NovaSBE

Work Project - Research Master in Economics

Exchange Market Pressure and Capital Controls: The case of Brazil

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Abstract

When defining monetary policy, emerging countries tend to protect their independent monetary policy, by intervening in foreign exchange markets to stabilise the exchange rate and by using capital controls to insulate their domestic economy from international investment fluctuations. In this scenario, currency volatility is dampened by official interventions and so an index that reveals the actual pressure affecting a currency is necessary. This work proposes an Exchange Market Pressure measure for the Brazilian economy, incorporating an endogenous proxy for capital control policies. We find out that there is evidence of pressure being relieved by the Brazilian central authorities and that the inclusion of a capital control proxy in the measure inflates the power of reserves in relieving currency pressure.

Key words: Brazil, Capital Controls, Exchange Rate Market Pressure, Time Varying Coefficients.

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The usual disclamer applies.

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1 Introduction

Almost all over the world the national currencies are fiduciary. With no gold pattern, currencies are in reality just like any other good that is traded in specified markets for a price: the exchange rate. As a key economic variable, the exchange rate can be subject to government control (via direct or indirect intervention) or it may be left to float freely, depending on several circumstances.

This decision is part of the monetary policy definition, usually done by the Central Bank (CB). Literature shows, however, that some policies regarding the exchange rate seem to conflict with other monetary policy goals. Aizenman (2010) redefined the concept of impossible trinity, or trilemma, applied to the the open economy set up. The author states that policy makers face a trade-off when choosing two of three policy goals: exchange rate stability, independent monetary policy and open capital markets. The idea is simple, if a Central Bank increases the reference policy interest rate for a domestic reason (following an independent monetary policy), while in an open capital market set up, capital flows tend to increase, leading to an appreciation of the exchange rate.

In reality, most developing economies use, or have already used, monetary policy to sustain some exchange rate goal, in order to stabilise the domestic economy and induce economic growth. The literature supporting this policy decision is far from settled and this work aims precisely into developing an additional information tool to support policy makers.

Brazil, as an emerging economy with relatively well developed financial markets is an interesting case study in this set up. It pursues an independent monetary policy (targeting inflation), it has a floating currency and is known to exert some controls over capital markets. The current Brazilian currency, Real, was introduced in 1995 at par with the US dollar. In its early history, as the credibility of the crawling peg to the US dollar was put in question, it faced strong depreciation pressure, losing almost 75% of its value between 1997 and 2003. After 2005, the exchange rate exhibited relative stability, mostly attributed to better macro-fundamentals, deriving form the overall benefits of Lula da Silva's governance[1].

[1] Brazil has a presidential regime, in which the President it both the head of the state and of the government. Lula da Silva was in office between 2003 and 2010.

A closer look into some macro-variables seems to point out that monetary policy also played an important role. Foreign reserves increased exponentially since 2006, there was significant capital flow volatility and several discretionary capital control measures were implemented, inverting the capital liberalization trend observed between 1997 and 2006. So it would be interesting to evaluate and quantify the impact of these policy measures in the value of the Brazilian currency.

Whenever a country has some sort of explicit or implicit goal over the exchange rate, the pressure over a currency is not translated simply by changes in the exchange rates. For instance, if a Central Bank is worried about a depreciating currency, it can ward off the pressure leading to it by increasing official interest rates (indirect intervention) or buying domestic currency in foreign exchange markets (direct intervention). A supplementary indirect tool to promote exchange rate stability could be the establishment of capital controls.

Regardless of its type, whenever some intervention over the value of a currency is performed it is desirable to have a measure of the pressure that is being relieved, either to provide further knowledge in fighting currency crises or simply for Central Banks to have a better understanding on how currency intervention can be done in a effective way.

The last empirical study about exchange market pressure in Brazil was done by Connolly & Silveira (1979) and in this work we develop an Exchange Market Pressure (EMP) for Brazil based on more recent literature developments. The main goal is to understand if all or part of the recent exchange rate stability was policy induced. We do so considering the traditional direct intervention tools (the use of foreign reserves), but also including capital controls in the measure. We draw back essentially from the model developed by Li (2012), that incorporated a capital control parameter in Weymark's (1995) measure.

We start by presenting some considerations about EMP indices and Capital Controls definitions and their implications. Then we exhibit some stylized facts about the Brazilian economy, fundamental to understand our approach to measure policy intervention in Real. The third section presents the baseline model that will be used to build the EMP index. Finally, section four presents the estimation method and the results, while section five concludes.

2 Motivation

2.1 EMP and Capital Controls - Review of relevant literature

The concept was first presented by Girton & Roper (1977)[2] in a seminal work that defined EMP as a measure of the volume of intervention necessary to achieve a specified exchange rate target. Weymark (1995) and Klassen & Jager (2011) further developed this definition in a model-free way:

Definition 1. *EMP measures the total excess supply for a currency in international markets as the exchange rate change that would have been required to remove this excess supply in the absence of forex market intervention, given the expectations generated by the exchange rate policy already in place.*

Intuitively, EMP can be viewed as an index that incorporates the wedge between a counterfactual exchange rate[3] and the observed exchange rate, that is:

$$EMP_t = \Delta e_t + e_t^c - e_t$$

Where e_t is the nominal exchange rate, expressed as the domestic price of one unit of foreign currency. The difference between the counterfactual exchange rate and the actual exchange rate represents the portion of exchange rate volatility dampened by the CB through official intervention. So a positive amount of pressure (depreciation) over a currency would be correctly described by the actual depreciation of the currency (exchange rate change increase) plus the amount of depreciation that the policy maker is avoiding.

This means that EMP might be computed based on:

$$EMP_t = \Delta e_t + \eta_i x_i \tag{1}$$

Where x_i stands for a vector of policy variables used by the central authority to intervene in

[2]This section details the milestones of EMP literature. A more comprehensive description is provided in Annex 1

[3]The counterfactual here is the one of a passive policy maker, which would have no exchange rate goals when designing monetary policy.

the forex market and η_i represents the efficiency of a specific policy. Different studies consider different policy variables, but changes in foreign reserves and changes in the interest policy rate are two common examples.

Naturally, there are several other policy actions that could be used to affect the exchange rate. The financial crises of 2008 brought up the discussion over capital controls again. Several studies try to contribute to a policy making process that includes some sort of financial openness restriction to insulate domestic economies from international crisis.

According to IMF, capital controls "encompass regulations that influence capital flows and include various measures that regulate the conclusion of execution of transactions and transfers and the holding of assets in the country by non-residents and abroad by residents"[4]. Such regulations are broad and are commonly used, mainly in times of financial distress. However, current literature does not provide definite conclusions about the impacts of capital flows or about the effectiveness of any measures to regulate them.

Capital inflows occur when foreign investors perceive that the rate of return of a particular potential receiving country is higher than the international rate of return, reflecting any risk considerations that might exist. Capital flows are broadly classified as foreign direct investment (FDI), portfolio investment and also on a residual category including all non-tradable instruments.

The expected effects and risks of capital inflows vary according to the actual type of inflow occurring. FDI, for instance, is assumed to be a stabilising factor during crises in emerging markets, due to its more permanent effect and highest degree of risk sharing between the receiver and the investor. Short-term external debt and stock purchases are, on the other hand, perceived as much riskier because they can be easily reversed. The effects also vary according to the receiving country specificities[5]. Theory argues that for most industrial countries capital flows are largely beneficial, while for developing and emerging countries the benefits must be weighed with some important risks (like the volatility of flows, the increase of exposure to international shocks or the reduction of the scope of domestic policy instruments).

[4]Source: IMF - AREAER (2012)

[5]Capital flows determinants are generally classified as pull or push factors. While pull factors represent the country-specific determinants (like high domestic interest rates), push factors are generally common exogenous determinants (like international crises).

This short discussion aims only to provide some insight about the motivation of the numerous studies that try establish formal correlations between capital flows and economic or financial variables. For this work, the most important correlations are the ones regarding any effects over the exchange rate. Aside from indirect effects, the simple fact that capital flows imply economic transactions between countries with different currencies must influence the demand and the supply with corresponding effects on the relative prices of currencies. Those are some of the effects that policy makers may wish deal with using official intervention, like the imposition of capital controls.

Incorporating capital controls in the EMP measure would allow us to to expand clearly its scope providing policy markers with an additional layer of information. This incorporation is not straightforward, as it raises a problem of measure on the intensity of capital controls. Common capital control measures are related with tax legislation (to reduce short-term and promote long-term inflows), limits on offshore borrowing, taxes on financial transactions or even the legal prohibition of some kinds of capital transactions. With such possible broadness in instruments any numerical measure is hard to compute.

Aizenman, Chinn and Ito (2013) developed the Trilemma index which aims at providing a numerical measure of the baseline monetary policy components: a measure of monetary independence based on the correlation of the domestic and the the foreign interest rate, a measure of exchange rate stability, based on exchange rate volatility (to assess the flexibility of the exchange rate) and a financial openness index, based on capital flows restrictions. The later is the one that matters the most for this work.

The index of financial openness (or Chinn-Ito Index) measures the extent of capital liberalization using binary dummy variables that mimic the specification of capital account restriction in IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). This index has, by construction, mean zero and its interpretation is based on the deviation to that mean. A country with high degree of financial openness, within the sample, is assigned a positive value, while the converse occurs for the countries with low degree of financial openness, with negative figures. Despite informative, such index has an important drawback: a specific value has little intrinsic meaning. As it depends on the distribution of the sample, so this index is not suitable to be directly incorporated in an EMP measure. Such incorporation would mean that the economic interpretation of EMP would be linked to the relative position of a country in the distribution, providing no stand alone information. Even so, for comparative purposes (relative to the sample and across time) the index for Brazil will be reported in Annex 2.

Our EMP measure can be seen as a development of Li (2012), where the index is set in a way that the role of capital controls can be included. Using a small open economy monetary model in the spirit of Weymark(1995), the author introduced a wedge in the uncovered interest parity condition (UIP) to illustrate the evolution of capital controls. In this context, the multiplicative time-varying parameter added to UIP represents the risk premium between domestic and foreign investment. The underlying assumption is that the risk premium can adequately summarize capital mobility rigidities, generated by the capital controls policy. This innovation enters the measure as part of the weighting factor of foreign reserves (the only policy instrument considered by the author) yielding the following measure:

$$EMP_t = \Delta e_t - (a_2 - b_2\lambda_t)^{-1}\Delta r_t \tag{2}$$

Where Δr_t are the log changes in foreign reserves. The difference from Weymark (1995) measure is specifically the inclusion of λ_t, that enters the measure jointly with b_2, the semi-elasticity of money demand to changes in interest rates. The author chooses to proxy this variable exogenously, using the Chinn-Ito Capital Controls Index referred above. The author applies its measure to the Chinese economy to evaluate whether the inclusion of capital controls is evidence of over or under estimation of the Weymark measure of EMP, that neglects it.

In this work we contribute to EMP theory by estimating an endogenous proxy of capital controls, nested in a general monetary model, used to evaluate the exchange market pressure in Brazil between 2002 and 2014. More details about this proxy and its inclusion on the EMP measure are presented in section three.

2.2 The case of Brazil

Brazil is a very important emerging economy and has some economic and monetary characteristics that make it a very interesting case study for the measure proposed in this work. In this section we present some relevant stylized facts about the economy.

Brazil has had a tumultuous currency history. Since the 1940's Brazil has known four currencies as a result of very high depreciation pressure, fuelled by chronically high inflation[6]. To stabilize inflation, *Banco Central do Brasil* pursued a very active inflation stabilization policy, mainly based on the maintenance of a very high reference interest rate until 1994 (interest rates were sometimes well above 1000%).

The turnaround happened in 1995 with the *Plano Real* that was implemented to perform an adjustment of fiscal accounts, followed by a monetary reform, leading to the introduction of the actual currency: Brazilian Real.[7] This currency started as a crawling peg to the US dollar, suffered from high inflation between February 1999 and September 1999, when it was classified as a freely falling currency, but has stabilized since then, evolving into a managed float and finally a floating currency, according to Iltzetzki, Reinhart & Rogoff (2011).

Real has undoubtedly been a more stable currency (specially when comparing with the previous Brazilian currencies), Figure 1 shows the quarterly evolution of the nominal exchange rate of the currency per unit of US dollar as well as a fine classification of the exchange rate regimes[8].

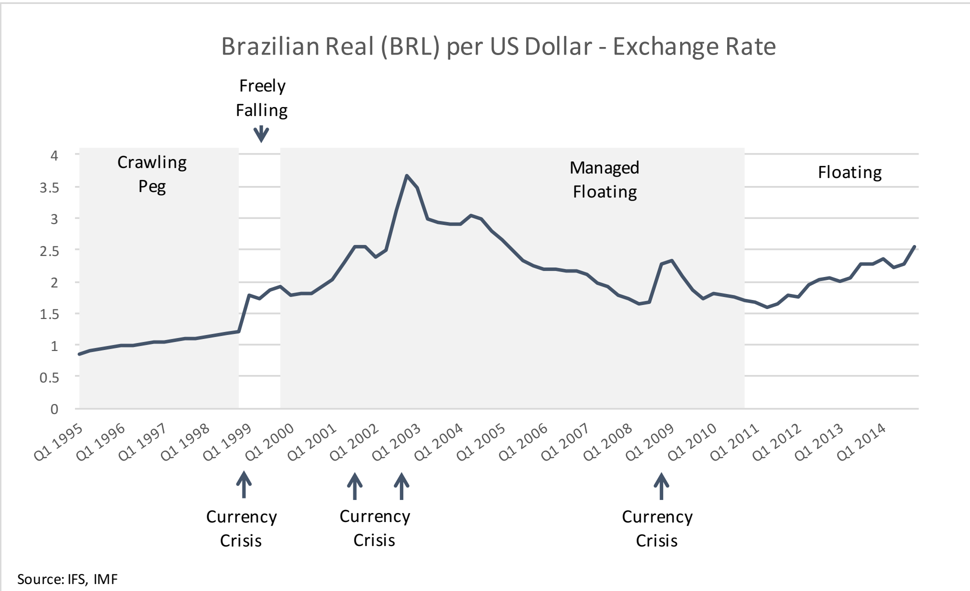

Figure 1: BRL to USD Exchange Rate

[6]As in other South American countries, inflation has been a very significant problem for economic development and stability on Brazil, with figures of more than 6000% in annualized terms in the beginning of 1990, for instance.

[7]For more details about the brazilian currency history and *Plano Real* see Frenkel & Rapetti (2010), for instance.

[8]Ilzetzki, *et al.* (2011) differs from official IMF classification between 1999 and 2010. According to IMF, Brazilian Real is a floating currency since 1999, however many studies classify the currency as a dirty or managed float.

The crawling peg regime is clear in the first years, after which there was a significant trend of currency depreciation that was inverted in 2003 and led to a period of relative exchange rate stability. Since 1995, Real faced four currency crises[9]: in 1999 due to the speculative pressure put over the credibility of the peg to the US dollar, in 2001 and 2002 associated with the domestic presidential elections, the Argentine debt crisis and the 09.11 on the US and finally in 2008 after the bankruptcy of Lehman Brothers'. Since 2005 the exchange rate floated between a band of 1.5 and 2.5, relative to USD, showing a relative stability never seen in Brazil's currency history. This is precisely the period in which this work focuses its attention: was this stability only due to better macro fundamentals or was it policy induced?

To assess if in fact some central authority action was taken to induce this stability we should look at the evolution of some relevant macroeconomic variables. Figure 2 gives a bird eye view of some relevant variables for our analysis.

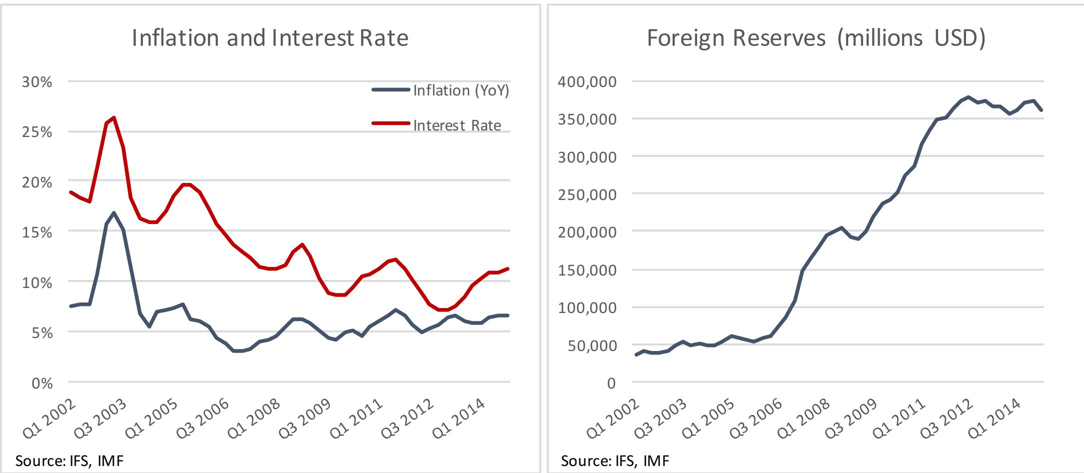

Figure 2: Collection of relevant macro-variables for Brazil

The money market interest rate, here presented as a proxy[10] for a short term interest rate, and inflation are presented in the first graph. The policy rate is tightly controlled by the CB in an inflation targeting monetary policy set up - the strong correlation between the two variables is clear in the graph. Despite the high volatilities in the beginning of the sample, since 2008

[9]Currency crises are defined as a period in which annual depreciation versus a relevant foreign currency (the US dollar) was 15% or higher, according to Reinhart & Rogoff (2009). For comparative purposes, the same study pinpoints 37 episodes of crisis between 1940 and 1995, which equates approximately to a share of 66% years in currency crisis, compared to 27% between 1996 and 2010.

[10]Brazil does not issue short term bonds with frequency and so most studies typically use the CB reference rate -SELIC.

both inflation and the interest rate seem to have stabilized around 6 % and 10%, respectively. These figures are in line with the idea of greater monetary stability brought to the country by *Plano Real*[11]. Even so, it is relevant to note that this reference interest rate is significantly high, particularly when compared with other inflation-targeting policy induced rates.

The graph on the right shows the evolution of foreign reserves, exhibiting a clearly upward trend since 2006. The significant increase in foreign reserves was observed not only in Brazil, but also in several emerging countries. Publicly, the Central Banks of these countries argue that such sharp increase has nothing to do with exchange rate goals and aims only at avoiding liquidity problems deriving from international crises. Recent research on this common upward trend, on the other hand, defends that the the goals of such reserve accumulation are far beyond the protection against liquidity problems.

When computing an exchange market pressure measure, as proposed in equation (1), a set of policy variables must be selected. Literature provides several examples, but the most broadly used policy variables are foreign reserve changes and short term interest rates. At this point, it seems reasonable to assess if both of these policy variables are a desirable inclusion in the measure developed for Brazil.

To infer a possible relationship between foreign reserves and the exchange rate we can analyse the lagged changes in foreign reserves held by the Central Bank as well as the change in the exchange rate:

[11] Reinhart & Rogoff, in their 2009 study, also provide information about inflation crises, defined as years when inflation was higher or equal to 20%. For Brazil, the share of years under inflation crisis is around 68% between 1940 and 1995 (38 episodes over 56 years), while no inflation crisis occurred between 1996 and 2010.

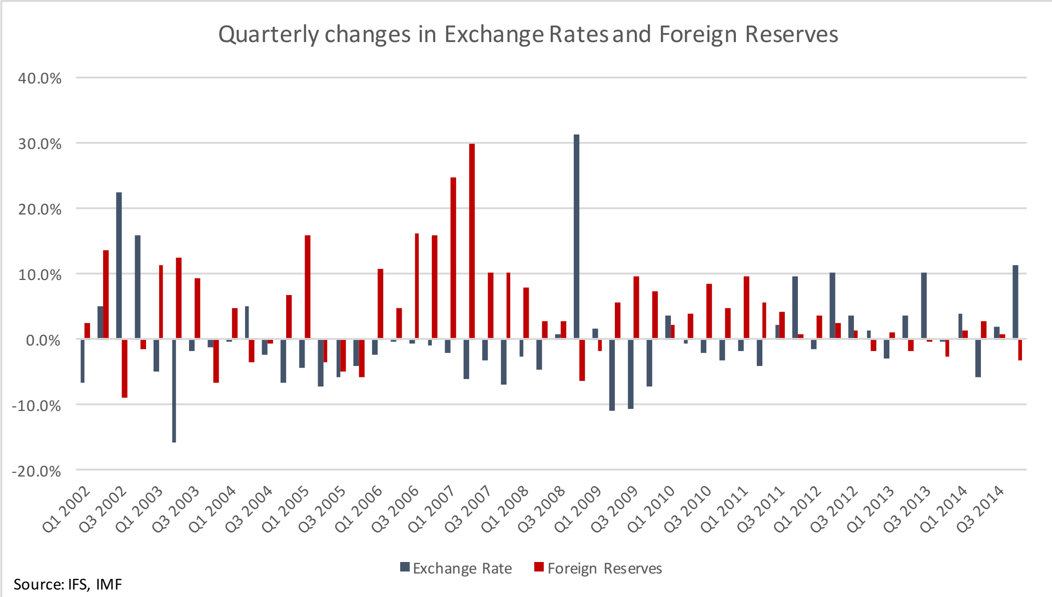

Figure 3: Log change in Exchange Rate and Foreign Reserves

The strong negative relationship between changes in the exchange rates and in foreign reserves is generically clear all over the sample, meaning that they are probably used to influence the exchange rate, even past the managed float period (Q1 2011). Such relation makes it an adequate variable to include in out measure.

An interest rate component, however, may not be an adequate inclusion in this particular model, once most changes in the short term interest rate are directed to inflation control. Moreover, as the interest rate is relatively high, including it as a policy variable for this matter could inflate the EMP measure, specially because there is no effective way of isolating interest rate changes that target the exchange rate rather than the inflation rate.

To complete this preliminary analysis we must evaluate the stance of Brazil regarding capital flows and capital controls. Brazil as most emerging economies is known to pursue protectionist policies, both by restricting international trade and by posing significant controls on the capital account to protect domestic economy. To do so, a natural first step is to analyse the composition of the financial account and the current account of Brazil:

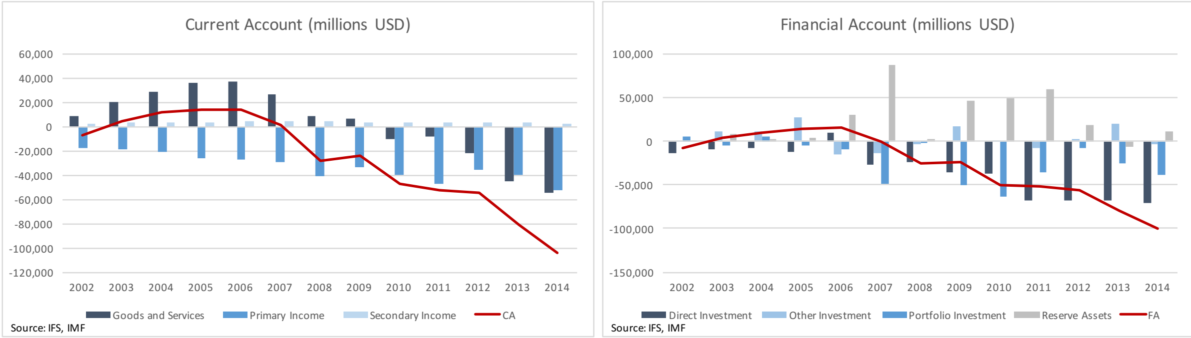

Figure 4: Current Account and Financial Account balances and composition.

Between 2003 and 2007 the current account was positive, mainly due to the figures of the goods and services components. After the domestic crisis associated with the presidential elections and the contagion from the Argentine crisis, the economy started to grow steadily[12], supported by accelerating exports and imports, generating positive trade balances. The international financial crisis of 2008 had a significant impact on growth and on net exports, leading to a strong and increasing current account deficit in the last years of the sample, due to increasing negative figures in net exports[13].

On the Financial Account side, it is clear that Brazil was a net lender between 2003 and 2006, receiving little net foreign investment. As stated before, the improving performance of the economy (and the high interest rates in Brazil) contributed to the significant increase of capital flows in 2007 (particularly portfolio investment). This inflow was suddenly reversed in aftermath of the 2008 crisis, leading to a major currency depreciation. From 2009 on, there was a very significant increase in capital inflows. Up to 2010 portfolio investment (much more volatile) dominated and from that point on there was a steady increase of direct investment (generally harder to reverse). Additionally, it is relevant to stress that 2008 is the only year with no significant increase in net foreign reserves between 2006 and 2011. This fact is certainly associated with the depreciation hike in 2008, to which the CB reacted by reducing foreign reserve holdings.[14]

[12] Average GDP growth was 4% in this period, according to the World Bank Statistics.

[13] Several studies, like Costa & Sbardellati (2012) show that the composition of Brazilian exports shifted substantially during the 2000s. Non-manufactured products represent the highest share of Brazilian exports after 2009. This fact is commonly associated with the appreciation of the currency and loss of international competitiveness.

[14] Quarterly data shows net accumulation of reserves in Q1 to Q3 of 2008, followed by a very steep net reduction in Q4 (-20 billions USD).

The strong capital inflow reversal in 2008 and the capital flows that flooded Brazil from 2009 on re-ignited the panic about capital flow volatility in the country. As a result, Brazil implemented several capital control measures between 2009 and 2012. The most common measure was the manipulation of a Financial Operations Transaction Tax (IOF acronym in Portuguese), to amplify the wedge between domestic and foreign investment. A short description of the main capital control's measures, for the sample period, is presented in the following table:

Major Capital Control Policies & Regulations, in sample period		
Mar. 2005	Loosen	Limits on FDI by nonfinancial private companies lifted.
	Loosen	CB approval on some personal capital transactions was lifted.
Sep. 2006	Loosen	Controls on transfers abroad abolished.
Oct. 2009	Tighten	IOF tax rate of 2% on equity and fixed-income PI, for non-residents.
Oct. 2010	Tighten	Increase of IOF tax to 4% (fixed-income PI and equity funds).
	Tighten	Increase of IOF tax to 6% on fixed-income investment.
	Tighten	Regulations on shifting investment from equity to fixed-income.
Jan. 2011	Tighten	Non-interest reserve requirement of 60% of bank's short dollar positions in Forex Spot Market.
Mar. 2011	Tighten	Increase of IOF tax to 6% on new foreign loans with maturities up to a year.
Apr. 2011	Tighten	6% IOF tax extendend to new and renewed foreign loans with maturities up to 2 years.
Dec. 2011	Loosen	IOF on equity and fixed income linked with infrastructure projects is eliminated.
Mar. 2012	Tighten	6% IOF extended for foreign loans with maturities up to 5 years.
	Tighten	Export advanced payment transactions with maturities of more than a year prohibited.
Jun. 2012	Loosen	6% IOF restricted to new and renewed foreign loans with maturities up to two years.
Dec. 2012	Loosen	6% IOF restricted to new and renewed foreign loans with maturities up to a year.
Jun. 2013	Loosen	Tax on fixed-income flows eliminated.

Source: Adapted from Prates & Fritz (2013) and Baba & Kokenyne (2011)

Table 1: Main Capital Control measures

This short analysis shows that Brazil is an interesting case study for our Exchange Market Pressure set up. First, it recently experienced relative exchange rate stability, in the context of a managed float regime and a float regime (starting in 2011). This stability is certainly related with better fundamentals, but the behaviour of some policy variables may signal that some relevant policy intervention occurred in this period. Clearly, the exponential increase in foreign reserves, since 2006, may be related with some exchange rate goals, either to prevent appreciation or mitigate depreciation pressure. Finally, there was a clear inversion of the capital liberalization trend started in the 1990s. The huge capital inflows from 2009 on brought new capital control measures, used to insulate domestic economic from capital volatility. In this context, an EMP measure including foreign reserves as a policy measures and reflecting the capital openness stance may provide relevant additional information.

As referred above, the span of the analysis is between the Q1 2002 until Q4 2014, in order to include three benchmark periods. First, between 2002 and 2007, when in the aftermath of a turmoiled period there is economic expansion, in a capital liberalization environment associated with currency appreciation. This growth path is interrupted by the financial crisis of 2008, leading to a second period, between 2008 and 2012. This phase is characterised by a sudden depreciation and a re-appreciation of the currency, mainly due to the massive capital inflows between 2009 and mid-2012, where capital controls were used. The final period, between mid-2012 and 2014, is a period of economic slowdown, in which capital flows seem to stabilize, capital controls are relaxed and intervention in forex market is lower.

3 Model

As referred above, in this work a typical monetary model of a small open economy will be used to derive the EMP measure, given the following assumptions:

- purchasing power parity (PPP) does not necessarily hold;
- domestic output and the foreign price level are exogenous;
- market participants observe only contemporaneous exchange and interest rates;
- well developed financial markets;
- domestic and foreign assets may not be perfect substitutes (uncovered interest parity (UIP) holds exactly only when $\lambda_t = 1$);
  - λ_t works as a proxy of capital controls, based on the wedge in the UIP being interpreted as summing up capital control restrictions;
- domestic residents hold domestic currency for transaction purposes and hold speculative balances of foreign claims.

This model is described by the following conditions:

$$m_t^d = b_{0,t} + p_t + b_{1,t}y_t + b_{2,t}i_t + v_t \tag{3}$$

$$p_t = a_{0,t} + p_t^* + a_{1,t}e_t \tag{4}$$

$$i_t - i_t^* = \lambda_t \left(E[e_{t+1}|t] - e_t\right) \tag{5}$$

$$m_t^s = m_{t-1}^s + \Delta d_t + \Delta r_t \tag{6}$$

$$\Delta r_t = -\rho_t \Delta e_t \tag{7}$$

The first equation is a standard money demand condition, where domestic demand for money depends on a time-varying intercept, the domestic price level (p_t), the exogenous output (y_t) and the interest rate (i_t), as well as on a random shock (v_t). Domestic price level evolves according to the second condition, depending on the foreign price level (p_t^*) and the exchange rate (e_t). This condition reduces to PPP if $a_{0,t} = 0$ and $a_{1,t} = 1$.

The third equation links domestic (i_t) and foreign (i_t^*) interests rates through the differential between the expected ($E[e_{t+1}|t]$) and the actual (e_t) exchange rates, weighted by λ_t. This time-varying parameter works as a capital control index in the sense that it drives a wedge between perfect substitutability between domestic and foreign goods, deviating from a perfect UIP condition whenever $\lambda_t \neq 1$. In normal circumstances we would expect λ_t to be positive, once expected depreciation of the currency (increase in the exchange rate gap), should lead to an increase in the interest rate gap (due to an increase of the domestical interest rate) to provide adequate incentive to foreign investment in the country. A negative value would be counterintuitive. However, such figures could mean the expectation system was particularly distorted, like in the event of severe unexpected shocks hitting the economy.

The fourth condition states, as usual, that changes in money supply are the result of changes in domestic credit (Δd_t) and in foreign currency reserves (Δr_t).

We assume that the changes in reserves occur only as a response to changes in the exchange rate, so the last equation is the behavioural condition explaining the evolution of foreign exchange reserves. In this sense, ρ_t works as a time-varying CB policy response parameter[15]. Note that:

- If $\rho_t = 0$ the reserves of the CB don't change in response to changes in the exchange rate, so the CB allows e_t to float freely;
- If $\rho_t = \infty$ the CB imposes a fixed exchange rate regimes by compensating any change in the exchange rate with a change in reserves;
- If $0 < \rho_t < \infty$ the CB runs an intermediate exchange rate regime.

[15] We report the time evolution of ρ for the sample period in Brazil in Annex 3. Negative values for ρ would mean reserves were varying directly with the exchange rate, signalling either movements that are not due to exchange rate goals or procyclical use of reserves.

The negative sign in this response function is intuitive: if Δe_t is positive the currency is depreciating, so the response of foreign reserves must be of the opposite sign. The CB must decrease international reserves by selling foreign reserves and buying domestic currency in forex markets.

Substituting (4) and (5) in (3) yields the money demand function specification:

$$m_t^d = a_{0,t} + b_{0,t} + p_t^* + (a_{1,t} - b_{2,t}\lambda_t)e_t + b_{1,t}y_t + b_{2,t}i_t^* + b_{2,t}\lambda_t E[e_{t+1}|t] + v_t$$

Therefore, changes in the money demand can be defined as:

$$\begin{aligned}\Delta m_t^d \equiv& m_t^d - m_{t-1}^d \\ \Leftrightarrow \Delta m_t^d =& \alpha_{0,t} + \Delta p_t^* + (a_{1,t} - b_{2,t}\lambda_t)\Delta e_t + \Delta(a_{1,t} - b_{2,t}\lambda_t)e_{t-1} + b_{1,t}\Delta y_t + \Delta b_{1,t}y_{t-1} + \\ &+ b_{2,t}\Delta i_t^* + \Delta b_{2,t}i_{t-1}^* + b_{2,t}\lambda_t \Delta E[e_{t+1}|t] + \Delta(b_{2,t}\lambda_t)E[e_t|t-1] + \Delta v_t\end{aligned}$$

where $\alpha_{0,t} = (a_{0,t} + b_{0,t}) - (a_{0,t-1} + b_{0,t-1})$. Now, assuming that the money market clears continuously, so that $m_t = m_t^d = m_t^s$ and using (7), we can derive the money market equilibrium as:

$$\begin{aligned}\Delta m_t^s =& \Delta d_t + \Delta r_t = \Delta m_t^d \\ \overset{(7)}{\Leftrightarrow} \Delta d_t - \rho_t \Delta e_t =& \alpha_{0,t} + \Delta p_t^* + (a_{1,t} - b_{2,t}\lambda_t)\Delta e_t + \Delta(a_{1,t} - b_{2,t}\lambda_t)e_{t-1} + b_{1,t}\Delta y_t + \Delta b_{1,t}y_{t-1} + \\ &+ b_{2,t}\Delta i_t^* + \Delta b_{2,t}i_{t-1}^* + b_{2,t}\lambda_t \Delta E[e_{t+1}|t] + \Delta(b_{2,t}\lambda_t)E[e_t|t-1] + \Delta v_t\end{aligned}$$

Solving for Δe_t yields:

$$\begin{aligned}-(a_{1,t} - b_{2,t}\lambda_t)\Delta e_t - \rho_t \Delta e_t =& X_t \\ \Delta e_t =& -\frac{1}{a_{1,t} - b_{2,t}\lambda_t + \rho_t} X_t\end{aligned} \tag{8}$$

where $X_t = \alpha_{0,t} + \Delta p_t^* + \Delta(a_{1,t} - b_{2,t}\lambda_t)e_{t-1} + b_{1,t}\Delta y_t + \Delta b_{1,t}y_{t-1} + b_{2,t}\Delta i_t^* + \Delta b_{2,t}i_{t-1}^* + b_{2,t}\lambda_t \Delta E[e_{t+1}|t] + \Delta(b_{2,t}\lambda_t)E[e_t|t-1] + \Delta v_t - \Delta d_t$.

Using the general definition and the measure of EMP proposed by Weymark (1995), the EMP index can be calculated from:

$$EMP_t = \Delta e_t + \eta_t \Delta r_t$$

As shown above, η_t is a conversion coefficient that aims at converting Δr_t into the corresponding comparable Δe_t units. This coefficient can be obtained from (8), considering that $\Delta r_t = -\rho_t \Delta e_t$:

$$\begin{aligned} & -(a_{1,t} - b_{2,t}\lambda_t)\Delta e_t - \rho_t \Delta e_t = X_t \\ & \Leftrightarrow -(a_{1,t} - b_{2,t}\lambda_t)\Delta e_t + \Delta r_t = X_t \\ & \qquad \Leftrightarrow \Delta e_t = -\frac{1}{(a_{1,t} - b_{2,t}\lambda_t)}[X_t - \Delta r_t] \end{aligned} \tag{9}$$

According to Weymark η_t corresponds to the symmetric of the marginal effects that changes in reserves have on changes in the exchange rate:

$$\eta_t = -\frac{d\Delta e_t}{d\Delta r_t} = -\left[\frac{\partial \Delta e_t}{\partial X_t} \cdot \frac{dX_t}{d\Delta r_t} + \frac{\partial \Delta e_t}{\partial \Delta r_t} \cdot \frac{d\Delta r_t}{d\Delta r_t}\right]$$

The channels through which reserves can affect the exchange rates are represented by the derivatives in the last equality. First, there is an effect indirect effect: whenever changes in reserves affect other variables, that in turn affect exchange rate changes. The second effect is a direct one, that is nay impact that changes in reserves have directly over the changes in the exchange rates. Given the model specification assumed above, the effect of changes in reserves in any variable contained in X_t is equal to zero, hence:

$$\eta_t = -\left[\frac{\partial \Delta e_t}{\partial X_t} \cdot 0 + \frac{\partial \Delta e_t}{\partial \Delta r_t} \cdot \frac{d\Delta r_t}{d\Delta r_t}\right] = -\frac{1}{a_{1,t} - b_{2,t}\lambda_t} = -\omega_t \tag{10}$$

Where ω_t is the sensitivity of changes in the exchange rate with respect to changes in the reserves, and η_t is this elasticity associated with a negative sign deriving from the definition of EMP. The associated index is given by:

$$EMP_t = \Delta e_t - \frac{1}{a_{1,t} - b_{2,t}\lambda_t}\Delta r_t \tag{11}$$

Which depends positively on the changes in the exchange rates and negatively on the changes in foreign reserves. The reserves' component enters the measure with a model specific weight, depending on:

- $a_{1,t}$, the parameter that measures the sensitivity of domestic price level to the exchange rate (from equation (3));
- $b_{2,t}$, the interest rate semi-elasticity of money demand (from equation (2));
- λ_t, the capital control proxy.

Naturally to compute the measure suggested these coefficients must be estimated for any economy one wishes to study.

From a purely numeric perspective a comparison of the index derived here and the one obtained by Weymark is straightforward. Recalling that Weymark (1995) index is given by:

$$EMP_t^W = \Delta e_t - \frac{1}{a_{1,t} - b_{2,t}} \Delta r_t \tag{12}$$

it is easy to observe that the presence of the capital control index will imply an over or under estimation of EMP_t^W, whenever $\lambda_t \neq 1$.

4 Estimation Results

The EMP measure proposed in Section 3 requires that some structural parameters are estimated. Recall equation (11), to compute it we need to estimate $a_{1,t}$, $b_{2,t}$ and λ_t. These estimates will be derived from the following equations:

$$m_t^d - p_t = b_{0,t} + b_{1,t} y_t + b_{2,t} i_t + v_t \qquad \text{(money condition)}$$

$$p_t - p_t^* = a_{0,t} + a_{1,t} e_t + u_t \qquad \text{(pricing condition)}$$

$$i_t - i_t^* = \lambda_t \left(E[e_{t+1}|t] - e_t \right) + w_t \qquad \text{(interest rate condition)}$$

In this work the structural parameter estimation is done using the Time-Varying Coefficient method (TVC)[16], following Hall, Kenjegaliev, Swamy & Tavlas (2013).

Previous model dependent studies on EMP measures have used two-stage least squares methods to compute structural parameters, in order to account for simultaneity and endogeneity issues. However, such estimators may be inconsistent once the model specification may yield incorrect functional forms and neglect important explanatory variables. Hall *et al.* (2013) used the TVC method to estimate model dependent coefficients incorporated in their EMP measure. Moreover, to understand changes in policy responses over a large time span, time varying parameters could provide additional relevant information.

According to Swamy and Mehta (1975) and Granger (2008), any nonlinear functional form can be exactly represented by a linear model, if the coefficients of the explanatory variables are allowed to vary across time. Therefore, by allowing time variability of coefficients any relationship between a dependent and some independent variables can be estimated in a linear way, even if the correct functional form is unknown. Based on this theorem, and with a complete set of explanatory variables (with no measurement error), consistent estimates of the true partial derivatives of the explained variable with respect to the regressors can be obtained with a TVC method. However, if the set of independent variables is not complete (and it is likely not to be in any parsimonious model) or any measurement error is present the estimates become biased. The TVC method proposed by Swamy, Tavlas, Hall & Hondroyiannis (2010) can then be used to decompose the estimates, by identifying the bias part that can be subtracted to the total estimates to yield an unbiased and consistent estimator.

According to the authors, the use of this method implies two parametric assumptions. First, TVCs are assumed to be determined by stochatic equations, so they are functions of some exogenous regressors (defined as coefficient-drivers). Additionally, so that the relationship can be represented by TVCs and the decomposition between the biased and the unbiased part can occur, some of these drivers are considered to be correlated with the time variation of the non-linear functional form and others with the misspecification biases (omitted variables and measurement errors).

[16]In a state space model set up, in Eviews.

The cumbersome part of this procedure is precisely the choice of the coefficient-drivers. Hall, Swamy & Tavlas (2014) provided some guidelines to the selection and split of this variables into two subsets, so that the coefficient decomposition is possible. Broadly, the set of drivers should be related with predictive power and relevance. Increasing the predictive power could be guaranteed by including a large set of coefficient drivers, however for relevance purposes drivers coefficients should also be significantly different from zero. Predictive power can be assessed with an analogue[17] of the conventional R^2, while relevance can be evaluated by standard t-tests, as the full TVC method produces a covariance matrix for all the driver's estimated coefficients.

With a set of drivers defined, the spilt of these variables in two sets should be done according to the correlation with the unbiased coefficient and the drivers correlated with the misspecification. In practical terms, some drivers should be explicitly selected to capture the nonlinearity, while all the others are assumed to be correlated with the misspecification, which leads to the bias of the structural parameters estimation.

In the following section we present and interpret the results of the parameter estimation, as well the EMP measures resulting from it. All the data is obtained from the IMF-IFS database, the exception are two series: the exchange rate expectations obtained from *Banco Central do Brasil* and EMBI+ from IBGE[18].

4.1 Coefficient estimates

To get a better understanding about the relationship between the variables expressed in the conditions referred we first estimate the benchmark relationship using OLS both in levels and in first differences. The results are presented in the tables below.

[17] $\tilde{R}^2 = 1 - \frac{\sum_t(\varepsilon_t - \bar{\varepsilon})^2}{\sum_t(y_t - \bar{y})^2}$, where ε_t are the residuals and y_t the explanatory variable.

[18] *Instituto Brasileiro de Geografia e Estatística*

A. OLS estimates in levels									
Interest Condition	λ_0	λ_1	**Money Condition**	b_0	b_1	b_2	**Price Condition**	a_0	a_1
Coefficients	0,1201***	0,0706	**Coefficients**	-10,5402***	1,2991***	-2,6544***	**Coefficients**	0,1797***	-0,2994***
Standard Errors	0,0062	0,1047	**Standard Errors**	2,9719	0,0460	0,3664	**Standard Errors**	0,0589	0,0724
Adjusted R-squared	-0,0108		Adjusted R-squared	0,9426			Adjusted R-squared	0,2399	
Equation: $(i_t - i_t^*) = \lambda_0 + \lambda_1[(E(e_{t+1}\|e_t) - e_t] + \varepsilon_t$			Equation: $(m_t - p_t) = b_0 + b_1 y_t + b_2 i_t + \varepsilon_t$				Equation: $(p_t - p_t^*) = a_0 + a_1 e_t + \varepsilon_t$		

B. OLS estimates in first differences									
Interest Condition	λ_0	λ_1	**Money Condition**	b_0	b_1	b_2	**Price Condition**	a_0	a_1
Coefficients	-0,0012	0,0171	**Coefficients**	0,0135***	0,8805***	-0,1214	**Coefficients**	0,0099***	0,0562***
Standard Errors	0,0022	0,0317	**Standard Errors**	0,0035	0,0441	0,2490	**Standard Errors**	0,0015	0,0186
Adjusted R-squared	-0,0144		Adjusted R-squared	0,8947			Adjusted R-squared	0,1372	
Equation: $\Delta(i_t - i_t^*) = \lambda_0 + \lambda_1\Delta[(E(e_{t+1}\|e_t) - e_t] + \varepsilon_t$			Equation: $\Delta(m_t - p_t) = b_0 + b_1\Delta y_t + b_2\Delta i_t + \varepsilon_t$				Equation: $\Delta(p_t - p_t^*) = a_0 + a_1\Delta e_t + \varepsilon_t$		

Table 2: OLS estimates: (A) in levels (B) in first differences

Panel A presents the results of the baseline OLS regression in levels. For the money equation, the estimates have the expected sign. There is a positive relationship between output and the deflated money demand and a negative and strong relationship between the short term interest rate and the deflated money demand. The adjusted R^2 is near one, however this could be the result of a spurious regression due to the usual nonstarionarity issues. In the price equation the results are less robust: the exchange rate coefficient does not have the expected sign and the adjusted R^2 is relatively low. This suggests that the gap between domestic price level and foreign price level (here proxied by US CPI) cannot be satisfactorily explained by changes in the price of the Brazilian currency relative to the US dollar. The interest condition, that links the interest rate gap[19] and the exchange rate gap (between the expected exchange rate[20], at $t+1$, and the current observed exchange rate, at t), shows that the effect of the exchange rate gap is small and not statistically significant. Moreover, the explanatory power of the exchange rate gap seems to be small, suggesting that other variables should be included to explain the interest rate gap. Panel B present the results for the same equations when all the variables are in first differences, generically the relationships are weaker than in levels (lower explanatory power, smaller coefficients and lower statistical significance).

Our next step is to use the TVC approach to estimate the same elasticities. The estimation results presented in Table 3 were obtained using a set of coefficient drivers to estimate three signal equations based on seven state equations, the actual equations are presented in Annex 4.

[19]Between Brazil's short term interest rate and the US 3-month Treasury Bill.

[20]Here referring to the exchange rate expectation of the following quarter, based on the information available in the first days of the previous three months, forecasted by *Banco Central do Brasil*.

As state in the previous section, the selection of the coefficient drivers aims at capturing both non-linearities of the functional form and biases arising from omitted variables. In general terms, to capture non-linearities we include in each state equation the regressor for which we are trying to compute the TVC, in such specification that term reflects a simple non-linearity (quadratic) in the functional form, as proposed by Swamy *et al.* (2014). To capture bias from omitted variables we use an extensive set of variables[21]: exports and import values, net exports, an EMBI+ index of risk for Brazil[22], the index of industrial production, the BOVESPA index (Stock index of São Paulo), inflation, terms of trade index and nominal and real effective exchange rates. The selection of these variables is made by evaluating its statistical significance in each equation.[23] The final variables included in each equation are also presented in Annex 4.

After estimating what we call the total effect of the variable, we must split the coefficients into the unbiased and the biased part, once only the unbiased part represents the true partial derivative of a given dependent variable with respect to a specific regressor. Following Hall *et al.* (2014), the decomposition is clear: to get the unbiased estimate we need to subtract to the total coefficient the effect from the omitted variables, as well as the error term of the respective state equation. This decomposition is only done for the elasticities that matter for EMP calculation ($a_{1,t}$, $b_{2,t}$ and $\lambda_{1,t}$), that are highlighted in bold in the following table.

TVC estimates period averages

Interest Condition	λ_0	λ_1
Total effects		
Coefficients Av.	0,1139***	-0,0396***
Root MSE	0,0111	NA
Bias-free effects		
Coefficients Av.	-	**0,6318**
Equation: $(i_t - i_t^*) = \lambda_0 + \lambda_1[(E(e_{t+1}\|e_t) - e_t] + \varepsilon_t$		
R-squared analog	-	0,1501

Money Condition	b_0	b_1	b_2
Total effects			
Coefficients Av.	4,0403***	0,73336***	-2,4673***
Root MSE	0,0000	0,0021	0,0984
Bias-free effects			
Coefficients Av.	-	-	**-1,1879**
Equation: $(m_t - p_t) = b_0 + b_1 y_t + b_2 i_t + \varepsilon_t$			
R-squared analog	-	-	0,4358

Price Condition	a_0	a_1
Total effects		
Coefficients Av.	-0,0393***	0,2505***
Root MSE	0,0078	0,0111
Bias-free effects		
Coefficients	-	**1,0019**
Equation: $(p_t - p_t^*) = a_0 + a_1 e_t + \varepsilon_t$		
R-squared analog	-	0,8280

Table 3: Time Varying Coefficients estimates, sample averages.

For the money and the price conditions, all the coefficients have the expected sign, both in

[21]In levels and changes, for both contemporaneous and lagged values. Nominal values were converted to real values when appropriate and seasonal adjustments were performed using Eviews toolkit.

[22]The Emerging Markets Bond Index (EMBI+) is constructed by JPMorgan to assess the risk of investing in emerging economies, namely Brazil, on a daily basis. The idea is to proxy a risk measure for countries that don't issue debt in a regular manner, by evaluating the spread of the return on a portfolio of external debt instruments (foreign currency denominated fixed-income) in a country versus the comparable return for investment in risk-free assets (generally US bonds).

[23]We estimate the model with all the variables, in all equations, in a first step. Then the model is estimated again only with the statistical significant variables, with the exception of the intersepts that are kept even if the not significant.

terms of total and bias-free effects. The relevant bias-free estimates are, on average, -1.19 (b_2) and 1.00 (a_1). Regarding the interest condition and the capital control proxy, the total effect is significant, but weak. Besides it is negative which, as discussed before, is not the expected sign. The bias-free estimate, on the other hand, is positive and quite different from 1 (0.63), indicating that capital controls were present across the sample[24].

The average conversion factor, ω_t as defined in equation (10), for the EMP measure based on these estimates is:

	With Capital Controls	Without Capital Controls
TVC Average (Unb)	0,5706	0,4567

Table 4: Conversion factors

The conversion factors are relatively small, but have the expected sign (ω_t is expected to be positive, so that η_t is negative). Actually, the average conversion factor is relatively higher due to the inclusion of the capital controls parameter, which might indicate that capital controls could inflate the power of the foreign reserves in affecting the exchange rate.

To close this section we present the time-varying unbiased estimates of the elasticities used to compute the time-varying EMP measure that we present in the next section:

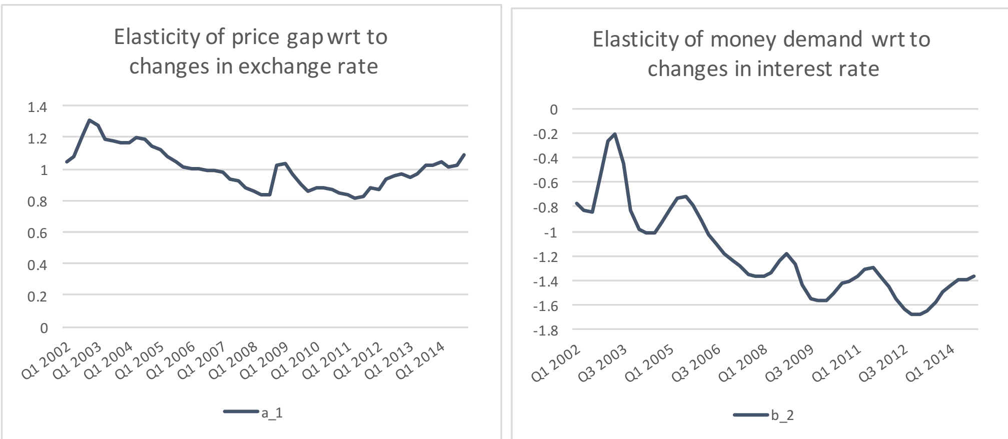

Figure 5: Time-Varying Coefficients: $a_{2,t}$ and $b_{2,t}$

The graph on the left shows that the relation between the price gap and the exchange rate is

[24] Recall that we assumed that if no capital controls existed, then the uncovered interest parity holds and $\lambda = 1$

steadily positive as theory suggests, the time variation shows a downward trend (only interrupted by the crises of 2002/2003 and 2008), that we may associate with the steady decline of the inflation rate in Brazil (following the interest rate stabilization observed in this period). The elasticity of the money demand with the interest rate, on the right, is increasingly negative across all the sample, as we could expect in an economy with a well developed financial system, in which the interest rate is substantially high due to inflation targeting goals.

Finally, the uncovered interest parity imbalance (the proxy for capital controls) shows very high volatility, as shown below by the blue line.

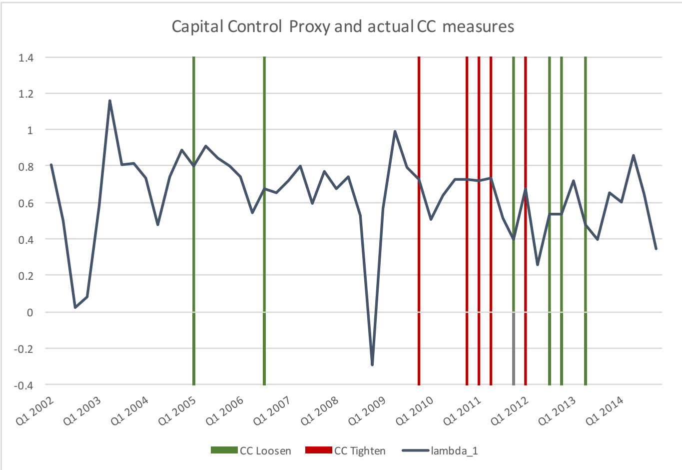

Figure 6: Time-Varying capital control proxy and discretionary capital flow regulations.

The peaks are associated with periods of very steep depreciation or appreciation pressure. In such periods, the process of generating expectations may be weakened due to unantecipated shocks hitting the economy. As discussed in section 2.2, in 2002 and 2008 the economy was affected by the most significant crises in the sample period. Overall, our endogenous measure of capital controls captures relatively well the time evolution of the capital flows management policy. From 2003 to 2007, a period of capital liberalization, the proxy average is 0,75, while the average for 2009 to 2012, when capital market restrictions increased, is 0,61. Although the difference is not major, this index seems to reflect the time variability of the policies, as the average in the capital liberalization period is closer to 1.

In order to have a more detailed idea about the accuracy of the measure, we add vertical lines to graph 6, illustrating the main discretionary policy measures regarding capital flows presented in Table 1. We get a reasonably good fit. Green vertical lines represent loosening capital control measures, in most cases the implementation of the measure is followed by an upward movement in the parameter in the next period or, at most, two periods ahead. This upward movement means an approximation towards 1, the political stance with no capital controls. Tightening measures are represented in red. In this case results are better, once the response is more consistent. After the establishment of measure there is a downward movement of the parameter, generally in the following period.

With these reasonable and consistent time-varying estimates we move to the next section, where we compute the EMP measure.

4.2 EMP measure

Using the estimates of $a_{1,t}$, $b_{2,t}$ and λ_t from the previous section, we can calculate the Exchange Market Pressure, as defined in equation (11), with a time-varying coefficient conversion factor that includes the capital control proxy. To illustrate the gains of such inclusion, we also show the corresponding measure with no capital controls (as defined in equation (12)):

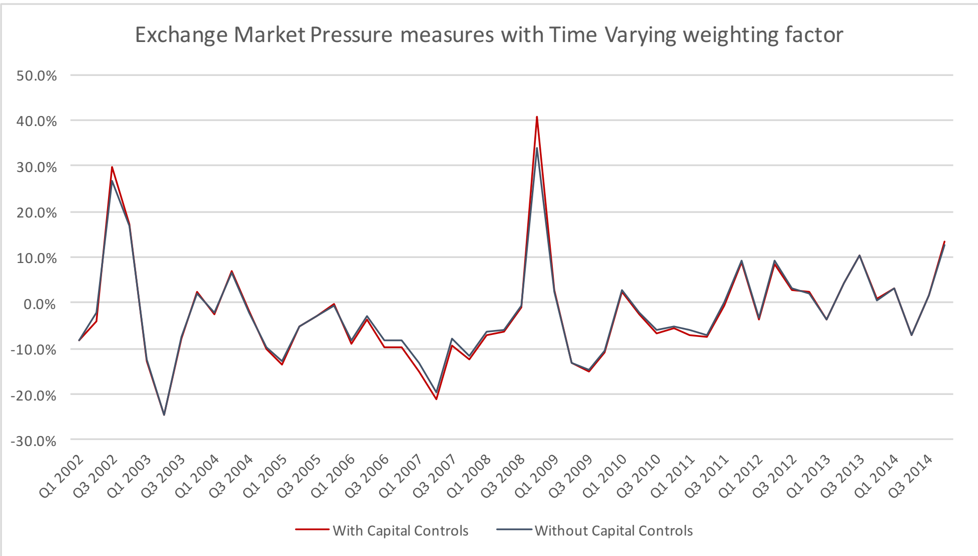

Figure 7: EMP with time varying conversion factor, with and without capital controls.

Clearly the measures capture significant currency pressure. A comparison with the actual contemporaneous exchange rate change picks up two major periods of policy intervention, aside from the crises periods. Between 2003 and 2007 the central bank actively and extensively used reserves to prevent further appreciation of the currency (EMP is negative). Then, between 2009 and 2011, the CB acted again to prevent further appreciation of the currency in the response to the huge capital inflows entering the Brazilian economy after the 2008 crisis. During this second period the amount of reserves used was smaller. Finally, after 20011 most of the depreciation pressure revealed by the EMP index is relieved directly by exchange rate changes, signalling lower CB intervention as one would expect in a pure float exchange rate regime.

The encouraging results described so far show, however, very little relevance in the inclusion of the capital control proxy. In reality, the two measures yield virtually the same results, with the only exception being crises periods. The measure that includes the capital control proxy picks up a slightly higher pressure (measure with capital controls is presented by the red line) in those periods. These results are somehow expected once the capital control proxy is only inflating or deflating the power of reserves in dampening exchange rate movements, as it enters the model only as a component of the weighting factor. However, we could expect higher (more significant) differences in the actual measure, if reserve movements were higher, or if the capital control measures were more severe, creating a wider gap in the interest parity.

On the other hand, as the capital control measures were actively in place, it might be the case that the actual change in reserves needed to attain a given exchange rate goal was influenced by an inflated power of reserves in wedging of pressure, due to the presence of increasing capital controls between 2009 and 2012. To assess such claim we can verify the time evolution of the conversion factor itself (ω_t):

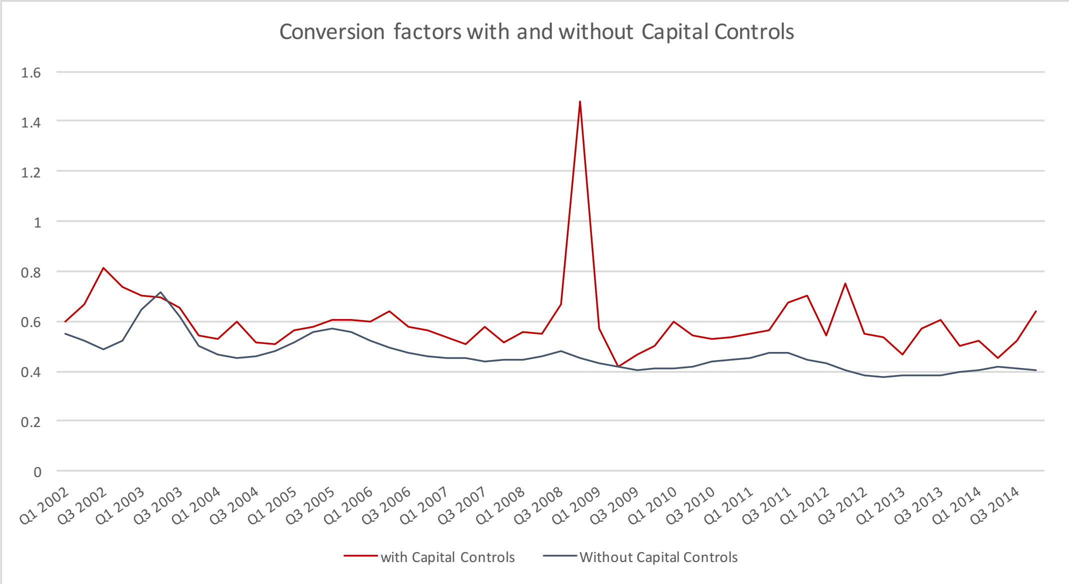

Figure 8: Conversion factor with and without capital controls.

We can see that the inclusion of a capital control proxy in the conversion factor inflates substantially the power of reserves in the EMP measure. Excluding the 2002 and the 2008 peak, we see that the two conversion factors are closer between 2003 to 2007, than between 2009 and 2012. This is consistent with our previous claim. With more severe capital control measures we could expect the gap between the conversion factors to widen and therefore a most significant impact in the EMP measure.

Overall, it is plausible to conclude that policy-makers could see these results as indication that capital controls may actually be an adequate policy measure to dampen some exchange rate volatility, used in conjunction to changes in foreign reserves. We showed that capital control restrictions may be an amplifying tool, increasing foreign reserves power and efficiency for exchange rate management purposes. Naturally further study is encouraged to develop a better understanding of which kinds of capital controls are more suitable to this effect, as well as to understand the most adequate timings to implement them in order to magnify efficiency of reserves. It would also be interesting to replicate the analysis in this framework to other countries to verify the consistency of these results in other contexts.

5 Conclusions

The definition of adequate monetary policies is a complex task, particularly in an open economy set up. The impossible trinity states precisely that an independent monetary policy, open capital markets and exchange rate stability can't be attained simultaneously. This problem is specially relevant for emerging countries, which are generally more affected by fluctuations in the international economic environment.

In this context, emerging countries tend to defend their monetary policy autonomy by restricting capital flows or inducing currency stability using intervention over the foreign exchange market. Whenever central authorities maintain the currency artificially over or undervalued, a measure of the actual pressure affecting the currency is needed. The Exchange Market Pressure Index was first developed by Girton & Roper (1977) to this effect. In this work we focus on the role of capital controls in inducing currency stability via the most typical policy intervention tool in the forex marker, foreign reserves, and its adequate incorporation in an EMP measure.

The inclusion of capital controls in any numerical model is affected by a measurement problem: with a very broad scope of policy instruments quantifying the overall restrictions in capital mobility in a country is a very demanding process. We contribute to the literature by developing an endogenous proxy of capital controls nested in simple small open economy model, applied to the Brazilian economy.

Brazil encompasses several suitable characteristics that make it an interesting empirical application for this work, we find out that between 2002 and 2014 it experienced a relative stabilization of the exchange rate and we question if that stability was policy induced. In fact, Brazil increased substantially its foreign reserve holdings after 2006 and capital openness decreased after the 2008 crisis, as a response to the huge capital inflows from the developed world.

Using a time-varying coefficient method we estimate structural parameters for the Brazilian economy, used to compute the EMP measure. We find out evidence of appreciation pressure being wedged of in two different periods. First, between 2003 and 2007, in a context of a capital liberalization process and second, between 2009 and 2012, in a context of increasing restriction of capital mobility. This last period is particularly relevant due to the conjunction of direct intervention over the forex and the increase in capital controls. Although we don't evaluate capital controls effects directly over the exchange rate, we find evidence that they can amplify the power of foreign reserve changes in relieving currency pressure.

Our results could be interesting to the policy-maker, as they suggest a broader framework to monetary policy design. In fact, the adequate use of capital controls may ease forex intervention and require fewer amount of reserves to attain a particular exchange rate goal. Naturally this work is not a complete addition to the policy-maker information set, as further developments could clarify relevant questions. Namely, which capital control policies work best for each exchange rate goal. More detailed study about asymmetric effects might also be relevant: do capital outflows or inflows restrictions have similar impacts? should the policy response differ in appreciation and depreciation episodes? Empirical studies with higher frequency data could also pinpoint other relevant details, like the most adequate timing to conjugate the two policy instruments to attain the best possible outcome.

Naturally this study could be even more relevant for Brazilian policy-makers. In 2015 the Brazilian economy started to plunge, as GDP declined, inflation rose and the exchange rate depreciated fast. Soon policy-makers may actually be forced to intervene to avoid a major crisis and they may wish to consider a forex policy intervention that requires fewer accumulation of foreign reserves.

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Annexes

Annex 1 - Literature Review

After the initial definition and measure developed by Girton & Roper (1977), the literature expanded essentially in two branches: computing the EMP measure in a model dependent manner or in a model free way. There are some basic trade-offs between those two branches: any measure that is model independent is easier to compute but might perform worst when applied to specific country, on the other hand a model specific measure could be expected to be more accurate when providing information about the pressure on a specific economy but it is much harder to apply once generally structural parameters for the economy must be estimated first. This work focuses on a model dependent measure but eventually some model dependent measures are going to be calculated for comparative purposes. In what follows a brief detour of the main works done in this subject are presented. To avoid a very extensive review, this section discussion will include only the works that contributed the most to the theoretical debate about the EMP determination, many other important works were developed, focusing specially on the empirical applications of the measure. A list of these works is provided in the end of this section and the respective references are included in the dedicated chapter.

The concept of EMP was first defined by Girton & Roper. Using a monetary model and the asset market approach to exchange rate determination, the authors first derive the first model dependent measure of EMP as:

$$EMP_t = \Delta e_t + \Delta r_t \tag{13}$$

For Girton and Roper EMP was a measure of the intervention necessary to achieve a specified exchange rate goal. To test their measure, the authors develop an empirical application for the case of the post war Canadian dollar, calculating the EMP against the US dollar. Based on the results, an appreciation of CB intervention was done and, more broadly, an evaluation of monetary policy independence in the context of an open economy was performed.

In 1995, 1997 and 1998 Weymark develops a series of works with the goal of generalizing and clarifying the EMP concept and measure. In fact, it is Weymark who formally defines EMP in a model independent fashion. Her definition departs in two ways of the one provided by Girton and Roper. First, Weymark defines EMP as the excess demand for domestic currency in international markets, rather than in domestic markets, which allows the concept to be applied to monetary models of exchange rate determination as well as to other determination approaches. Additionally, she clarifies that the measure of excess demand for currency must be associated with the expectations about the exchange rate policy in place, rather than the one obtained based on a comparison of the external imbalance that would have occurred with a free floating exchange rate regime.

Based on this model independent definition, and using a small open economy monetary model with rational expectations, Weymark suggests a measure for this index:

$$EMP_t = \Delta e_t + \eta \Delta r_t \tag{14}$$

where $\eta = -\partial \Delta r_t / \partial \Delta e_t$, obtained from the exchange rate determination condition, is a model specific conversion factor that allows the disparate units in which Δe_t and $\Delta r_t'$ are measured to be combined. It's actual value will depend on the model specification chosen. In the standard small open economy model used by Weymark $\eta = (a_2 + b_2)^{-1}$, where a_2 is the sensitivity of domestic prices to changes in forex reserves and b_2 is the semi-elasticity of the mony demand to changes in the interest rates. With this definition the author derives a Central Bank intervention index applied to the Canadian economy.

Another important work in this domain was one developed by Eichengreen, Rose and Wyplosz in 1995, in the context of currency crises analysis. ERW argue that EMP could be used as a good index to evaluate the likelihood of a given economy being vulnerable to a currency crises, once it informs about the under or over-evaluation of currencies following official intervention. Stressing that most models of exchange rate determination perform poorly (specially in the short and medium run), ERW develop a model independent measure of EMP:

$$EMP_t = \Delta e_t + \eta_r \Delta r_t + \eta_i \Delta i_t \tag{15}$$

This index is model independent both in the variables included and on the weighting scheme used so that all the components are expressed in comparable units. ERW choose to include a foreign reserves component and an interest rate component in their measure based on the fact that these are the instruments usually used by the central authority to influence the observed exchange rate: changes in reserves work as a direct intervention mechanism, while changes in the policy interest rate work as indirect intervention. This conclusion is based on the analysis of Central Bank actions rather than on a monetary model. Recognizing that the unit of measurement of changes in reserves and changes in interest rates may be substantially different than the units in which changes in the exchange rate are measured, ERW propose a simple way of correcting for these different dimensions: defining the weights as a ratio of standard deviations.

$$\eta_i = \frac{std(\Delta i_t)}{std(\Delta e_t)} \qquad \eta_r = -\frac{std(\Delta r_t)}{std(\Delta e_t)} \tag{16}$$

With the weights set in this way, all the variables have the same conditional volatilities and so they can be added up to form the measure. Note that the negative sign on the reserves component is justified by the expected effect of changes in this variable: an increase in foreign reserves means that the supply of domestic currency in foreign markets increases, which will in principle increase the exchange rate, making domestic currency cheaper than it would be without intervention which indicates that a downward Exchange market pressure is being done.

In 1999 Spolander developed a model dependent measure of EMP (and Central Bank intervention) that reflects that most Central Bank interventions on the foreign exchange market are sterilized via domestic market operations,so that they have no impact over the domestic money market and the interest rate. The respective measure is given by:

$$EMP_t = \Delta e_t + \eta^d (1 - \zeta) \Delta r_t \tag{17}$$

where η^d is the negative of the elasticity of the change in the exchange rate with respect to changes in the monetary base (which works as a structural parameter, depending on the specifications of the economy being modelled) and ζ is an index of sterilization that reflects the portion of reserve changes that were actually sterilized. The author then performs an empirical investigation about the Finnish economy calculating the degree of sterilisation of official interventions and the EMP measure, as well as the respective intervention index.

Klassen and Jager (2011) further develop the literature by reckoning that generally policy instruments are used for more than one goal and ideally any EMP measure should consider this fact: not all changes in policy interest rates, for instance, are performed to affect the exchange rate. In this sense the authors defend that there is a domestically desired set of variables (called counterfactual variables) that would be set independently from any exchange rate goal. Therefore only the gap between these theoretical domestically desired variables and the actual variables should be included in the EMP measure:

$$EMP_t = e_t^c - e_{t-1} \tag{18}$$

Which opposes to previous literature, that defined the pressure as resulting from wedges between current value and lagged value of the variables. Departing from a monetary model set up, the authors proceed and provide an explicit EMP measure using a less demanding set of assumptions[25]:

$$EMP_t = \Delta e_t + \eta_i(i_t - i_t^d) + \eta_c \Delta c_t \tag{19}$$

In this definition Klassen and Jager (2011) include both an interest rate component and a reserves' components: c_t stands for the change in reserves scaled by the monetary base, while the interest rates enter and as the gap between actual rate and the domestically desired rate (that can be proxied by a simple Taylor rule, or by the policy interest rate of a reference country like the US, whose monetary policy is believed to be independent). The weights of the components in the measure, η_i and η_c are computed in the spirit of ERW, so that conditional volatilities are equalized. The main difference in this measure is, however, the fact that interest rates enter in levels: the authors defend that facing a currency pressure that must be wedged off for several periods the Central Bank could raise the interest rate and keep it in that high level

[25]The authors argue that exchange rate determination models have poor predictive power, and therefore a less demanding (opposed to one derived from a monetary model) measure is desirable, specially for empirical applications.

while the pressure is still perceived, in such case lagged changes of interest rate would reveal no intervention (because there was no actual change across periods). By including the interest rate in levels authors make sure that such kind of policy intervention is captured in the measure as long as it occurs. Then, to empirically test the validity of their measure, Klassen and Jagger apply their approach to the Exchange Rate Mechanism crisis of the European Monetary System as well as to the Asian Crisis.

Aside from the works presented above, it is important to refer that other relevant empirical investigations on EMP were performed: Connolly and Dantas da Silveira (1979) computed EMP for Brazil; Modeste (1981) tested the EMP measure for Argentina; Kim (1985) adapted the model to the South Korean reality; Pentecost et al (2001) estimated the EMP of German Mark in five members of the European exchange rate mechanism; Stavarek (2007) computed EMP for Czech Republic, Hungary, Slovakia and Poland; Macedo, Pereira and Reis (2008) calculated the Exchange Market Pressure for five african countries members of CPLP[26]; Lopes and Santos (2010) evaluated the financial credibility of West and South African Countries, Hall et al. (2013) estimated the currency pressure for the UK, China and Japan and Franco, Delgado, Monteiro& Silva (2015) estimated an EMP model for Angola.

[26] Community Portuguese-speaking Countries

Annex 2 - Brazil and the Chinn-Ito Index.

A broader view about the stance of Brazil in terms of capital closedness (both across time and relative to the other countries policies) can be illustrated by the Chinn-Ito Index, presented below.

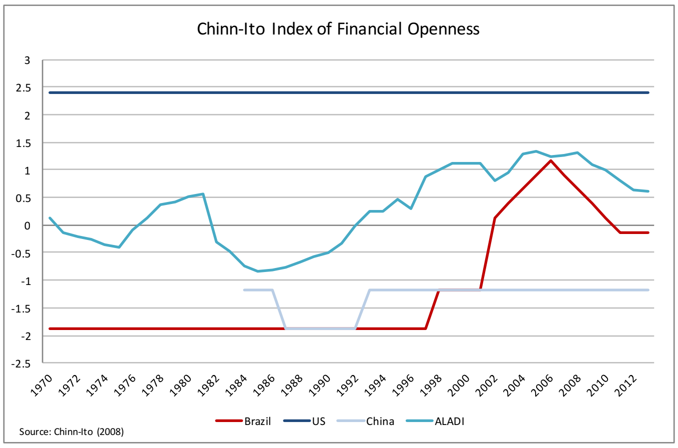

Figure 9: Chinn-Ito Financial Openness Index

As explained this index has, by construction, zero mean with higher values being associated with higher financial openness and so fewer capital controls. Although this index is not subject to direct incorporation in an EMP measure, it provides important information about the evolution of capital control measures relative to the other countries in the sample.

The dark blue line reports the index for the US, the country with lowest level of capital controls in comparative terms. The light blue line represents China, a country that extensively uses capital controls (with an average index value of -1.33, across the sample).

Brazil's results are shown by the red line. Across the sample Brazil has shown low financial openness (the average performance is -1.20). Contrasting with a period of higher financial liberalization, between 1998 and 2006, the following years evidence a tighter control over capital flows. These figures are specially relevant when compared with the simple average of the ALADI[27] countries indices, excluding Cuba (for which data wasn't available) and Brazil. These countries show higher financial openness than Brazil (with a sample average of 0.31). Therefore, even comparing with other Latin-American countries, Brazil relies heavily on capital controls.

[27]Latin-American Integration Association - Argentine, Bolivia, Brazil, Chile, Colombia, Cuba, Ecuador, Mexico, Panama, Paraguay, Peru, Uruguay and Venezuela.

Annex 3 - Time-Variant response of CB to exchange rate changes

In the spirit of Hall *et al.* (2013), a measure of the degree of intervention in the forex market can be derived from the response function of the Central. Condition (7) is the response function of the Central Bank that relates the exchange rate changes with the changes in foreign reserves. In this equation, ρ is the elasticity of exchange rate change with respect to changes in foreign reserves. Hence it can be interpreted as the extension to which changes in reserves are used to respond to changes in the exchange rate.

To estimate ρ we will use a five period centred moving average (with equal weighting scheme) of the ratio of reserves and exchange rate changes, that is:

$$\rho_t \approx -\frac{\Delta r_t}{\Delta e_t}$$

The reason for the moving average is to filter any variations in external reserves related with current transactions with the rest of the world. These changes are not targeting exchange rate and should not be considered. The time variation of ρ is presented below:

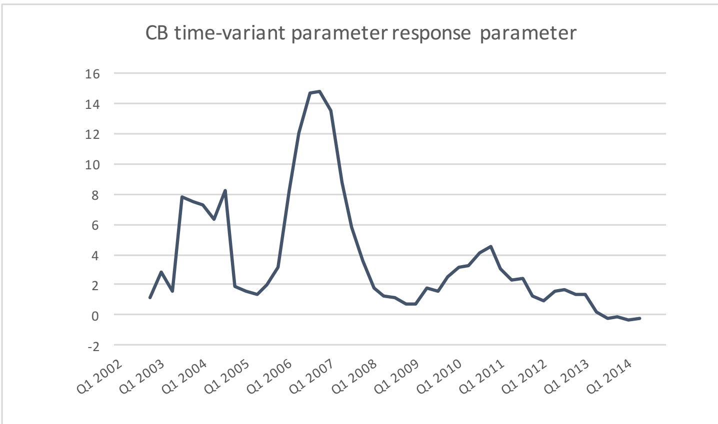

Figure 10: Elasticity of exchange rate changes to changes in foreign reserves.

Until 2011 reserves were highly sensitive to changes in the exchange rate. This is the period of the managed float, where Brazil extensively used reserves to dampen exchange rate fluctuations. The end of the sample ρ becomes negative meaning that reserve changes were not associated with exchange rate changes, which is consistent with the float exchange rate regime classification. Both observations are consistent with the results presented so far.

Annex 4 - Variables and TVC estimation description

Interest Condition Estimation

Equations:

$$Signal:$$

$$intgap_t = \lambda_{0,t} + \lambda_{1,t}exgap + v_t$$

$$States:$$

$$\lambda_{0,t} = \alpha_{0,0} + \alpha_{0,1}lnebmi_t + \alpha_{0,2}lninprodbz_{t-1} + \alpha_{0,3}infbz_t + \varepsilon_{0,t}$$

$$\lambda_{1,t} = \alpha_{1,0} + \alpha_{1,1}exgap_t + \alpha_{1,2}infbz_{t-1} + \alpha_{1,3}ttrade_t + \alpha_{1,4}\Delta lngdprbzsa + \varepsilon_{1,t}$$

Estimation results:

Sspace: CCONTROL
Method: ML (Marquardt)
Sample: 2002Q1 2014Q4
Included observations: 52

	Coefficient	Std. Error
alpha_0,0	-0,5503***	0,1580
alpha_0,1	0,0520***	0,0053
alpha_0,2	0,0693**	0,0306
alpha_0,3	0,9151***	0,1669
alpha_1,0	0,61974***	0,2018
alpha_1,1	4,0418*	2,1679
alpha_1,2	-9,7131***	3,0113
alpha_1,3	0,6441***	0,1709
alpha_1,4	-4,1732***	1,8241

	Final State	Root MSE
lambda_0	0,1139***	1,11E-02
lambda_1	-0,0396***	0,0000

Table 5: Total Coefficients - UIP Condition

Data:

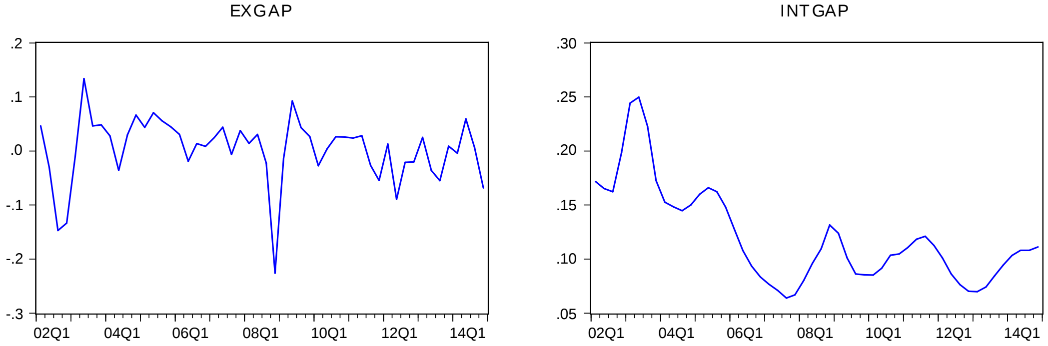

Figure 11: Data used in Uncovered Interest Parity Estimation

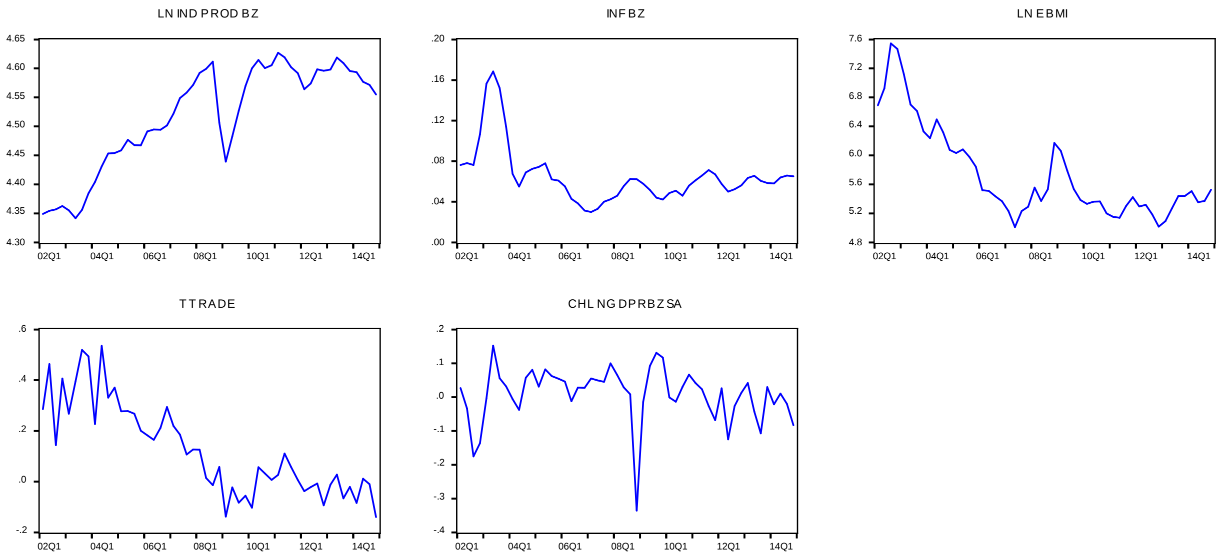

Figure 12: Coefficient Drivers used in Uncovered Interest Parity Estimation

Money Demand Estimation

Equations:

$$Signal:$$

$$lnm2defsa_t = b_{0,t} + b_{1,t}lngdprbzsa + b_{2,t}mmrate_t + v_t$$

$$States:$$

$$b_{0,t} = \alpha_{0,0} + \alpha_{0,1}mmrateus_t + \alpha_{0,2}lnebmi_t + \varepsilon_{0,t}$$

$$b_{1,t} = \alpha_{1,0} + \alpha_{1,1}lngdprbzsa_t + \alpha_{1,2}infbz_t + \varepsilon_{1,t}$$

$$b_{2,t} = \alpha_{2,0} + \alpha_{2,1}mmrate_t + \alpha_{2,2}infbz_{t-1} + \alpha_{2,3}ttrate_t + \varepsilon_{2,t}$$

Estimation results:

Sspace: MONEY
Method: ML (Marquardt)
Sample: 2002Q1 2014Q4
Included observations: 52

	Coefficient	Std. Error
alpha_0,0	3,2711	3,4036
alpha_0,1	-4,2174***	1,0372
alpha_0,2	0,1627**	0,0657
alpha_1,0	0,3045	0,2229
alpha_1,1	0,0165***	0,0041
alpha_1,2	0,1347**	0,0568
alpha_2,0	-2,2300	1,8026
alpha_2,1	7,6752	7,2084
alpha_2,2	-1,9523***	0,7391
alpha_2,3	-21,11989***	5,8096

	Final State	Root MSE
b_0	4,040282***	0,0000
b_1	0,733562***	0,0021
b_2	-2,487271***	0,0984

Table 6: Total Coefficients - Money Demand Condition

Data:

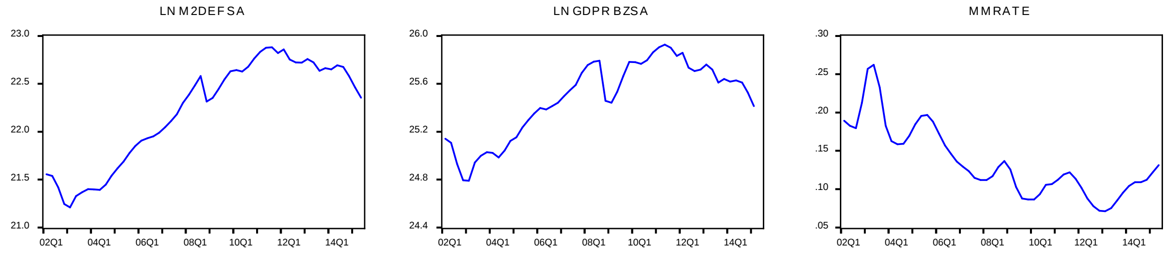

Figure 13: Data used in Money Demand Estimation

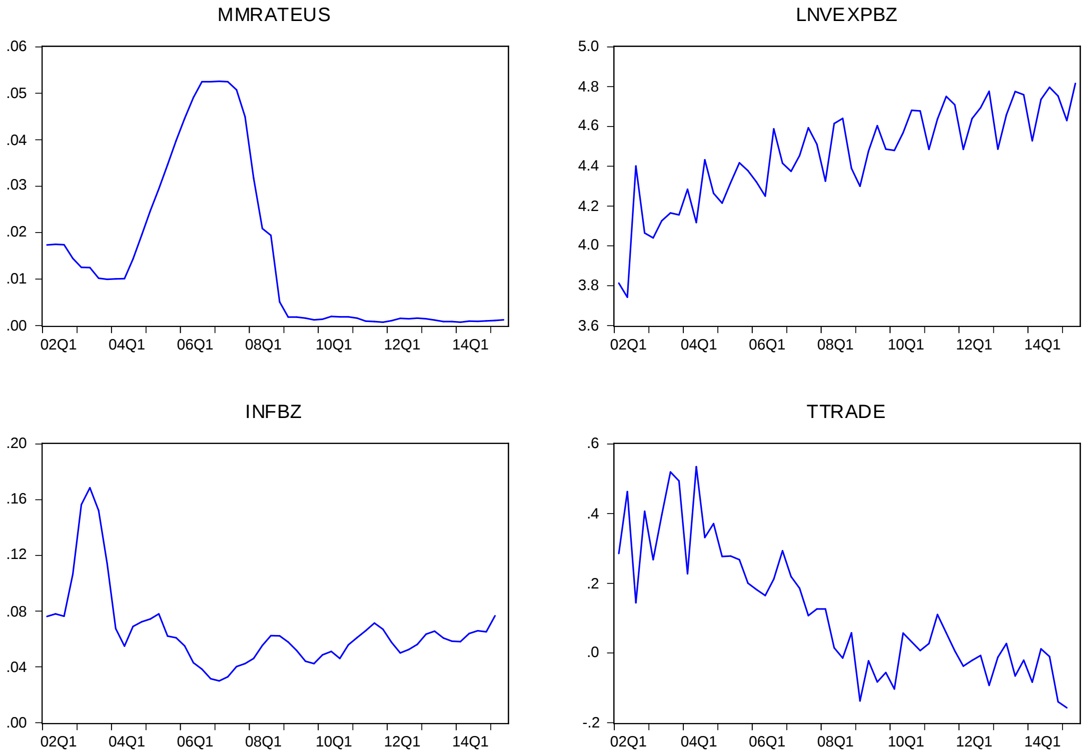

Figure 14: Coefficient Drivers used in Money Demand Estimation

Pricing Condition Estimation

Equations:

$$Signal:$$

$$pricegap_t = a_{0,t} + a_{1,t}exrate + v_t$$

$$States:$$

$$a_{0,t} = \alpha_{0,0} + \alpha_{0,1}mmrate_t + \alpha_{0,2}lnm2defsa_t + \alpha_{0,3}lnebmi_t + \varepsilon_{0,t}$$

$$a_{1,t} = \alpha_{1,0} + \alpha_{1,1}lnexrate_t + \alpha_{1,2}lnvexpbz_t + \alpha_{1,3}lnebmi_t + \varepsilon_{1,t}$$

Estimation results:

Sspace: PRICING
Method: ML (Marquardt)
Sample: 2002Q1 2014Q4
Included observations: 52

	Coefficient	Std. Error
alpha_0,0	-7,1806***	0,2864
alpha_0,1	0,3985***	0,1085
alpha_0,2	0,2941***	0,0121
alpha_0,3	0,0823***	0,0182
alpha_1,0	0,5301***	0,1310
alpha_1,1	0,5996***	0,0336
alpha_1,2	0,0628***	0,0173
alpha_1,3	-0,2060***	0,0181

	Final State	Root MSE
a_0	-0,0393***	7,79E-03
a_1	0,2504***	0,0111

Table 7: Total Coefficients - Pricing Condition

Data:

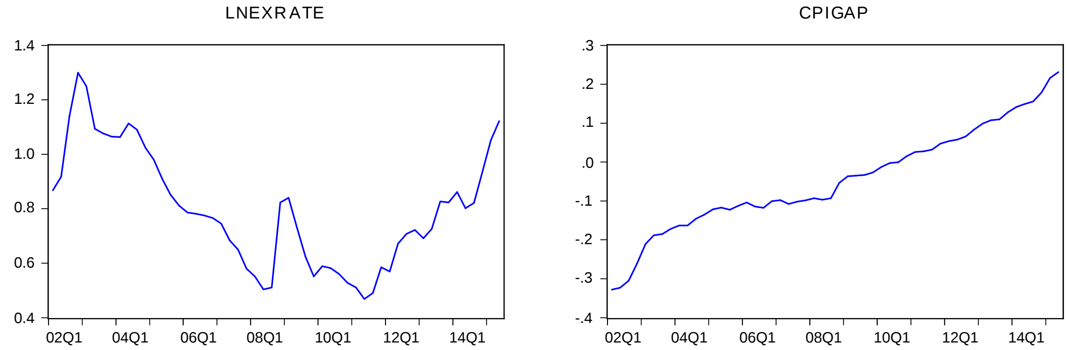

Figure 15: Data used in Price Condition Estimation

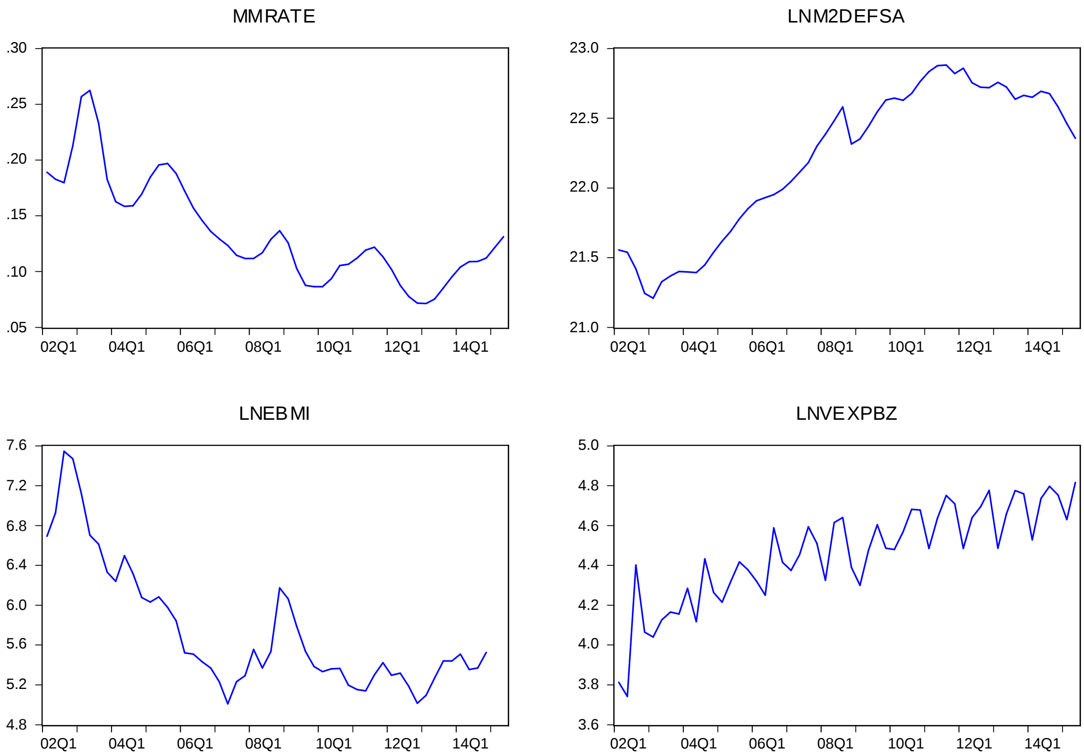

Figure 16: Coefficient Drivers used in Price Condition Estimation