.5), the equilibrium condition for the exchange rate.

$$\epsilon_t = \frac{e_t}{P_t} = \frac{1}{\alpha}\left(\frac{c_t^T}{c_t^N}\right)^{1-\alpha} \tag{1.16}$$

$$\hat{d}_t = \frac{d_t}{P_{t-1}} \tag{1.17}$$

$$\tilde{q}_t(y^T, d_{t+1}) = \frac{q_t}{\epsilon_t} \tag{1.18}$$

$$c_t^T = y_t^T + \tilde{q}_t \hat{d}_{t+1} - \frac{\hat{d}_t}{\epsilon_t \pi_t} \tag{1.19}$$

Equations (1.20), (1.21) and (1.22) present the problem in recursive form. As usual in the literature, variables with apostrophe represent values at $t+1$. For the value functions and restrictions defined below, we obtain policy functions for default (f), consumption of traded goods (c^T), inflation (π), and next period debt (d^* or d depending on the currency of denomination). For the sovereign, the value of repaying is expressed by (1.20) subject to the resource constraint: equation (1.14) in case of FC debt or equation (1.19) in case of LC debt. The value of defaulting, (1.21), depends only on the current endowment. The parameter θ measures the exogenous probability of regaining access to the international markets with zero debt after default. Equation (1.22) depicts the discretionary government deciding at every period whether to repay and or to default.

[9] See the appendix for a more detailed expression connecting q_t and $\tilde{q}_t$, and to see why the latter is not a function of the current debt level.

$$V^R(y^T, \hat{d}) = \max_{\hat{d}', c^T, \pi} \{u(C(c^T, y^N), \pi) + \beta E_y[V(y^{T\prime}, \hat{d}')] \,, \tag{1.20}$$

subject to (1.14) for FC debt or (1.19) for LC debt.

$$V^D(y^T) = u(C(y^{T,a}, y^N), 0) + \beta E_y[\theta V^R(y', 0) + (1-\theta)V^D(y^{T\prime}) \tag{1.21}$$

$$V(y^T, \hat{d}) = \max_{f \in \{0,1\}} \{(1-f)V^R(y^T, \hat{d}) + fV^D(y^T)\} \tag{1.22}$$

The model is a stochastic dynamic game played by a discretionary sovereign, who cannot commit to a planned policy path, against a continuum of small identical foreign lenders. Given the lack of commitment I focus on Markov Perfect Equilibrium.

Definition. Let $s = \{y^T, d^*\}$ for FC debt and $s = \{y^T, d\}$ for LC debt. A Markov perfect equilibrium is defined by:

i) A set of value functions $V(s), V^R(s), V^D(s)$ defined above;

ii) Policy functions for default, $f(s)$, consumption of traded goods, $c^T(s)$, inflation, $\pi(s)$, and borrowing, $d^{*\prime}(s)$ for FC debt and $d'(s)$ for LC debt;

iii) A bond price function: q^* for FC debt and $\tilde{q}$ for LC debt,

such that

I) Given a bond price function, the policy functions solve the Bellman equations (1.20) - (1.22);

II) Given the policy functions, the bond price function satisfies equation (1.12) for FC debt or (1.18) for LC debt[10].

[10] Equation (A2) in the appendix shows the exact association between $\tilde{q}$ and the policy functions.

1.4 Calibration

I solve the model for two different specifications, one under risk-neutrality ($\kappa = 0$) and other with risk-averse lenders ($\kappa > 0$). Seven out of the ten model parameters have the same value for both specifications (Table 1.2). The choices for the risk-free international interest rate, $\mathrm{r}^* = 0.04$ for annual frequency, and for the domestic risk aversion coefficient, $\sigma = 2$, are standard in the literature. In line with estimates by Gelos, Sahay and Sandleris (2011), the probability of redemption after default, θ, is set at 0.5. This leads to two years of exclusion from markets on average. As Ottonello and Perez (2018), for simplicity I set equal shares for tradables and non-tradables in the consumption aggregator[11], $\alpha = 0.5$. For the cost of inflation, I use $\gamma = 1.30$. According to Ottonello and Perez (2018), such value generates welfare costs of inflation in line with estimates by Lucas (2000) and Burstein and Hellwig (2008). This differs from the approach of Nuno and Thomas (2016) and Du, Pflueger and Schreger (2017), who set the inflation cost parameter to target a desired average inflation.

Table 1.2 – Parameter values

Parameter	Description	Value	
		Benchmark	Risk averse lenders
σ	Domestic risk Aversion	2.00	2.00
r*	Risk free rate	0.04	0.04
γ	Inflation cost	1.30	1.30
θ	Probability of re-entry after default	0.50	0.50
ω	Share of traded output	0.50	0.50
ρ	GDP persistence	0.70	0.70
η	Std. Deviation of innovation to GDP	0.026	0.026
κ	Pricing kernel parameter	0.00	10.00
β	Domestic discount factor	0.77	0.60
ψ	Direct output cost of default	0.89	0.90

For the remaining country-dependent parameters, I use Brazil as a reference. Together with Mexico and Argentina (and more recently Greece and Spain), this emerging market economy, and serial defaulter (Reinhart, Rogoff and Savastano, 2003), is one of the common references in the related literature. It is also one of the first non-advanced economies to adopt an inflation target regime. Besides, Brazil is a representative case of the ongoing change in the currency

[11] In the appendix, I show how this simplifies the model solution.

denomination of external debt. Using the cyclical component of the Brazilian GDP from 1948 to 2014 in, I obtain estimates for ρ and η[12]. Given such values, the simulation method proposed by Schimitt-Grohé and Uribe (2009) provides a transition matrix for the endowment.

In the specification with risk-neutral lenders, I start setting $\kappa = 0$. Next, I choose the values of the two remaining parameters (β and ψ) so that the model with FC debt matches two targeted moments for the years from 1970 to 2006. The intention is that the FC artificial economy replicates Brazil during the period with external debt denominated exclusively in foreign currency. Then, I find a solution for the economy issuing LC debt using the parameters determined by the targeting exercise of the FC case. In this manner, there are no targeted statistics for the LC model.

The first targeted moment is the default frequency. I set it to 2.7%, reflecting one default between 1970 and 2006 (Reinhart and Rogoff, 2008). Similar values are used in other studies in this literature, as Aguiar et al (2016) and Arellano (2008). The second targeted value is the average external debt as a share of GDP, 23.4%. In order to reconcile data and model, I do not use this value. In the model, after a default, the economy re-enters markets without debt. However, this full repudiation of liabilities (haircut rate of 100%) does not appear in the data. According to Cruces and Trebesch (2013), the average haircut rate (excluding cases of heavily indebted poor countries) is 29.7%. Therefore, I target an average debt level of only 29.7% of the original statistic, leading to a debt-to-GDP ratio of interest of 7% (23.4×29.7%)[13]. Such procedure delivers $\beta = 0.77$ and $\psi = 0.89$ for the parameters governing the domestic discount factor and the direct output cost of default, respectively[14].

In the specification with risk-averse lenders, the calibration strategy is identical. The only difference is that I target three moments and use three parameters: κ, β, ψ. The targeted debt level is the same as before. The second target is the average spread on FC Brazilian bonds until 2006[15], 7.7% on average, higher than default frequency used in the previous exercise. With

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[12] The cyclical component is obtained using the HP filter. I do not use GDP data for more recent years because they are computed from quarterly estimates and still subject to revisions. The estimates are close to the ones obtained by Ottonello and Perez (2018) using only the GDP of the tradable sector with data from a panel of emerging countries.
[13] Chatterjee and Eyigungor (2012) use this same calibration approach in a seminal paper of the related literature.
[14] The values are close to those used by other papers in the related literature. For the discount factor, see Nuno and Thomas (2016), Alfaro and Kanczuk (2017) and even the seminal paper of Arellano (2008). For the output cost, see again Arellano (2008), considering that in the current paper only the traded sector suffers from such cost.
[15] Spread data start in 1994, when Brazil regains accesses to international financial markets after a default. See the appendix.

risk-averse lenders, the FC spread reflects both the quantity and the price of risk; under risk-neutral pricing, the spread reflects only the quantity of risk, i.e., the default probability. The last target is the share of the FC spread related to the default premium, 38%, according to Longstaff et al (2011)[16]. The values retrieved are $\kappa = 10$, $\beta = 0.60$ and $\psi = 0.90$.

I solve the model numerically using value function iteration in a discrete state space. As suggested by Hatchondo et al (2010), I use a one-loop algorithm that iterates simultaneously on the value and bond price functions. This corresponds to finding the equilibrium as the limit of the equilibrium of the equivalent finite-horizon economy.

1.5 Results

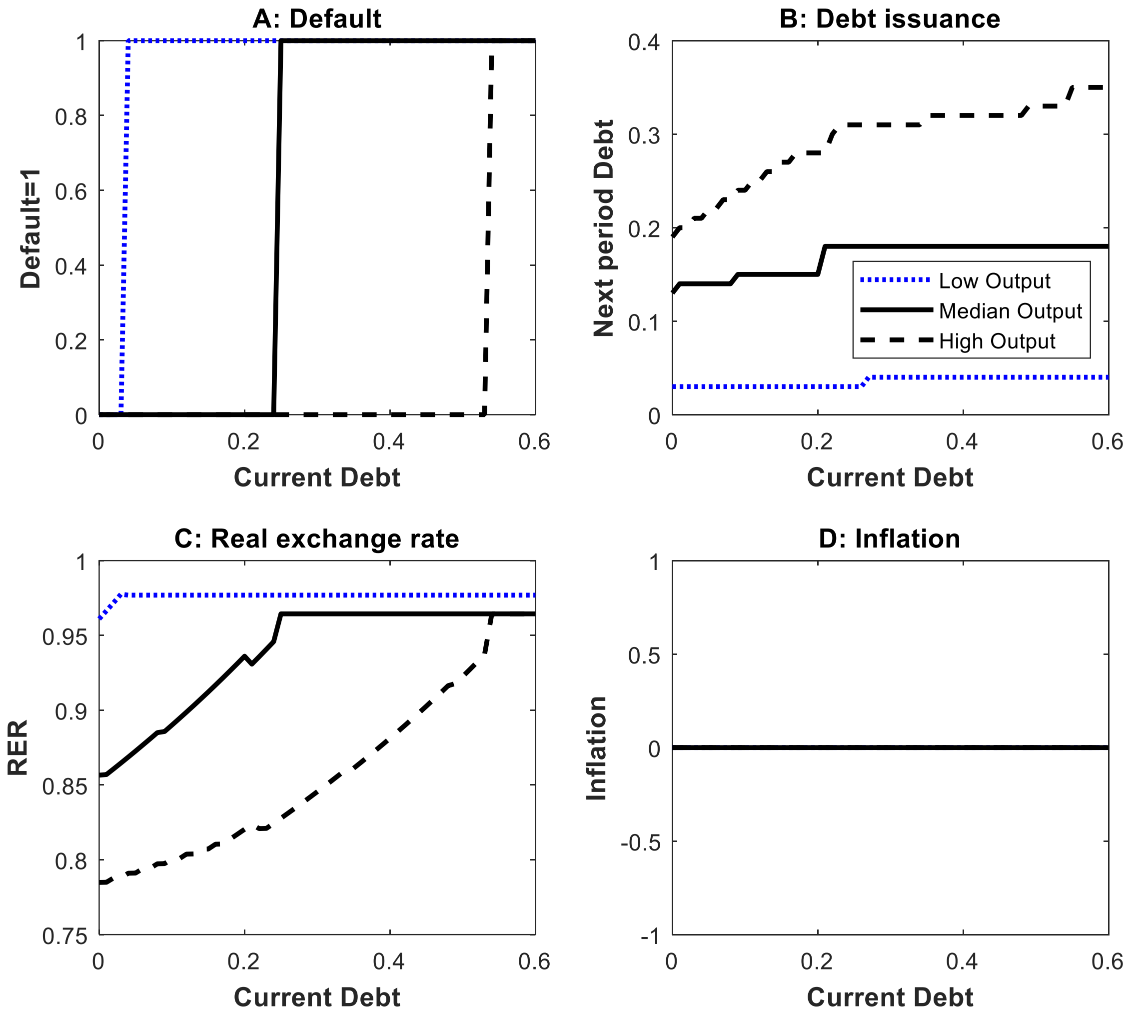
1.5.1 Policy functions

Figures 1.2 and 1.3 present the policy functions for the FC and LC cases, respectively, with the benchmark calibration. In each panel, the lines represent the policy function for different realizations of the endowment. The horizontal axis depicts the current debt level (not the amount borrowed in period t, i.e., the chosen level of debt for the next period).

For the FC economy, default is more likely to happen in bad times (low realizations of the endowment process) and when debt level is elevated (panel A of Figure 1.2). In panel B we can see that more debt is accumulated in good times. This suggests a pro-cyclical trade balance in the economy, because consumption exceeds output when the latter is higher. Since default probability is lower in good times, interest rates are also reduced (debt prices are higher). Furthermore, Figure 1.4 displays that the interest rate charged increases with debt levels, because default is more probable when debt is high.

[16] I use the average of the estimates of the fraction of the risk premium to total spread from table 5, excluding Bulgaria, that presents a negative value.

Figure 1.2 – Policy functions for an economy with FC debt



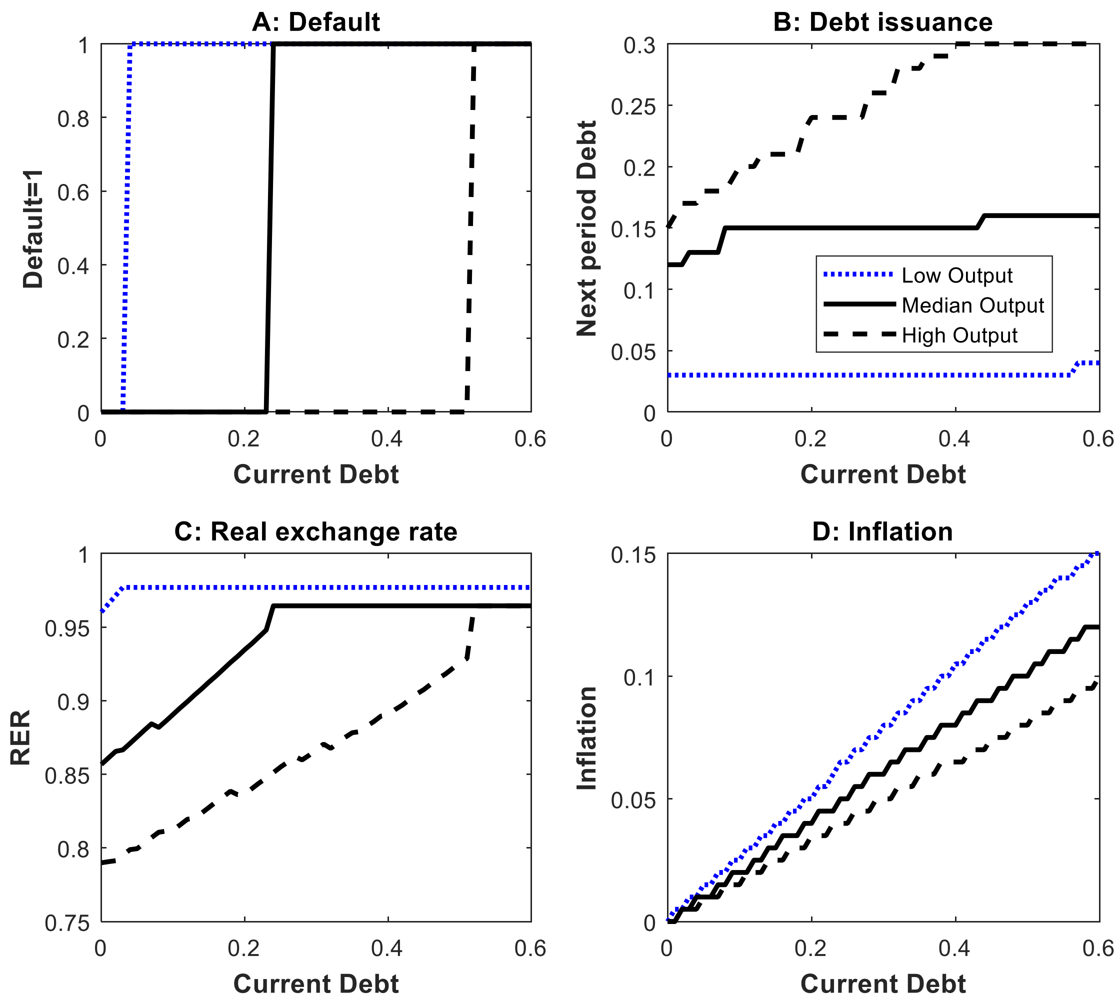
Note: Each panel in this figure plots the plots a policy function for three different levels of output: the lowest, the median, and the highest. The horizontal axis represents the current debt level at the start of the period. Results are from the benchmark calibration.

Panel C plots the real exchange rate, and we can see that it depends both on the debt level and the output shock realization. The real exchange rate is lower (appreciated local currency) when output is above its mean, as commonly observed in emerging markets[17]. Notice that the real exchange rate policy function turns into a plateau at the debt level from which default is the optimal choice. To the right of such point, the debt level is not relevant, because the sovereign defaults. Panel D shows that inflation is always zero.

[17] See table 1.3 in this text and table 4 in Alfaro and Kanczuk (2017).

The economy with LC debt (Figure 1.3) has policy functions similar to those of the FC case, except for inflation. Default is still more likely in when debt is high and output is low; more borrowing takes place during good times; the real exchange rate rises with current debt and diminishes with output. The novelty is the inflation choice (panel D)[18]. As expected, the sovereign has more incentives to inflate when debt is high and, for a fixed quantity of debt, when output is low. Facing adverse shocks, the sovereign raises inflation to free up resources for consumption. The increases in inflation and real exchange rate implies higher nominal exchange rates in moments of low output.

Figure 1.3 – Policy functions for an economy with LC debt



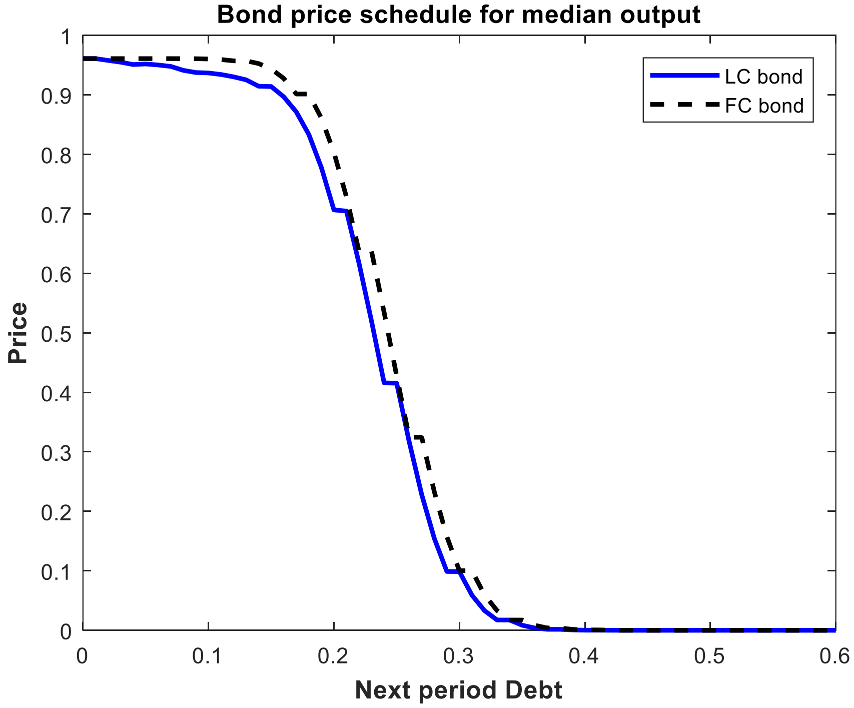
Note: Each panel in this figure plots the plots a policy function for three different levels of output: the lowest, the median, and the highest values. The horizontal axis represents the current debt level at the start of the period. Results are from the benchmark calibration.

[18] When the government defaults, the optimal inflation is zero even with LC debt. For illustrative purposes, panel D in Figure 1.3 plots the inflation rate that the government chooses if it decides to honor its obligations even when default is the optimal choice.

Figure 1.4 plots the prices of FC and LC debt for the benchmark calibration. The price falls as the amount of debt to be repaid in the next period increases. In the FC economy, this occurs exclusively because the probability of default rises with the amount of debt issued. In the LC economy, the default risk is not the only factor behind the declining debt prices. As debt issuance increases, the expected nominal exchange rate depreciation also moves up. As exhibited in the previous figure, both inflation and real exchange contribute to the expected nominal depreciation.

For the specification in Figure 1.4, the price of LC debt is lower than the FC one, meaning that the total risk of LC debt (default plus exchange rate) is higher. However, as Table 1.3 in the next subsection shows, the default risk is lower in the LC economy than its equivalent in the FC case. It is possible that, for some parametrizations, the total risk in the LC economy is lower than in the equivalent FC economy. One such case appears in Table 1.3. It is the situation for an economy with arbitrarily large utility costs of inflation ($\gamma = +\infty$), in which the sovereign never inflates and defaults less often.

Figure 1.4 – Price of debt



Note: The figure plots the bond price function for the median level of output. The horizontal axis represents the choice of next period debt. Different lines represent economies issuing debt denominated in different currencies. LC stands for local currency; FC, foreign currency. Results are from the benchmark calibration.

1.5.2 Simulations and welfare

The first two columns in Table 1.3 bring data from the Brazilian economy for two different terms. In the first (1971-2006) debt was issued in US dollars, and in the more recent (2007-2017) the role of the local currency has been increasing. The remaining columns present statistics calculated using simulated data from different specifications of the model.

Table 1.3 – Basic statistics: Data and Model

Variables	Data		Model					
			Benchmark		Risk averse lenders		γ=0.85	γ=∞
	1971-2006	2007-2017	FC debt	LC debt	FC debt	LC debt	LC debt	LC debt
	1	2	3	4	5	6	7	8
	Average							
Default frequency	2.7	--	2.4	1.4	3.4	3.0	1.4	1.8
Debt/GDP	7.0	1.4	7.8	7.5	6.2	6.3	7.3	7.9
Inflation	--	4.3	--	2.9	--	2.4	4.2	0.0
Default Risk Premium	7.7	2.5	2.8	1.5	6.8	5.9	1.4	1.8
Nominal Spread	--	10.2	--	4.7	--	9.4	6.0	--
	Standard deviation							
Trade balance	2.7	1.0	1.5	1.2	1.6	1.4	1.2	1.4
Inflation	--	2.4	--	0.6	--	0.8	0.9	--
Real exchange rate	21.9	10.4	2.3	2.1	2.3	2.2	2.1	2.2
Default Risk Premium	3.0	0.7	1.7	1.0	3.1	3.4	1.0	1.2
Nominal Spread	--	0.7	--	1.0	--	2.8	1.2	--
	Correlation with Output							
Trade balance	-0.5	-0.8	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Inflation	--	0.3	--	0.5	--	0.5	0.5	--
Real exchange rate	-0.4	-0.7	-0.8	-0.9	-0.8	-0.8	-0.9	-0.8
Default Risk Premium	0.0	-0.7	-0.7	-0.8	-0.7	-0.7	-0.8	-0.8
Nominal Spread	--	0.1	--	0.6	--	-0.4	0.7	--
	Welfare change							
Equivalent consumption	-	-	-	-0.05	-	-0.01	-0.10	0.07

Note: Columns 1 and 2 present statistics calculated with Brazilian data described in the appendix. Each column from 3 to 8 reports statistics for a different model specification. They are calculated using simulated data for 500 thousand periods excluding those in which the economy is excluded from markets.

Columns 3 and 4 show results for the benchmark calibration with risk neutral debt pricing. In the FC economy (column 3), the simulated average debt and the default frequency match their targeted counterparties. Since the default risk premium (total spread in foreign currency) is directly linked to the default frequency, the model underestimates the average observed spread. The model fails to generate enough variability in the real exchange rate, but produces volatilities in the correct order of magnitude for trade balance and the default risk premium. Correlation with GDP is negative for exchange rate and trade balance, as in the data. These are not characteristics peculiar to the Brazil, but prevail in emerging economies[19]. The counter cyclical trade balance reflects that the sovereign issues more debt in good times, when spreads are lower, increasing even more its consumption[20].

Surprisingly, in Brazilian data, the correlation between the default premium and GDP is close to zero between 1994 and 2006. However, as Figure 1.5 reveals, this is influenced by an abrupt fall (and possible structural break) in the EMBI+ spread in 2005 and 2006. Excluding these two years, the correlation changes from -0.03 to -0.30. This last value is closer to the seen in the full sample (-0.27 in 1994-2017) and to the stylized fact for emerging markets as a whole. In general, the model with FC debt performs well in explaining the Brazilian experience in the period of US dollar denominated external debt.

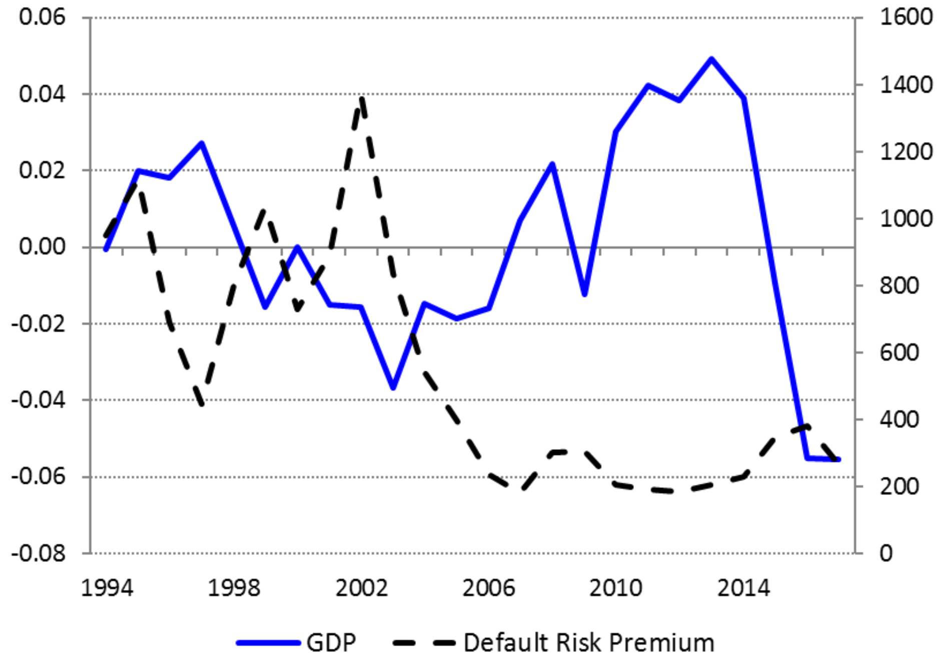
Compared to the previous case, the model with LC debt suggests decreases in: i) default frequency (and average default risk premium), ii) average debt, iii) real exchange rate volatility, and iv) mean and standard deviation of both risk premium and trade balance. All of these are in in line with the changes observed between the two periods.

The decline in the default frequency is a consequence of the use of inflation and real exchange rate depreciation during bad times. A reduction in the consumption of traded goods leads to a real depreciation that contributes to a relief of the debt burden. In the FC economy, the decline in the consumption of traded goods also increases the real exchange rate, but does not affect the debt burden. In this sense, I combine the two previously mentioned literatures. In the first, real exchange rate plays a role but monetary policy is muted (Gumus, 2013). In the second one, monetary policy is discretionary, but there is no exchange rate effect because there is only a single traded good (Nuno and Thomas, 2016, Onder and Sunel, 2016).

[19] Alfaro and Kanczuk (2018), and Uribe and Schimitt-Grohe (2017), respectively.

[20] In this model debt accumulation and trade balance are directly associated. As usual in this literature, I compare the model and the data looking at the debt for averages and at trade balance for variances and correlations.

Figure 1.5 – GDP (LHS) and Default Risk Premium (RHS)



Note: GDP refers to the cyclical component of the log of GDP obtained with the HP filter. Default Risk premium is the Emerging Markets Bond Index Plus (EMBI+) for Brazil.

Although it is not a targeted variable, the model generates average inflation of 2.9%. Such amount represents a significant share of the average inflation in the period (4.3%). This suggests the relevance of the proposed mechanism – ability to use inflation to erode debt – in the inflationary bias of emerging markets[21].

In column 2, the debt-to-GDP ratio is the average LC external debt (4.7%) multiplied by the typical haircut rate (29.7%). Although the model points to a reduction in the average debt level, we observe a more pronounced fall in the data. One possible explanation for this difference, as exposed by Alfaro and Kanczuk (2017), is that Brazil is still transitioning between the two regimes. The trend in LC external debt as a share of GDP in Figure 1.1 supports this view. An alternative interpretation is that the domestic impatience decreased since 2006. In the model, this is a raise in the domestic discount factor (β). In the literature of quantitative models of sovereign default, this parameter is calibrated with values lower than those used in the business cycles studies. The customary interpretation is that this might reflect political myopia. Bianchi, Hatchondo and Martinez (2018) use this decrease in political myopia, in a model of debt and

[21] Onder and Sunel (2016) find similar a result in a quantitative model of default with a single traded good calibrated for Spain.

default, as an explanation for the accumulation of international reserves in emerging markets. Here, such a reduction in the domestic impatience/political myopia may also serve as a cause of lower debt levels.

In the LC economy, the default risk premium is the spread that would be paid in the absence of the nominal exchange risk. Therefore, it is the spread on the foreign currency debt assuming that the government defaults jointly on all its liabilities. It falls from the FC to the LC case, as it did in the Brazilian economy between the two periods analyzed. However, the default risk premium is lower in the model than in the data. The nominal spread (includes default and exchange rate risk) is also lower than the empirical counterpart. The model performance in this criterion improves with the inclusion of risk-averse lenders.

The model replicates well volatilities for trade balance, default risk premium and nominal spread, but explains only part of the inflation variability. It is still unable to generate the correct amount of real exchange rate volatility. However, this statistic falls from the FC to the LC case, as noticed in the data. In model terms, this reduction in real exchange rate volatility maps exactly in consumption volatility.

Correlation with GDP has the right sign for all variables. As in Brazil from 2007 to 2017, the model exhibits counter-cyclical behavior for default risk premium, trade balance, and real exchange rate, and pro-cyclical for inflation[22]. The policy function shows that the sovereign inflates more in bad times for a given debt level. Nevertheless, the pro-cyclical inflation appears because, during periods of high output, the sovereign accumulates more debt and, thus, is more tempted to use inflation. As a consequence, the model creates pro-cyclical nominal spreads. Even if in the data this correlation is only slightly positive, clearly it is different from the categorical negative association between output and default risk premium.

To assess welfare gains from changing the denomination of debt, I calculate the flow certainty equivalent consumption for models in columns 3 and 4 using the same procedure as Chatterjee and Eyingungor (2012). I find the value of c that solves equation (1.23) below, in which $\Pi(y^T)$ is the invariant distribution of the Markov chain for y^T.

$$\frac{c^{1-\sigma}}{(1-\beta)(1-\sigma)} = \sum_y v(y^T, 0)\Pi(y^T) \tag{1.23}$$

[22] Ottonello and Perez (2018) and Onder and Sunel (2016) also document the positive correlation between inflation and GDP for a sample of emerging countries and for Spain, respectively.

The benefits of the LC case are fewer defaults and less volatility in the real exchange rate (and consumption, consequently). The costs are the lower debt sustainability and the positive level of inflation, which affects utility directly. All considered, I find that a change from the FC to the LC regime leads to a welfare loss equivalent to 0.05% decrease in consumption.

Other papers have assessed the welfare consequence from such change in the currency denomination using quantitative models of default. Each model is calibrated to a different situation, so comparisons must be made with this caveat in mind. Gumus (2013) finds gains of 0.02% in equivalent consumption in a model with two sectors and no discretionary inflation. In an environment with a single traded good and with discretionary monetary policy, Nuno and Thomas (2016) arrive at losses of 0.3%. Their results remain in this range for a wide set of robustness exercises. They only find gains from nominal debt if the output growth volatility is 20%, much higher than 3.2% in their benchmark calibration. Onder and Sunel (2016), also in a setting with only one good and discretionary inflation, find losses of up to 1% in their benchmark calibration. This happens as a consequence of inflation increasing from zero to 2.5% and of debt-to-GDP ratio falling by half. The welfare losses reduce to less than 0.10% if the parameter governing inflations costs is changed, so that average inflation is 0.4% and debt-to-GDP ratio falls only 10%. They also find welfare gains, less than 0.2%, if the variance of the exogenous shock of output process increases from 1% to 3.5%.

The first robustness exercise is the inclusion of risk-averse lenders (columns 5 and 6). This modification allows the model with FC debt to replicate the average default premium seen in the data, while maintaining the other relevant results. The insertion of this feature in the model with LC debt also brings few modifications. The main advantage is that the model mimics the average nominal spread, but this variable becomes counter-cyclical, in opposition to the data. Compared to the FC case, the model with LC debt still indicates reductions in: i) default frequency (and average default risk premium), ii) real exchange rate volatility, and iii) mean and standard deviation of both risk premium and trade balance. However, now the average debt remains constant. Overall, the welfare loss reduces from 0.05% to 0.01%.

Column 7 brings another robustness check. It consists of the use of a lower utility cost of inflation, what can be interpreted as a decrease in the credibility of monetary policy (Onder and Sunel, 2016, Du, Pflueger and Schreger, 2017). I set $\gamma = 0.85$, instead of 1.3, making the model's average inflation match its observed counterparty (4.2%). I keep the same value of the benchmark calibration for the other parameters in the model. Volatilities and correlations with output do not change in a meaningful manner. Comparing with the model in column 2 (the parameter γ does not influence the FC economy), the decline in the mean debt is greater than in the benchmark scenario. This suggests that lower inflation credibility might be a reason why the observed average debt level in Brazil is lower than suggested by the benchmark LC model. All things considered, the welfare loss from changing from FC to LC is larger with the lower credibility of monetary policy, 0.10% instead of 0.05%, in line with Nuno and Thomas (2016) and Onder and Sunel, (2016) in models without real exchange rate movements.

The opposite case, present in column 8, is when the monetary policy is fully credible and can commit to zero inflation ($\gamma = +\infty$). Then, only the real exchange rate relieves the debt burden during bad times. Default frequency declines to 1.8% (column 3), lower than under FC debt, but higher than when the use of inflation is possible (column 4). In the absence of inflation risk, debt sustainability increases in comparison to the FC case. The general effect is a welfare gain from issuing LC debt of 0.07% of the certainty equivalent consumption, in accordance with Gumus (2013). This type of analysis is not possible in the framework with a single traded good, because, in such setting, foreign currency and local currency are exactly the same if inflation is always zero.

1.6 Conclusion

This paper uses a quantitative model of external debt and sovereign default with real exchange rate and discretionary inflation to investigate the consequences for emerging countries of borrowing from foreigners in domestic currency. The model replicates relevant features of the Brazilian economy since 2007, when external debt denominated in local currency started to become relevant. Both in the data and in the model, default risk premium, trade balance, and real exchange rate are counter-cyclical variables, while inflation is pro-cyclical. This last feature, similar to a Phillips curve, occurs because during periods of high output the sovereign accumulates more debt and is more tempted to use inflation.

Results suggest that altering the currency denomination of external debt from foreign to local currency has modest welfare implications. In the case of discretionary monetary policy, issuing LC debt entails welfare losses; the higher the degree of discretion, the greater the losses. The negative effects of issuing debt in domestic currency originate from higher inflation and lower levels of sustainable debt. Nevertheless, if the policy maker can commit to price stability, the economy has welfare gains from switching to nominal debt. In this scenario, the depreciation of the real exchange rate relieves the debt burden during bad times. Regardless of the credibility of the monetary policy, however, the frequency of explicit defaults invariably falls.

Such relation between monetary policy credibility and the welfare consequences from the currency denomination of external debt presents an alternative explanation for the “original sin”. If the monetary policy credibility is very low (as high inflation in emerging markets before they adhered to reliable monetary policy regimes suggest), issuing LC debt might lead to meaningful welfare losses. Hence, denominating debt in FC is a choice, and not necessarily a consequence of the inability to issue LC debt for foreign investors due to an incompleteness in international financial markets.

The current analysis might be of interest not only for emerging economies that are gaining capacity to borrow from abroad in domestic currency, but also for countries in the periphery of the Euro Area. By joining the monetary union, these countries borrow only in Euros and, therefore, renounce the ability to inflate the debt away.

1.7 Appendix to chapter 1

1.7.1 Data

Figure 1.1. Net foreign currency debt comes from the Central Bank of Brazil Time Series Management System (code 11420). I use it due to its long sample, since 1970. Although it includes debt issued abroad in any currency (including the Brazilian Real), it does not include debt issued in Brazil and held by nonresidents. Since 2004 it is possible to check the share of local currency denominated debt in this variable. I find that it is, on average, less than 2% for the period 2004-2006, when this variable is used. Net local currency debt is the amount of fixed income bonds issued in the domestic market held by nonresidents (code 22160 in the Central Bank of Brazil Time Series Management System), available since 2001. It comprises mostly foreign holdings of domestically issued central government debt. I consider that the gross amount of this type of debt equal its net amount, since I assume that debt type assets held abroad by Brazilians are always denominated in foreign currency. More details about this assumption are present in this appendix in the discussion about Table 1.1.

Table 1.1. It lists 12 emerging countries whose gross external debt (excluding intercompany lending operations, classified as direct investment) exceeds US$ 50 billion in 2015 and for which its currency composition is available. Together they amount to US$ 2.7 trillion in debt liabilities. Debt data by currency come from the Quarterly External Debt Statistics Database (QEDS), a collaboration between the World Bank and the IMF. This information is available only for countries that subscribe to the IMF's Special Data Dissemination Standard. Currency composition comes from Table 2 in "Country Tables" and Table C5 in "Cross Country Tables". I compare the latter data with those in Table C2 in "Cross Country Tables" to check for which countries the gross external debt statistics contains intercompany lending, which I classify as Direct Investment instead of Debt. I also i) compare the data to the sovereign investor base estimates of Arslanalp and Tsuda (2014), and ii) check the Metadata by country, to exclude countries whose statistics available at QEDS do not include non-residents participation in domestic bond markets.

In order to construct net external debt measures by currency, it is necessary to subtract assets held by the emerging markets. I restrict the analysis to assets classified as debt instruments or international reserves, both obtained from the IMF Balance of Payments and International Investment Position Statistics. Since there is not information available by currency denomination for such assets, I suppose that all of them are denominated in foreign currency. Fortunately, data available for Brazil suggest that this a sensible assumption for an emerging market. Using data from the Central Bank of Brazil, I find that in 2015 only 0.2% of debt-type assets and reserves were denominated in Brazilian Real. See tables 4 and 33 in the monthly Press Release for the External Sector Statistics, available at http://www.bcb.gov.br/ingles/notecon1-i.asp. Since the totality of international reserves is denominated in foreign currency, I obtain the estimate using assets by currency denomination (excluding intercompany lending) from table 33

Table 1.3.

Output: Brazilian GDP data since 1947 obtained from the System of National Accounts calculated by IBGE, the Brazilian national statistical office. For the most recent years, the information comes from the Quarterly National Accounts. I use the Hodrick-Prescott filter to recover the cyclical component of the logarithm of the GDP. This information is used to calculate the correlations with output.

Foreign and local currency net external debt: see the details in Figure 1.1.

Inflation: Difference between inflation rates of Brazil and USA. For Brazil I use the IPCA (broad consumer price index), calculated by IBGE. This is the reference rate for the Brazilian inflation target regime. For the USA I use the ‘Consumer Price Index for All Urban Consumers: All Items’ from the BLS.

Real exchange rate: Trade-weighted real exchange rate using CPI inflation. It is obtained in the Central Bank of Brazil Time Series Management System (code SGS BCB 11752). The sample starts in 1988.

Trade balance: Trade balance as a share of the GDP. Data come from the Central Bank of Brazil Time Series Management System (codes 23467 and 2302). The more recent time series using the methodology of the 6th edition of the Balance of Payments and International Investment Position Manual starts in 1995. For previous years, I use the information calculated using the guidance of the 5th edition of the Manual. The GDP data in dollars comes from the same source (code 7324). The final variable is available since 1962.

Default risk premium: Emerging Markets Bond Index Plus (EMBI+) for Brazil. Available since 1994. It measures the default risk for sovereign foreign currency bonds issued abroad and is available since 1994. Even for the period 2007-2016, I choose to use this variable, since it is a direct measure of credit risk exclusively. Du and Schreger (2016) compute local currency default risk for 10 emerging countries between 2004 and 2015 and find an average value of 1.45%, close to its equivalent in foreign currency, 2.01%. Although I model the total amount of external debt, I use government debt spreads due to data availability and its high correlation with corporate debt spreads, as pointed by Durbin and Ng (2005).

Nominal spread: Difference between local currency government bond interest rates in Brazil and USA. For Brazil, I use the interest rates on the NTN-F bond. This is a fixed-rate nominal bond, as the debt in the model. It is also the preferred bond of foreign investors. In December 2017, this type of bond represented 89% of the holdings of foreign investor in the Brazilian government debt market. Brazilian data comes from the Monthly Debt Report produced by the Brazilian National Treasury, Ministry of Finance (table 4.1). The USA interest rate is the 5-Year Treasury Constant Maturity Rate.

1.7.2 Model

A Relation between q_t and $\tilde{q}_t$: Starting from equations (1.13) and (1.5), one can obtain (A1) and, subsequently, (B2). The latter shows that $\tilde{q}$ does not depend on the current state of the economy.

$$q_t = P_t \alpha \left(\frac{c_t^T}{c_t^N}\right)^{\alpha-1} E_y[m_{t+1}(1 - f_{t+1}) \frac{1}{\alpha} \frac{1}{P_{t+1}} \left(\frac{c_{t+1}^T}{c_{t+1}^N}\right)^{1-\alpha}] \qquad (A1)$$

$$q_t = \alpha \left(\frac{c_t^T}{c_t^N}\right)^{\alpha-1} E_y\left[m_{t+1}(1 - f_{t+1}) \frac{1}{\alpha} \frac{1}{\pi_{t+1}} \left(\frac{c_{t+1}^T}{c_{t+1}^N}\right)^{1-\alpha}\right] = \epsilon_t \tilde{q}_t \qquad (A2)$$

Solution for the resource constraint in the LC case: Resource constraint (1.19) can be re-written as (A3). Given the other parameters and variables, this is a non-linear equation in c_t^T. Joining all variables and parameters except c_t^T in constants A and B, we have equation (A4). In the empirically relevant case with $\alpha = 0.5$, there is a closed form solution, (A5), used in the numerical problem (one root is discarded because it leads to a negative association between consumption and inflation).

$$c_t^T = y_t^T + \tilde{q}_t \hat{d}_{t+1} - \frac{1}{\alpha} \left(\frac{c_t^T}{c_t^N}\right)^{1-\alpha} \frac{\hat{d}_t}{\pi_t} \qquad (A3)$$

$$c_t^T = A - B(c_t^T)^{1-\alpha} \qquad (A4)$$

$$c_t^T = \frac{\left(-\sqrt{B^2+4A} - B\right)^2}{4} \qquad (A5)$$

2 INTERNATIONAL RESERVES AND PARTIAL SOVEREIGN DEFAULT

2.1 Abstract

Despite the cost imposed by the interest rate spread between sovereign debt and international reserves, emerging countries' governments maintain stocks of both. I investigate the optimality of this joint accumulation of assets and liabilities using a quantitative model of sovereign debt, in which: i) international reserves only function to smooth consumption, before or after a default; ii) the sovereign's decision to repudiate debt determine the spread; iii) lenders are risk-averse; and iv) default is partial. Simulated statistics from the benchmark model match their observed counterparts for average debt and spread, consumption volatility, and the main correlations among the relevant variables. Due to the presence of partial default and risk-averse lenders, the model also produces a mean reserve level of 7.7% of GDP, indicating that the optimal policy is to hold positive amounts of reserves.

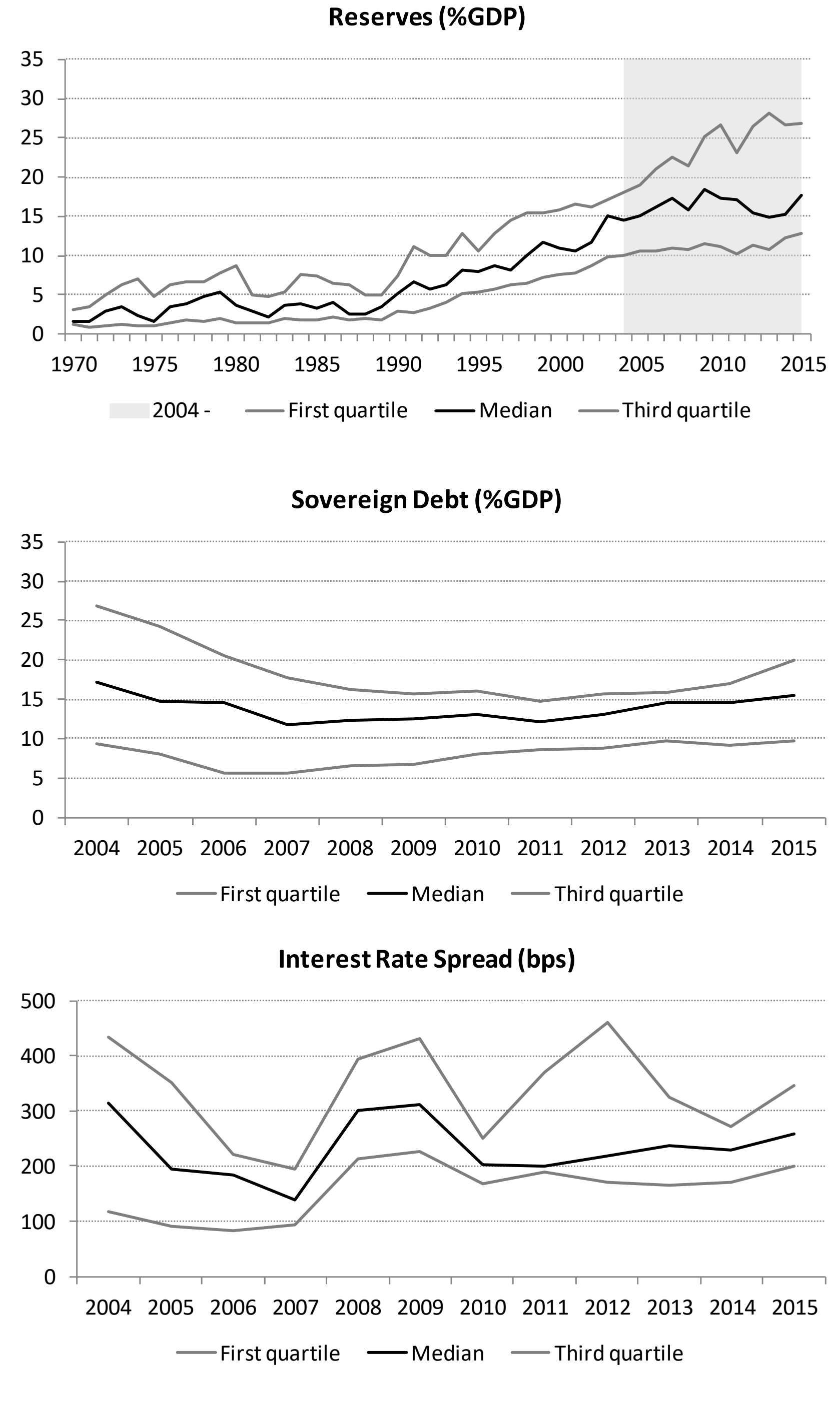
2.2 Introduction

The amount of international reserves held by emerging countries in recent years is much higher than in previous decades (Figure 2.1). Currently, such governments also maintain positive quantities of sovereign debt[23] whose interest rates frequently exceed those earned on the international reserves by 200 basis points (Figure 2.1). Since governments could sell their reserves and reduce their indebtedness, the difference in yields makes the cost of keeping such stock of reserves meaningful (Rodrik, 2006).

In this paper, I investigate whether it is optimal for emerging markets to hold positive levels of both sovereign debt and foreign exchange reserves. To do so, I develop a quantitative model of strategic sovereign default in which debt, spreads, and reserves are endogenous. In this setting, international reserves are a tool to smooth consumption even after a delinquency. In this manner, I contribute to a vast literature that considers the recent build-up of international reserves as a form of precautionary savings to be used in moments of crises.

[23] Public debt owed to non-residents, issued abroad or at home.

Figure 2.1 – International Reserves, Sovereign Debt, and Spreads in Emerging Markets.



Note: The figure plots the median and the interquartile range for international reserves, sovereign debt and interest rate spreads for a balanced panel of 22 emerging countries. Foreign exchange reserve data come from the updated and extended version of dataset constructed by Lane and Milesi-Ferretti (2007). Sovereign debt is from Arslanalp and Tsuda (2014), includes foreign participation in local government debt markets, and starts in 2004. Spreads information comes from the Emerging Markets Bond Index Plus (EMBI+ blended). Countries in the sample are Argentina, Brazil, Chile, China, Colombia, Egypt, Hungary, India, Indonesia, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, Turkey, Ukraine, Uruguay. The shaded area in the first panel represents the common sample to the three variables.

I extend the baseline model to incorporate partial debt repudiation, a feature present in the data (Cruces and Trebesch, 2013). I calibrate the model to mirror relevant characteristics of emerging market economies and quantitatively show that the optimal policy is to hold positive amounts of reserves. With risk-averse lenders, the model exhibits: i) average sovereign debt of 15.4% of GDP, ii) average spread of 242 bps, and iii) a ratio between volatilities of consumption and output of 0.97. Besides these targeted statistics, the model generates a stock of foreign exchange reserves of 7.7% of GDP, below the 16.4% observed in my sample of emerging markets between 2004 and 2015, but notably different from zero.

In the model with full debt repudiation, the value of defaulting is independent from the current debt. This happens because, after a temporary exclusion triggered by the default, the government returns to markets holding zero debt, regardless of the debt level existent in the moment of default. However, in a model with partial default, the value of defaulting decreases as debt raises. In this case, when the exclusion from credit markets finishes, the sovereign reentries the international debt market carrying a share of its previous liabilities. Thus, the inclusion of partial repudiation increases the incentives for repayment. Due to this mechanism, governments have more incentives to issue debt and accumulate reserves during good times (periods of high output), in line with the empirical evidence. Furthermore, the gathering of reserves during good times also generates a negative correlation between spreads and reserves, as in the data.

This paper relates to the literature that studies the simultaneous accumulation of sovereign debt and international reserves by emerging markets using quantitative models of default. Alfaro and Kanczuk (2005), Arellano (2008), and Aguiar and Gopinath (2006) developed this methodology based on the theoretical works of Grossman and van Huyck (1988) and Eaton and Gersovitz (1981)[24].

The first article to include the option to accumulate international reserves (a risk-free asset) in this setting is Alfaro and Kanczuk (2009). In their model, the only use of reserves is to smooth consumption, particularly after a default occurs and the economy is excluded from international financial markets. However, reserves are costly because their return is lower than the interest rate paid on sovereign debt. Such spread reflects the probability of default, a strategic choice by the local sovereign who cannot commit to honor its obligations. Thus, the local government

[24] Recent surveys of this approach are Stahler (2013), Aguiar and Amador (2014), and Aguiar et al (2016).

chooses quantities of debt and reserves, and when to default. Alfaro and Kanczuk (2009) find that the optimal policy is not to hold reserves at all, despite their low cost (average spread of only 60 bps, in their benchmark calibration) [25]. Instead, they recommend that governments should use reserves to reduce their indebtedness.

Salomão (2013) develops a model whose only difference from the one of Alfaro and Kanczuk (2009) lies in the functional form of the direct output cost of default[26]. Instead of proportional costs, she uses an asymmetric functional form proposed by Arellano (2008)[27]. In this case, costs are smaller when output is low. Her model presents positive average levels of debt and reserves, but mean spreads remain low, 60 bps. The shape of the direct cost of default matters, because with asymmetric costs the model produces higher average debt using a more patient domestic sovereign[28]. This agent perceives the cost of holding reserves (the interest rate spread) as lower, and chooses to accumulate more assets.

Alfaro and Kanczuk (2017) change the benchmark model turning it into a two-sector economy with traded and non-traded goods. They show that if sovereign debt is issued in local currency, a pattern observed recently in several emerging markets, it is possible to sustain positive levels of debt and international reserves even in an economy with proportional costs of default. Nevertheless, average spreads in simulated data remain low, 40 bps.

Bianchi, Hatchondo and Martinez (2018) obtain positive levels of both debt and reserves in a model with asymmetric costs of default[29] by changing the maturity of debt from short-term (one period bonds) to long-term (an infinite stream of coupons that decay at an exogenous rate). They also obtain average spreads of 240 bps, a value similar to the one observed in recent years in emerging markets. Their results are quantitatively more relevant when the economy faces rollover crises (exogenous increases in lender's risk aversion) and fiscal rigidity (a required fixed level of expenditure in a public good). Hernandez (2016) extends the model with long-

[25] In their model, with full default, the average spread is approximately the same as the default frequency. Given the average stay in autarky of two years, it is possible to infer that 1.29% of time excluded from markets implies 0.65% of default frequency and similar spreads.

[26] This extra cost, beyond exclusion from markets, is a common feature in this class of model and is necessary to induce positive levels of debt in equilibrium. See Aguiar and Amador (2014), and Phan (2017).

[27] Aguiar et al (2016) show that the assumption of proportional costs is better suited for a model in which output growth has a stochastic trend, as in Aguiar and Gopinath (2006). Assuming proportional costs and no stochastic trend for output growth, the model is unable to generate realistic levels of debt and spread/default frequency.

[28] The impatience is measured by the value of the domestic subjective discount factor, usually denoted in the macroeconomics literature by β. Alfaro and Kanczuk (2009) and Salomão (2013) use $\beta = 0.40$ and $\beta = 0.948$, respectively. In both cases, the international risk-free rate is 4%.

[29] They insert the immediate cost of default directly in the utility function.

term debt and investigates the role of reserves when the self-fulfilling rollover crises and multiple equilibria are possible.

I contribute to this literature by showing that the inclusion of partial default and risk-averse lenders in a model with short-term debt allows it to generate sensible levels of sovereign debt, spread, and consumption volatility, and yet explain a large part of the international reserves holdings of emerging countries.

Other modeling approaches also highlight the role of international reserves as a precautionary savings mechanism. For investigations of the optimal level of international reserves in models with exogenous debt limits (or spread) and sudden stops, see Durdu, Mendoza, and Terrones (2009), Jeanne and Ranciere (2011), and Shousha (2017). Studies using the framework of Diamond and Dybvig (1983) include Aizenman and Lee (2007), Hur and Kondo (2016), and Corneli and Tarantino (2016). For an analysis of the relevance of the potential size of domestic financial fragility to explain observed levels of international reserves, see Obstfeld, Shambaugh, and Taylor (2010).

Dooley et al (2004) present an alternative view on the accumulation of reserves by emerging markets. They suggest that the build-up of reserves derives from a mercantilist policy to increase net exports by devaluating the domestic currency. Korinek and Servén (2016) formalize this idea in a model in which the accumulation of reserves undervalues the real exchange rate and stimulates the production of tradable goods, a sector with learning-by-investing externalities.

Gosh et al (2016), Obstfeld, Shambaugh, and Taylor (2010), and Aizenman and Lee (2007) provide empirical evidence on the determinants of the size of reserve holdings and compare the precautionary and mercantilist views.

2.3 Model

I model a dynamic small open economy in which the benevolent central planner receives a stochastic endowment every period. This agent issues only non-state-contingent debt, bought by foreign lenders, and buys a risk-free asset (international reserves). Since the sovereign lacks commitment to repay, every period it chooses whether to default on the stock of debt. In case of default, the sovereign is excluded from international markets by a random number of periods and faces a direct output cost. As default is partial, the new stock of debt upon reentry in the credit market is a share of the one defaulted upon.

Consider a representative agent whose preferences are given by equation (2.1), in which E denotes the expectation operator, c_t is the consumption of goods in period t, β is the domestic subjective discount factor, and σ is the coefficient of constant relative risk aversion.

$$U = E\left[\sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}\right] \tag{2.1}$$

The endowment of the single good available in the economy, y_t, follows the autoregressive process described in equation (2.2) with ε_t representing a white noise with standard normal distribution.

$$ln(y_t) = \rho ln(y_{t-1}) + \eta\varepsilon_t \tag{2.2}$$

If the government chooses to honor its current obligations, it faces the budget constraint (2.3), in which q_t is the price of a one-period bond. This security pays one unit of the single good in the next period if the government chooses not to default. The planner can increase consumption borrowing from foreigners by issuing debt, d_{t+1}, or depleting the current stock of international reserves, a_t, whose constant price is q^a.

$$c_t = y_t + q_t d_{t+1} - d_t - q^a a_{t+1} + a_t \tag{2.3}$$

If the government decides to default, expression (2.4) presents its budget constraint. It expresses that the planner can still use and buy reserves, but cannot issue new debt. Beyond exclusion from international bond markets for a random number of periods, the domestic economy also faces a direct output cost after default. I use the specification in equation (2.5), proposed by Arellano (2008), frequently used in this literature, and consistent with the empirical evidence. This asymmetric function means that there are no direct costs of default up to a certain threshold (ψ), but they become positive beyond that point. Since sovereign defaults are associated with disruptions in the domestic financial market and credit is an essential input, this functional form captures the idea that output cannot be high even under a good productivity shock[30].

[30] See Mendoza and Yue (2012) for a general equilibrium model of sovereign defaults and business cycles that generates non-linear output costs. The asymmetry happens due to working capital financing constraints for imported inputs that lack perfect domestic substitutes.

$$c_t = y_t^a - q^a a_{t+1} + a_t \tag{2.4}$$

$$y_t^a = \begin{cases} y_t, if\ y_t \leq \psi \\ \psi,\ if\ y_t > \psi \end{cases} \tag{2.5}$$

Now I write the sovereign problem in recursive form to understand the role of partial default. As usual in the literature, variables with apostrophe represent values at $t+1$. For the value functions and restrictions defined below, I obtain policy functions for default (f), debt issuance (d'), and asset acquisition and consumption under repayment (a_R', c_R) and default (a_D', c_D).

Every period the sovereign decides to default or repay according to equation (2.6),

$$v(y,d,a) = \max_{f \in \{0,1\}} \{ (1-f) v^R(y,d,a) + f v^D(y,d,a) \}, \tag{2.6}$$

in which the value of repaying is expressed by

$$v^R(y,d,a) = \max_{c_R, d', a_R'} \{ u(c) + \beta E_y [v(y', d', a_R')] \}, \tag{2.7}$$

subject to (2.3), $d' > 0$, and $a_R' > 0$, and the value of defaulting is given by

$$v^D(y,d,a) = \max_{c_D, a_D'} \{ u(c) + \beta E_y [\theta v(y', \lambda d, a_D') + (1-\theta) v^D(y', d, a_D')], \tag{2.8}$$

subject to (2.4), (2.5) and $a_D' > 0$.

In the previous equation the parameter θ measures the exogenous probability of regaining access to the international markets with debt level equal to λd. This modeling choice for partial default is similar to the ones used by Önder and Sunel (2016) and Hur, Kondo and Perri (2017). Nonetheless, I extend it to incorporate the presence of the risk-free asset. Hence, the value of defaulting depends on the current debt level due to the existence of partial default.

The price of international reserves, given by equation (2.9), is constant and depends only on the risk-free rate, r^*. Meanwhile, the price of debt reflects the sovereign's incentives to repay as perceived by risk-averse foreign lenders. They price the bond's payoff using the reduced form stochastic discount factor in equation (2.10). Arellano and Ramanarayanan (2012) and Bianchi, Hatchondo and Martinez (2018) use this specification in their quantitative models of sovereign default. In expression (2.10), the parameter κ dictates the risk premium and its correlation with the stochastic process for y_t. While $\kappa = 0$ leads to risk neutral lenders, positive values imply that lenders value more returns in states with negative income shocks, when default is more likely to happen.

$$q^a = exp(-r^*) \tag{2.9}$$

$$m_{t+1} = exp(-r^* - \kappa\eta\varepsilon_{t+1} - 0.5\kappa^2\eta^2) \tag{2.10}$$

Due to partial default, the price of sovereign bonds, q, depends on its own price during the exclusion from capital markets, q^D. Let $s = (y, d, a)$, $s_\lambda = (y, \lambda d, a)$ and E_y denote the conditional expectations operator. Then, equations (2.11) and (2.12) present the respective prices.

The price of debt depends on the current endowment, which brings information about its next realization, and on the future values of debt and reserves. Quantities of assets and liabilities in the following period are the relevant information for the lenders, because that is when the sovereign decides to repay or not. If the sovereign chooses to honor its obligations, the lender receives one unit of the good. In case of delinquency, the creditor holds a bond worth $q^d(y', d'', a'')$.

$$q(y, d', a') = E_y\{m_{t+1}[(1 - f(s') + f(s')q^d(y', d'', a'')]\}, \tag{2.11}$$

with:

$a'' = a'_D(y', d', a')$,

$d'' = d'$.

During the exclusion from markets, the price also hinges on the current endowment and on the future values of debt and reserves. If the exogenous exclusion from markets remains for one more period, bonds are priced $q^d(y', d'', a''_1)$. On the other hand, if exclusion ends, the recovery rate λ is applied and there are two possibilities: the government defaults again, and bonds are worth $q^d(y', \lambda d'', a''_2)$, or repays.

$$q^d(y,d',a') = E_y\left\{m_{t+1}\left[(1-\theta)q^d(y',d'',a_1'') + \theta\lambda\left(1-f(s_\lambda')+f(s_\lambda')q^d(y',\lambda d'',a_2'')\right)\right]\right\}, \quad (2.12)$$

with:

$a_1'' = a_D'(y',d',a')$,

$a_2'' = a_D'(y',\lambda d',a')$,

$d'' = d'$.

The model represents a dynamic game played between a discretionary sovereign against a continuum of small identical foreign lenders. Given the lack of commitment, I focus on Markov Perfect Equilibrium.

Definition. A Markov perfect equilibrium is defined by:

i) A set of value functions $v(s), v^R(s), v^D(s)$ defined above.

ii) Policy functions $f(s)$, $d'(s)$, $a_R'(s)$ and $a_D'(s)$, and $c_R(s)$ and $c_D(s)$.

iii) Bond price functions $q(y,d',a')$ and $q^d(y,d',a')$.

such that

I) Given bond prices, the policy functions solve the Bellman equations (2.6) - (2.8).

II) Given the policy functions, the bond prices satisfy equations (2.11) - (2.12).

2.4 Calibration

Table 2.1 presents the benchmark values for the parameters in the model. As a period in the model refers to one year, I use $r^* = 0.04$, a standard choice. The probability of redemption after default, θ, is 50%, entailing an average stay in autarky for two years, in line with estimates by Gelos, Sahay and Sandleris (2011). The recovery rate, λ, matches the complement of the average haircut (excluding highly indebted poor countries) estimated by Cruces and Trebesch (2013), 29.7%, considering 157 debt restructurings from 1978 to 2010.

For the endowment process, the parameters ρ and η are the same used by Alfaro and Kanczuk (2009), who obtained them from GDP data for a sample of emerging markets. These values are very close to the more recent estimates of Uribe and Schimitt-Grohé (2017). In order to discretize this process, I use the simulation method proposed by Schimitt-Grohé and Uribe (2009).

I calibrate the remaining four parameters $(\sigma, \beta, \psi, \kappa)$ to match four targets in the data: i) average sovereign debt of 14.1% of GDP[31]; ii) average interest rate spread of 234 bps; iii) 35% of this spread related to risk premium, and the remaining reflecting default probability; and iv) a ratio of 0.98 between volatilities of consumption and GDP. While the first two targets reflect the data in Figure 2.1, the decomposition of total spreads between its two components and the volatility ratio come from Longstaff et al (2011) and Uribe and Schimitt-Grohé (2017) respectively.

I obtain a domestic discount rate, $\beta = 0.905$, similar to the values of Bianchi, Hatchondo and Martinez (2018), and Hernandez (2016). The resulting direct output cost of default is $\psi = 0.86$. Such parameters are mainly relevant for the first two targets: average debt and spreads. The value of the pricing kernel parameter, $\kappa = 7$, is the main determinant of the shares of the total spread associated with default risk and risk premium.

The risk aversion coefficient achieved is $\sigma = 5$. Du, Pflueger and Schreger (2017) set $\sigma = 10$ in a model of the currency composition of sovereign debt. This last figure is at the upper end of values considered plausible by Mehra and Prescott (1985) and within the range of estimates by Bliss and Panigirtzoglou (2004) and from other studies they summarize.

[31] Similar values are used by other studies of sovereign debt, as Hernandez (2016), Ottonello and Perez (2016), and Du, Pflueger and Schreger (2017).

The model is solved numerically using value function iteration in a discrete state space. As suggested by Hatchondo, Martinez and Sapriza (2010), I find the equilibrium by solving the limit of the equivalent finite-horizon version of the model.

Table 2.1 – Parameter values

Parameter	Description	Value
σ	Domestic Risk Aversion	5
β	Domestic discount factor	0.905
ψ	Direct output cost of default	0.86
κ	Pricing kernel parameter	7
θ	Probability of re-entry after default	0.5
r*	Risk free rate	0.04
ρ	GDP persistence	0.85
η	Std. Deviation of innovation to GDP	0.044
λ	Recovery rate	0.7

2.5 Results

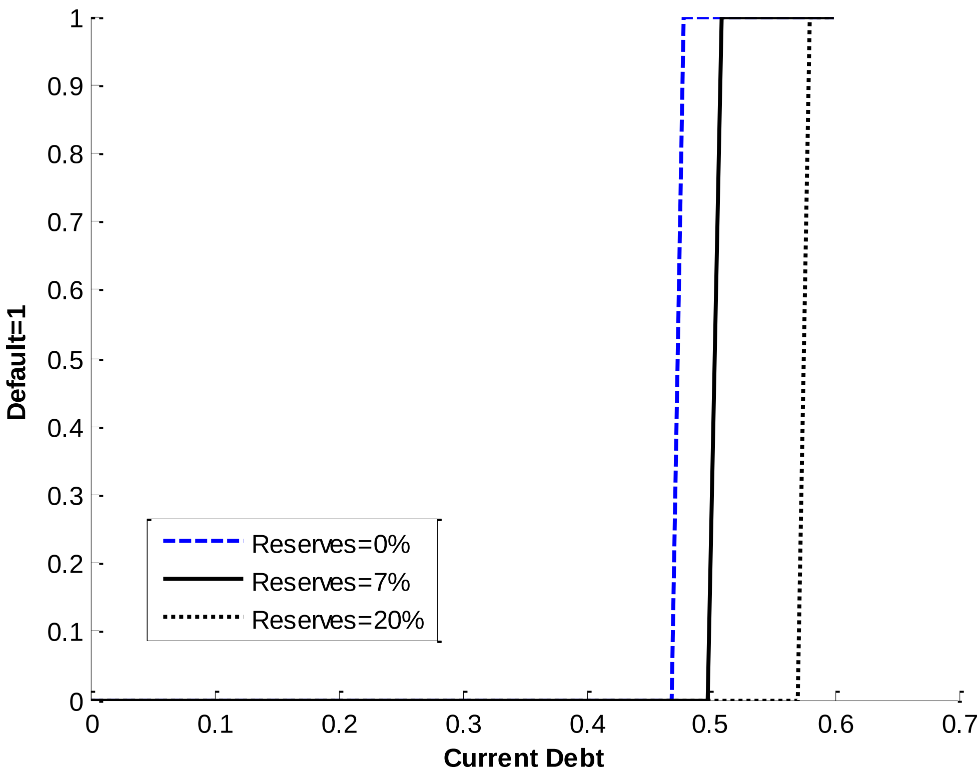
Alfaro and Kanczuk (2009) point that reserve holdings reduce the cost of exclusion from capital markets and increase the temptation to repudiate debt. On the other hand, reserves are an option to avoid the costly tool of default and might contribute to debt sustainability. The default policy function for the benchmark calibration, depicted in Figure 2.2, shows that the existence of a stock of reserves increases the amount of sustainable debt for a given level of output, opposite to the result of Alfaro and Kanczuk (2009). In the same direction, price functions in Figure 2.3 indicate lower spreads (higher prices) when the sovereign decides to accumulate more assets for a given debt level[32], in line with the empirical evidence (Henao-Arbelaez and Sobrinho, 2017).

Partial default plays a relevant role in this result by allowing the model to achieve the desired debt level with a more patient sovereign (higher β). If I solve the model setting $\lambda = 0$, full debt repudiation, and targeting the same average debt (therefore, changing the value of β), I obtain a result similar to that of Alfaro and Kanczuk (2009): reserves decrease debt sustainability. If I

[32] In the model of Hernandez (2016), the sovereign can increase the amounts of both reserves and debt, keeping a fixed net position, and still face lower spreads. This happens due to the role of reserves in avoiding self-fulfilling rollover crises.

fix $\beta = 0.905$ and use $\lambda = 0$, the current quantity of reserves do not influence debt sustainability; the default policy function for the median output level is the same for different amounts of assets. In this case ($\beta = 0.905$ and $\lambda = 0$), the model generates a lower average debt level (5.5% of GDP).

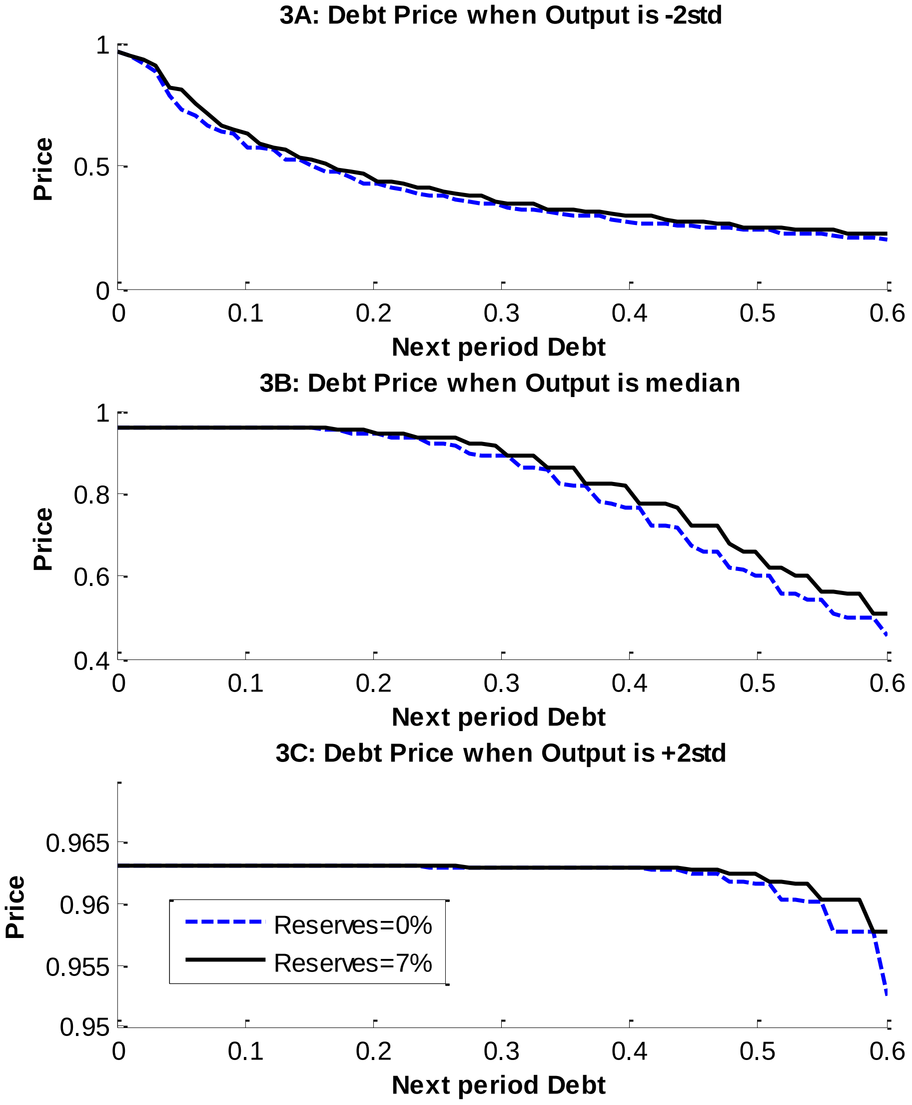
Figure 2.2 – Default Policy Function for the Median Output Level



Note: This figure plots the default policy function for the median level of output. When the optimal choice is to default, the policy function is one. The horizontal axis represents current debt level in relation to the median output. Each line represents the policy function for a different level of reserves measured as a share of median output.

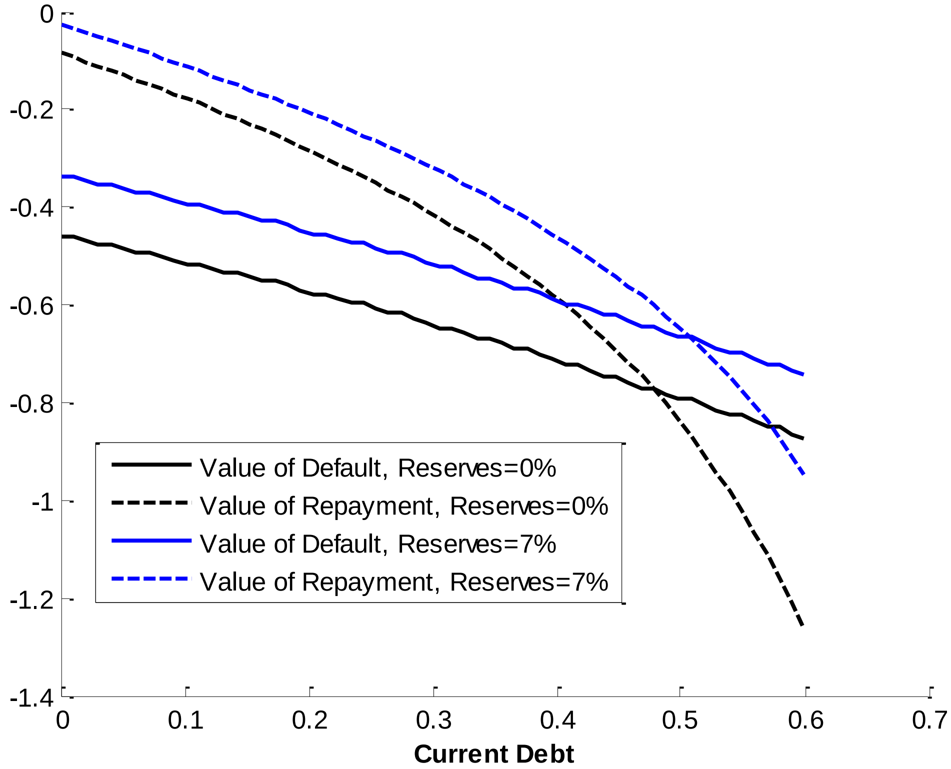
In the traditional model with complete default, the value of repayment (v^R) decreases with the debt level, but the value of default (v^D) is constant. Figure 2.4 shows that, due to partial repudiation, the value of default also falls as debt escalates, increasing debt sustainability. This creates an incentive for the joint accumulation of reserves and debt.

Figure 2.3 – Bond Price Function for Different Output Levels



Note: This figure plots the bond price function for three different levels of output: the median and plus or minus two standard deviations. The horizontal axis represents the choice of next period debt in relation to the median output. Each line represents the price function for a different choice of reserves level in the next period, measured as a share of the median output.

Figure 2.4 – Value Functions for Default and Repayment for the Median Output Level



Note: This figure plots the value functions for default (solid line) and repayment (dashed line) for the median output level. The horizontal axis represents current debt level in relation to the median output. Each color (for a pair of lines) represents the value functions for a different level of reserves, measured as a share of median output.

Table 2.2 reports basic statistics in the data and in model simulations. The benchmark model, presented in column 2, matches the four targeted statistics and produces average reserves of 7.7% of GDP. This number is below the observed in emerging markets since 2004, but close to the results of other papers in the literature, between 3% and 6%. This difference leaves room for alternative explanations for the recent surge in reserves, seeing that in this model reserves are useful only to smooth consumption. Positive correlations between reserves and both debt and GDP arise because during good times (high output) governments issue debt to accumulate reserves, in line with Figure 4. Interest rate spread is counter-cyclical and negatively correlated with reserves[33].

[33] In a panel of 22 countries, Bianchi, Hatchondo and Martinez (2018) also find: i) negative correlation between debt (or reserves) and spread, and ii) i) positive correlation between debt (or reserves) and GDP growth.

Table 2.2 – Basic Statistics: Model and Data

Variables	Data	Models				
	2004-15	Benchmark	Debt only	Risk Neutral	Full default	Total Ext. Debt
	1	2	3	4	5	6
				Average		
Default frequency	--	3.8	3.9	6.1	0.7	3.8
Debt/GDP	14.1	15.4	9.5	20.4	5.5	33.0
Spread	234	242	248	189	164	229
Risk Neutral Spread	152	148	152	189	88	142
Reserves/GDP	16.4	7.7	--	3.3	5.1	5.4
				Standard deviation		
Consumption	0.98	0.97	0.99	0.96	0.97	1.05
Debt/GDP	4.4	8.2	3.8	6.0	4.6	7.7
Spread	85	540	551	376	336	499
Reserves/GDP	3.7	12.4	--	7.3	8.9	10.0
				Correlation with GDP		
Debt	0.0	0.5	-0.6	-0.2	0.6	0.5
Spread	-0.6	-0.6	-0.6	-0.6	-0.6	-0.7
Reserves	0.4	0.6	--	0.5	0.6	0.6
				Other correlations		
Debt & Reserves	0.3	0.8	--	0.2	0.8	0.9
Debt & Spread	-0.1	-0.2	0.3	0.2	-0.3	-0.1
Spread & Reserves	-0.4	-0.3	--	-0.2	-0.3	-0.2

Note: Column 1 presents basic statistics for emerging countries using data from figure 2.1. Each column from 2 to 6 brings statistics calculated from simulated data (500,000 observations) of a different model. See the main text for the calibration used in each column. Debt and reserves ratios to GDP appear as percentage points and spreads as basis points. Standard deviation for consumption reported relative to that of output. In column 1, growth rates are used to calculate correlations, except for spreads.

The benchmark model does not work so well in replicating volatilities, except the targeted one. The standard deviation of the spread of 85 bps – the median in the sample of 19 countries for the period 2004-2015 – is low in historical terms. Even extending the initial period of the sample, the standard deviation increases only to 160 bps. The only countries with standard deviation of the spread higher than the generated by the model, 551 bps, are Argentina (1620 bps), Russia (907 bps) and Ukraine (633 bps). The next one is Brazil with 353 bps[34]. The model also overstates the volatilities of sovereign debt and international reserves, and by a magnitude similar to the one identified by Shousha (2017) in a framework with exogenous spreads,

[34] See Aguiar et al (2016) for a discussion of the ability of this type of model to match spread volatility and the peculiarity of the Argentinean case studied in Arellano (2008), in which observed and simulated spreads are 544 bps and 636 bps respectively.

financial frictions and sudden stops[35]. Nevertheless, the excessive model volatility might be reconciled with the data if the decade under investigation is considered as a sequence of good output realizations leading to low spreads, and high debt and reserves stocks with low volatility. Corroborating this interpretation, using data since 1970, the standard deviation of reserve holdings and total external debt[36], both as share of GDP, increase from 3.7% to 7.1% and from 6.9% to 16.1% respectively.

Comparing the benchmark model with the one in column 3, in which the government cannot buy assets, I highlight two main differences. The first is that in the “debt only” model the average sovereign debt is 9.5% of output, lower than 15.4% in the benchmark. It follows that when governments have access to risk-free assets they choose to accumulate more debt simultaneously. The second distinction is the sign of the correlation between debt and spreads. This correlation is negative, as in the data, only in the benchmark model. In this situation, the sovereign has more incentives to accumulate debt and reserves jointly in periods of elevated output, when spreads are low.

In column 4 of Table 2.2, I present results from a model in which lenders are risk-neutral ($\kappa = 0$) and the other parameters remain the same as in the model of column 1. Compared to the benchmark, average indebtedness rises, mean and volatility of the interest rate spread decrease[37], and consumption volatility continues unaltered. The optimal accumulation of reserves diminishes, but remains positive and in the range of results from other papers in the literature (3% to 6%). In this setting, reserves are still pro-cyclical and positively correlated with debt and negatively with spreads. These results indicate that the presence of risk-averse lenders increase the average level of reserves due to an amplification of the precautionary motive. With risk-averse lenders, spreads rise more during bad times. Not only the default risk grows, but also the premium charged by creditors. In this environment, foreign exchange reserves become an even more attractive form of insurance.

Data from a model with full default (zero recovery rate) and the same calibration of the benchmark model for other parameters appear in column 5 of Table 2.2. The model does not

[35] None of the other papers investigating reserve accumulation using quantitative models of sovereign default reports these statistics.
[36] In this exercise I use total external debt, because sovereign debt data from Arslanalp and Tsuda (2014), including foreign participation in local markets, starts in 2004.
[37] Nevertheless, average spread is still higher than 60 bps, the value in the papers of Alfaro and Kanczuk (2017) and Salomão (2013).

deliver a sensible debt level. The mean stock of reserves decreases, despite the lower spread, because the level of debt to be insured is smaller. Correlations do not change.

Table 2.3 – Basic Statistics: Model and Data

Variables	Data	Models				
	2004-15	Benchmark	g=0.12	σ=3.3, recalibrate	σ=2	σ=2, recalibrate
	1	2	3	4	5	6
	Average					
Default frequency	--	3.8	3.8	3.6	2.6	4.1
Debt/GDP	14.1	15.4	14.6	14.6	19.9	15.6
Spread	234	242	232	214	205	216
Risk Neutral Spread	152	148	143	148	116	171
Reserves/GDP	16.4	7.7	8.9	5.7	2.1	2.4
	Standard deviation					
Consumption/GDP	0.98	0.97	0.95	0.99	1.14	1.07
Debt/GDP	4.4	8.2	7.9	8.1	9.7	8.1
Spread	85	540	554	440	299	381
Reserves/GDP	3.7	12.4	13.0	10.9	5.9	6.7
	Correlation with GDP					
Debt	0.0	0.5	0.5	0.6	0.7	0.7
Spread	-0.6	-0.6	-0.6	-0.6	-0.7	-0.6
Reserves	0.4	0.6	0.7	0.6	0.5	0.5
	Other correlations					
Debt & Reserves	0.3	0.8	0.7	0.8	0.8	0.8
Debt & Spread	-0.1	-0.2	-0.2	-0.2	-0.3	-0.2
Spread & Reserves	-0.4	-0.3	-0.3	-0.3	-0.2	-0.2

Note: Column 1 presents basic statistics for emerging countries using data from Figure 2.1. Each column from 2 to 6 brings statistics calculated from simulated data (500,000 observations) of a different model. See the main text for the calibration used in each column. Debt and reserves ratios to GDP appear as percentage points and spreads as basis points. Standard deviation for consumption reported relative to that of output. In column 1, growth rates are used to calculate correlations, except for spreads.

In column 6, I recalibrate the model with $\beta = 0.78$, $\sigma = 10$, $\psi = 0.82$ in order to achieve an average debt of 31.5% of GDP. This new target refers to the average debt in the same sample of countries in the same period but considering public and private external debt[38]. I limit the coefficient of relative risk aversion to 10, in accordance with the discussion of the previous section. Such restriction leads to a ratio between volatilities of consumption and GDP of 1.05 instead of 0.98, but the other three targeted statistics are met. The average holding of

[38] Information from the updated and extended dataset of Lane and Milesi-Ferreti (2007).

international reserves declines to 5.4% of GDP, still indicating that the optimal policy is to accumulate assets and liabilities simultaneously[39].

In order to provide assess the role of rigidities in the government budget constraint, I solve the model changing equations (2.3) and (2.4) to (2.13) and (2.14) respectively. The insertion of this fixed government expenditure makes the adjustment to adverse shocks costlier and improves the quantitative performance of the model. When Bianchi, Hatchondo and Martinez (2018) recalibrate their model with $g = 0$, instead of $g = 0.12$, the average level of reserves falls from 6% to 3%. I insert the fixed government expenditure in my benchmark model with the same value of $g = 0.12$. Results appear in column 3 of Table 2.3. The average level of reserves increases from 7.7% to 8.9% and other statistics, targeted or not, do not change meaningfully. Such change indicates that fiscal rigidities also play a role in an economy with short-term debt.

$$c_t + g = y_t + q_t d_{t+1} - d_t - q^a a_{t+1} + a_t \tag{13}$$

$$c_t + g = y_t^a - q_t^a a_{t+1} + a_t \tag{14}$$

The remaining columns in Table 2.3 show robustness checks for the value of the coefficient of risk aversion. Changing it to $\sigma = 3.3$, as Bianchi, Hatchondo and Martinez (2018), and recalibrating the other parameters ($\beta = 0.92$, $\psi = 0.87$, and $\kappa = 5$), the model delivers similar results, with the stock of reserves declining from 7.7% to 5.7% of GDP. Reducing the coefficient of relative risk aversion to $\sigma = 2$, columns 5 and 6, leads to excessive consumption volatility, even with a new choice of parameters to meet the same targets ($\beta = 0.92$, $\psi = 0.88$, and $\kappa = 3$). In both cases, the mean level of reserves falls to approximately 2% of GDP[40]. To such a degree, the optimal policy still is to hold positive amounts of international reserves.

[39] If I restrict $\sigma = 5$, the model, recalibrated to meet the same targets, produces mean reserves of 3.5% of GDP.
[40] Hernandez (2016) is the only other paper in this framework to obtain positive amounts of both debt (15.9%) and reserves (4.0%) while also presenting sensible average interest rate spreads (180 bps) using $\sigma = 2$. However, his calibration of the endowment process is more than twice more volatile than suggested by Uribe and Schimitt-Grohé (2017) for quarterly frequency data. He obtains it based on the Mexican GDP multiplied by its real exchange rate. His defense of this choice relates to differences of the exchange rates regimes in Mexico and Argentina, the most frequent example in models of quantitative sovereign default. Volatile endowment processes help to achieve a solution with positive reserve accumulation using a lower coefficient of risk aversion. A high calibration of the volatility of income also appears in Alfaro and Kanczuk (2017).

2.6 Conclusion

I show that the combination of three facts currently observed in emerging markets – i) high level of international reserves, ii) positive amount of sovereign debt, and iii) positive interest rate spread – is compatible with results from a quantitative model of sovereign default in which these variables are endogenous. In this structure, the only use of reserves is to smooth consumption, even after a default, when the economy is excluded from international financial markets.

Differently from previous studies, I focus on the roles of partial default to generate the above-mentioned trio. In this case, the joint accumulation of assets and liabilities does not erode debt sustainability as much as under full debt repudiation. While a higher stock of foreign exchange reserves increases the value of defaulting, higher debt decreases it. The last effect occurs owing to governments carrying a share of their previous liabilities upon reentry on international debt markets after a default. In this setting, governments accumulate debt and reserves during periods of economic growth and deplete the former as the boom fades away. This leads to reserves being positively correlated with debt and output and negatively with spreads, in accordance with the data for emerging markets in the last decade. The addition of risk-averse lenders in the model increases the optimal level of international reserves due to an amplification of the precautionary motive. With this feature, spreads rise even more during bad times than under risk-neutral pricing, because both the default risk and the risk premium increase.

The model has a good quantitative performance and suggests that the optimal policy is to hold a positive quantity of foreign exchange reserves. Nonetheless, it does not reproduce the total volume of assets held by emerging countries' governments in the last decade. I consider that the present model offers a starting point for the discussion on the optimal level of international reserves, since there are other reasons to hold them beyond consumption smoothing – as indicated by Gosh et al (2016), Obstfeld, Shambaugh, and Taylor (2010), and Aizenman and Lee (2007).

3 LOSS AVERSION AND SEARCH FOR YIELD IN EMERGING MARKETS SOVEREIGN DEBT

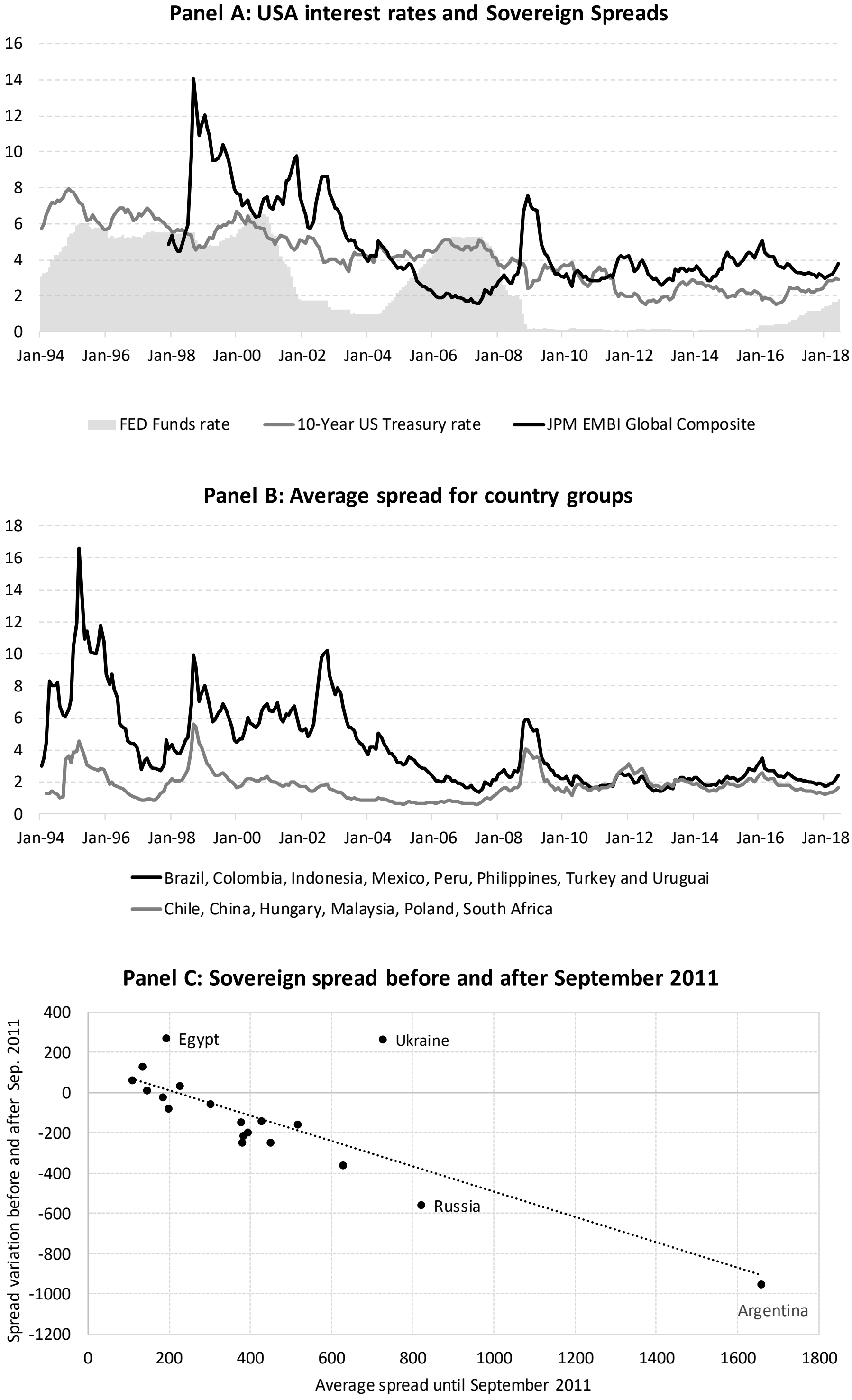
3.1 Abstract

Empirical evidence indicates that a decline in international risk-free interest rates decreases emerging markets (EM) sovereign spreads. A standard quantitative model of sovereign debt and default does not replicate this feature even if the risk aversion of lenders moves with international interest rates. In the present work, I show that a model with lenders that are loss-averse and have reference dependence, traits suggested by the behavioral finance literature, replicates the noticed stylized fact. In this framework, when international interest rates fall, EM sovereign spreads decline despite increases in debt and default risk. This happens because investors search for yield in risky EM bonds when the risk-free rate is lower than their return of reference. I find that larger spread reductions occur for i) riskier countries, ii) greater declines in the risk-free rate, and iii) higher degrees of loss aversion.

3.2 Introduction

Since the most recent global financial crisis, international risk-free interest rates remain low (panel A of Figure 3.1). Empirical evidence (Arora and Cerisola, 2001, Uribe and Yue, 2006, Gonzáles-Rozada and Levy Yeyati, 2008; and Foley-Fisher and Guimarães, 2013) indicates that such low rates reduce sovereign spreads for emerging markets (EM), in line with data in Figure 3.1. For Shin (2013), the current decline of risk premiums for debt securities in EM is a manifestation of a search for yield (SFY), a shift towards riskier investments when risk-free rates are low, by foreign lenders. This view also appears in the financial press, that noted the appetite of foreign investors for risky EM sovereign bonds (Doff and Provina, 2017; Russo, Cota and Verma, 2017). Besides, SFY behavior is widely documented in several other financial markets, as: bank loans (Maddaloni and Peydró, 2011; Jiménez et al, 2014), money market funds (Chodorow-Reich, 2014; Di Maggio and Kacperczyk, 2017), mutual funds (Choi and Kronlund, 2018), corporate bonds (Becker and Ivashina, 2015), pension funds (Chodorow-Reich, 2014; Andonov, Bauer and Cremers, 2017), and long-term government bonds (Hanson and Stein, 2015).

Figure 3.1 – USA interest rates and spreads in emerging markets.



Note: Panel A plots a measure of the sovereign interest rate spread for emerging countries (JP Morgan Emerging Markets Bond Index Global Composite) and short (Fed Funds) and long-run (10-year treasuries) interest rates in the USA. Panel B presents the same spread measure for two groups of countries, with average spread higher or lower than 300 bps until September 2011. I select countries with data available for spread and sovereign debt (Arslanalp and Tsuda, 2014) and exclude Argentina, Egypt, Russia and Ukraine due to default, war or political unrest. Panel C shows the correlation between average spread until September 2011 and the spread change before and after such date.

In this paper, I extend an otherwise standard quantitative model of strategic sovereign debt and default to investigate if lower international risk-free rates lead to SFY in EM bonds, defined as lower spreads even under higher risk. This type of model is suitable for this inquiry because it offers a micro-foundation of the sovereign risk and the associated spread. I alter the model so that the emerging economy faces periods of high or low international risk-free interest rates, instead of a constant one. Then, I observe that the conventional model does not generate lower spreads when the risk-free rate falls, even if the risk aversion of foreign lenders declines simultaneously to the interest rate. In this setting, when international rates reduce, EM countries borrow more and become riskier. Consequently, their spreads rise.

Therefore, I propose an alternative explanation for the SFY in EM bonds. I replace the traditional preference of foreign lenders with one grounded on traits of investor psychology. Following the Prospect Theory (Kahneman and Tversky, 1979), I assume they are loss-averse and have reference dependence. I choose this behavioral approach inspired by the recent paper of Lian, Ma and Wang (2018). Until then, most theoretical work on SFY, as Acharya and Naqvi (2016) and Matinez-Miera and Repullo (2017), relied on informational and principal-agent problems to explain SFY. Since most evidence comes from intermediated markets, these are reasonable frameworks, because financial institutions might choose higher risks than the final investor wish. However, recent experimental evidence with individual investors (Lian, Ma and Wang, 2018; Ganzach and Wohl, 2018) suggests that SFY exists even in the absence of this type of institutional friction. Additionally, Lian, Ma and Wang (2018) show that SFY by individuals is incompatible with conventional portfolio theory and supply evidence in favor of a theory based on investor psychology.

Hence, I assume that foreign lenders have the typical international risk-free rate (4%, for example) as a reference point, because they are used to it. When safe returns are lower than this (decrease to 2%, for example), a relatively rare occurrence, they are considered losses relative to the return of reference. Since investors are loss-averse, they dislike such loss more than they like an equivalent gain, increasing their SFY in risky EM bonds. In this setting, investors search for these securities because they offer the opportunity to achieve their return of reference (4%).

Simulated data from a calibrated model with loss aversion and reference dependence show that EM countries borrow more and become riskier when the international interest rate declines. However, their sovereign spreads fall, in accordance with the empirical evidence. The magnitude of changes in average debt and spread is similar to the observed in EM in recent years of low interest rates in developed countries.

Results are robust to changes in the main parameters of the numerical model. The conclusions remain regardless of the duration of the bouts of low risk-free rates. Spreads reductions are larger for riskier countries, in line with the information in panels B and C of Figure 3.1. Countries with very low risk of default, that rarely have spreads high enough to achieve the return of reference, exhibit lower spread reductions when international interest rates go down. If the drop in risk-free rates is larger (for example from 4% to zero, instead of 2%), EM countries increase their indebtedness even more. The model also reveals that greater degrees of loss aversion of lenders are associated with larger increases in indebtedness and reductions in spreads, ie, more SFY.

The model also offers some guidance on the riskiness of the normalization of monetary policy in developed countries for EM debt. In the first year with high international risk-free interest rates after a cycle of low rates, an EM sovereign default is more likely. During periods of high and low risk-free rates, the default frequency is 1.8% and 2.3% respectively. Restricting the sample only to the first year of periods of high risk-free rates, default frequency climbs to 2.6%. In addition, average spreads raise from 3.5% to 4.5% from the last year with low rates to the first year with high rates.

This paper contributes to the literature of quantitative models of strategic default as a micro foundation of sovereign spreads. This approach, based on the theoretical models of Grossman and van Huyck (1988) and Eaton and Gersovitz (1981), was developed by Alfaro and Kanczuk (2005), Arellano (2008), and Aguiar and Gopinath (2006) [41]. In particular, this work is closely related to studies that investigate how external financial conditions influence debt sustainability and spreads. Using quantitative models, Lizarazo, (2013), Arellano and Ramanarayanan (2012), Uribe and Schimittt-Grohé (2017), and Bianchi, Hatchondo and Martinez (2018) analyze the risk aversion of lenders[42].

Just as Alfaro and Kanczuk (2017), I also incorporate features from behavioral economics in this type of open economy macroeconomic model. While I insert loss aversion in the preference of lenders and study changes in international interest rates, they investigate the optimality of

[41] Stahler (2013), Aguiar and Amador (2014), and Aguiar et al (2016) survey this literature.
[42] In a theoretical model with analytical solutions, Guimarães (2011) corroborates the importance of shocks to the international risk-free rate to explain the level of sustainable debt.

fiscal rules when the sovereign is present biased due to quasi-hyperbolic preferences (Laibson, 1997).

The present work also offers an alternative interpretation for the positive relation between international risk-free interest rates and sovereign spreads and defaults in EM. Among the studies exploring this question empirically with a broad variety of methods we have: Arora and Cerisola (2001), Uribe and Yue (2006), Gonzáles-Rozada and Levy Yeyati (2008), Hartelius, Kashiwase and Kodres (2008), Ciarlone, Piselli and Trebeschi (2009), Hilscher and Nosbusch (2010), Longstaff et al (2011), Akinci (2013), Foley-Fisher and Guimarães (2013), Kennedy and Palerm (2014), Kaminsky and Vega-Garcia (2016), and Kaminsky (2017). Likewise, this paper relates to the recent theoretical and empirical literatures on search for yield already mentioned in this introduction.

3.3 Model

In a dynamic small open economy, a central planner receives a stochastic endowment, issues debt to foreign lenders, and decides whether to default on the stock of debt every period. If he defaults, the country is excluded from international markets by a random number of periods and experiences an output loss. Equation (3.1) presents the preferences of the domestic representative agent. E denotes the expectation operator, c_t is the consumption of goods in period t, β is the domestic subjective discount factor, and σ is the coefficient of constant relative risk aversion.

$$U = E\left[\sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}\right] \tag{3.1}$$

Equation (3.2), in which ε_t represents a white noise with standard normal distribution, describes the stochastic process of the endowment of the single good available in the economy, y_t.

$$ln(y_t) = \rho ln(y_{t-1}) + \eta\varepsilon_t \tag{3.2}$$

If the sovereign honors his obligations, d_t, he can issue new debt, d_{t+1}, and his budget constraint is (3.3). The price of debt, a security that pays one unit of the good in the next period if the government chooses not to default, is q_t.

$$c_t = y_t + q_t d_{t+1} - d_t \tag{3.3}$$

In case of default, the sovereign is in autarky, cannot borrow and consumes his endowment, y_t^a, as in (3.4). Equation (3.5) exhibits the direct output cost after a default according to the functional form proposed by Arellano (2008) frequently used in this class of model[43]. This non-linear function means that direct output costs of default start when the endowment is above a certain amount (ψ). The particular specification captures the idea that, if the economy defaults, high output is not feasible even under a good productivity shock. The reason is that defaults disrupt the domestic financial market and credit is an essential input for production[44].

$$c_t = y_t^a \tag{3.4}$$

$$y_t^a = \begin{cases} y_t, if\ y_t \leq \psi \\ \psi,\ if\ y_t > \psi \end{cases} \tag{3.5}$$

International risk-free interest rate, r_t, follows a two-state Markov process with values r^* and r_L, with $r^* > r_L$ and transition probabilities π_{HL} (from high to low rates) and π_{LH} (from low to high rates). Equations (3.6) to (3.8) represent the problem in recursive form. Variables with apostrophe symbolize values at $t+1$. Given the debt price, the solution to this problem is represented by the policy functions for default (f), debt issuance (d'), and consumption in case of repayment (c). If the government defaults, $f = 1$, otherwise, $f = 0$. The parameter θ in equation (3.8) expresses the exogenous probability of regaining access to the international markets without debt.

[43] Aguiar et al (2016) point that an asymmetric output cost of default is indispensable if for this type of model to produce realistic values of average debt and default frequencies.

[44] Mendoza and Yue (2012) develop a general equilibrium model of sovereign debt and business cycles that generates asymmetric output losses from default. Working capital financing constraints for imported inputs and the lack perfect domestic substitutes are essential for the emergence of the non-linearity.

Every period the sovereign decides to default or repay according to equation (3.6),

$$v(y, d, r) = \max_{f \in \{0,1\}} \{ (1-f) v^R(y, d, r) + f v^D(y, d, r) \}, \qquad (3.6)$$

in which the value of repaying is expressed by

$$v^R(y, d, r) = \max_{c, d',} \{ u(c) + \beta E_y [v(y', d', r')] \}, \qquad (3.7)$$

subject to (3.3), $d' > 0$, and the value of defaulting is given by

$$v^D(y) = u(y) + \beta E_y [\theta v(y', 0, r') + (1-\theta) v^D(y'), \qquad (3.8)$$

subject to (3.4) and (3.5).

So far, the model is exactly the same one of Arellano (2008), except for the two possible values of r_t. As in the benchmark model, the price of debt still reflects the sovereign's incentives to repay as perceived by foreign lenders. For the lenders, the relevant decision of the sovereign is his choice to default or not in the next period. If the sovereign chooses to honor his obligations, the lender receives one unit of the good. Otherwise, the repayment is zero. The default decision, in its turn, depends on the future values of the endowment, the risk-free rate, and the quantity of debt. Different from the first two variables, the future quantity of debt is known in the current period. Since the current endowment and interest rate bring information about their next realization, the price of debt is a function of y, r' and d'.

From now on, I present the case in which foreign lenders price the sovereign bond according to the Prospect Theory (Kahneman and Tversky, 1979), i.e, they are loss-averse and have reference dependence[45]. Next, I present the traditional risk-neutral pricing according to the Expected Utility Theory as a particular case[46].

Assume that the international risk-free interest rate is high (r^*) most of the time and that investors consider it a reference point of investment returns. Experimental results with

[45] I disregard other characteristics of the Prospect Theory, as probability weighting and decreasing sensitivity of utility to returns, because they are not crucial to the results.
[46] In the Results section, as a robustness exercise, I also solve the model assuming the investors are risk-averse. In order to keep the exposition as simple as possible, I present the required changes in the pricing equations later.

individual investors from Lian, Ma and Wang (2018) corroborate this assumption. They find that individuals search for yield, i.e., invest a larger share of their portfolio in risky assets when risk-free returns are low even if the risk premium is constant. Moreover, their results show that individuals who face high risk-free interest rates before low rates search for yield even more than individuals who face interest rates in reverse order (first low and later high). The scenario of high and then low interest rates mimics the decade after the recent global financial crisis as Figure 3.1 suggests.

Additionally, as in Benartzi and Thaler (1995), foreign lenders have preferences over returns, rather than over the consumption levels that such returns help to bring. Thus, lenders consider returns higher (lower) than r^* as gains (losses). Since they are loss-averse, gains increases utility in one unit while losses decreases it in λ units ($\lambda \geq 1$). In this framework, equations (3.9a) and (3.9b) present the sovereign debt price.

If $q(y, d', r') < \frac{1}{(1+r^*)}$, then:

$$E_y\left\{(1 - f'(y', d', r'))\left[\frac{1}{q(y,d',r')} - (1 + r^*)\right] + \lambda f'(y', d', r')[0 - (1 + r^*)]\right\} = \lambda[(1 + r_t) - (1 + r^*)] \qquad \textit{(3.9a).}$$

The expression above defines the EM debt price by assuming that the foreign investors obtain the same utility buying risk-free (right hand side, RHS, of the equation) or risky bonds (left hand side, LHS, of the equation). On the RHS, if $r_t < r^*$, the investor considers the current risk-free return a loss. Since r_t is never higher than r^*, the RHS is at most zero, and therefore is multiplied by λ. The LHS presents the possibilities of default and repayment with respective gross returns of $\frac{1}{q(y,d',r')}$ and zero. In equation (3.9a), the current price of EM debt is supposed to be low enough to generate returns higher than the reference in case of repayment. If $r_t = r^*$, then $q(y, d', r') < \frac{1}{(1+r^*)}$ is always valid. If $r_t = r_L$, it is possible that the EM debt is not risky enough to yield returns as high as r^*. In this situation, the first term in the LHS is a loss and must also be multiplied by λ. In such case, equation (3.9b) reveals the price of EM debt. One can obtain the standard risk-neutral pricing simply using $\lambda = 1$ in equation (3.9a) as it collapses to the same expression as in (3.9b).

If $q(y, d', r') \geq \frac{1}{(1+r^*)}$, then:

$$q(y, d') = E_y \left\{ \frac{1}{1+r_t} [(1 - f(y', d', r')] \right\}. \tag{3.9b}$$

The environment described is a dynamic game played between the sovereign against a continuum of small identical foreign lenders. I focus on Markov Perfect Equilibrium because agents cannot commit to future actions.

Definition. A Markov perfect equilibrium is defined by:

i) A set of value functions $v(s), v^R(s), v^D(s)$,

ii) Policy functions $f(s)$, $d'(s)$, and $c(s)$,

iii) Bond price function $q(y, d')$,

such that

I) Given the bond price, the policy functions solve the Bellman equations (3.6) - (3.8).

II) Given the policy functions, the bond price satisfies equations (3.9a) and (3.9b).

3.4 Calibration

The benchmark values for the parameters in the model appear in Table 3.1. As usual in the quantitative macroeconomic literature, the domestic risk aversion coefficient is $\sigma = 2$. The parameters for the endowment equation match the cyclical properties of the GDP of EM countries (Alfaro and Kanczuk, 2009; Uribe and Schimitt-Grohé, 2017). I use the simulation method of Schimitt-Grohé and Uribe (2009) to discretize this output process. In order to get an average stay in autarky for two years, in line with estimates by Gelos, Sahay and Sandleris (2011), I set the probability of redemption after default, θ, to 0.5.

Since a period in the model indicates one year, I use $r^* = 0.04$ and $r_L = 0.02$ based on the recent behavior of the 10-Year US Treasury rate. The transition probabilities of the risk-free interest are $\pi_{\mathrm{HL}} = 0.01$ and $\pi_{LH} = 0.10$ to generate, on average, 90 years with risk-free rates equal to the reference return followed by a 10-year period of low rates, resembling the recent experience of international financial markets. I conduct robustness exercises with alternative values for these parameters.

The parameter governing the degree of loss aversion, λ, takes value 2.25, in line with experimental evidence (Tversky and Kahneman, 1992; Kahneman, Knetsch, and Thaler, 1990). This is the customary choice in the behavioral economics and finance literature (Benartzi and Thaler, 1995), but replacing it with 1.50 or 3.00 does not modify the main findings in a meaningful way.

I calibrate the remaining two parameters (β, ψ) to produce average values of sovereign debt and spreads for the model without loss aversion ($\lambda = 1$) close to the observed in the data during periods of high-interest rates. I obtain, $\beta = 0.80$ and $\psi = 0.85$, similar to the values of other works in this literature, as Alfaro and Kanczuk (2018), Uribe and Schimittt-Grohé (2017), and Nuno and Thomas (2016). The main results persist for different values of these parameters.

Value function iteration in a discrete state space is used to solve the model numerically. The equilibrium is obtained as the limit of the equivalent finite-horizon version of the model, as recommended by Hatchondo, Martinez and Sapriza (2010).

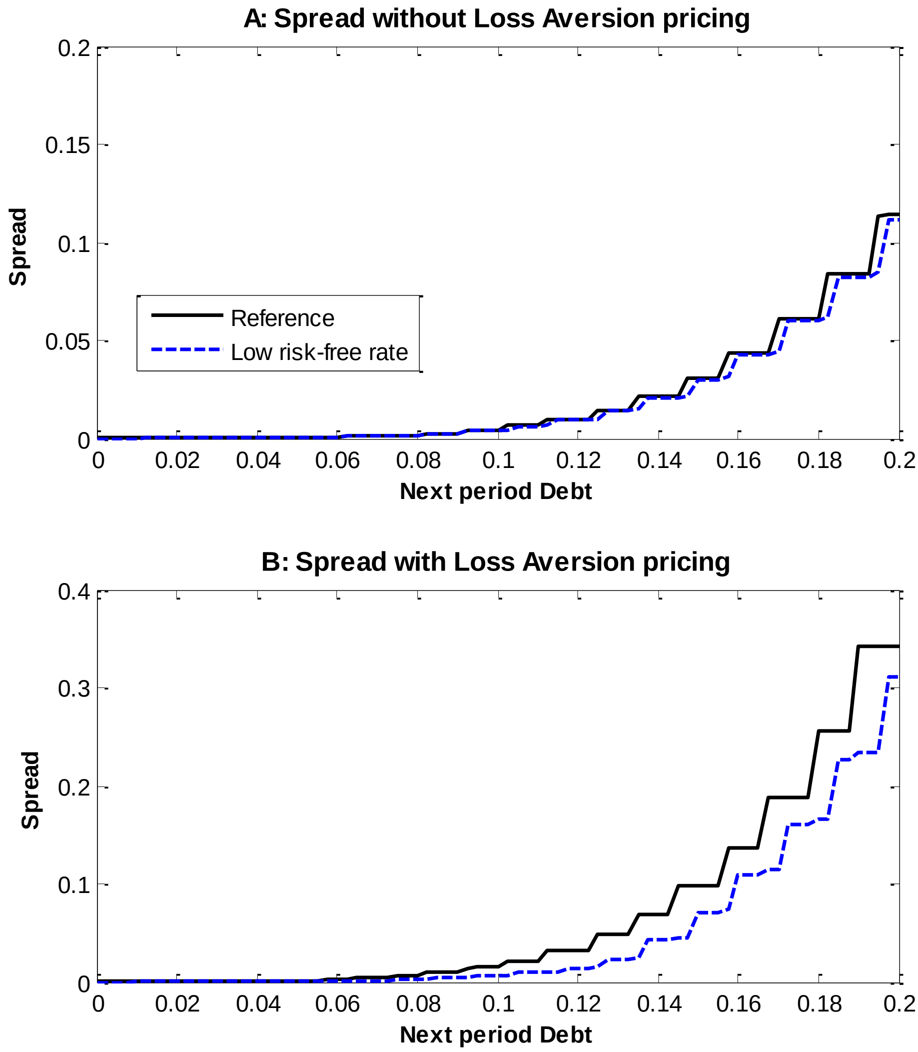
Table 3.1 – Parameter values

Parameter	Description	Value
β	Domestic discount factor	0.80
ψ	Direct output cost of default	0.85
σ	Domestic risk aversion	2.00
ρ	GDP persistence	0.85
η	Std. deviation of innovation to GDP	0.04
θ	Probability of re-entry after default	0.50
r^*	High risk-free rate	0.04
r_L	Low risk-free rate	0.02
π_{HL}	Probability of transiting to low risk-free rate	0.01
π_{LH}	Probability of transiting to high risk-free rate	0.10
λ	Degree of Loss Aversin	2.25

3.5 Results

Figure 3.2 exhibits the spread function, obtained from $q(y, d')$, for the baseline economies with $\lambda = 1$ (panel A) and $\lambda = 2.25$ (panel B). Regardless of the degree of loss aversion, spreads increase with the debt level, reflecting that defaults are more likely for higher indebtedness. Also for both economies, when endowment is high, defaults are less likely, spreads are lower, and countries issue more debt (policy functions not show here). Consequently, spreads and trade balance are counter cyclical. Inserting loss aversion, therefore, does not remove from the model its capacity to replicate such relevant features of the business cycles in EM economies.

Figure 3.2 – Spread Function for the Median Output Level



Note: This figure plots the spread (bond price) function for the median levels of output. The horizontal axis represents the choice of next period debt in relation to the median output. Each line represents the spread function for a different value of the international risk-free interest rate. Panels A and B show the cases without and with loss aversion respectively.

However, there is a striking difference between figures in panels A and B. When the international risk-free rate falls from r^* to r_L, spreads barely change in one case ($\lambda = 1$) and decline substantially in the other ($\lambda = 2.25$). The economy without loss aversion generates reduced average spreads during periods of low international rates (r_L) only if the sovereign is less indebted (and consequently is less risky) exactly at these times. Nonetheless, simulations in the next table show that this is not the case. A different result emerges in panel B. The reduction in spreads when r_t falls is much more pronounced and particularly sizable for higher debt levels, when the EM economy is riskier. In this case, when international rate is low, spreads do not rise as much because investors accept a smaller compensation for the risk to get returns closer to their reference rate, a form of SFY.

Tables 3.2 to 3.5 compare statistics from emerging economies, always in row 1, and simulated data, in the remaining rows. The first three columns bring the number of each row, a brief description of the model, and an indication if it contains loss-averse lenders. The next three columns present the default frequency and the averages for spread and debt when the risk-free rate is r^*. The same statistics when the risk-free rate is r_L appear in the last three columns.

Actual data shows that indebtedness build up and spreads reduce when international risk-free interest rates fall (before and after September 2011, the month when 10-Year US Treasury Constant Maturity Rate reach 2% for the first time in the sample[47]). This result does not emerge from the benchmark model without loss-averse lenders (row 2 in Table 3.2). When the risk-free rate falls, it becomes cheaper to frontload consumption. Thus, EM countries borrow more, become riskier and, consequently, their spreads rise. According to panel A of Figure 3.2, even in the benchmark model without loss aversion, spreads decline modestly when the risk-free rate falls if the level of debt remains constant. This happens because when $r_t$diminishes the value of defaulting does not change and the value of repaying increases. But the simulations results in row 2 of Table 3.2 reveal that the sovereign optimally chooses to increase the debt level, instead of keeping it constant, when r_t drops. Due to the increase in the default risk, spreads rise.

[47] Dividing the sample in January 2009, when the Fed Funds rate goes below 0.25%, does not change the results.

Table 3.2 – Basic Statistics: Model and Data

		When risk-free rate is r^*			When risk-free rate is r_L		
	Loss Aversion	Default freq.	Average Spread	Average Debt	Default freq.	Average Spread	Average Debt
1 Data	--	--	5.2	14.0	--	3.6	14.9
2 Benchmark	No	4.3	5.0	16.6	4.4	5.1	17.1
3 Benchmark	Yes	1.8	4.4	12.8	2.3	3.6	14.1
4 $\pi_{LH} = 0.20$	No	4.3	5.0	16.6	4.5	5.3	16.7
5 $\pi_{LH} = 0.20$	Yes	1.8	4.4	12.8	2.0	3.5	13.6
6 $\pi_{LH} = 0.50$	No	4.2	5.0	16.6	4.4	5.2	16.7
7 $\pi_{LH} = 0.50$	Yes	1.9	4.4	12.8	2.0	3.3	13.4
8 $\pi_{LH} = 0.01$	No	4.3	4.9	16.6	4.5	5.3	17.2
9 $\pi_{LH} = 0.01$	Yes	1.7	4.4	12.9	2.3	3.6	14.5

Note: Row 1 presents statistics for a sample of 18 emerging countries with debt and spread information available. Spread is the JP Morgan EMBI Global Composite for the periods before and after September 2011, when 10-Year US Treasury Constant Maturity Rate reaches 2% for the first time in the sample. Debt comes from Arslanalp and Tsuda (2014). Countries are Argentina, Brazil, Chile, China, Colombia, Egypt, Hungary, Indonesia, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, Turkey, Ukraine, and Uruguay. Each row from 2 to the last one brings statistics calculated from 200,000 simulated observations of a different model.

The model with loss aversion and reference dependence with the benchmark calibration ($\lambda = 2.25$ and $r^* = 4\%$), row 3 in Table 3.2, reproduces the pattern seen in the data. In this case, when the international interest rate declines, EM countries borrow more, become riskier, and their spreads fall. This reduction in spreads despite the escalation of default risks is a consequence of the SFY of investors used to higher risk-free rates. Although this model is not calibrated to match average debt and spread, both statistics are still close to the observed counterparts. Furthermore, the magnitude of changes in these two variables between interest rate regimes is similar to the observed in EM recently.

Beyond the statistics exhibited in Tables 3.2 to 3.5, all the models also perform well in other dimensions. As usual in EM data, all specifications display: i) counter cyclical spreads and trade balance, ii) debt and consumption positively correlated with GDP, and iii) consumption more volatile than output. The inclusion of loss aversion also improves the model performance in one more aspect. As pointed by Uribe and Schimittt-Grohé (2017), average spreads typically exceeds observed default frequency by 230 basis points, and a model with risk-neutral lender does not deliver such result. Introduction of lenders with a degree of loss aversion in line with experimental evidence ($\lambda = 2.25$) generates excessive spreads in the correct amount[48].

From now on, I show that the main conclusion so far is robust to changes in the values of the model parameters. Still in Table 3.2, rows 4 to 9 present how the same outcomes emerge if the π_{LH} is modified to alter the average length of the bouts of low risk-free rates. Setting the value of π_{LH} to 0.2, 0.5 or 0.01 changes the average duration of the periods with low risk-free rates. Regardless of the persistence of such intervals, only the model with loss-averse lenders generates SFY: higher default risk and lower spreads.

Table 3.3 – Basic Statistics: Model and Data

			When risk-free rate is r^*			When risk-free rate is r_L		
		Loss Aversion	Default freq.	Average Spread	Average Debt	Default freq.	Average Spread	Average Debt
1	Data	--	--	5.2	14.0	--	3.6	14.9
2	Benchmark	No	4.3	5.0	16.6	4.4	5.1	17.1
3	Benchmark	Yes	1.8	4.4	12.8	2.3	3.6	14.1
4	β = 0.70	No	6.2	7.7	18.6	6.4	7.9	19.1
5	β = 0.70	Yes	3.0	7.6	14.2	3.4	6.4	14.6
6	β = 0.90	No	1.9	2.1	12.0	2.3	2.6	12.8
7	β = 0.90	Yes	0.7	1.6	9.3	1.2	1.5	11.3
8	β = 0.90, ψ = 0.80	No	1.1	1.2	20.7	1.3	1.4	22.0
9	β = 0.90, ψ = 0.80	Yes	0.5	1.1	17.5	0.9	1.0	20.2

Note: Row 1 presents statistics for a sample of 18 emerging countries with debt and spread information available. Spread is the JP Morgan EMBI Global Composite for the periods before and after September 2011, when 10-Year US Treasury Constant Maturity Rate reaches 2% for the first time in the sample. Debt comes from Arslanalp and Tsuda (2014). Countries are Argentina, Brazil, Chile, China, Colombia, Egypt, Hungary, Indonesia, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, Turkey, Ukraine, and Uruguay. Each row from 2 to the last one brings statistics calculated from 200,000 simulated observations of a different model.

In Tables 3.3 to 3.5, as in Table 3.2, the rows 1 to 3 bring statistics calculated with EM data or with simulated data from the benchmark calibrations. Solving the model for different values of β and ψ (rows 4 to 9 in Table 3.3) leads to different average levels of debt and spread and default frequency. However, it still reveals that SFY only appears in models with loss aversion. Besides, we see that spreads reductions between international interest rate regimes are larger in riskier calibrations. Row 9 in Table 3.3, the case with lower default risk, displays a situation in which spreads fall only 0.1 p.p. when r_t goes from 4% to 2%. The reason is that foreign investors do not search for yield in these markets because they rarely have spreads high enough

[48] Lizarazo (2013) demonstrate that a similar result is attainable with risk-averse lenders.

to achieve the return of reference. This finding is in line with the information in panels B and C of Figure 3.1 that show bigger spread declines for the group of riskier countries. Comments in the financial press (Doff and Provina, 2017; Russo, Cota and Verma) corroborate this view by suggesting that investors shift their portfolios particularly towards riskier EM sovereign bonds.

Table 3.4 – Basic Statistics: Model and Data

		When risk-free rate is r^*			When risk-free rate is r_L		
	Loss Aversion	Default freq.	Average Spread	Average Debt	Default freq.	Average Spread	Average Debt
1 Data	--	--	5.2	14.0	--	3.6	14.9
2 Benchmark	No	4.3	5.0	16.6	4.4	5.1	17.1
3 Benchmark	Yes	1.8	4.4	12.8	2.3	3.6	14.1
4 $r_L = 0$	No	4.2	5.0	16.7	4.6	5.6	17.5
5 $r_L = 0$	Yes	1.8	4.4	12.8	2.8	3.7	15.2
6 λ = 1.50	Yes	2.7	4.7	14.5	3.0	4.3	15.7
7 λ = 3.00	Yes	1.3	4.2	11.9	1.9	2.9	13.5

Note: Row 1 presents statistics for a sample of 18 emerging countries with debt and spread information available. Spread is the JP Morgan EMBI Global Composite for the periods before and after September 2011, when 10-Year US Treasury Constant Maturity Rate reaches 2% for the first time in the sample. Debt comes from Arslanalp and Tsuda (2014). Countries are Argentina, Brazil, Chile, China, Colombia, Egypt, Hungary, Indonesia, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, Turkey, Ukraine, and Uruguay. Each row from 2 to the last one brings statistics calculated from 200,000 simulated observations of a different model.

Distinctions between the models with and without loss aversion are even more pronounced if we assume that $r_L = 0$, as results in rows 4 and 5 of Table 3.4 demonstrate. This case reflects the assumption that the Fed Funds rate is the relevant measure of an international risk-free interest rate instead of the 10-years US government yield. Focusing in the case with loss aversion (row 5), there is more SFY when $r_L = 0$, because spreads decline the same amount as in the benchmark case while the economy becomes riskier (default frequency jumps from 1.8% to 2.8%, instead of 2.3% in the baseline scenario). Model outcomes are also qualitative invariant to the degree of loss aversion of lenders (rows 6 and 7 of Table 3.4). Even the quantitative performance does not change drastically despite the use of a wide variation in λ. Moreover, when lenders are more averse to losses, there are greater increases in indebtedness and reductions in spreads.

To investigate if changes in risk-aversion generate SFY in the model, I replace the pricing equations, (3.9a) and (3.9b), by expressions (3.10) and (3.11). Equation (3.10) brings a reduced form stochastic discount factor, m_t, already used by Arellano and Ramanarayanan (2012) and Bianchi, Hatchondo and Martinez (2018) in quantitative models of sovereign default. The parameter κ governs the risk premium and its correlation with the stochastic process for y_t. Positive values of κ imply that foreign lenders value more returns in states with negative income shocks in the EM economy, when default is more likely to happen.

$$m_{t+1} = exp(-r_t - \kappa\eta\varepsilon_{t+1} - 0.5\kappa^2\eta^2) \tag{3.10}$$

$$q(y, d', r') = E_y\{m_{t+1}[(1 - f(y', d', r')]\} \tag{3.11}$$

Table 3.5 – Basic Statistics: Model and Data

	Loss Aversion	When risk-free rate is r^* Default freq.	Average Spread	Average Debt	When risk-free rate is r_L Default freq.	Average Spread	Average Debt
1 Data	--	--	5.2	14.0	--	3.6	14.9
2 Benchmark	No	4.3	5.0	16.6	4.4	5.1	17.1
3 Benchmark	Yes	1.8	4.4	12.8	2.3	3.6	14.1
4 κ = 7	No	2.3	4.9	13.5	2.3	5.3	13.8
5 κ = 7, κ = 0	No	2.3	5.0	13.4	4.2	5.3	16.2
6 κ = 5, κ = 0	No	2.7	5.0	14.4	4.2	5.3	16.5
7 κ = 3, κ = 0	No	3.3	5.1	15.2	4.3	5.3	16.9

Note: Row 1 presents statistics for a sample of 18 emerging countries with debt and spread information available. Spread is the JP Morgan EMBI Global Composite for the periods before and after September 2011, when 10-Year US Treasury Constant Maturity Rate reaches 2% for the first time in the sample. Debt comes from Arslanalp and Tsuda (2014). Countries are Argentina, Brazil, Chile, China, Colombia, Egypt, Hungary, Indonesia, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, Turkey, Ukraine, and Uruguay. Each row from 2 to the last one brings statistics calculated from 200,000 simulated observations of a different model.

I use $\kappa = 7$ (row 4 of Table 3.5), because with this value the model generates the same average spread during periods of high international rates as the benchmark case (row 2 of Table 3.5). As in the case of risk-neutral pricing, there is no SFY. The next step is to assume that κ takes over two different values following the same Markov process as r_t. When $r_t = r^*$, κ is positive and lenders are risk-averse, but when r_t changes to r_L, lenders automatically become risk-neutral ($\kappa = 0$). Hence, the risk-aversion decreases mechanically with the risk-free rate. This hypothesis is a very straightforward way to try to force the model to deliver lower spreads when the risk-free rate falls. Rows 5 to 7 differ by the parameter value for κ when $r_t = r^*$; all of them demonstrate that even the strong assumption of variable risk aversion perfectly correlated with

r_t does not produce SFY. In this case, although the risk premium disappears, EM borrow even more and become much riskier to the point that their spreads increase.

This quantitative result, using an *ad hoc* stochastic discount factor to represent risk-averse lenders, is in line with the theoretical findings of Lian, Ma and Wang (2018). Assuming a constant distribution for the excesses return of a risky asset, they show that an investor with conventional utility function (decreasing absolute risk aversion or CRRA) with access to two assets (one risk-free and one risky) allocates a smaller share of his wealth to the risky one as the risk-free return decreases. This happens because the investor becomes poorer when the risk-free rate falls. If he has decreasing absolute risk aversion and the risk premium is constant, the optimal allocation in the risk-free asset increases. This the opposite of the SFY observed in their empirical findings with individual investors in an experimental setting and the reason why they propose behavioral theories to interpret the data. Hence, my results coupled with theirs suggest that modelling the foreign lenders as risk-averse agents who solve a portfolio problem between risky and risk-free assets, as Aguiar et al (2016) and Uribe and Schimitt-Grohé (2017), would lead to similar consequences.

In general, debt accumulation and default risk always increase when the risk-free rate declines, but spreads only fall if lenders exhibit loss aversion. Therefore, loss aversion is a determinant factor of SFY in this class of model.

I conduct a last exercise to show that this model might be useful to understand the risks that the normalization of monetary policy in developed countries offers for EM debt. Using the simulated data from the benchmark model with loss aversion (row 3 of Table 3.2), I find the first year with $r_t = r^*$ after a spell with $r_t = r_L$. In these years, sovereign default frequency is 2.6%, higher than the average frequency both during periods of high and low risk-free rates, 1.8% and 2.3% respectively. In addition, from the last year with low rates to the first year with high rates, average spreads move from 3.5% to 4.5%.

3.6 Conclusion

EM sovereign spreads move in the same direction as international risk-free interest rates, and, therefore, are low since the aftermath of the 2008 Global Financial Crisis. This might reflect a search for yield (SFY) by foreign investors – a shift in the composition of their portfolios towards riskier assets when risk-free rates fall – leading to lower spreads in EM. I show that a standard quantitative model of sovereign default does not replicate this result even if the decline in the international interest rate comes with a fall in the risk aversion of foreign lenders. In this conventional approach, when international rates reduce, EM countries borrow more, become riskier and their spreads rise.

Nevertheless, if foreign lenders are loss-averse and have reference dependence, the model replicates the SFY by foreign lenders. In this setting, investors buy EM sovereign bond because they offer the opportunity to achieve their return of reference, a goal higher than the current risk-free rate. Thus, when the international interest rate decreases, EM countries borrow more and become riskier, and their spreads fall, in accordance with the evidence. The model also shows that spread reductions are larger for: i) riskier countries, ii) greater declines in the external risk-free rate, and iii) higher degrees of loss aversion of investors. Such results suggest that aspects of investor psychology might have consequences for international sovereign bonds markets.

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