International Reserves, Credit Constraints, and Systemic Sudden Stops*

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Abstract

Why do emerging economies simultaneously hold high levels of international reserves and foreign liabilities? Moreover, why did these countries barely depleted reserves during the Global Financial Crisis? I argue that including reserves as implicit collateral for foreign borrowing in a small open economy subject to credit constraints can explain these facts. In this setting, the optimal policy yields reserves and foreign liabilities levels similar to those of Latin America. Additionally, it implies reserve accumulation before sudden stops and modest depletion during them. Finally, keeping reserves constant yields results close to optimal, clarifying why they might not be used during crises. (*JEL* F32, F34, F41)

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"An economy which maintains an adequate level of reserves gives the rest of the world the assurance that it will honor its commitments in exceptional situations." - Banco Central de Chile (2011)

Although we have seen a remarkable increase in the hoarding of international reserves in emerging market economies, this practice has been the subject of an intense debate. Some authors argue that countries have over-invested in international reserves (Rodrik (2006)), while others see this strong buildup as the optimal response for the possible feedback effects of balance of payments crises (Mendoza (2006)). Moreover, most countries had a small and short-lived international reserves depletion during the Global Financial Crisis (GFC), which is at odds with the conventional wisdom that countries accumulate reserves to provide self-insurance against sudden stops.

This paper proposes a new motive for international reserves accumulation, namely its role as implicit collateral for external borrowing in a small open economy subject to external financial shocks. Although policy-makers and financial market participants have often thought that international reserves can serve as collateral for external borrowing, this role has not yet been formally evaluated. To do that, I include international reserves as collateral for external borrowing in a small open economy model with credit constraints, similar to those in Mendoza (2002) and Bianchi (2011). In this context, I want to understand whether the role of international reserves as collateral for foreign borrowing can explain their high levels in emerging economies and analyze their behavior and that of macroeconomic variables in crises in such an environment.

My framework sheds some light on the puzzling fact that emerging market economies hold very high levels of international reserves and foreign liabilities simultaneously and these holdings are positively correlated, as we can see in Figure 1.[1] In my model, when the economy is hit by an external shock, there is a drastic reduction on the amount of output that can be pledged as collateral for external borrowing. However, as international reserves are very liquid assets, their collateral value is always the same independent of the state of global financial markets. Consequently, the government

1. The correlation between the two variables is 0.4 in the sample of 33 countries shown in Figure 1.

may choose to pay the cost of holding elevated levels of international reserves during normal times to relax the credit constraint when the economy is hit by an external financial shock.[2] This policy action allows consumers to hold much more debt than would be possible otherwise and softens the drastic effect of negative financial exogenous shocks on consumption. Implicitly, international reserves serve as collateral for a credit line provided by foreign investors in periods when the country's ability to borrow is heavily constrained by an external financial shock.

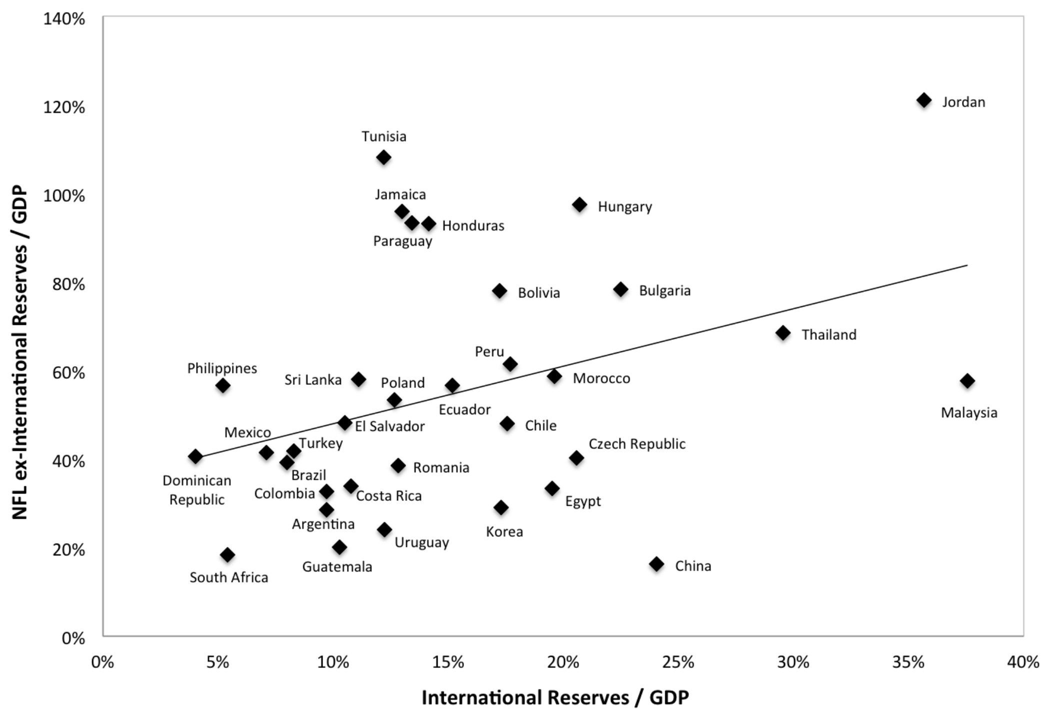

FIGURE 1: Net Foreign Liabilities ex-IR and International Reserves (% of GDP)

Note: The data are the simple average sampled annually from 1991 to 2011. All variables are expressed in percentage points of GDP.

Source: Authors' computations based on the updated and extended version of the dataset constructed by Lane and Milesi-Ferretti (2007).

Quantitative analysis show that the model does well in several dimensions. I find that we can obtain international reserves holdings close to the average international-reserves-to-GDP ratio in Latin American countries and these results are robust to different parametrizations. Thus, when we consider the decision by a country to jointly

2. Rodrik (2006) estimates the income loss due to reserve accumulation in developing countries to be close to 1% of GDP.

hold foreign debt and international reserves, the government chooses to hold a significant amount of reserves even if we just allow for one-period debt. This result contrasts with those of Alfaro and Kanczuk (2009b) and Bianchi, Hatchondo, and Martinez (2016), who find that the optimal policy when you have only one-period debt is not to hold international reserves at all.[3] Moreover, the optimal behavior during crises implies an increase in reserve holdings before a sudden stop and a small reduction during it, which coheres with what was observed in the GFC. Finally, an alternative policy of keeping reserves at a constant level equal to its average value yields results very similar to the optimal policy during sudden stops, highlighting the stabilizing role of reserves even if central banks don't use them at all, as noted by De Gregorio (2011).

I also provide a formal explanation for the behavior regarding international reserves during the GFC. Contrary to the results of almost all models that try to determine the adequate level of international reserves, most countries had a small and short-lived international reserves depletion during the GFC, rebuilding their stocks very quickly after that.[4] Due to this fact, Aizenman and Sun (2012) stated that during the GFC the "fear of losing reserves seems to play a key role in shaping the actual use of international reserves by emerging markets".[5] Although this behavior could lead to a reevaluation of the role of international reserves as insurance against sudden stops, especially when we have a floating exchange rate regime, the financial resilience of emerging market economies during the GFC strongly suggests that having a high level of international reserves can help countries deal with sharp changes in global financial conditions in a much better way even if they are not heavily used.[6]

This paper is robust to the critique about the assumption of the use of international reserves as collateral because they are legally protected against attachment by credi-

3. Bianchi, Hatchondo, and Martinez (2016) find that having long-duration bonds is key to obtaining significant levels of foreign liabilities and international reserves simultaneously.

4. Dominguez (2012) also examines how countries managed international reserves during the GFC, showing that they were reluctant to use them.

5. Bussiere et al. (2015) also state that "international reserves should be viewed as being akin to 'nuclear weapon' having a deterrent effect, rather than to true gunpowder, to be used in intervention.". They also conclude that the level of short-term debt is the main determinant of the level of reserves, which supports my conclusions.

6. De Gregorio (2013) also points out the important role of international reserves in the resilience displayed by emerging market economies during the GFC.

tors under different law systems.[7] In my setup, the idea behind the assumption that international reserves serve as an implicit collateral is not based on any contractual arrangement but relies on the fact that there would be strong reputational effects if the government or the private sector defaulted in the presence of international reserves that could be used to comply with these obligations. In fact, Aizenman (2009) and De Gregorio (2013) point out that the credibility of Brazil's, Mexico's and Korea's anti-crisis measures unveiled in the second half of 2008 was reinforced by their massive stock of reserves.

Related Literature. This paper is related to the literature that tries to explain international reserves accumulation in emerging market economies. Some authors argue that international reserves accumulation has a mercantilist motive and is related to competitiveness in international trade. Dooley, Folkerts-Landau, and Garber (2004a) attribute this motivation specifically to China, where a strategy of export promotion and consequently the desire for a depreciated currency leads to sizable reserve accumulation. Moreover, international reserves could serve as collateral for foreign direct investment and all the learning externalities that might come with investment in the tradable sector (Dooley, Folkerts-Landau, and Garber (2004b)). To address this issue, Korinek and Servén (2016) build a stylized model that incorporates learning-by-investment externalities and a capital-intensive tradable goods sector. Their calibrated model suggests that the welfare benefits of reserve accumulation are outweighed by its costs for standard parameter values. This work contributes to this literature by introducing another way by which international reserves can serve as an implicit collateral; namely, for foreign borrowing by private agents.

Another strand of the literature sees international reserves accumulation as a form of precautionary savings against sudden stops and rollover risk (Aizenman and Lee (2007); Durdu, Mendoza, and Terrones (2009); Alfaro and Kanczuk (2009b); Jeanne and Ranciere (2011); Bianchi, Hatchondo, and Martinez (2016); Hur and Kondo (2016)). This paper departs from this literature by introducing international reserves as an implicit collateral for foreign borrowing in a small open economy model subject to

7. See Panizza, Sturzenegger, and Zettelmeyer (2009).

exogenous financial shocks. I show that this feature leads to optimal ratios of international reserves and foreign liabilities to GDP that are similar to what we observe in Latin America. Moreover, this result is obtained in an environment where there is only short term debt, contrary to the findings of Alfaro and Kanczuk (2009b) and Bianchi, Hatchondo, and Martinez (2016), who argue that in the presence of only non-state-contingent short-term debt the optimal holdings of international reserves are very close zero. In fact, as shown by Broner, Lorenzoni, and Schmukler (2013), emerging economies borrow mostly short term because investors charge a higher risk premium on long-term bonds.[8] Additionally, another implication of the models previously studied in the literature is that, in the event of a crisis, countries should heavily reduce their international reserves holdings, which is at odds with the behavior we see in the data for countries with a floating exchange rate, especially during the GFC. In my framework, the international reserves depletion is small and short lived because there is a trade-off between using the reserves today to increase tradable consumption and keeping international reserves untouched to be able to borrow more tomorrow.

Finally, extending the precautionary approach, some authors argue that international reserves accumulation is a tool for managing domestic financial instability and smoothing exchange rate fluctuations in the presence of underdeveloped domestic financial markets. Obstfeld, Shambaugh, and Taylor (2010), for example, build a model based on the idea that, in a double drain scenario, domestic capital flight is financed through withdrawals of domestic bank deposits. In their setup, the growth of banking systems and financial markets in emerging market economies explains almost all of the recent buildup of reserve holdings. Dominguez (2010) also focuses on the implications of underdeveloped capital markets for emerging market economies. Following Caballero and Krishnamurthy (2001), she shows that underdeveloped capital markets lead to an undervaluation of international resources by the private sector, increasing the exposure of these economies to capital shortfalls. In this environment, international reserves accumulation can mitigate the costs of this excessive exposure, working as insurance

8. Broner, Lorenzoni, and Schmukler (2013) analyze a database on sovereign bond prices, returns and issuance at different maturities for eleven emerging economies - including Argentina, Brazil, Colombia, and Mexico - during the period from 1990 to 2009.

against sudden stops. I contribute to this literature by developing a framework where the quantitative implications of the role of international reserves as implicit insurance for private-sector foreign borrowing can be evaluated. I also show that this feature explains international reserves holdings of Latin American countries over the last 25 years.

Layout. The rest of the paper is organized as follows. Section 2 illustrates the mechanism behind my results in a simple environment. Section 3 builds a quantitative business cycle model that includes international reserves as collateral for foreign borrowing. Section 4 details the calibration and simulation of the model, presents its unconditional moments and the behavior of different variables during crises, and analyzes the implications of an alternative policy where we keep international reserves at constant levels for all periods. Section 5 evaluates the robustness of the results to some specific parameters. Section 6 concludes.

1 Three-Period Economy

I present a simple model to provide some intuition on how the mechanism works. The economy lasts for three periods, receives a deterministic endowment only in the last one, and might face an exogenous shock in the intermediate period that limits the amount of borrowing to a multiple of the international reserves held by the government, which gives a motive for reserve accumulation. I present the full model in the next section.

1.1 Environment

The economy lasts for three periods t = 0,1,2. There is only one good and a representative agent receives a deterministic sequence of endowments given by $y_0 = y_1 = 0$ and $y_2 > 0$. The household only values consumption in periods 1 and 2 and maximizes the discounted expected future flow of utility using a subjective discount factor $\beta \in (0, 1)$. Households can borrow from abroad subject to an exogenously determined interest rate r. I assume for simplicity that $\beta(1 + r) = 1$ and the utility function is given by $u(c) = ln(c)$.

The economy is subject to a ”sudden stop shock” in period 1. If the sudden stop shock materializes, borrowing in period 1 is limited to a multiple κ^{ir} of the international reserves held by the government. A sudden stop occurs with probability $\pi\epsilon[0, 1]$.

At $t = 0$, the government can accumulate reserves through lump-sum taxation on households. The only reason to accumulate international reserves is to use them as collateral for external borrowing if the economy is faced with a sudden stop shock in period 1.

Let b_{t+1} denote the bond purchased by agents in period t. A negative value means an issuance of bonds by households. The budget constraints for each period for the whole economy are given by

$$IR_1 \leq -b_1$$

$$c_1 \leq (1 + r)b_1 - b_2 + IR_1$$

$$b_2(s_0) \geq -\kappa^{ir} IR_1$$

$$b_2(s_1) \geq -\frac{c_2 - y_2}{1 + r}$$

$$c_2 \leq y_2 + b_2(1 + r)$$

where s_0 denotes a sudden stop state and s_1 denotes a normal state. Figure 2 shows the timing of decisions and correspondent utilities at each period for the simple model when all budget constraints are satisfied with equality.

1.2 Analytical Results

A social planner maximizes the expected utility by choosing the optimal level of international reserves and consumption at $t = \{1, 2\}$. If the economy is not subject to a sudden stop shock, the solution is trivially $c_1^* = c_2^* = y_2/(2+r)$. However, a sudden stop may prevent agents from borrowing in period 1 if there are no international reserves in place. Substituting the budget constraints for different states into the utility function,

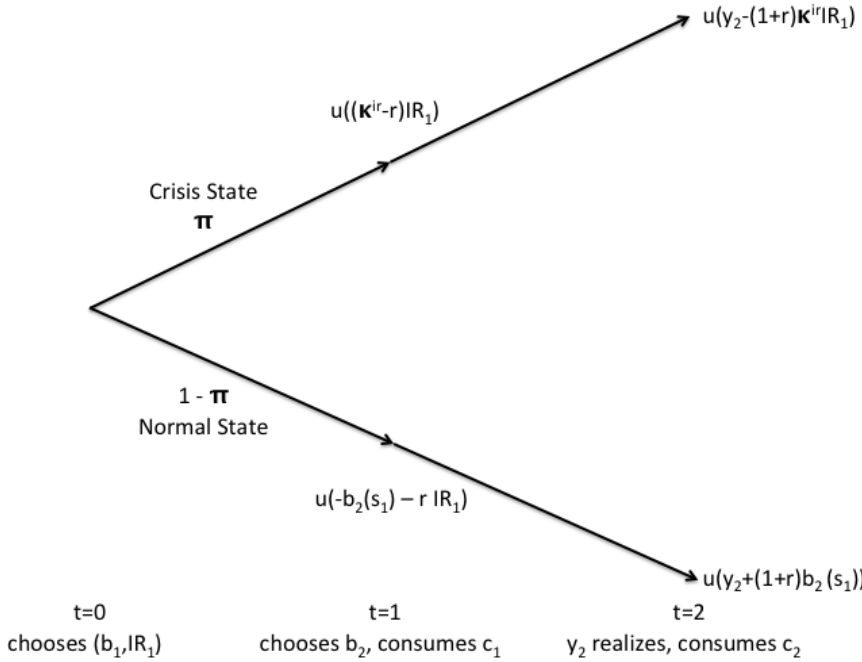

FIGURE 2: Timing of Decisions and Utilities - Simple Model

the problem for the social planner is given by

$$\max_{IR_1, b_2(s_1)} \pi\{ln[(\kappa^{ir}-r)IR_1]+\beta ln[y_2-(1+r)\kappa^{ir}IR_1]\}+(1-\pi)\{ln[-b_2(s_1)-rIR_1]+\beta ln[y_2+b_2(s_1)(1+r)]\}$$

The costs and benefits of holding reserves are clear from the social planner's problem: on the one hand, there is the cost of carrying reserves from period 0 to 1, which is given by rIR_1 as the agents must issue bonds to finance the acquisition of international reserves; on the other hand, if the economy is hit by a sudden stop shock, it allows an increase in consumption by $\kappa^{ir}IR_1$ in period 1.

Using the first-order conditions, the optimal level of reserves holdings is given implicitly by the following expression:

$$\frac{y_2-(2+r)k^{ir}IR_1}{y_2-\kappa^{ir}IR_1(1+r)} - \left(\frac{1-\pi}{\pi}\right)\frac{r(2+r)IR_1}{y_2-r(1+r)IR_1} = 0$$

which has as solution a linear function in y_2

$$IR_1 = K(r, \pi, \kappa^{ir}) y_2$$

where the constants are given by[9]

$$K(r, \pi, \kappa^{ir}) = \frac{K_2 - K_3}{K_1}$$

$$K_1 = 2r(2 + r)(1 + r)\kappa^{ir}$$

$$K_2 = (2 + r)\kappa^{ir}\pi + r(2 + r - \pi)$$

$$K_3 = \sqrt{K_2^2 - 2\pi K_1}$$

and has the following properties

(i) IR_1 is strictly increasing in π

(ii) IR_1 is strictly decreasing in r

(iii) IR_1 is strictly decreasing in κ^{ir}

(iv) IR_1 is strictly increasing in y_2 as $K\epsilon(0, 1/2]$

Consequently, if the probability of a sudden stop is high, the optimal level of international reserves is also higher as insurance against it. Moreover, if the opportunity cost of holding international reserves is high, the optimal international reserves holdings are lower. Additionally, if the collateral value of international reserves is high, the optimal holdings are also lower as we need less international reserves to get the same foreign borrowing level. Finally, if output will be higher in the future, it pays to carry more international reserves as insurance against the bad state.

In the next section, I present a detailed model that will allow me to evaluate the quantitative implications of the role of international reserves as collateral to account

9. $K(r, \pi, \kappa^{ir}) = (K_2 + K_3)/K_1$ violates the feasibility conditions in the economy as it is greater than 1, so we have as a unique solution $K(r, \pi, \kappa^{ir}) = (K_2 - K_3)/K_1$.

for the level of international reserves holdings in emerging market economies and their behavior during crises.

2 Model

This section presents a small open endowment economy where foreign creditors constraint the amount that they lend to a share of tradable output and a multiple of the international reserves held by the government. In this setting, the main purpose of international reserves is to facilitate external borrowing when the economy is hit by an exogenous shock that drastically reduces the amount of output that can be pledged as collateral. This way, the government faces a trade-off between the benefits of keeping international reserves that serve as collateral for foreign borrowing in bad times and the cost of carrying this stock of reserves, as we saw in the simple model in section 2. After detailing the model, I present both the competitive equilibrium and the socially optimal one.

2.1 Theoretical Framework

I model a small open endowment economy where the preferences of the representative consumer are represented by a time-separable utility function,

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(c_t) \right\} \tag{1}$$

where $\beta \in (0, 1)$ is a subjective discount factor.

The consumption basket is a CES aggregator with elasticity of substitution η between tradable c_t^T and nontradable goods c_t^N,

$$c_t \equiv A(c_t^T, c_t^N) = [\omega(c_t^T)^{-\eta} + (1-\omega)(c_t^N)^{-\eta}]^{-\frac{1}{\eta}}$$

Every period, consumers receive an endowment of traded y_t^T and nontraded y_t^N goods. Markets of contingent claims are incomplete so consumers can only trade one-period bonds on international capital markets.[10] The face value of these bonds specifies the amount that will be paid in the next period, b_{t+1}. I normalize the price of tradables to 1 and define the relative price of nontradables as p_t^N. I also assume that the government accumulates international reserves through lump-sum taxation τ_t. The household's budget constraint is consequently

$$c_t^T + p_t^N c_t^N + b_{t+1} + \tau_{t+1} = y_t^T + p_t^N y_t^N + (1 + r_t) b_t \tag{2}$$

and as the government runs a balanced budget and only taxes agents to accumulate international reserves, its budget constraint is given by

$$\tau_{t+1} = \Delta IR_{t+1} \tag{3}$$

The central assumption of the model is that creditors constrain the amount that they lend to a fraction κ_t^T of tradable income plus κ^{ir} times the total stock of international reserves

$$b_{t+1} \geq -[\kappa_t^T y_t^T + \kappa^{ir} IR_t] \tag{4}$$

where κ_t^T is an exogenous parameter that represents the state of international financial markets. I assume that both κ_t^T and r_t can take two different values, $\kappa^{T,N}$ and r^N, which are related to normal times, and $\kappa^{T,C}$ and r^C, which are related to disruptions in financial markets, capturing the feature that extreme capital flows episodes are significantly related to global risk, as we can see for example in Calvo (2005) and Forbes and Warnock (2012).[11] The level of international reserves is taken as given from the perspective of the households. We can think of this borrowing limit as being the result of

10. I limit my analysis to short-term debt instead of long-term debt as in Bianchi, Hatchondo, and Martinez (2016) based on the results of Broner, Lorenzoni, and Schmukler (2013). They argue that the predominance of short-term debt in developing countries happens because investors charge a higher risk premium on long-term bonds, and this relative cost increases even more in a crisis, making it much cheaper for emerging markets to borrow short-term. Alfaro and Kanczuk (2009a) also show that the optimal structure for emerging market economies is usually to have only short-term debt, although in their model this arises from the fact that the costs of defaulting increase more than the benefits when maturity increases.

11. Eggertsson and Krugman (2012) also have a model where views about safe levels of leverage change abruptly over time, an event they call a Wile E. Coyote moment based on the famous Road Runner cartoon.

an incentive constraint coming from information asymmetries between borrowers and lenders and the presence of underdeveloped financial markets, which leads to limited enforcement. For simplicity, I assume that the borrowing limit is exogenously given.

The possibility of using international reserves as collateral has been challenged by different authors such as Alfaro and Kanczuk (2009b). However, although central bank assets are legally protected against attachment by creditors under the U.S. Foreign Sovereign Immunities Act of 1976 and comparable laws, the argument for the inclusion of international reserves as collateral relies on the reputational costs of a default in external borrowing by the government or the private sector in the presence of international reserves that could be used to fulfill these obligations. In practice, we usually see a positive correlation between the stocks of international reserves and short-term foreign debt. Dominguez (2012), for example, find that countries that accumulated larger stocks of reserves prior to the GFC also had higher short-term-debt-to-GDP ratios. I will show later that this is also the case for the crises episodes I study in this paper.

2.2 Competitive Equilibrium

Households choose $\{c_t^T, c_t^N, b_{t+1}\}_{t\geq 0}$ to maximize expected utility (1) subject to the budget constraint (2) and the borrowing limit (4), taking b_0, p_t^N, τ_{t+1}, IR_t, κ_t^T and r_t as given. Defining $G(c_t^T, c_t^N) \equiv U'(c_t)A_1(c_t^T, c_t^N)$, the first-order conditions are

$$G(c_t^T, c_t^N) = \lambda_t \tag{5}$$

$$p_t^N = \left(\frac{1-\omega}{\omega}\right)\left(\frac{c_t^T}{c_t^N}\right)^{\eta+1} \tag{6}$$

$$\lambda_t = \beta(1+r_t)E_t\lambda_{t+1} + \mu_t \tag{7}$$

$$\mu_t \geq 0, \quad \mu_t[b_{t+1} + \kappa_t^T y_t^T + \kappa^{ir} IR_t] = 0 \tag{8}$$

Market clearing conditions are given by

$$c_t^N = y_t^N \tag{9}$$

$$\tau_{t+1} = \Delta IR_{t+1} \tag{10}$$

Definition 1 (Decentralized Competitive Equilibrium): A competitive equilibrium is a set of processess $\{c_t^T, b_{t+1}, \mu_t\}_{t\geq 0}$ satisfying

$$G(c_t^T, y_t^N) = \beta(1+r_t)E_t G(c_{t+1}^T, y_{t+1}^N) + \mu_t \tag{11}$$

$$b_{t+1} = y_t^T - c_t^T + (1+r_t)b_t - \Delta IR_{t+1} \tag{12}$$

$$b_{t+1} \geq -\left[\kappa_t^T y_t^T + \kappa^{ir} IR_t\right] \tag{13}$$

$$\mu_t \geq 0, \quad \mu_t \left[b_{t+1} + \kappa_t^T y_t^T + \kappa^{ir} IR_t\right] = 0 \tag{14}$$

given processes $\{y_t^T, y_t^N, IR_t\}_{t\geq 0}$ and the initial condition b_{-1}.

2.3 Socially Optimal Equilibrium

So far I have stated that households solve their optimization problem taking the stock of international reserves as exogenously given. To determine the optimal amount of international reserves at each period t, I write the optimization problem in recursive form and solve the social planner's problem. The social planner's problem consists in choosing $\{IR_{t+1},\ b_{t+1},\ c_t^T\}$ given $\{IR_t,\ b_t,\ y_t^T,\ y_t^N, \kappa_t^T, r_t\}$ to maximize expected utility subject to the budget constraint and the collateral constraint

$$V(IR, b, \mathbf{y}, \kappa^T, r) = \max_{IR', b', c^T} u(c(c^T, y^N)) + \beta E\{V(IR', b', \mathbf{y'}, \kappa^{T'}, r')\}$$

subject to

$$c^T + b' + IR' = y^T + b(1+r) + IR$$

$$b' \geq -(\kappa^T y_t^T + \kappa^{ir} IR)$$

The first order conditions associated with this problem are now

$$G(c_t^T, y_t^N) = \beta(1+r_t)E_t G(c_{t+1}^T, y_{t+1}^N) + \mu_t \tag{15}$$

$$G(c_t^T, y_t^N) = \beta E_t\{G(c_{t+1}^T, y_{t+1}^N) + \mu_{t+1}\kappa_{ir}\} \quad (16)$$

$$\mu_t \geq 0, \quad \mu_t \left[b_{t+1} + \kappa_t^T y_t^T + \kappa^{ir} IR_t\right] = 0 \quad (17)$$

Note that the competitive and the socially optimal equilibria have the same Euler equation and differ only because now the planner also chooses the optimal level of international reserves through equation (16). Thus, to implement the social planner's equilibrium as a competitive equilibrium, the planner chooses the optimal IR_{t+1} given current conditions and then finances it through lump-sum taxation of the households making $\tau_{t+1} = \Delta IR_{t+1}$.

3 Quantitative Analysis

This section calibrates and simulates the model, showing that it can yield international-reserves-to-GDP ratios close to what we see in practice. I also find that the cyclical behaviors of the current account and net foreign liabilities excluding international reserves are very close to what we observe in practice, while that of international reserves is somewhat different. Moreover, the optimal policy leads to international reserves accumulation before a sudden stop and a small depletion during it, which is close to what we see in the data. Finally, I evaluate the behavior of the model under a simpler passive rule for international reserves accumulation where the central bank keeps international reserves levels constant and find that the behavior of consumption in crises under the passive rule is very similar to what is obtained under the optimal policy.

3.1 Long-Run Business Cycle Moments in the Data

I begin the analysis by looking at the main statistics regarding international reserves, net foreign liabilities excluding international reserves, and current account balance for the larger Latin American countries, shown in Table 1. As we can see, the average ratio of international reserves to GDP is close to 10% while that of net foreign liabilities ex-international reserves is 36%. Moreover, international reserves are acyclical while the other variables are countercyclical.

Table I
Summary statistics - Latin America (% of GDP)

	Average	Std	Autocorr.	Correl(y)
International Reserves	9.9%	2.1%	0.55	0.07
Net Foreign Liabilities ex-IR	36.0%	11.9%	0.66	-0.31
Current Account	-1.6%	2.5%	0.68	-0.40

Note: The data are the simple average of the indicators for the five main Latin American countries (Argentina, Brazil, Chile, Colombia and Mexico). To calculate the standard deviations and correlations, I detrend the ratios of the log of Real GDP, International Reserves to GDP and Net Foreign Liabilities excluding International Reserves to GDP taking out a linear and a quadratic trend. The Current-Account-to-GDP ratio is not detrended, as it is stationary. The data are from the World Development Indicators database from the World Bank, and the updated and extended version of the dataset constructed by Lane and Milesi-Ferretti (2007) complemented by the updated international capital flows database constructed by Alfaro, Kalemli-Ozcan, and Volosovych (2014). The data are sampled annually from 1991 to 2015.

3.2 Sudden Stops Episodes

Following Calvo, Izquierdo, and Mejia (2008) and Alberola, Erce, and Serena (2016), I focus on systemic sudden stops, i.e., episodes triggered by an exogenous financial shock.[12] I use the JP Morgan EMBI Global Index to identify periods of global financial stress in emerging market economies. These periods are defined as quarters where there is a spike in the EMBI Global spread with respect to its two-year moving average. This way, I have four global financial stress events iny 1995, 1999, 2002 and 2009, which are the well-known Tequila, Russian-Asian, Argentine, and Global Financial Crises. Using these global crisis dates we can then identify the sudden stop episodes, which are those dates where the country experiences a one standard deviation reversal in the current account conditional on being in a global crisis year. The methodology yields eight sudden stop episodes for the five Latin American countries studied in this paper. The list of episodes is in Table 2.

Figure 3 shows the average behavior of the ratios of the current account, international reserves, and net foreign liabilities excluding international reserves to GDP in

12. Calvo, Izquierdo, and Mejia (2008) argue that focusing on systemic sudden stops is desirable because they exclude idiosyncratic crises that can result from factors such as political turmoil and disasters. These idiosyncratic crises have several different features compared to the ones I isolate here.

Table II
Sudden Stops Episodes

Country	Years of Sudden Stops
Argentina	1995, 2002
Brazil	2002
Chile	1999, 2009
Colombia	1999
Mexico	1995, 2009

crises. The behavior of these variables is close to what was obtained in previous works by Eichengreen, Gupta, and Mody (2008) and Jeanne (2007). The ratios of both international reserves and net foreign liabilities excluding international reserves to GDP increase in the onset of a sudden stop episode and decrease afterward. The real exchange rate appreciates before the sudden stop, suffers a strong depreciation during it, and stays at this more depreciated value afterward.

3.3 Functional Forms and Calibration

The utility function has a constant relative risk aversion (CRRA), ie

$$U(c) = \frac{c^{1-\sigma} - 1}{1-\sigma}$$

The endowment process follows a VAR(1):

$$log(\mathbf{y_t}) = \boldsymbol{\rho} log(\mathbf{y_{t-1}}) + \boldsymbol{\epsilon}_t$$

with $|\boldsymbol{\rho}| < 1$ and $\epsilon_t \sim N(0, V)$. I use an average of the process estimated for Argentina, Brazil, Chile, Colombia and Mexico[13], which yields as $\boldsymbol{\rho}$ and $\mathbf{V}$

$$\rho = \begin{bmatrix} 0.920 & -0.314 \\ 0.277 & 0.573 \end{bmatrix}$$

13. See the Appendix for a description of the construction of each time series

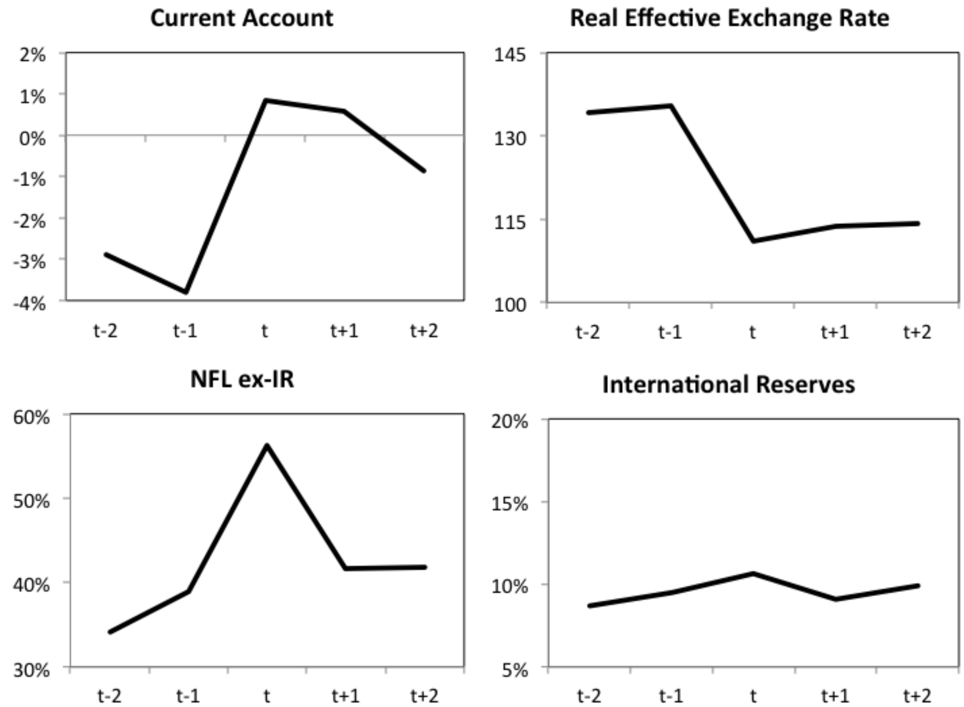

FIGURE 3: Macro Dynamics around Sudden Stops Events

Note: The five-year window is centered on a sudden stop occurring at time t. The list of countries and sudden stops is given in Table 2. All variables are expressed in percentage points of GDP except for the Real Exchange Rate.

Source: Authors' computations based on the World Bank World Development Indicators database and the updated and extended version of the dataset constructed by Lane and Milesi-Ferretti (2007) complemented by the updated international capital flows database constructed by Alfaro, Kalemli-Ozcan, and Volosovych (2014).

$$V = \begin{bmatrix} 0.00248 & 0.00142 \\ 0.00142 & 0.00143 \end{bmatrix}$$

I discretize the process into a first-order Markov process with four grid points for each shock using the methods of Terry and Knotek (2011), which allows for arbitrary error covariance structures.[14]

κ_t^T can take two values, $\kappa^{T,H}$, which is related to normal times, and $\kappa^{T,L}$, which is related to disruptions in international financial markets. The probability of entering a period of disruptions in international financial markets is given by π while the probability of going back to normal times is given by ψ.

14. I would like to thank Ed Knotek for providing the code to implement this method.

All of the benchmark parameter values can be seen in Table 3. A period in the model refers to a year.

TABLE III
CALIBRATED PARAMETER VALUES

Parameter	Value	Source/target
Interest rate in normal times	$r^N = 0.03$	Sample average
Interest rate in financial distress	$r^C = 0.08$	Sample average
Risk aversion	$\sigma = 2$	Standard value
Atemporal elasticity of substitution	$1/(1+\eta) = 0.8$	Conservative value
Weight on tradables in CES	$\omega = 0.23$	Share of tradable output = 23%
Discount factor	$\beta = 0.932$	Average NFL ex IR-GDP ratio = 36.0%
Probability of entering financial distress	$\pi = 0.2$	CA reversal = 3.9%
Probability of going back to normal times	$\psi = 0.4$	CA recovery = 1.4%
y^T credit coefficient in financial distress	$\kappa^{T,L} = 0.2$	CA standard deviation = 2.5%
IR credit coefficient	$\kappa^{ir} = 2.87$	Frequency of Sudden Stops = 6.4%

The interest rate r is set to 3% in normal times and 8% during disruptions in financial markets. The values are the averages of the real interest rates calculated for all countries in the sample during each type of event.[15] The coefficient of risk aversion is set to 2, which is a standard value in quantitative business cycle analyses for emerging market economies. The range of estimates for the atemporal elasticity of substitution $1/(1+\eta)$ is between 0.40 and 0.83, as we can see in Mendoza (2005), so I use 0.8 as a conservative value. The parameter ω defines the share of tradable goods in the CES aggregator and is defined such that we have a 23% share of tradable production, which is the average for the countries in my sample.

The subjective discount factor β is set to match the average ratio of net foreign liabilities excluding international reserves to GDP for Latin American countries, which is 36% for the period from 1991 to 2015. This criterion yields a beta of 0.932, which is reasonable for an annual frequency.

I calibrate $\kappa^{T,H}$ such that the collateral constraint is never binding in normal times.[16] The parameters concerning the behavior of international financial markets

15. The country specific interest rate in international financial markets is measured as the sum of J. P. Morgan's EMBI+ sovereign spread and the U.S. real interest rate. The U.S. real interest rate is measured by the interest rate on the three-month U.S. Treasury bill minus a measure of the U.S. expected inflation.

16. As $\kappa^{T,H}$ is very high, the lower bound of bond holdings becomes $b_{min} > -\frac{y^T_{min}}{r_{max}}$, which is the largest debt that the country can repay.

disruptions are $\kappa^{T,L}$; the credit coefficient for tradable output in financial distress periods; π, the probability of entering a financial distress period; and ψ, the probability of going back to normal times. The parameters are set to obtain a current account standard deviation of around 2.5%, a current account reversal of close to 3.9% of GDP in the year of a sudden stop (compared to the average of the previous three years) and a posterior reduction in the current account result of 1.4% (compared to the average of the three years after the sudden stop), which were obtained from the data analysis shown previously. This procedure yields $\kappa^{T,L}$ equal to 0.2, π equal to 0.2 and ψ equal to 0.4. The parameters values obtained for π and ψ are consistent with what is observed in the sample, as we have four international crises in 25 years and they usually last for two years.

Finally, I obtain κ^{ir} by matching the frequency of sudden stops for my sample of countries. I obtain κ^{ir} equal to 2.87, which seems reasonable because, as noted by Siritto (2016), the collateral solves an asymmetric information problem about the resources available to the borrower at the time of repayment, creating incentives to tell the truth and allowing agents to borrow more funds than by just selling the assets.[17]

3.4 Borrowing and International Reserves Decisions

Figure 4 shows the bond decision rules for both $\kappa^{T,H}$, which I call the normal period, and $\kappa^{T,L}$, which I call the crisis period. As the average value of tradable output is equal to 1, we can interpret the results as ratios of the average level of tradable output. As we can see, for the same level of current bond holdings, agents decide to have more debt in t+1 when the tradable output is lower during periods when the collateral constraint is not binding. However, when it is binding, agents are restricted to a level of debt around 1.5 times the tradable output.

Figure 5 shows the international reserves decision rules for, again, both normal and crisis periods. As we can see, the decision about international reserves holdings

17. García-Schmidt (2015) includes asymmetric information in a model of sovereign borrowing with default and finds that it improves the fit for debt and spreads a lot, which indicates that this is an important feature of emerging market economies' debt markets.

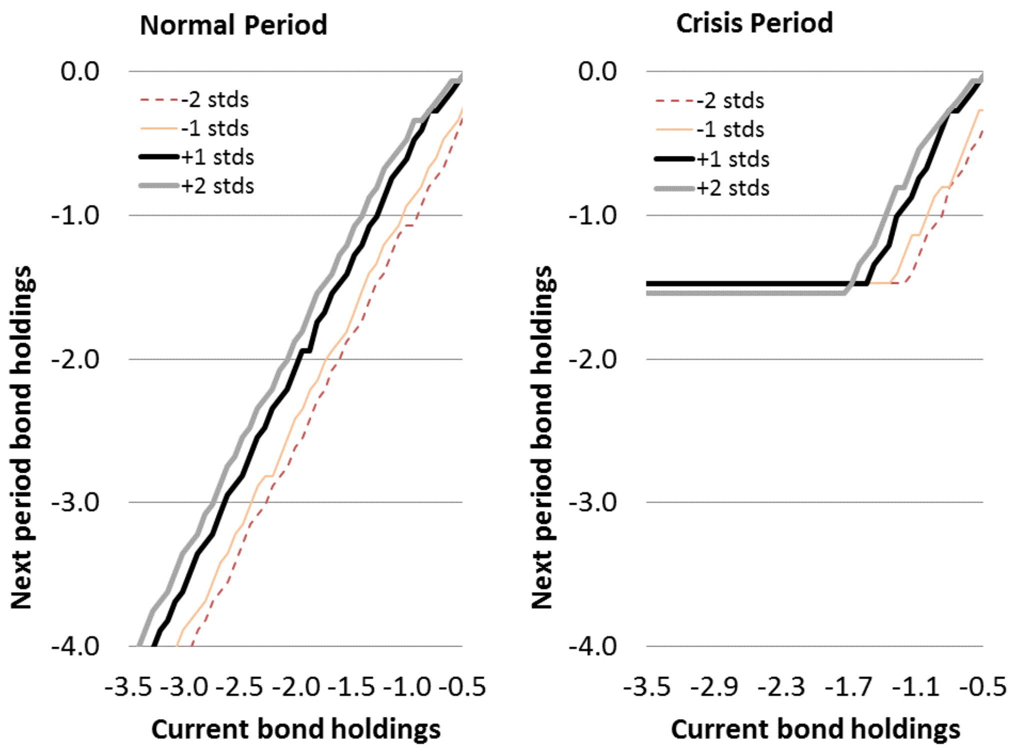

Figure 4: Bond Policy Functions

Note: The bond policy functions are calculated for $IR_t = 0.40$, which is the average stock of international reserves in tradable units.

depends crucially on whether we are in normal or crisis times. In normal times, the higher the current debt, the more international reserves are accumulated because the country is in a more dangerous zone, closer to a binding collateral constraint if international finance conditions turn out to be bad in the following period. During crises, there is a tradeoff between reducing international reserves to consume more today and keeping the reserves in case the crisis lasts. Thus, international reserves holdings are kept somewhat around the current level when the collateral constraint is binding and debt levels are not too high as an additional insurance if the crisis continues. However, there is some reduction in international reserves holdings when the current debt is very high to compensate for the strong deleveraging necessary in the current period due to the binding constraint.

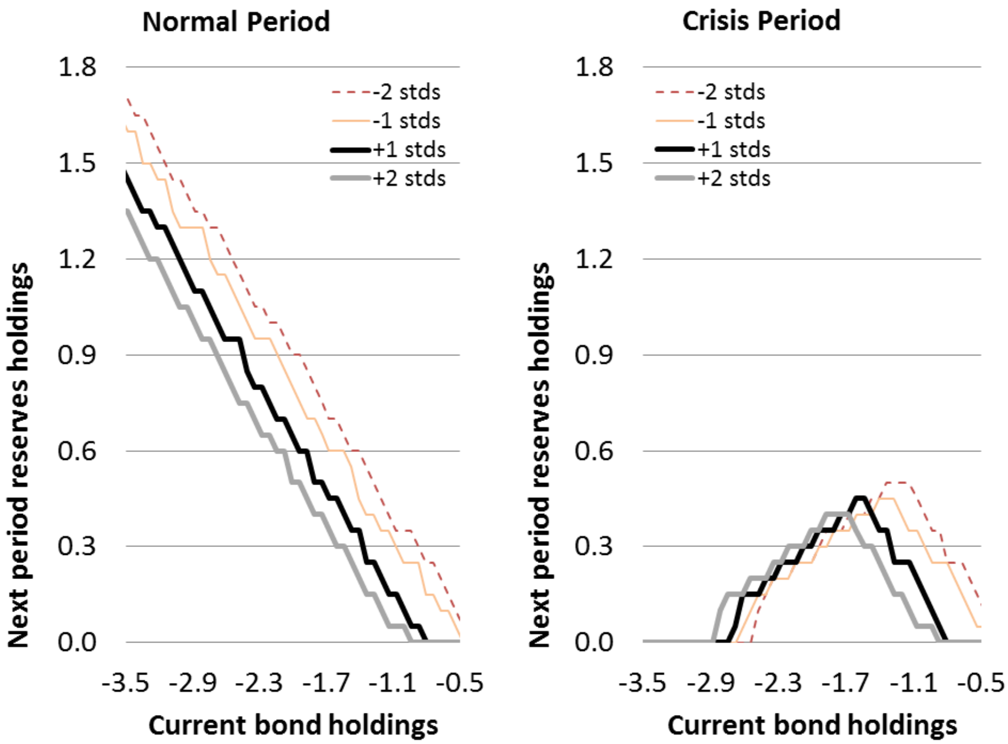

FIGURE 5: International Reserves Policy Functions

Note: The international reserves policy functions are calculated for $IR_t = 0.40$, which is the average stock of international reserves in tradable units.

3.5 Long-Run Business Cycle Moments

In this section, I compare the model unconditional moments to the data. To do so, I conduct a one-million-period simulation of the model by drawing a sequence of endowments $\{y_t^T, y_t^N\}$ and tradable output credit constraint coefficients $\{\kappa_t^T\}$ from their distributions and feed them to the policy functions to get the time-series for $\{b_t$, c_t^T, c_t^N, $IR_t\}$.

Table 4 shows that, in general, I am able to reproduce the main moments in the data. First, I manage to obtain an average international-reserves-to-GDP ratio very close to the data. Second, I find countercyclical fluctuations for the current account and net foreign liabilities excluding international reserves, and I find procyclical fluctuations for the real exchange rate, again with results close to the data.[18] However, I also obtain countercyclical international reserves, which is at odds with what we see in practice.

18. I use the relative price of nontradables as a measure of the real exchange rate in the model.

Finally, the standard deviation of both international reserves and net foreign liabilities excluding international reserves are higher than what we see in the data.

TABLE IV

LONG-RUN BUSINESS CYCLE MOMENTS

Targeted Moments	Model	Data
Average NFL ex-Reserves-to-GDP ratio	36.0%	36.0%
Frequency of Sudden Stops	6.4%	6.4%
σ(CA/Y)	2.4%	2.5%
Reversal	3.1%	3.9%
Recovery	1.8%	1.4%

Non-Targeted Moments	Model	Data
Average Reserves-to-GDP ratio	10.8%	9.9%
σ(IR/Y)	10.8%	2.1%
σ(NFL ex-IR/Y)	30.3%	11.9%
ρ(y,IR/Y)	-0.64	0.07
ρ(y,-b/Y)	-0.66	-0.31
ρ(y,CA/Y)	-0.42	-0.40
ρ(y,REER)	0.77	0.30

The high standard deviation of international reserves and net foreign liabilities ex-international reserves might be explained by the absence of any adjustment costs for agents to change their foreign assets positions, as in Schmitt-Grohé and Uribe (2003). The presence of convex portfolio adjustment costs would curb the volatility of both international reserves and net foreign liabilities ex-international reserves, which might lead to numbers closer to the data. It could also solve the issue of the countercyclicality of international reserves, as the government would accumulate more reserves during good times to avoid paying high adjustment costs when it gets closer to a binding collateral constraint. As this was not the main subject of this paper, I decided not to include any adjustment costs.

3.6 Sudden Stops Experiments

I now analyze the dynamics of the model during a sudden stop and compare it with the data. To construct the implied sudden stop events using the model, I use the following steps

(i) Identify crisis events: I define t as a crisis event where we get a current account reversion of one standard deviation and a binding collateral constraint;

(ii) Compute averages of macro quantities of the model centered around these events, were t represents the crisis episode;

(iii) Compare the outcomes with the average crisis in the data.

As we can see in Figure 6, the model can generally explain the behavior of macroeconomic variables in sudden stops. First, the optimal policy implies that the economy enters the crisis with a higher level of international reserves than what we see in the data. Moreover, international reserves have a small depletion after the onset of a crisis both in the model and in the data. Second, the optimal policy is to keep international reserves somewhat stable after a sudden stop and consequently the model cannot explain the rebuilding of international reserves levels after crises that we see in practice. Finally, the behavior of the ratio of net foreign liabilities excluding international reserves to GDP is close to what we see in the data, although we find a higher and more stable level before and after the crisis in the model.

3.7 A Passive Central Banker

I now compare the optimal policy with a passive central banker who keeps international reserves constant at the average level in tradable goods units in the base scenario for all periods, regardless of the state of the economy. The behavior of different variables during a crisis can be seen in Figures 7 and 8. The economy with a constant level of international reserves enters the sudden stop with a lower level of net foreign liabilities excluding international reserves but also has to deleverage as it enters the crisis with a lower level of international reserves. Moreover, the implied path of tradable consumption is almost the same for both economies, which implies that the welfare benefits of holding international reserves during sudden stops are quite similar if the central bank behaves optimally by accumulating more international reserves before sudden stops and depleting some of them during it; or if it keeps a constant buffer that allows

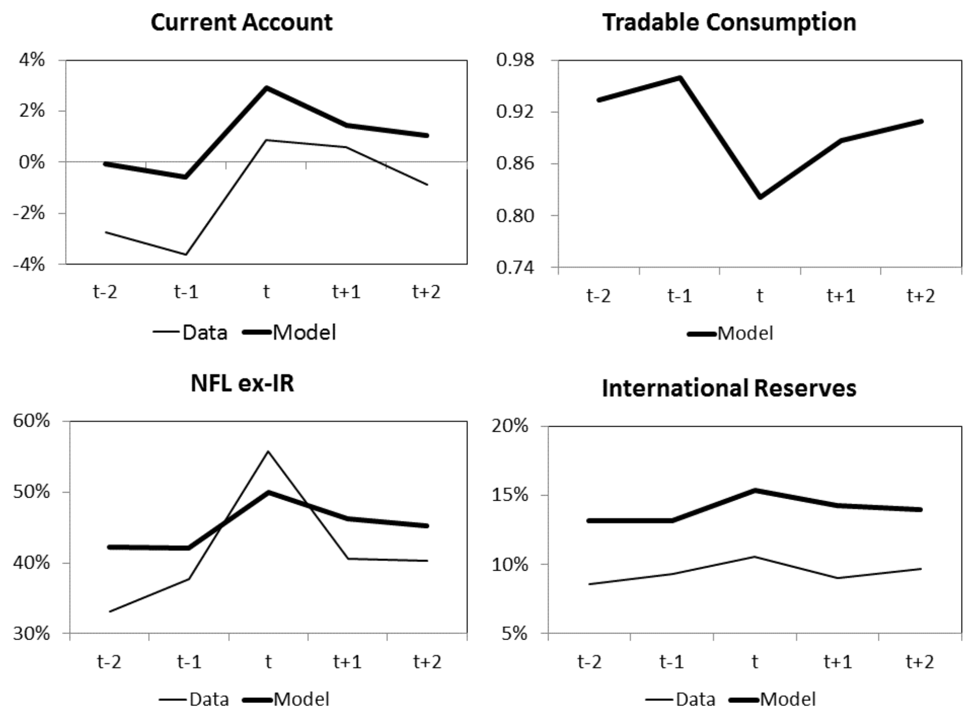

FIGURE 6: Dynamics around Sudden Stops Events

agents to maintain their level of external borrowing. Finally, the level and behavior of international reserves during a crisis are very close to what we see in the data. These results can explain the fear of losing international reserves identified by Aizenman and Sun (2012) during the GFC and is consistent with what De Gregorio (2011) noted:

> "Countries hoard reserves because they see them as a safety net for periods of financial stress but, in practice, they seldom use them (...) reserves play a stabilizing role simply because they are there and not necessarily to be used."

However, this passive policy increases the frequency of sudden stops to 8.8% and reduces welfare when the country is far from hitting the collateral constraint, at which point it would be optimal to reduce the level of international reserves to consume more. Moreover, when the country is in states where the collateral constraint might bind in the near future, the optimal policy is to hold a higher level of international reserves than the average to allow for more consumption if the economy is hit by a negative shock in international financial markets.

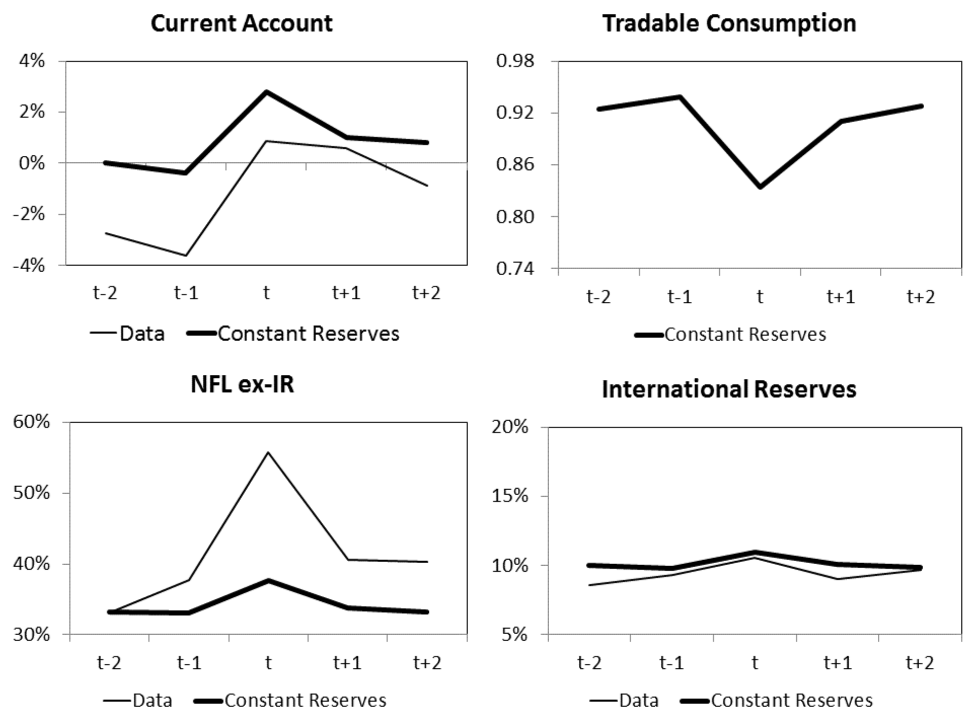

FIGURE 7: Dynamics around Sudden Stops Events - Alternative Policy vs Data

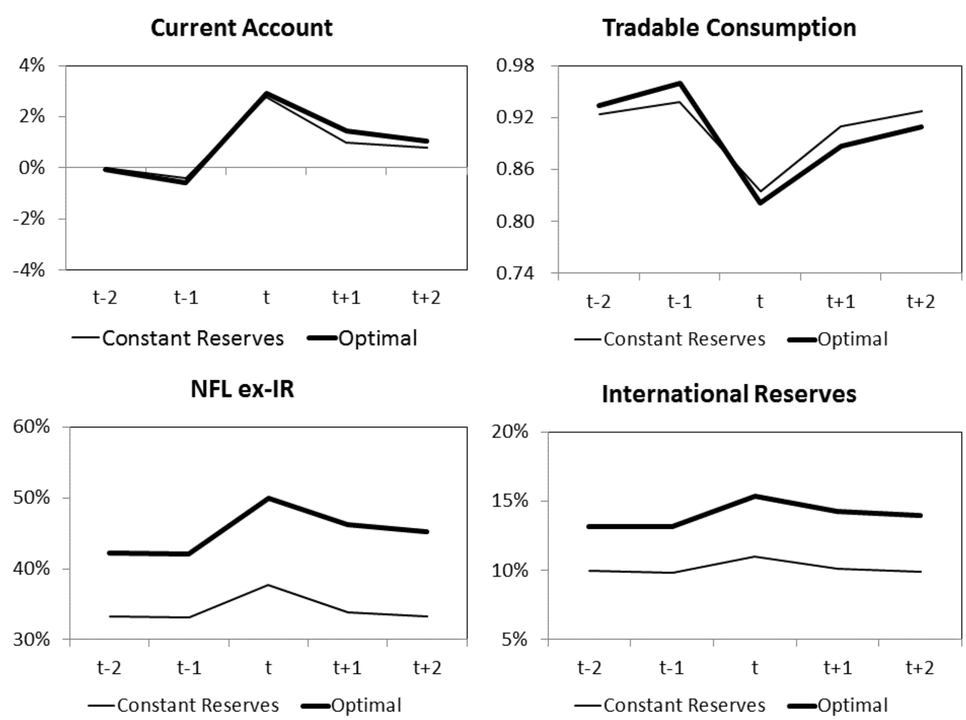

FIGURE 8: Dynamics around Sudden Stops Events - Alternative vs Optimal Policy

4 Can the Model Explain Any Level of International Reserves?

I now analyze what would happen to the results if I change the value of κ^{ir} and adjust the subjective discount factor β accordingly to get the same average level of net foreign liabilities ex-international reserves. As we can see in Figure 9, the optimal ratio of international reserves to GDP is between 9% and 16% of GDP. In fact, changing κ_{ir} mainly changes the frequency of sudden stops, which goes from 15% to 4%. This result shows that, contrary to what some people might expect, the model cannot tautologically generate any level of international reserves just by changing the value of κ_{ir}.

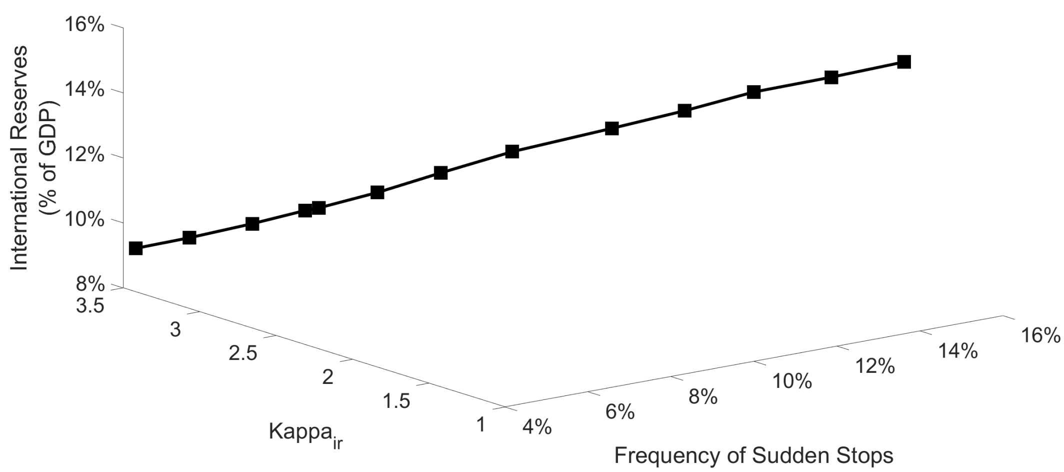

Figure 9: International Reserves - Sensitivity to κ_{ir}

5 Conclusion

Why do emerging market economies simultaneously hold very high levels of international reserves and short-term foreign liabilities? This work explains this puzzling fact by explicitly introducing international reserves as collateral for external borrowing in a dynamic, stochastic model of a small open economy with credit constraints subject to exogenous financial shocks.

I find that the model can explain the observed average ratio of international reserves to GDP in Latin America without considering any additional motives for international reserves accumulation. Moreover, the optimal policy implies that the government accumulates international reserves before a sudden stop, and there is a small depletion during it. Finally, the welfare implications of the optimal policy are quite similar to those of a policy of constant international reserves, which sheds some light on the fear of losing international reserves observed in the recent GFC.

It is important to emphasize that I abstract from some potentially important features of models where foreign liabilities and international reserves are chosen together. First, I do not consider the role of international reserves to reduce output costs in sudden stops. Including this feature would unambiguously lead to an increase in the optimal level of reserves. Second, I do not consider the possibility of sovereign default. On the one hand, Alfaro and Kanczuk (2009b) show that holding international reserves increase the country's willingness to default and consequently make external debt more costly. On the other hand, Levy Yeyati (2008) argues that international reserves reduce the probability of default during crises and consequently reduce spreads in external borrowing. Therefore, the effect of international reserves accumulation in the cost of external borrowing when we allow for sovereign default is still debatable. Finally, I abstract from any exchange rate management policies, which might be another important motive for international reserves accumulation.

The role of international reserves as collateral for foreign borrowing is an important and unexplored aspect of the recent process of international reserves accumulation by emerging market economies, which is still a puzzle in the international macroeconomics literature. The policy implications of this feature and its potential consequences for the policies pursued by multilateral institutions such as the IMF and central banks around the world make it an important area for future research.

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A Data

The dataset includes annual data for Argentina, Brazil, Chile, Colombia, and Mexico. The sample period is from 1991 to 2015. I chose the main Latin American Countries as my sample because they belong to the set of countries included in J. P. Morgan's EMBI+ data set for emerging-country spreads and have consequently access to borrowing in international markets.

Annual series for nominal GDP (total and sectoral), total international reserves, and current account balance in U.S. dollars; total and sectoal real GDP; and real effective exchange rates are from the World Bank's World Development Indicators databank. The net foreign liabilities positions are from the updated and extended version of the External Wealth of Nations dataset constructed by Lane and Milesi-Ferretti (2007), complemented by the updated international capital flows database constructed by Alfaro, Kalemli-Ozcan, and Volosovych (2014). The JP Morgan EMBI Global Index spread used to identify the Sudden Stop episodes is measured using data on spreads from JP Morgan. The endowment process for each country is estimated using the HP-filtered cyclical component of tradables (agricultural and manufacturing industry) and nontradables (industry ex-manufacturing and services) GDP.

B The High Frequency Behavior of International Reserves

Although we do not see much international reserves depletion during crisis on an annual basis, there might be larger international reserves losses if we look at higher frequencies.[19] Aizenman and Sun (2012), for example, show that most emerging market economies began exhibiting large international reserves losses during the second half of 2008 and regained most of their losses by the first quarter of 2009. If we look at quarterly data, there is indeed a larger international reserves depletion also in my sample, as we can see in Figure B.1, where the average international reserves level falls

19. I thank Pablo Ottonello for pointing out this fact.

around 15% in US dollars. However, this fall is compensated by the fall in GDP in US dollars due to currency depreciation and recessions experienced by some countries and, consequently, we still get on average an increase in the ratio of international reserves to GDP, coherent with their annual counterpart. Moreover, although it is true that we see some cases of stronger international reserves depletion, as in Argentina in the 2002 crisis, these episodes are related to fixed exchange rate regimes, which are not the subject of this paper, where I abstract from studying the effects of different exchange rate policies on international reserves accumulation. Finally, the fact that countries international reserves holdings start to recover rapidly is another evidence that although they might be used for another purpose in the short term, their role as collateral leads to an urgency of having them back quickly to the previous levels.

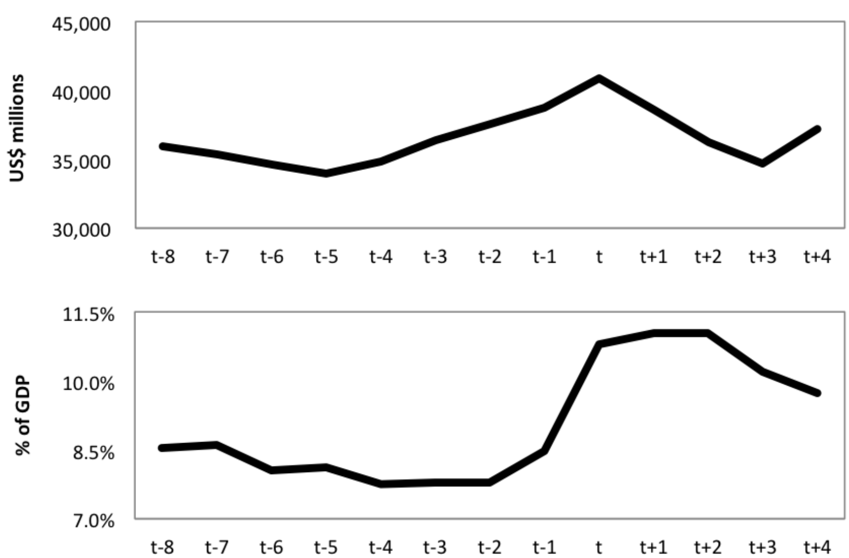

Figure B.1: International Reserves around Sudden Stops - Quarterly Data

C Do International Reserves Serve as Collateral?

I have assumed that international reserves are used as collateral, is this really the case? Unfortunately, as the main idea is that reserves serve as an implicit collateral, we cannot infer directly from any database if this is true. However, an implication of my setup is that during periods of international financial stress countries with a higher level of international reserves before these crisis are able to hold more net foreign liabilities excluding international reserves during the crises. I check this implication for several emerging market economies, the results are presented in Figure C.1. As we can see, there is a strong positive correlation between b_{t+1} and IR_t and thus it indicates that foreign lenders do lend more during crises to countries that have a higher level of international reserves.

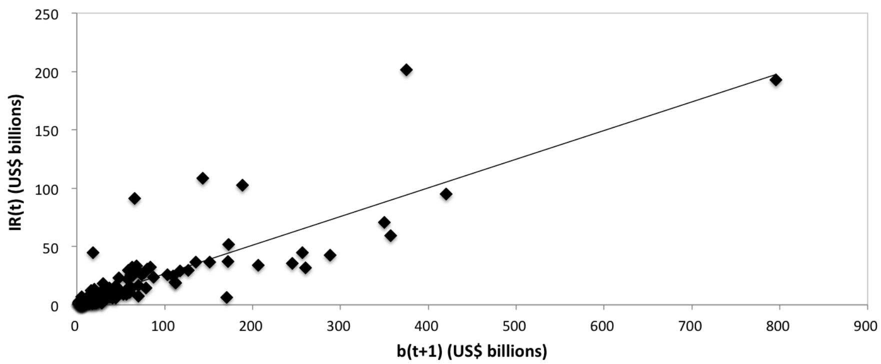

FIGURE C.1: Net Foreign Liabilities ex-International Reserves and International Reserves in International Crises

Note: Each point represents data for a specific country during an international crisis episode. The years of international financial stress are 1995, 1999, 2002 and 2009. The value of international reserves is measured in the beginning of the year of an international financial stress period while that of net foreign liabilities ex-international reserves is measured in the beginning of the following year. The countries included are Argentina, Bolivia, Brazil, Bulgaria, Chile, Colombia, Costa Rica, Czech Republic, Dominican Republic, Ecuador, Egypt, El Salvador, Guatemala, Honduras, Hungary, Jamaica, Jordan, Korea, Malaysia, Mexico, Paraguay, Peru, Philippines, Poland, Romania, South Africa, Sri Lanka, Thailand, Tunisia, Turkey and Uruguay.

Source: Authors' computations based on the updated and extended version of the dataset constructed by Lane and Milesi-Ferretti (2007).

D Additional Tables and Figures

Table D.1
International Reserves (% of GDP)

	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015
Argentina	4.0%	7.4%	10.1%	11.8%	6.9%
Brazil	3.7%	6.2%	6.5%	8.8%	15.1%
Chile	17.5%	19.8%	17.9%	11.3%	14.9%
Colombia	11.3%	9.2%	9.8%	8.7%	10.7%
Mexico	3.7%	4.8%	6.6%	8.6%	13.1%

Table D.2
Net Foreign Liabilities ex-International Reserves (% of GDP)

	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015
Argentina	14.1%	30.3%	67.0%	11.0%	3.1%
Brazil	24.1%	33.2%	45.7%	32.9%	48.6%
Chile	51.4%	56.7%	56.8%	22.9%	30.5%
Colombia	25.7%	37.5%	34.2%	30.9%	38.6%
Mexico	34.6%	38.8%	34.9%	41.8%	54.2%

Table D.3
Current Account (% of GDP)

	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015
Argentina	-2.5%	-3.8%	3.7%	2.0%	-1.5%
Brazil	-0.2%	-3.6%	-0.3%	-1.0%	-3.3%
Chile	-2.5%	-2.9%	0.0%	2.2%	-2.4%
Colombia	-1.1%	-2.7%	-1.1%	-2.5%	-4.1%
Mexico	-4.4%	-2.1%	-1.5%	-1.1%	-2.0%

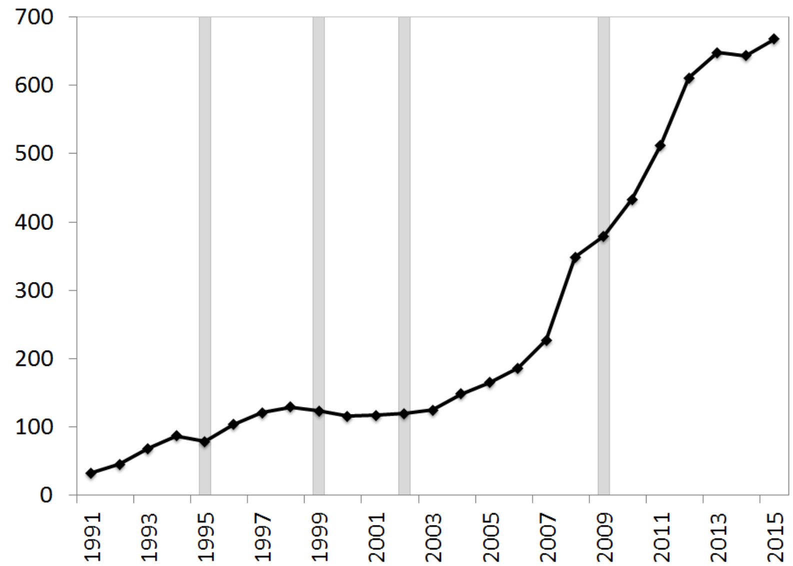

Figure D.1: International Reserves - Full Sample - US$ billions

Note: The data are the sum of the value for the five main Latin American countries (Argentina, Brazil, Chile, Colombia and Mexico). The shaded areas are the systemic sudden stops events identified in section 4.2.

Source: Authors' computations based on World Bank World Development Indicators database.

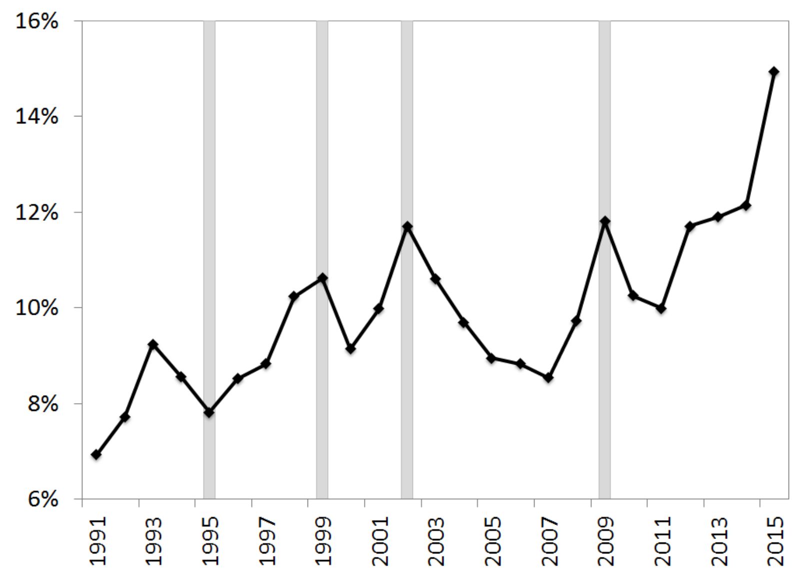

Figure D.2: International Reserves - Full Sample - % of GDP

Note: The data is the simple average of the indicator for the five main Latin American countries (Argentina, Brazil, Chile, Colombia and Mexico). The shaded areas are the systemic sudden stops events identified in section 4.2.

Source: Authors' computations based on World Bank World Development Indicators database.