Exchange Rate Dynamics and the Central Bank's Balance Sheet*

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Abstract

In theory, nominal exchange rates are a function of the relative difference in supply and demand of money. In practice, some central banks issue debt. In this study we ask: are nominal exchange rate variations linked to these remunerated central bank liabilities? We use two measures of implied exchange rates using central bank balance sheet data: one measure is a traditional measure that includes the monetary base, while the other also includes remunerated liabilities. We provide a simple theoretical framework to put these measures in context and to shed light on the relationship between exchange rates and the balance sheet of the central bank. We then move on to the formal empirical analysis. Nonlinear cointegration techniques are used to compare these two measures with the actual exchange rate for a set of seven Latin American countries using monthly data for the 2004:1-2019:12 period. The nonlinear cointegration technique allows both the number and location of thresholds to be endogenously determined based on the percentage difference between the exchange rate and the implied exchange rate. We find the exchange and implied exchange rate are cointegrated for most of the set of Latin American countries. For cointegrated series, the implied exchange rate always adjusts to restore the long run relationship while the exchange rate adjusts for only half of the cointegrated series. This empirical finding indicates that the exchange rate is the dominant series and that central bank debt matters for understanding exchange rate dynamics.

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1 Introduction

An increase in the domestic money supply, other things equal, is usually associated with a currency depreciation. However, some central banks issue debt at the same time Some central banks, namely, remunerated liabilities, that offset part of the increase of the monetary base.[1] In this paper we show, using theory and data from seven Latin American economies, that these remunerated liabilities can affect exchange rates.

To interpret the data, we can consider a simplified balance sheet for a central bank with zero net worth:

Assets	Liablities
Foreign Exchange Reserves	Monetary Base
Financial Claims	Remunerated Liabilities
Domestic Credit	

Table (1) shows these components, as a fraction of GDP, for six Latin American countries in 2018 (ranked by remunerated liabilities, in the last column).[2] The stock of remunerated liabilities as a fraction of GDP averaged 10% across these countries, with considerable heterogeneity: the stock of central bank debt was around a fourth of GDP in Uruguay and almost non-existent in Colombia.

We show this same ranking for the period 2010-2019 and 85 economies in Table (A4) in the Appendix C, where it is shown that the relative position of these economies in terms of their liabilities is similar.

To put these countries' in an international perspective, it can be seen in Table (A4) that Uruguay is -together with Malasia- the country with the highest ratio in the full sample. Brazil and Chile also are among the top 10 countries in terms of remunerated liabilities. Mexico and Colombia, in turn, belong to the large group of countries with little to no remunerated liabilities. Then,

[1] Explaining the reasoning motivating this unconventional form of monetary sterilization goes beyond the scope of this paper. Some literature elaborates on this point, e.g., see Sosa-Padilla and Sturzenegger [2021] for a discussion on a potential explanation based on the risk hedging properties of local debt funded reserves accumulation setups.

[2] The criteria we followed to choose these countries is: South American countries plus Mexico. Argentina and Peru are unfortunately not included in the IMF-IFS data for these variables (for Argentina, we obtain the data from the UCEMA Centro de Economía Aplicada (UCEMA-CEA)). Ecuador isn't included in IMF-IFS for these variables either, and its omitted, along with Bolivia, because they work under a fixed exchange rate regime. Finally, Venezuela is not included as it does not have monthly data in the database.

Table 1: Balance Sheet Components as a fraction of GDP, 2018

Country	Reserves	Financial Claims	Domestic Credit	Monetary Base	Remunerated Liabilities
Uruguay	0.30	0.00	0.10	0.06	0.25
Brazil	0.22	0.01	0.26	0.10	0.17
Chile	0.14	0.00	0.00	0.06	0.10
Paraguay	0.21	0.01	0.00	0.12	0.06
Mexico	0.15	0.02	0.00	0.07	0.02
Colombia	0.16	0.01	0.01	0.10	0.00

we can see that there is a relevant heterogeity in our considered sample of countries that fits the international extremes.

Our main research question is whether at to what extent the remunerated liabilities represent a relevant fundamental for understanding the exchange rate fluctuations. To address this question we peform empirical exercises that use the information of the balance sheets of the central banks of the economies mentioned above (and Argentina). To address these questions, we carry out exercises that rely on the comparison of the observed exchange rate with two implied exchange rate measures that are computed using components of the balance sheet data for these economies: each implied rate considered is obtained as the ratio of domestic liabilities (measured in domestic currency) to foreign assets (measured in foreign currency, US dollars). These implied rates are sometimes used in economics and by financial market analysts as described by Ávila [2018], and they will depreciate (increases) when the liabilities increase and appreciate (decrease) if there is a higher accumulation of assets. Importantly, the difference between the two implied rates we considered is that one will use the monetary base as a measure of liabilites, while the other will also include the remunerated liabilities. In Section (4) we provide a simple theoretical framework to derive and further understand these measures.

We refer to these measures as the "Conversion Exchange Rate" (CER henceforth).[3] We will first define the "CER Base" as the measure that only incorporates the monetary base in the numerator and the "CER Full" as the measure that includes both the monetary base and remunerated liabilities. So the measures are (in pesos per dollar):

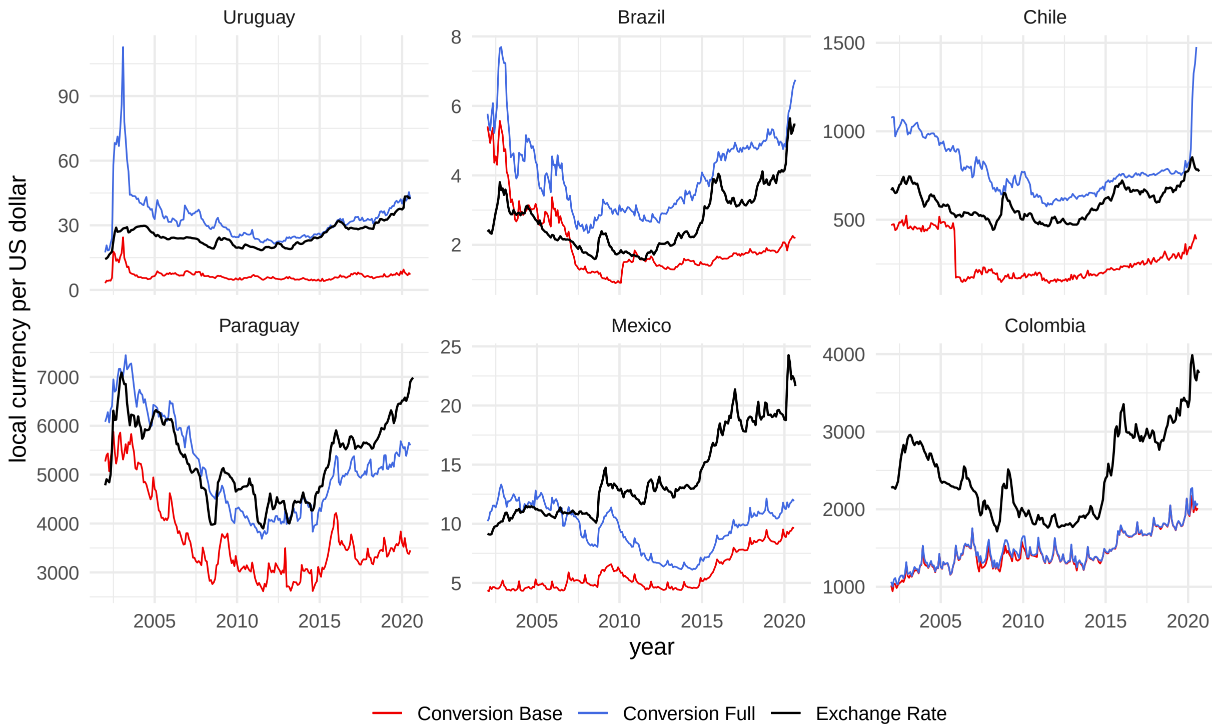
$$\text{CER Base} \equiv \frac{\text{Monetary Base}}{\text{International Reserves}} \tag{1}$$

[3] In spanish this is known as "Tipo de Cambio de Conversión" (Ávila [2018]).

and

$$\text{CER Full} \equiv \frac{\text{Monetary Base+Remunerated Liabilities}}{\text{International Reserves}}. \qquad (2)$$

Figure 1: Monthly Exchange Rates and CER Base, and CER Full. 2004-2019

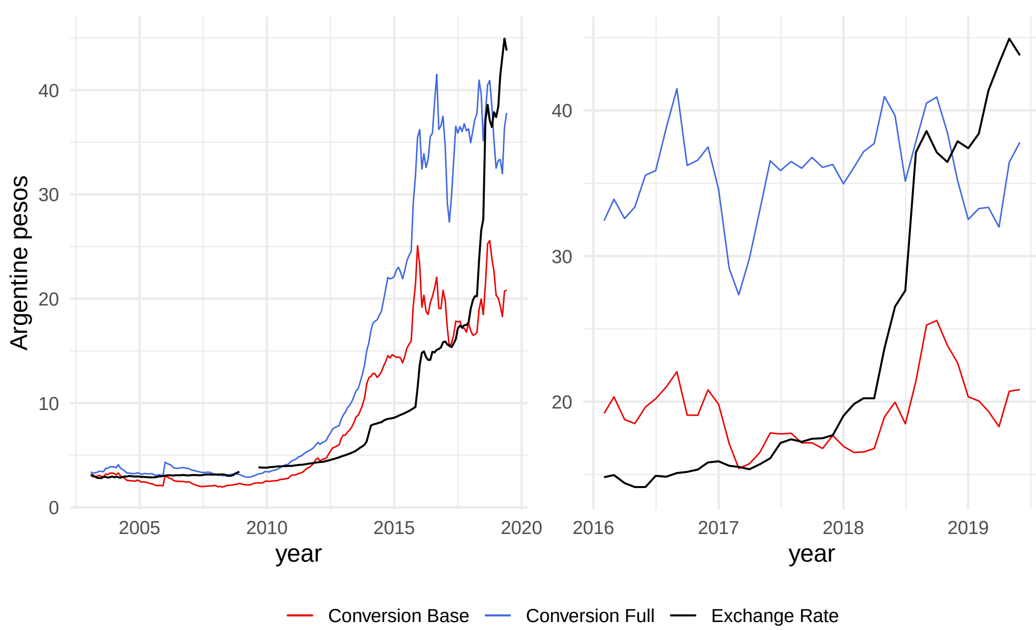


Source: Author's calculations using IMF IFS data.

Figure (1) depicts the exchange rate and implied exchange rates for the six Latin American countries. The implied exchange rate levels seems consistent with the actual exchange rate for four of these countries (Brazil, Chile, Paraguay and Uruguay). The difference between the CER Full and the CER Base is explained by the existence of remunerated liabilities. The larger the remunerated liabilities, the larger the difference between the two lines. The CER Full seems to track the exchange rate better than the CER Base, suggesting that remunerated liabilities matter. For Colombia and Mexico, however, the exchange rate and CER do not seem to be related. Recall from Table (1) that these two countries had little to no remunerated liabilities. A pattern seems to emerge: countries with substantial remunerated liabilities (e.g., larger than 2% of GDP) have exchange rates that move closely with the balance sheet of the central bank, while countries without remunerated liabilities have exchange rates that are decoupled with the balance sheet of the central bank. We formally test the link between these implied and observed rates in a non-linear cointegration context.

We also include large depreciations in our analysis. For this we focus on the currency crisis in Argentina in 2018. Between April and September 2018 the argentine peso lost half its value: it went from around 20 to 40 pesos per US dollar. The central bank had accumulated around 8% of GDP in remunerated liabilities during the previous two years.[4] As Figure (2) shows, the magnitude of this depreciation coincided with the difference in the CER Base and CER Full. In the crisis, the actual exchange rate jumped from the former to the later. This might be suggesting that the fundamental exchange rate value is indeed given by balance sheet measures that include remunerated liabilities.[5] Through this lens, before May 2018 the currency was overvalued, relative to the fundamentals given by the Central Bank balance sheet.

Figure 2: Monthly spot Exchange Rate, CER Base, and CER Full for Argentina: full sample (left) and currency crisis episode (right).



Source: Author's calculations calculation based on UCEMA-CEA.

[4]For the case of Argentina we focus in the January 2016 - July 2019 period since before and after this there were tight currency controls, and thus a black foreign exchange price.

[5]For the period after the crisis (around May 2018), the CER Full is underestimated, since the IMF bailout transfers were temporarily recorded as international reserves by the Central Bank (thus the actual reserves were lower, which implies a higher CER Full). We thank Jorge Ávila for this insight.

With these figures in mind, we start our explorations by verifying the potential endogenous relationship between the different components of the balance sheet. We obtain that these variables are indeed interconnected but that their individual links to the exchange rate don't seem as strong as intuition would suggest. To explore further, and to circumvent issues related to the disconnect of the exchange rate with its fundamentals, we shift our focus to analyses that compare pairs of exchange rates directly (rather than exchange rate to fundamentals), and analyze the potential long-run comovement between the spot (observed) exchange rate and the two balance sheet implied counterparts (CER Base, and CER Full).

Our non-linear cointegration analysis suggests that the remunerated liabilities are a relevant determinant of the exchange rate in the long-run for most of the countries in our sample, and particularly for those with a longer tradition of managed floating currency regimes or that hold important amounts of remunerated liabilities. In most of these cases, the spot exchange rate comoves more closely with the implied rate measure that considers the public debt in the liabilities, showing that this type of policy instrument matters, and that in the long-run, the exchange rate is not only a measure of the relative amount of each currency (local vs. reserves) in the economy, and instead, the currency composition of the debt issued by the Central Bank can becomes an important determinant for it's long run dynamics.

Related Literature. Monetary theory tells us that variation of the exchange rate is a function of the difference in supply and demand of money, relative to the foreign country, as exposed in for instance Obstfeld and Rogoff [1995]. An increase in the money supply (or monetary liability), other things equal, leads to a currency depreciation. These theories, however, usually abstract from two features that are present in many emerging markets:

1. Many central banks follow intermediate exchange rate regimes (neither fixed or flexible exchange rate regimes): Frankel [2019] proposes to define an intermediate regime, called "systematic managed floating", as an arrangement where the central bank regularly responds to changes in total exchange market pressure by allowing some fraction to be reflected as a change in the exchange rate and the remaining fraction to be absorbed as a change in foreign exchange reserves.

2. Many central banks issue remunerated liabilities, as reported before. Foreign exchange reserves are sometimes financed by issuing central bank debt. Sosa-Padilla and Sturzenegger [2021] study the link between remunerated liabilities and bond yields. We however focus on the link with exchange rates.

Our intention is not in predicting exchange rates or linking it to determinants in the short-run: a long-standing puzzle in international economics is the difficulty of tying floating exchange rates to macroeconomic fundamentals such as money supplies, outputs, and interest rates (see Engel and West [2005] and references therein).

Instead, our contribution consists of the provision of Central Banks' balance-sheet based empirical evidence of the existence of a long-run link between remunerated liabilities and the observed exchange rate, which is of particular relevance for studies suggesting the existence of policy incentives for the accumulation of these type of debt that include the hedging of debt risks associated with strong fluctuations in the value of the domestic currency.

We support our empirical result with a basic theoretical framework that shows how we expect the remunerated liabilities issuance, and other components in the banks' balance sheet to affect the exchange rate dynamics. Our findings thus may have empirical and theoretical implications for open economy macroeconomics, in particular for the existence of the Mundell-Fleming trilemma (Mundell [1963], Fleming [1962]), and additional trade-offs involved in the decision of a "de-facto" currency regime. Such choice, as we find, is not independent of the link between the exchange rate dynamics and the other components of the central banks balance sheet aside the money supply.

This paper are also related to the literature on the currency composition of debt, both from a central government as well as the central banks' perspective. According to these studies, local currency debt provides a risk hedge based on the countercyclicality of exchange rates (e.g., Korinek [2009], Devereux and Wu [2022]). Other authors explain that, although, this is the case, the capacity of indebtedness is limited by the presence of original sin (incapacity to get indebted in local currency) and potential country risk premia and policy credibility issues that imply a countervailing effect to the perceived incentives to hold larger shares of local currency debt (e.g., Ottonello and Perez [2019], Engel and Park [2022]).

Our results align with both of these stances. We obtain that some countries with a relatively high policy credibility and inflation targeting regimes opt for an active local debt issuance, which in turn, affects the long-run exchange rate dynamics.

The rest of the paper is organized as follows: in Section (2) we perform a VAR analysis to study the components of the balance sheet, while in Section (3) we move to the non-linear cointegration analysis. In Section (4) we provide a simple theory of the implied exchange rates that supports the empirical results obtained in the paper.

2 VAR Models for Balance Sheet Components

We estimate vector autorregresive models (VAR) for each economy based on the variables represented in (2) to investigate endogenous interactions between the balance sheet components involving the CER-Full (and implicitly the CER-Base). In each case our estimation equation is:

$$\begin{aligned} X_t &= \Phi X_{t-1} + u_t \\ u_t &\sim N(0, \Sigma_u) \end{aligned} \tag{3}$$

Where $X_t = [er\ h\ mb\ rl]'$, and er : exchange rate, h: foreign reserves, mb: monetary base, rl: remunerated liabilities. A separate VAR model is estimated for each of the seven countries with monthly data spanning 2004:01-2019:12. We transform the data by its logarithm and model it in levels or first differences depending on the presence of cointegration in each economy, which we test for using the Johansen Multivariate cointegration test Johansen [1991].

In addition, the model in (3) denotes the (companion) VAR(1) representation of each VAR(p) model, i.e., we allow the model in each case to have a higher lag order which is assigned according to the AIC criterion with a maximum lag length of 6, as shown in table A1 in appendix B. Finally, in each country we verify the absence of autocorrelation in the reduced form errors.[6]

[6] Additional results related to this VAR exercise are reported in appendix B

Table 2: Johansen cointegration test results, by country

Number of Cointegration Relationships from Johansen Test						
Country	Deterministic component			Decision by type of test		
	None	Const	Trend	Trace	Max. Eigenv.	Final Model (selected)
Argentina	0 / 0	1 / 1	1 / 1	0 - None	0 - None	VAR(differences)
Brazil	1 / 0	2 / 1	0 / 0	0 - Trend	0 - None	VAR(differences)
Chile	1 / 1	1 / 1	1 / 1	1 - None	1 - None	VEC/VAR(levels)
Colombia	2 / 1	3 / 3	2 / 1	2 - None	1 - None	VEC/VAR(levels)
Mexico	0 / 0	1 / 1	1 / 1	0 - None	0 - None	VAR(differences)
Paraguay	1 / 1	3 / 3	1 / 0	1 - None	0 - Trend	VAR(differences)
Uruguay	1 / 1	3 / 2	1 / 1	1 - None	1 - None	VEC/VAR(levels)

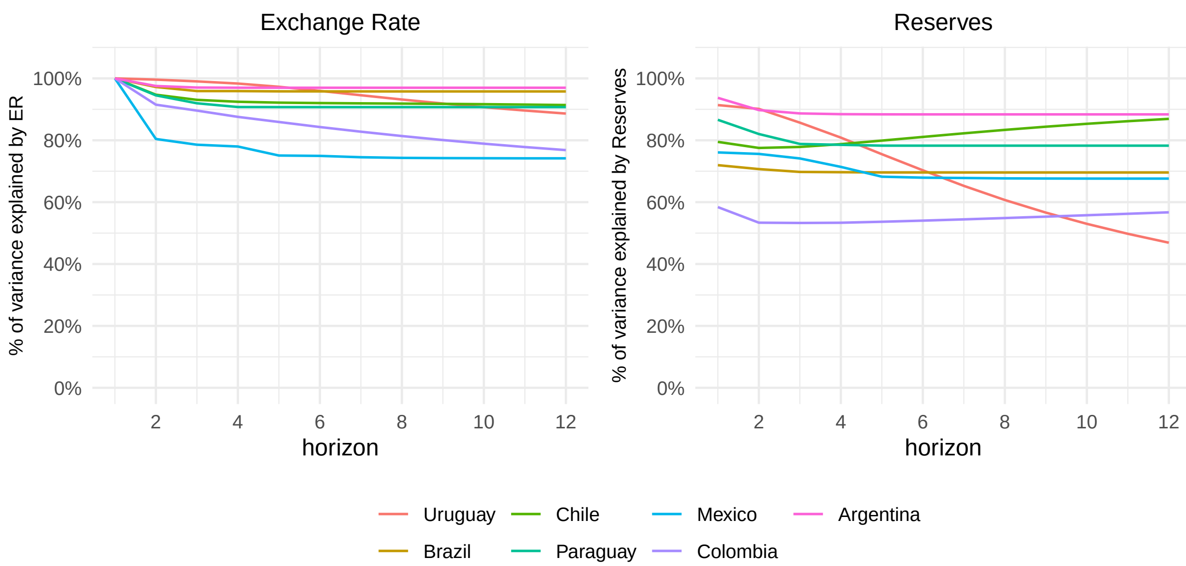
Note: each entry denotes the number of relations in each test as: "trace test / max. eigenvalue test". The deterministic component refers to additional terms included in the cointegration relationship. Decision rule: pick the simplest model (in number of relations and type of component) for which the test is rejected.

From a Balance Sheet Approach to an Implied Exchange Rates Analysis. The evidence on the importance of the remunerated liabilities based on the multivariate exercises that represent the structure of the balance sheet of the central banks is mixed. First, we test for multivariate cointegration, the results are shown in table 2. The results suggest that in five out of seven countries we should proceed with a VAR model in differences, i.e., abstract from cointegration. We carry out the model indicated in the last column of the table.

The causality tests (based on Granger [1969] and a modified Wald test to consider the contemporaneous relationships) show some sings of the remunerated liabilities causing the rest of the balance sheet, it granger causes the other variables for Brazil, Paraguay, and Chile (at the 10% level). Furthermore, the forecast variance error decompositions shows that for Brazil, Paraguay, Chile, and Uruguay the remunerated liabilities explain about 2% or more (up to 10%) of the exchange rate variance. In light of these results, for all countries except Colombia the effect of remunerated liabilities on the dynamics of the currency is not necessarily trivial.

To state this, we take a look at the percentage of the variance of the exchange rate that is caused by itself (figure 3 left panel). It turns out, this variable is particularly persistent and self-determined in a more marked way than the rest of the balance sheet (e.g., see figure 3 right panel). In that sense, explaining 6% of the residual variance is still relevant. However, the high degree of self-determination in this system that is displayed by the exchange rate poses a challenge for establishing a meaningful relationship with other fundamentales and can be traced to the exchange rate disconnect puzzle (Obstfeld and Rogoff [2001]). Thus, it seems exploring the relevance of the liabilities from a multivariate balance sheet perspective is not too promising.

Figure 3: Percentage of variance of Exchange Rate (left) and Reserves (right) explained by itself



Nevertheless, we can take an alternative venue to verify the relevance of the liabilities for the (observed) spot rate dynamics: an exchange-to-exchange rate cointegration analysis. In particular, we can assess the co-movement (over several horizons) of the spot rate with two balance sheet implied measures of the exchange rate, the CER Full that accounts for the effect of the remunerated liabilities on the balance sheet and the CER Base that abstracts from it. If the former is more closely related to the actual spot rate, then we could say that the way reserves accumulation are funded matters (and not only the overall level of reserve assets does).

This approach is further justified by the empirical literature, e.g., Engel et al. [2015] and Verdelhan [2018] which show evidence in favor strong comovements between exchange rates in international markets against their base currency. A simplified implication of such thinking is that exchange rates, spot or implied, that are related to the same base currency will also co-move strongly.

3 Cointegration Analysis

We test for threshold cointegration between pairs of spot rate against each of the two measures of implied exchange rates (CER Base and CER Full) for the set of Latin American countries for monthly data from 2004:1-2019:12. In each case our econometric analysis consists of three steps. First, we transform data by its logarithm and investigate the order of integration of each series using the Augmented Dickey Fuller (ADF) unit root test (Dickey and Fuller [1979, 1981]) and a minimum Lagrange multiplier unit root test that allows for structural breaks in level and trend given by Lee and Strazicich [2003]. When the series are found to be integrated of the same order, we employ the threshold cointegration technique of Sephton and Mann [2013] which combines the threshold selection method of Gonzalo and Pitarakis [2002] with the F test developed by Seo [2008]. The test for threshold cointegration examines the residuals from the cointegrating regression in equation (4), and conditional on selecting one or more thresholds (for expository purposes, we assume there are three in equation (5), denoted by τ_1, τ_2 and τ_3) it examines the null hypothesis that all correction coefficients are zero ($\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$) against the alternative they are not jointly zero. In the case of a single threshold, the testing equation (5) would delete the term involving the residual between the thresholds. In the case of zero thresholds the method collapses on the testing equations of the traditional cointegration test of Engle and Granger [1987]. Finally, to draw inference for threshold cointegration tests we use residual block based bootstrapping and inference for Engle Granger cointegration tests that follow critical values as in MacKinnon [1996].

$$Y_t = \beta_1 + \beta_2 Trend_t + \beta_3 X_t + \varepsilon_t \tag{4}$$

$$\triangle\varepsilon_t = \delta_1 \varepsilon_{t-1} \mathbb{1}_{\varepsilon_{t-1}<\tau_1} + \delta_2 \varepsilon_{t-1} \mathbb{1}_{\tau_1<\varepsilon_{t-1}<\tau_2} + \delta_3 \varepsilon_{t-1} \mathbb{1}_{\tau_2<\varepsilon_{t-1}<\tau_3} + \delta_4 \varepsilon_{t-1} \mathbb{1}_{\tau_3<\varepsilon_{t-1}} + \sum_{i=1}^{p} \alpha_i \triangle\varepsilon_{t-i} + v_t \tag{5}$$

such that

- Y_t and X_t are the logged implied exchange rate (*Base* or *Full*) and the exchange rate (*er*).
- ε_t is the residual from the cointegrating regression from equation (4).
- $\tau_1 < \tau_2 < \tau_3$ are the thresholds that divide observations in each regime.

- $\mathbb{1}_{\text{condition}}$ is a Heaviside indicator function taking the value of 1 if the subscript condition holds, and Δ is the difference operator.

The advantage of Sephton and Mann [2013] over the traditional approach is that it endogenously determines both the number of thresholds and their location. Most cointegration techniques, both in theory and applications, assume the absence of thresholds (e.g., Engle and Granger test); that a single threshold exists and is equal to zero (hence separating observations into two regimes with ε_{t-1} being positive in the first and negative in the second); or that two thresholds exist that are symmetric around zero. Here we allow for as many as four thresholds, and as few as zero. If the procedure chooses two thresholds, they may be symmetric about zero, but this decision is no determined a priori - the data determines the number of thresholds and their locations. For further details on the threshold cointegration technique see Sephton and Mann [2013].

Finally, when we reject the null hypothesis for the cointegration test an error correction model (ECM) is used to determine how the variables move through time, and which of them adjusts to restore the system to the long-run relationship. The ECM also provides estimates of the speed at which the adjustment takes place. Incorporating the threshold into the ECM allows both the speed at which the adjustment takes place to vary by regime.

An ECM with four thresholds is expressed in equation system (6-7). Our estimations, are based in these two equations, where the lag order on changes in Y_t and X_t is set to be the same across equations and as prescribed by the AIC. The estimated equations for the cases with fewer thresholds are only a slight modification of this setup (with the associated threshold coefficients set to zero).

$$\begin{aligned}\triangle Y_t = \gamma_1 \varepsilon_{t-1} \mathbb{1}_{\varepsilon_{t-1}<\tau_1} + \gamma_2 \varepsilon_{t-1} \mathbb{1}_{\tau_1<\varepsilon_{t-1}<\tau_2} + \gamma_3 \varepsilon_{t-1} \mathbb{1}_{\tau_2<\varepsilon_{t-1}<\tau_3} + \gamma_4 \varepsilon_{t-1} \mathbb{1}_{\tau_3<\varepsilon_{t-1}} \\ + \sum_{i=1}^{p} (\alpha_i \triangle Y_{t-i} + \beta_i \triangle X_{t-i}) + u_t\end{aligned} \tag{6}$$

$$\begin{aligned}\triangle X_t = \gamma_5 \varepsilon_{t-1} \mathbb{1}_{\varepsilon_{t-1}<\tau_1} + \gamma_6 \varepsilon_{t-1} \mathbb{1}_{\tau_1<\varepsilon_{t-1}<\tau_2} + \gamma_7 \varepsilon_{t-1} \mathbb{1}_{\tau_1<\varepsilon_{t-1}<\tau_2} + \gamma_8 \varepsilon_{t-1} \mathbb{1}_{\tau_2<\varepsilon_{t-1}} \\ + \sum_{i=1}^{p} (\chi_i \triangle Y_{t-i} + \delta_i \triangle X_{t-i}) + v_t\end{aligned} \tag{7}$$

where

- Y_t and X_t are the logged implied exchange rate (*Base* or *Full*) and the exchange rate (*er*).
- ε_t is the residual from the cointegrating regression from equation (4).
- $\tau_1 < \tau_2 < \tau_3$ are the thresholds that divide observations in each regime.
- γ_i are the regime specific speeds of adjustment to the long-run relationship.
- $\mathbb{1}_{\text{condition}}$ is a Heaviside indicator function and Δ is the difference operator.

Estimates of the speeds of adjustment coefficients identify which series adjusts to restore the long run relationship when it is out of balance. If one of the series does not adjust, it is considered weakly exogenous and termed the dominant series.

Cointegration Results. Results from the unit root tests are consistent across all seven countries as shown in Table 3; we fail to reject the null hypothesis of a unit root for all implied exchange rates. The pairwise threshold cointegration tests and the coefficient estimates for the cointegrated pairs are shown in Table **??**. We obtain that there is cointegration between the spot and the implied base rate (CER Base) for four out of seven economies (Chile, Paraguay, Colombia, Mexico), the specific thresholds and estimated parameters indicate the implied rate is adjusting to the actual (spot) rate over the long-run.

We also show the test and estimates for the implied rate with remunerated liabilities (CER Full), in this case five countries display cointegration and there is evidence of more thresholds in the long-run relationship, which suggests the non-linear nature of the spot rate is better captured by the implied rate incorporating more information from the balance sheet (debt). For this cointegration relationship, the implied rate also adjusts to the spot rate in the long-run, meaning that the latter is the dominant series.

At each country level, we see that the CER Full rate is more closely aligned to the spot rate for economies that rely on issuing remunerated liabilities, which is the majority of our sample. For countries like Uruguay and Brazil this is the only implied rate for which cointegration occurs. For other countries with cointegration, we are able to capture more regimes in the non-linear relationships of the rates when we consider the Full rate (with remunerated liablities). On the other hand, for countries like Colombia and Mexico, with a near zero share of liabilities, the CER

Base rate seems to be at least just as good as the Full rate in adjusting to the spot rate as expected. Finally, Argentina does not show cointegration between the observed and either of the implied rates.

Table 3: ADF Unit Root Test Results for Exchange Rate (*er*) and Implied Exchange Rate (*Base* and *Full*) 2004:1-2019:12

Country and exchange rate	ADF	LS	Country and exchange rate	ADF	LS
Argentina			Mexico		
Spot	0.125		Spot	TBA	TBA
Base	-2.292		Base	TBA	TBA
Full	-1.949		Full	TBA	TBA
Brazil			Paraguay		
Spot	-1.092	-4.085*	Spot	-1.655	-4.81
Base	-1.585	-3.748	Base	-2.467	-3.882
Full	-1.425	-3.872	Full	-1.096	-4.02
Chile			Uruguay		
Spot	-2.076		Spot	-0.494	-2.015
Base	-2.112	-2.063	Base	-2.549	-2.445
Full	-1.444		Full	-1.521	-1.624
Colombia					
Spot	TBA	TBA			
Base	TBA	TBA			
Full	TBA	TBA			

Notes: The null hypothesis is a unit root. Deterministic components, number and type of structural breaks determined visually from time series plot; lag length for unit root tests is selected by the AIC from a maximum of $T^{1/3}$. Significance at α = 0.10, 0.05 and 0.01 absence of a structural break.

Table 4: Threshold Cointegration Equation Estimates

			Dependent variable: ΔY_t				Dependent variable: ΔX_t			
Case	No. thresholds	Test Statistic	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8
CER Base										
Chile	3	23.168**	-0.162***	0.257	-0.328***	-0.192*	-0.002	-0.007	-0.004	-0.008
Brazil	2	11.282	-	-	-	-	-	-	-	-
Paraguay	1	60.184***	-0.171**	-0.661***	-	-	0.097***	-0.001	-	-
Uruguay	3	19.100	-	-	-	-	-	-	-	-
Colombia	1	15.724**	-0.431***	-0.304***	-	-	-0.136	-0.097	-	-
Mexico	3	27.190**	-0.127***	-0.035	0.149	-0.191	0.009	-0.073	0.005	0.022
Argentina	0	-2.150	-	-	-	-	-	-	-	-
CER Full										
Chile	2	16.570**	-0.125***	0.153	-0.097**	-	0.056*	-0.0199	0.052*	-
Brazil	3	24.042*	-0.089*	-0.117	0.229	-0.127***	0.036	0.121***	0.035	0.045*
Paraguay	3	25.684**	0.049	-0.405***	-0.068	-0.196***	0.083***	0.005	-0.108	0.009
Uruguay	3	27.190**	-0.128***	-0.035	0.149	-0.191***	0.009	-0.073	0.005	0.022
Colombia	3	38.571***	-0.303***	-0.741***	-0.109	-0.325***	-0.099	-0.079	-0.092	-0.093
Mexico	3	17.228	-	-	-	-	-	-	-	-
Argentina	0	-1.871	-	-	-	-	-	-	-	-

Notes: The null hypothesis is no cointegration against an alternative of (threshold) cointegration. Input specifications for Engle-Granger test (i.e., zero thresholds): lag length for the testing equations is selected by the AIC from a maximum of $T^{1/3}$; critical values follow MacKinnon (1996). Input specifications for the threshold cointegration tests (i.e., 1, 2, or 3 thresholds): threshold locations include the middle 90% of observations divided into 50 increments; each regime requires a minimum of 24 observations (not binding); AIC used throughout; critical values for the threshold cointegration test simulated following the residual-based block bootstrap methodology by Seo (2008) with a block length of 6 and 9,999 replications under the null. Significance at α = 0.10, 0.05 and 0.01 denoted by *, **, and *** respectively.

4 Understanding the mechanism

What are the origins of equations (1) and (2)? How can we think of the relationships described previously? In this section we provide a simple theoretical link between exchange rates and remunerated liabilities.

We follow the main building blocks and notation in Engel and West [2005] (see references therein for earlier contributions), however we extend the framework to allow for accumulation of international reserves and remunerated liabilities.[7]

[7] We use reduced form equations, but many of these equations can be derived from microfounded models, as in Obstfeld and Rogoff [1995] or Vegh [2013].

Assume that in the home country there is a money market relationship given by

$$m_t = p_t + \gamma y_t - \alpha i_t + v_{m,t}. \tag{8}$$

Here, m_t is the log of the home money supply, p_t is the log of the home price level, i_t is the level of the home interest rate, y_t is the log of output, and $v_{m,t}$ is a shock to money demand. We assume a similar equation holds in the foreign country, where the analogous foreign variables are m_t^*, p_t^*, i_t^*, y_t^* and $v_{m,t}^*$, and the parameters of the foreign money demand are identical to the home country's parameters.

The nominal exchange rate equals its purchasing power parity (PPP) value plus the real exchange rate:

$$s_t = p_t - p_t^* + q_t. \tag{9}$$

The (uncovered) interest parity relationship obtained from the financial markets is:

$$E_t s_{t+1} - s_t = i_t - i_t^* + \rho_t. \tag{10}$$

Here, ρ_t is the deviation from the rational expectations uncovered interest parity. It can be interpreted as a risk premium or an expectational error. Putting these equations together and rearranging, we get an expression for the spot rate along the lines of Engel and West [2005]

$$s_t = \frac{1}{1+\alpha}\left[m_t - m_t^* - \gamma\left(y_t - y_t^*\right) + q_t - \left(v_{m,t} - v_{m,t}^*\right) - \alpha\rho_t\right] + \frac{\alpha}{1+\alpha}E_t s_{t+1}. \tag{11}$$

To interpret this equation, assume $\gamma = 1$, $q_t = 1$, $v_{m,t} = v_{m,t}^* = 0$, $\rho_t = 0$, and let $b = \frac{1}{1+\alpha}$, thus

$$s_t = b\left[m_t - m_t^* - (y_t - y_t^*)\right] + (1-b)E_t s_{t+1}. \tag{12}$$

The observable fundamentals are given by $f_{1t} = m_t - m_t^* - \gamma\left(y_t - y_t^*\right)$. Notice that equation (12) holds absent intervention of the central banks. It is thus a pure flexible exchange rate "counterfactual" equilibrium. We however consider an environment where the central bank regularly responds to changes in total exchange market pressure by allowing some fraction of it to be reflected as a change in the exchange rate and the remaining to be absorbed as a change in foreign exchange reserves (Frankel [2019]).

In this context, a positive productivity shock, for instance, that leads to an increase in output y_t might be reflected as combination of an appreciation and reserve accumulation. We thus need to introduce international reserves into the picture.

Central Bank's Balance Sheet A simplified Central Bank's balance sheet is given by

A	L
$s_t H_t$	MB_t
	RL_t

H are international reserves (in foreign currency, "dollars"), s the exchange rate, MB the monetary base and RL_t the remunerated liabilities issued by the bank (in domestic currency, "pesos").[8]

We consider an environment where the central bank's net worth is zero and does not vary over time (as typically assumed, see Vegh [2013] for examples in different models). Thus, assets and liabilities vary, in dollar terms, proportionally. This implies that international reserves equals, to a first degree, total liabilities in dollar terms, $H = \frac{MB+RL}{s}$. Rearranging, we get the relationship used in our empirical exercises (we abstract from the time subindex for simplicity):

$$s = \frac{MB + RL}{H} \tag{13}$$

Define total liabilities (TL) as the sum of monetary base and remunerated liabilities $TL = MB + RL$ and let $\omega \equiv \frac{MB}{MB+RL}$ be the weight of the monetary base in total liabilities (and thus $1 - \omega = \frac{RL}{MB+RL}$). Then, taking logs and differentiating with respect to time, the dynamics of the exchange rate is given by[9]

$$\frac{\Delta s}{s} = \omega \frac{\Delta MB}{MB} + (1 - \omega) \frac{\Delta RL}{RL} - \frac{\Delta H}{H} \tag{14}$$

where Δ represents changes. Equations (14) and (12) have some similarity: other things equal,

[8] We abstract from claims to financial institutions and from from domestic credit, mainly because we focus on foreign denominated assets). We also abstract from valuation of the assets held by the Central Bank, a more general framework could include some of these elements, in line with Ghironi et al. [2015].

[9] Analogously, we can obtain a log-linearized version of (14) given by: $\hat{s} = \omega \hat{MB} + (1-\omega)\hat{RL} - \hat{H}$ where hatted variables refer to the log-deviation with respect to its steady-state value. This equation would have the same interpretation, and furthermore, if the approximation at time t is made with respect to the variables in $t-1$ these expression are identical.

the exchange rate depreciates with increases in the monetary liabilities (which now also includes remunerated liabilities) and decreases with output growth (with tends to increase international reserves). [10] A framework that does not include remunerated liabilities ($\triangle RL = 0$) tends to ignore relevant sources of exchange rate variations, if the central bank indeed accumulated such type of debt. This, in fact, is what we verify empirically, the implied Base rate only considers variations stemming from MB and H, whereas the Full rate, which aligns better with the spot rate (s) over the long-run, incorporates the dynamics of RL.

The central bank can decide to intervene in the foreign exchange market. Given a shock on the exchange rate, the central bank might decide to prevent a movement in the exchange rate and let international reserves fully absorb the shock. Such a central bank, at least for this period, is fixing its exchange rate in de facto dollar terms (Levy-Yeyati and Sturzenegger [2005]). In this case, during the relevant period, international reserves are explained by variations in total liabilities (in real terms, since the exchange rate does not change), $\frac{\triangle H}{H} = \omega \frac{\triangle MB}{MB} + (1-\omega)\frac{\triangle RL}{RL}$. In this case, given a positive shock, international reserves will increase by the sum of total liabilities.[11]

In general terms, however, given a shock, the central bank can choose it to be reflected partially in the exchange rate and partially in international reserves. Thus, in general terms, the reflection of a shock in the balance sheet can be described by a vector $(\Delta s, \Delta H, \Delta MB, \Delta RL)$. The policy maker however cannot freely choose all of the elements of this vector.

Do remunerated liabilities give an extra degree of freedom that can be used to override the the Mundell-Fleming trilemma (Mundell [1963], Fleming [1962])? To the contrary: our framework suggests that remunerated liabilities worsen the trilemma.

To see this, consider this example. A central bank can choose two of the following: the exchange rate management, autonomous monetary policy or free capital mobility. In the framework we are thinking of, an extra decision layer is added, since central banks can choose the amount of remunerated liabilities. To set ideas, assume that the central bank has chosen to have free cap-

[10] The intuition for this is in the money market: the exchange rate is the equilibrium price of supply and demand for domestic money. Output growth tends to increase money demand, which tends to appreciate the currency under flexible exchange rates. Under predetermined exchange rates however the central bank increases the supply of money -by purchasing foreign exchange reserves- and hence the exchange rate does not change but reserves do increase.

[11] Not all liabilities are the same, however. On one hand, international reserves accumulation can be explained by increases in the monetary base in real terms, which we can call as a "genuine" source of accumulation since it is endogenous under predetermined exchange rates and grows with money demand (economic growth). On the other hand, international reserves can be financed by increases in remunerated liabilities (debt accumulation). Sosa-Padilla and Sturzenegger [2021] focus on these differences.

ital mobility and a predetermined, or pegged, exchange rate regime (so the interest rate and the amount of money are endogenous and pinned down by the dynamics of the base foreign monetary policy) but the central bank has remunerated liabilities. From equation (13) it is clear that central banks in this context cannot freely choose the amount of remunerated liabilities, since doing so will affect exchange rates (since the expected exchange rate moves according to these liabilities, and hence so does the spot exchange rate). Remunerated liabilities are in this sense "endogenous": they can only change as long as the monetary base or international reserves move to compensate them (which also are endogenous in this context due to the trilemma), in other words, their usage is bound to sterilization. If on the other hand the central bank chooses the amount of remunerated liabilities, then it cannot have a predetermined exchange rate. The Mundell-Fleming trilemma is in full force again, albeit now with remunerated liabilities.

In summary, the simplified theory laid out in this section is consistent with the empirical findings previously reported: exchange rates are related to the stock of remunerated liabilities when countries decide to make use of such policy instrument.

5 Conclusion

We analyze the link between the exchange rate and the structure of the balance sheet of the Central Banks. We tackle this problem by analyzing the endogenous movements between the sheet's components and by transitioning to an analysis based on spot against balance-sheet implied exchange rate measures. The two measures considered contain either only the monetary base or that variable and the remunerated liabilities issued by the central bank; the latter implied measure will capture more components of the central bank's balance sheet.

We obtain that the spot exchange rate is better aligned to implied measures that account for more components of the balance sheet aside the money supply, in particular the debt issuance decisions of the central banks (remunerated liabilities). This can change across countries, and is the case for economies that rely on this instrument and have managed floating regimes.

Since this instrument is used with other policy purposes other than affecting the exchange rate in the short or long run (interventions are made with the reserves themselves). Our results serve as a partial evidence of the actual effect of those policy interventions. That is, engaging on debt issuance similar to sterilization does have a long-run impact on the exchange rate and is not only a way to mitigate the effect of building reserves on the money supply, inflation, and other policy goals.

Consequently, these results also suggest the existence of additional policy trade-offs involved when deciding on an exchange rate regime, i.e., if the workings of a chosen regime, induce to higher debt issuance, this will have an impact in the long-run value of the currency that should be internalized when implementing policy actions.

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A Data Source

We use standardized central bank balance sheet data from the IMF-IFS statistics.[12] The Table below, from Sosa-Padilla and Sturzenegger [2021], summarizes the relevant balance-sheet data that we will use:

Assets	Liabilities
Claims on non-residents (1)	Liabilities to non-residents (a)
Claims on others depository corporations (2)	Monetary base (b)
Net Claims on Central Government (3)	Other Liabilities To Other Depository Corporations (c)
	Deposits and Securities other than Shares Excluded from Monetary Base (d)
	Loans (e)
	Financial Derivatives (f)
	Shares and equity (g)
	Other items (h)

Hence the CER Base is

$$\text{CER Base} \equiv \frac{\text{Monetary Base}}{\text{International Reserves}} = \frac{(b)}{(1)}$$

Following Sosa-Padilla and Sturzenegger [2021], we define the Remunerated Liabilities as the sum of (c), (d), (e) and (f). The CER Full is then

$$\text{CER Full} \equiv \frac{\text{Monetary Base+Remunerated Liabilities}}{\text{International Reserves}} = \frac{(b)+(c)+(d)+(e)+(f)}{(1)}$$

[12] As mentioned before, for Argentina we use the database in UCEMA-CEA, which provides data on monetary base and remunerated liabilities directly.

B Additional Results of the Balance Sheet based VAR estimations

Table A1: Lag Selection for VAR models

Country	AIC(n)	HQ(n)	SC(n)	FPE(n)
Argentina	1	1	1	1
Brazil	2	1	1	2
Chile	2	2	1	2
Colombia	2	2	2	2
Mexico	4	1	1	4
Paraguay	2	1	1	2
Uruguay	3	2	1	3

Note: The lag length selected corresponds to the AIC from a maximum of $T^{1/3}$ (6 for our sample size).

Table A2: Johansen cointegration test results, by country

Number of Cointegration Relationships from Johansen Test					
Country	Deterministic component		Decision by type of test		
	Constant	Trend	Trace	Max. Eigenv.	Final Model (selected)
Chile	1 / 1	1 / 1	1 - Constant	1 - Constant	VEC/VAR(levels)
Brazil	2 / 1	0 / 0	0 - Trend	0 - Trend	VAR(differences)
Paraguay	3 / 3	1 / 0	1 - Trend	0 - Trend	VAR(differences)
Uruguay	3 / 2	1 / 1	1 - Trend	1 - Trend	VEC/VAR(levels)
Colombia	3 / 3	2 / 1	2 - Trend	1 - Trend	VEC/VAR(levels)
Mexico	1 / 1	1 / 1	1 - Constant	0 - Constant	VAR(differences)
Argentina	1 / 1	1 / 1	0 - Constant	0 - Constant	VAR(differences)

Notes: each entry denotes the number of relations in each test as: "trace test / max. eigenvalue test". The deterministic component refers to additional terms included in the cointegration relationship. Decision rule: pick the simplest model (in number of relations and type of component) for which the test is rejected.

Here we replicate the cointegration test without the NONE (no deterministic component in the cointegration vector) to cover only cases where at least a constant is included for one or more variables. The conclusions are similar as in the baseline exercise.

Table A3: Causality Tests in the VAR models, by country

Instantaneous causality test					Granger causality test				
Country	ER	H	MB	RL	Country	ER	H	MB	RL
Chile	0.000	0.000	0.000	0.000	CHL	0.547	0.003	0.008	0.074
Brazil	0.000	0.000	0.000	0.000	BRA	0.427	0.038	0.005	0.031
Paraguay	0.000	0.000	0.000	0.000	PRY	0.045	0.002	0.000	0.001
Uruguay	0.000	0.000	0.009	0.000	URY	0.358	0.225	0.092	0.210
Colombia	0.000	0.000	0.805	0.562	COL	0.084	0.000	0.223	0.578
Mexico	0.000	0.000	0.012	0.005	MEX	0.016	0.000	0.051	0.502
ARG	0.003	0.000	0.000	0.000	ARG	0.058	0.290	0.048	0.479

Note: the p-value is shown. Null hyp.: the variable in the column causes (instantaneously or Granger) the rest of the system.

Figure A1: FEVD for the Exchange Rate (up-left), Reserves (up-right), and Monetary Base (bottom) (% explained by RL)

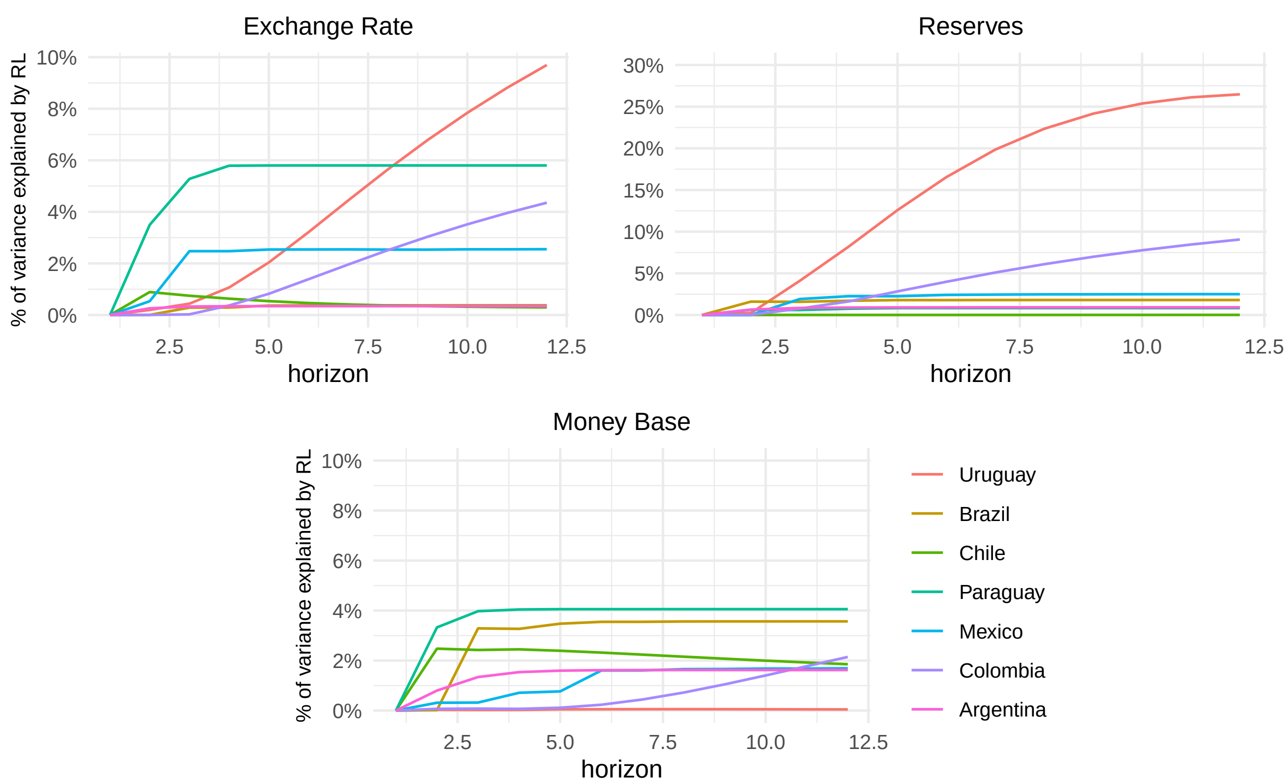
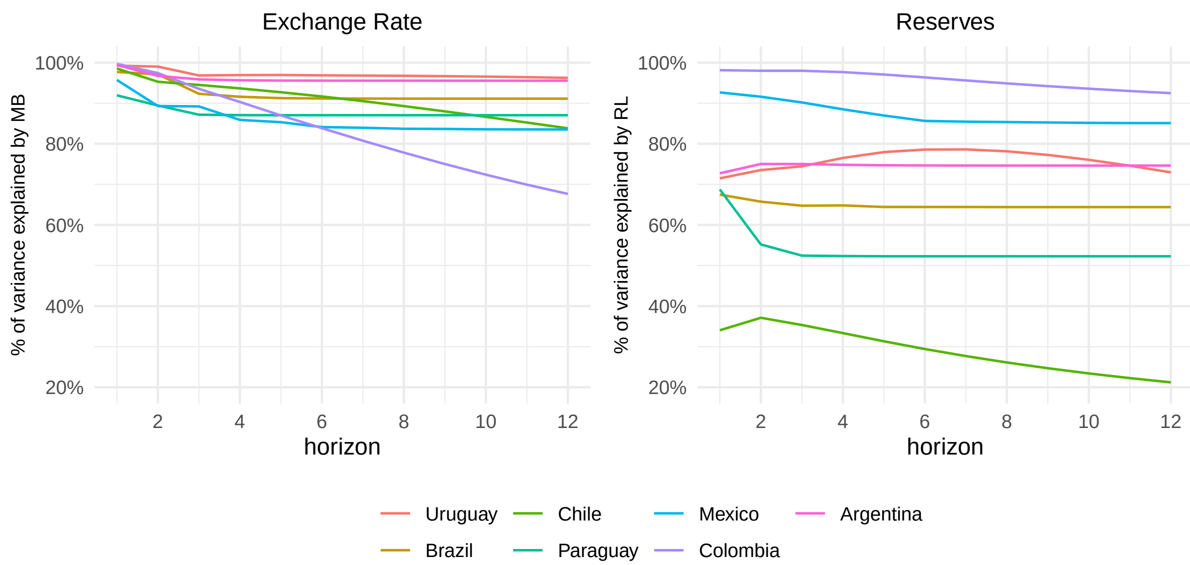
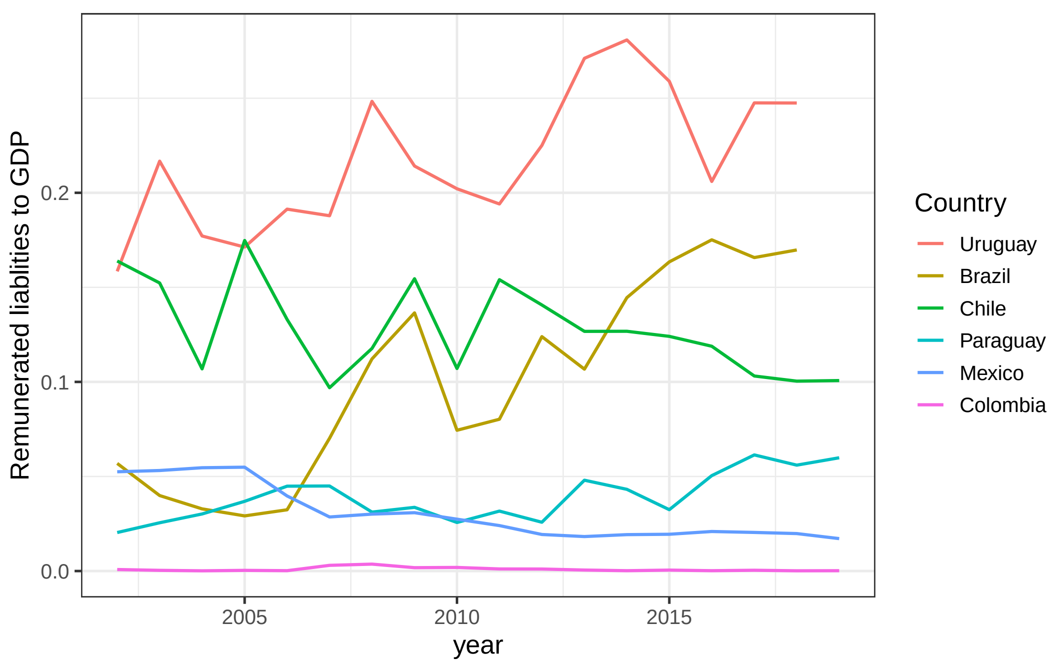


Figure A2: Percentage of Variance of Monetary Base (left) and Remunerated Liabilities (right) explained by itself



C Additional Plots and Tables

Figure A3: Evolution of Remunerated Liabilities as a fraction of GDP. 2004-2019



Source: Author's calculations based on IMF IFS.

Table A4: Balance Sheet Components over GDP (2010-2019)

Country	Reserves	Financial Claims	Domestic Credit	Monetary Base	Remunerated Liabilities
Malaysia	0.40	0.03	0.00	0.10	0.22
Uruguay	0.25	0.00	0.14	0.06	0.22
China, P.R.: Macao	0.73	0.01	0.00	0.08	0.14
Jamaica	0.18	0.00	0.10	0.10	0.14
Algeria	0.76	0.00	0.03	0.23	0.13
Chile	0.15	0.00	0.02	0.07	0.13
Korea, Rep. of	0.24	0.01	0.01	0.06	0.12
Dominican Rep.	0.07	0.02	0.12	0.11	0.11
Brazil	0.14	0.01	0.18	0.10	0.10
Philippines	0.24	0.00	0.03	0.13	0.08
Bolivia	0.37	0.03	0.07	0.25	0.07
Romania	0.22	0.01	0.00	0.09	0.06
Papua New Guinea	0.14	0.00	0.02	0.07	0.06
Nigeria	0.12	0.02	0.03	0.05	0.06
Mongolia	0.18	0.05	0.02	0.11	0.05
Seychelles	0.22	0.00	0.15	0.16	0.05
Botswana	0.63	0.00	0.00	0.15	0.04
Belarus, Rep. of	0.10	0.03	0.01	0.06	0.04
Bhutan	0.52	0.01	0.00	0.28	0.04
Paraguay	0.16	0.01	0.02	0.11	0.04
Venezuela, Rep. Bolivariana de	0.17	0.00	0.04	0.12	0.04
Ghana	0.09	0.01	0.07	0.07	0.03
Mexico	0.12	0.01	0.00	0.05	0.03
Guatemala	0.14	0.01	0.07	0.14	0.03
Maldives	0.14	0.00	0.11	0.18	0.02
Sweden	0.09	0.02	0.02	0.04	0.02
Rwanda	0.14	0.00	0.02	0.04	0.02
Cambodia	0.31	0.00	0.01	0.19	0.02
Azerbaijan, Rep. of	0.15	0.02	0.01	0.13	0.02
Angola	0.17	0.01	0.02	0.07	0.02
Mozambique, Rep. of	0.17	0.00	0.02	0.09	0.02
Vanuatu	0.24	0.00	0.03	0.19	0.02
Ukraine	0.18	0.04	0.09	0.17	0.01
Namibia	0.12	0.01	0.00	0.04	0.01
Samoa	0.14	0.01	0.00	0.10	0.01
Georgia	0.15	0.02	0.04	0.12	0.01
Kyrgyz Rep.	0.28	0.01	0.03	0.18	0.01
Bangladesh	0.08	0.01	0.03	0.09	0.01
Australia	0.05	0.03	0.00	0.04	0.01
Tajikistan, Rep. of	0.08	0.02	0.04	0.13	0.01
Sri Lanka	0.10	0.00	0.03	0.06	0.01
Japan	0.01	0.05	0.35	0.42	0.01
Kenya	0.10	0.01	0.02	0.07	0.01
Tanzania, United Rep. of	0.11	0.00	0.02	0.07	0.01
Turkey	0.13	0.02	0.02	0.10	0.01
St. Kitts and Nevis	0.24	0.00	0.00	0.22	0.01
Antigua and Barbuda	0.16	0.00	0.02	0.17	0.01
Suriname	0.14	0.00	0.06	0.13	0.01
Fiji, Rep. of	0.17	0.00	0.02	0.16	0.01
Trinidad and Tobago	0.37	0.00	0.15	0.15	0.00
Uganda	0.12	0.00	0.06	0.05	0.00
Dominica	0.20	0.00	0.00	0.17	0.00
Grenada	0.17	0.00	0.00	0.15	0.00
Croatia, Rep. of	0.26	0.00	0.00	0.21	0.00
St. Lucia	0.14	0.00	0.00	0.13	0.00
Russian Federation	0.26	0.04	0.01	0.14	0.00
Armenia, Rep. of	0.18	0.03	0.00	0.15	0.00
Barbados	0.12	0.00	0.07	0.16	0.00
Guyana	0.22	0.00	0.13	0.19	0.00
Kuwait	0.19	0.00	0.00	0.11	0.00
St. Vincent and the Grenadines	0.16	0.00	0.01	0.15	0.00
Belize	0.15	0.00	0.07	0.17	0.00
Nicaragua	0.18	0.00	0.31	0.16	0.00
Anguilla	0.16	0.00	0.01	0.16	0.00
Morocco	0.24	0.03	0.01	0.24	0.00
Myanmar	0.03	0.01	0.15	0.17	0.00
Comoros, Union of the	0.16	0.00	0.03	0.12	0.00
Sierra Leone	0.12	0.00	0.14	0.07	0.00
Albania	0.21	0.01	0.07	0.25	0.00
Costa Rica	0.14	0.00	0.01	0.20	0.00
Colombia	0.13	0.01	0.01	0.08	0.00
Gambia, The	0.11	0.00	0.06	0.10	0.00
Canada	0.00	0.00	0.04	0.04	0.00
Zambia	0.09	0.00	0.11	0.07	0.00
Honduras	0.22	0.00	0.06	0.20	0.00
Sao Tomé and Príncipe, Dem. Rep. of	0.00	0.00	0.00	0.00	0.00
Cameroon	0.09	0.00	0.02	0.09	0.00
Central African Rep.	0.11	0.00	0.13	0.13	0.00
Chad	0.07	0.01	0.05	0.08	0.00
Congo, Rep. of	0.23	0.00	0.05	0.15	0.00
Czech Rep.	0.31	0.00	0.00	0.28	0.00
Equatorial Guinea, Rep. of	0.14	0.00	0.02	0.08	0.00
Eswatini, Kingdom of	0.14	0.00	0.01	0.04	0.00
Gabon	0.10	0.00	0.04	0.09	0.00
Lesotho, Kingdom of	0.40	0.00	0.02	0.06	0.00

Note: Average components of the balance sheet as a percentage of GDP for the period 2010-2019. Source: IMF-IFS database.