OPTIMAL INTERNATIONAL RESERVES HOLDINGS IN EMERGING MARKETS ECONOMIES: THE BRAZILIAN CASE

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Abstract

This paper discusses the optimal international reserves holding for Brazilian economy. The optimal is determined with the buffer stock (inventory) model, using a time series approach. This paper differs from traditional approaches that run cross-section analysis. We evaluate Brazilian's reserves holdings with the model and discuss the role of IMF accord in the reserves holdings. The paper also presents evidence to support the idea of fewer needs to hold international reserves in a floating foreign exchange rate regime than in a fixed one. Conclusions highlight that Brazilians' foreign reserves are slightly above the optimal level and the model may allow the country to evaluate the needs of IMF accord renew.

Resumo

Este artigo discute o nível ótimo de reservas para a economia brasileira. O nível ótimo é determinado usando o modelo de *buffer stock*, a partir de uma abordagem de série temporal. O trabalho difere das abordagens tradicionais que fazem análises *cross section*. Nós avaliamos o nível de reservas do Brasil com o modelo e discutimos o papel dos acordos do FMI no nível de reservas internacionais. O artigo também apresenta evidências de que em regimes de câmbio flutuante as necessidades de reservas internacionais são menores do que em regimes de câmbio fixo. As conclusões destacam que o Brasil apresenta nível de reservas levemente acima do ótimo e que o modelo permite avaliar as necessidades de revisão dos acordos com o FMI.

Keywords: international reserves, buffer stock model, emerging markets, currency crisis, GARCH.

Palavras chave: reservas internacionais, modelo buffer stock, mercados emergentes, crises cambiais, GARCH

Área da Anpec: 3- Economia Internacional e Finanças

JEL Classification: E58, F32, F34, F37

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Antonio Francisco Silva Jr.

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1. Introduction

Despite many countries have shifted to floating exchange rate regimes during the last years, which naturally leads to a framework of less needs of holding reserves to prevent currency attacks, the level of international reserves increased. Global reserve holdings (excluding gold) were equivalent to 15 weeks of imports at the end of 1999, which is 56% higher than they were at the end of 1960 and 20% higher than they were at the start of 1990s. Furthermore, at the end of 1999, reserves were about 5% of global GNP,

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which is 50% higher than at the start of the 1990s (Flood and Marion, 2002). Empirical researches made distinction between the roles of international reserves for developing and developed countries and there are different demands for international reserves by developing countries that have maintained a fixed exchange rate policy and countries that devaluate (Edwards, 1983). Developed countries hold foreign currency reserves mainly for trade and monetary policies. Beyond these two tasks, developing countries hold reserves also to reduce their vulnerability to external shocks.

United States is running large current account deficits that are increasingly financed by foreign central banks willing to accumulate dollar assets. East Asian economies over the past several years, for instance, accumulate enormous international reserves. Some observers argue that it makes little economic sense for China to hold US$ 385 billion in reserves near the end of 2003, Taiwan US$ 200 billion, and South Korea US$ 145 billion (Bar-Ilan et all., 2004).

Frenkel and Jovanovic (1981) presented the buffer stock model for the demand of international reserves. This model is based on a balance between macroeconomic adjustment costs and opportunity costs. The adjustment cost is related to policy actions that, with the aim of covering balance of payments deficits, reflect in welfare reduction, such as decreases in GNP. An example of this kind of policy is the increase of domestic interest rate. So, reserves serve as a buffer stock accommodating fluctuations on balance of payments results.

In the particular case of emerging countries, the cost of holding reserves must take into account their external debt since they need to finance their balance of payments deficits due to interest and amortizations. There are basically three ways of financing: i) a positive trade account (a positive exports minus imports result); ii) foreign investments; and iii) international loans. The cost of the international loans and the interest rates paid on sovereign debt are higher than the return earned by foreign reserves, as central banks usually invest in very low risk-return assets. A widely used measure for this cost is the spread of sovereign debt over US Treasuries[1].

Our aim is to highlight some points of the optimal international reserves theory, always focusing in the particularities of emerging markets. The next section presents the economic reasons that may explain the demand for international reserves. Section 3 is devoted to the buffer stock model of Frenkel and Jovanovic (1981), henceforth FJ, and discusses its variations and empirical implementations. Section 4 presents an estimation of the model for Brazil, and highlights the issues particular to a single country analysis. Section 5 concludes.

[1] There are many indexes of the spread of sovereign debt over US Treasuries in the market and the most famous is JP Morgan's EMBI+, which is calculated using a basket of the most liquid sovereign bonds of a country and released every day.

2. The Rationale behind Reserves Holdings

International reserves have the aim to give international liquidity and to allow foreign exchange policy implementations. Nevertheless holding reserves is a costly practice as they are invested in low interest assets while governments pay high spreads on their outstanding debt. Grimes (1993) states that for a government with outstanding debt, the opportunity cost of holding reserves can be measured by the difference between the yield it pays on its own debt and the yield it receives on its reserve assets.

Reserves are held both to finance international transactions and as a buffer stock to face unexpected payments difficulties. So, the demand for international reserves is a function of the scale of the country (total imports or total income), the variability of its payments, its degree of openness and the opportunity cost of holding reserves (Edwards, 1983). One common liquidity indicator used by practitioners and researches is the period of imports covered by international reserves[2]. The use of imports is justified because imports are a factor of pressure of the balance of payments and they are a scale factor for a country. The relation between reserves and short-term debt is also a liquidity indicator[3]. Current account, capital account deficits of the balance of payments and the respective ratios to reserves may also be viewed as liquidity indicators among others. Grimes (1993) argues that if the cost of a reserve shortfall after intervention tends towards infinity, than reserves will optimally be such as to cover all possible outflows.

The costs of holdings reserves may be defined as costs that may be measured either in terms of net social opportunity costs, that is, the best alternative social yield on the resources tied up in reserves (hard to measure) minus the actual yield on the reserves, or in terms of marginal costs of borrowing in international markets. Considerations of creditworthiness, in particular in order to reassure foreign creditors, may often overturn the normally inverse relationship: a high level of reserves may facilitate and decrease the cost of borrowing, especially for developing countries (Lichtbuer, 1994).

A currency crash may be defined as a nominal depreciation of the currency of at least 25% that is also at least a 10% increase in the rate of depreciation (Frankel and Rose, 1996). Speculative attack literature examines several variables: the rate of growth of domestic credit, the government budget as a fraction of GDP, the ratio of reserves to imports, the current account as a percentage of GDP, the growth rate of real output, and the degree of over-valuation, Foreign Direct Investment (FDI) vs. portfolio flows, long-term vs. short-term portfolio capital, fixed-rate vs. floating-rate borrowing etc. Frankel and Rose (1996) do a 'study event' analysis and they conclude that crashes tend to occur when FDI inflows dry up, when reserves are low, when domestic credit growth is high, when northern interest rates rise and the real exchange rate shows overvaluation. Neither current account nor government budget deficits appear to play an important role in a typical crash.

[2] See Horne and Nahn (2000), Edwards (1983) and Flood and Marion (2002).
[3] Aizenman and Joshua (2002) discuss the role of external debt-to-reserve ratio.

Kohlscheen and O'Connell (2004) discuss the role for trade credit and international reserves and highlight a rationale for reserves that relies on the potential provision of liquidity services in the event of a cutoff from short-term trade credit during debt renegotiations. So they try to explain why developing countries hold substantial stocks of reserves in spite of the fact that their external liabilities carry a considerably higher interest rate. They conclude that international reserves directly affect the bargaining position of debtors during a debt renegotiation. The borrower accumulates reserves to guarantee its liquidity in anticipation of the bargaining game.

Flood and Marion (2002), henceforth FM, argue that most studies suggest that sterilized intervention rarely works and since intervention occurs infrequently, there is still the puzzle of why floaters hold so many reserves. According to them there are three trends in the international economy that could potentially have an important influence on reserve holdings: i) increasing capital mobility; ii) increasing frequency and intensity of currency and financial crises; and iii) increasing number of countries reporting a switch to flexible exchange rates. So the remarkable question is: how these trends affected central bank reserve holdings?

3. Modeling Optimal International Reserves Holdings

The buffer stock model (inventory model) is extensively discussed in the literature. FJ state that there is a dependence of the optimal holdings of reserves on the variability of international transactions. So, reserves are a buffer stock to accommodate fluctuations in external transactions and it is expected that the optimal stock depend positively on the extent of these fluctuations. FJ postulate that the demand for reserves holdings is a stochastic process driven by payments and receipts. So it can be modeled by the following equation:

$$dR_t = -\mu dt + \sigma dW(t) \tag{1}$$

Where $W(t)$ is a standard Wiener process. It is assumed that $R(0) = R_0$, the initial stock of reserves, is the optimal level. The variation in reserves in a small time span, (dt), is a normally distributed variable with mean $-\mu dt$, and variance $\sigma^2 dt$.

As international reserves earn a return that is lower than the market rate, it is expected that the optimal stock will be negatively related to the market interest rate. Additionally, every time the reserves hit an undesirable low level (by occurrence of current account deficits, for example) there is a need of adjusting the balance and this is done by reducing expenditures relative to income. This adjustment leads to a welfare cost. Due to the stochastic nature of balance of payments results, the adjustment cost is associated to the variance of the process, σ^2. So, by minimization of a cost function that connects both costs, FJ conclude that the optimal level of reserves is determined by:

$$R_0 = \sqrt{\left(\frac{2C\sigma^2}{\left(\mu^2 + 2r\sigma^2\right)^{1/2} - \mu}\right)} \qquad (2)$$

where, r is the cost of holding reserves per unit of time, representing the cost of forgone earnings; and C is a fixed cost per adjustment, related to the capacity to adjust expenditures to income.

A crucial assumption of FJ's model is that, on average, the balance of payments is in equilibrium, that is, the stochastic process has no drift, and hence $\mu = 0$. With this statement equation (2) can be rewritten as:

$$R_0 = 2^{1/4} C^{1/2} \sigma^{1/2} r^{-1/4} \qquad (3)$$

The buffer stock model implies an unchanged policy environment before and after restocking, so $\mu = 0$. However, it is more common for policy to change when reserves hit their lower bound or when they reach an upper bound. Indeed, it is this policy change that reverses the direction of the drift in reserves (Bar-Ilan et all., 2004).

Based on the above equation FJ estimated the two equations below (the second one adding a scale component: imports) using cross-sectional and time series (annual) data for 22 developed countries over five years (1971-5):

$$\ln R = b_0 + b_1 \ln \sigma + b_2 \ln r + u \qquad (4)$$

$$\ln R = b_0 + b_1 \ln \sigma + b_2 \ln r + b_3 \ln IM + u \qquad (5)$$

The results of FJ are close to the predictions of the model ($b_1=0.5$ and $b_2=-0.25$). Furthermore, the authors state that b_0 is a country specific factor that is a function of the fixed cost of adjustment.

FM replicated FJ's regression using revised data from IMF and found consistent results. They re-estimated FJ model trying several different scaling variables, with and without country fixed effects, over three different periods: 1971-75, 1976-1997 and 1971-1997. The work of FM gives another perspective for the empirical implementation of the buffer stock model. They advocate that constructing a measure of volatility must attempt to separate typical incremental volatility from the large upward restocking adjustments. Furthermore, speculative attack models, in an era of high capital mobility, were very new issues. So, they developed a test of the buffer stock model using the shadow exchange rate increments[4].

The authors also discuss a problem highlighted by FJ: the opportunity cost variable is difficult to measure, since a high interest rate is expected to attract reserves and a high interest rate is also considered as costly for reserves holdings. As in the 1990's many emerging countries moved to market-determined interest rates, FM use these data to calculate the opportunity cost measure as the difference between domestic and US interest rates on government bonds. The fact that greater exchange-rate flexibility is associated with lower reserves holdings is also considered.

Salman and Salih (1999) model the dynamics of international reserves using a GARCH specification and the aim is to explain the time variation in reserves holdings during crises. They used daily data of international reserves of Central Bank of Turkey, the exchange rate, the overnight interest rates and the Istanbul Stock Exchange index. Their main conclusions are that interest rate and the volatility of exchange rate have negative effects on reserves level. In fact, this occurs because these factors are indicators of currency crises and, as expected, a currency crisis has negative consequences in the balance of payments result.

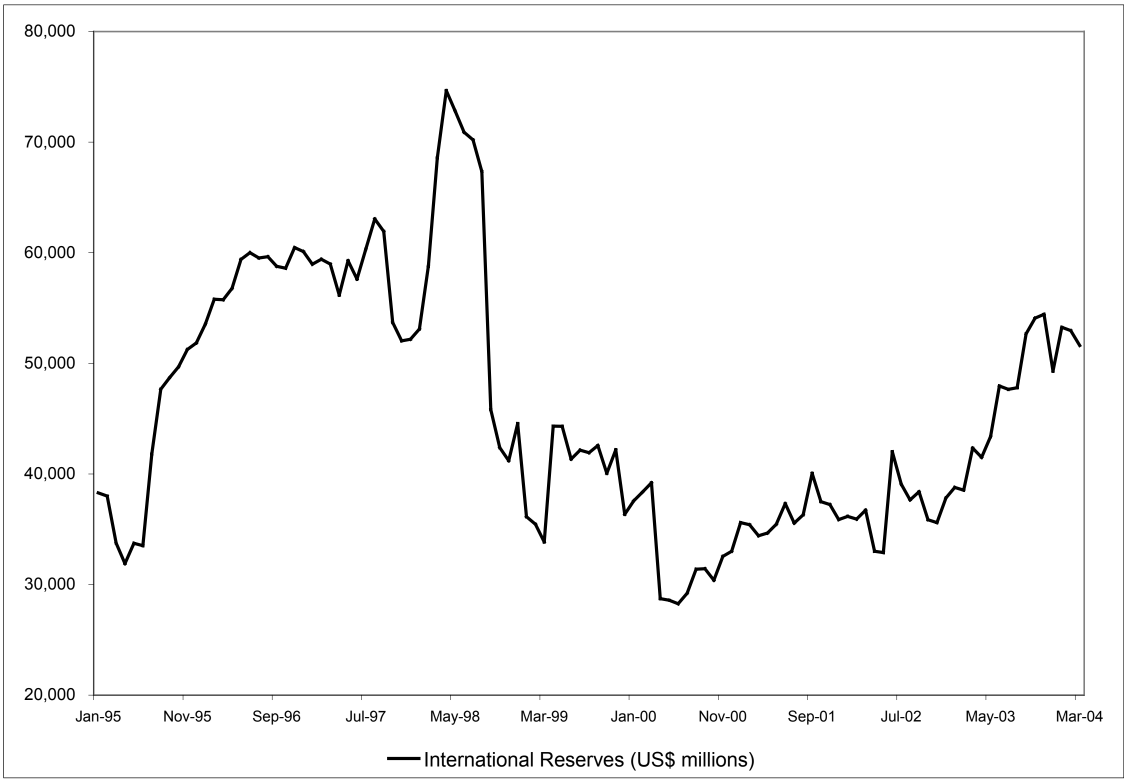
Ramachandran (2004) also discusses the use of standard deviation of change in reserves that assumes constant volatility over a fixed time period. As Salman and Salih (1999) he also works with ARCH and GARCH models. Another interesting feature in both works is the use of time series for individual countries (India and Turkey respectively) rather than working with cross-sectional data.

4. The Case of Brazil

In this section we discuss the optimal reserves holdings for the Brazilian Economy. Figure 1 shows historical data for Brazilian reserves since 1995. One can see that there are two different patterns, since there was a change in foreign exchange regime in January/1999, as we can see in figure 2. Reserves holdings increase in the period 1995-1998. There was a sharp decrease in the period of 1998-2000 and another increase in the period of 2000-2004. This behavior is a point to be investigated when we estimate the buffer stock model considering the hypothesis that there is no drift in the balance of payments result.

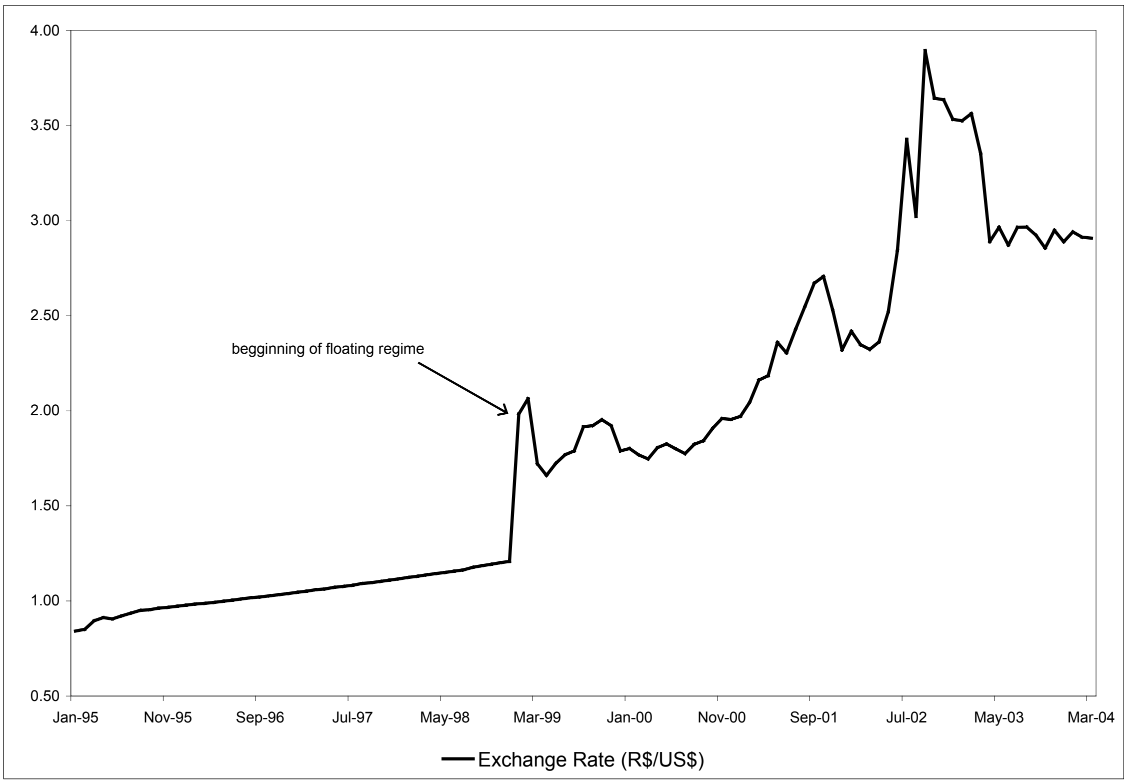
[4] The shadow exchange rate is the exchange rate that market would attain in the case of no international reserves. FM consider that the shadow exchange rate is a function of a fundamental as domestic credit, international price level etc.

Figure 1 - Brazilian International Reserves



Source: Central Bank of Brazil

Figure 2 - Brazilian Exchange Rate

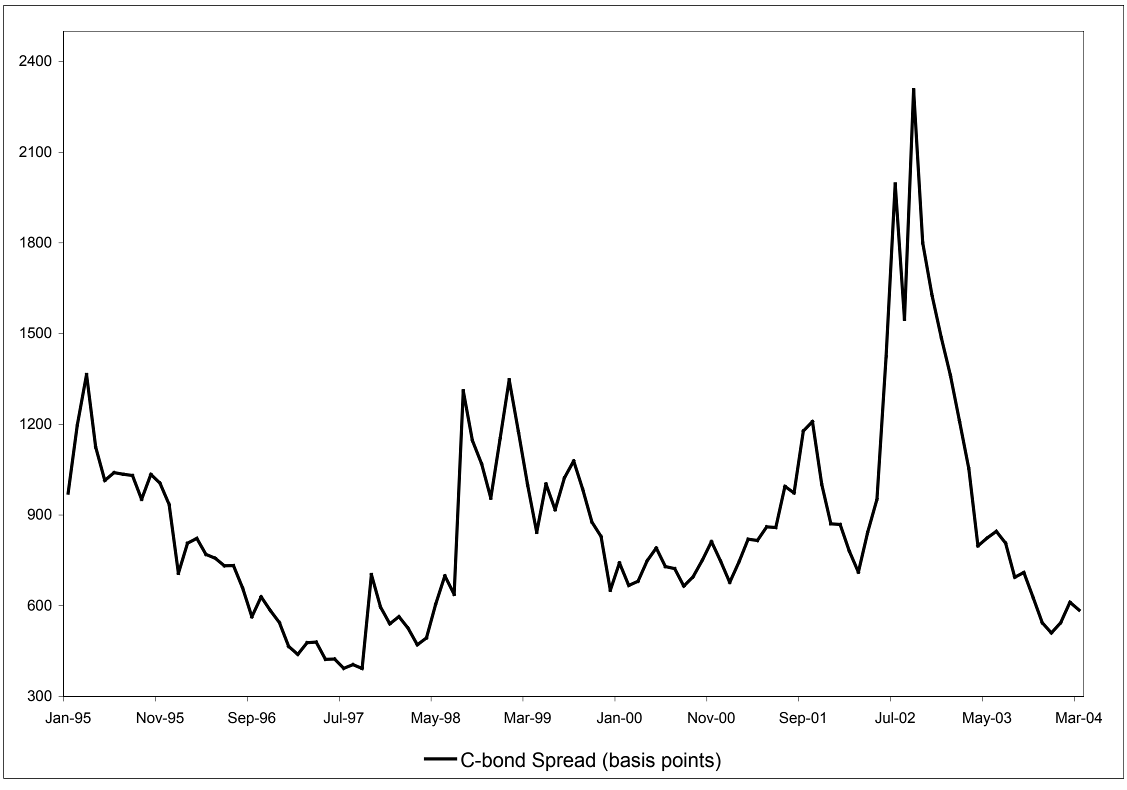


Source: Central Bank of Brazil

There were some periods of international crises that had impact in Brazilian foreign exchange market, as we can see from C-Bond[5] spread data in figure 3. We highlight Mexico, Asia, Russia and Argentina crisis as external events. Furthermore there were two periods of crises that emerged internally (the foreign exchange regime change in January/1999 and the presidential election in the second half of 2002). Each one of these crisis events pressured Brazilian's balance of payments result with consequences in the reserves holdings. The understanding of these crisis events is crucial to evaluate volatility models that capture the essence of reserves changes. This allows us to explain why a GARCH model is a virtual candidate to be used as the volatility model.

Government reaction to these crises events typically focuses in the domestic foreign currency market, with central bank interventions, and in the money market (increases in domestic interest rates). Figure 4 shows the domestic interest rates behavior in the period. We present in table 1 some economic indicators in crises events. The balance of payment result in table 1 is the sum of monthly negative numbers in the period near to the date when the event occurred. Russian crisis event causes the highest negative result in the Brazilian's balance of payments, but this occurs in a period of fixed foreign exchange rate regime. Following Russian crisis Brazil changed to a floating foreign exchange rate regime.

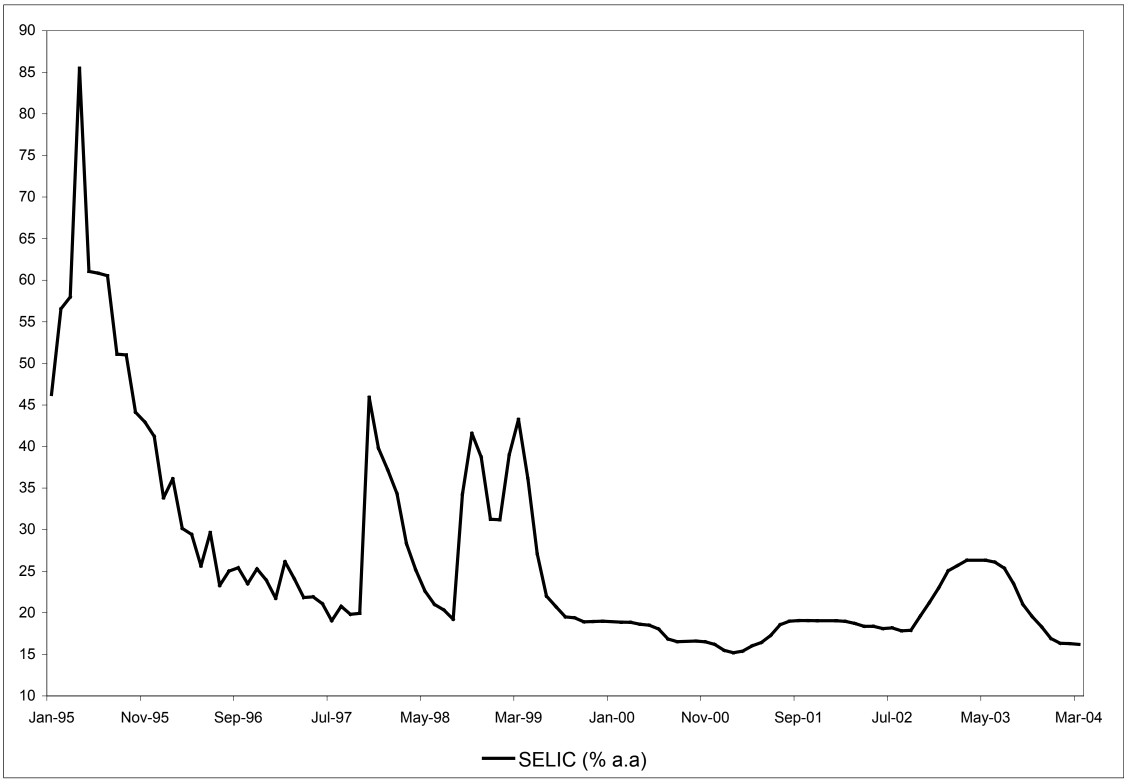
Figure 3 - Spread of C-bond



Source: IPEADATA

[5] C-Bond spreads give a proxy of spreads over Treasuries Brazilian's issues pay in international market and can be viewed as a risk perception for the country.

Figure 4 - Annual SELIC rate



Source: Central Bank of Brazil

Table 1 - Currency Crises

Crisis	Date	BP result (US$ millions)	selic*	R$/US$	Country Risk**
Mexican	mar - apr/95	(6,156.00)	85.47%	0.896	1365
Asian	out - nov/97	(10,355.15)	19.93%	1.1031	703
Russian	mai - nov/98	(33,654.24)	41.58%	1.1856	1147
Brazilian - Change to Floating	jan - mar/99	(10,495.12)	38.97%	1.9832	1347
Argentina	oct/01 - mai/02	(6,911.71)	18.51%	1.8067	749
Brazilian - Presidential Election	jul - nov/02	(6,480.68)	21.25%	3.645	1800

* one month after the period of highest outflow
** end of the month after the period of highest outflow

With the aim of applying the buffer stock model of optimal international reserves holdings for Brazilian data we follow three main steps: i) search for an adequate model for the volatility of payments and receipts; ii) estimation of the buffer stock model; iii) analysis of the results, with comparison of actual level of international reserves with the ideal level pointed by the theoretical model parameters.

As we chose the volatility of the change in the total reserves (excluding gold) as the adequate proxy for the volatility of payments and receipts, the first task was to model this volatility. We tested various specifications of the traditional fixed window volatility calculations and of the GARCH (p, q) volatility estimation, as suggested by Salman and Salih (1999). We found that the GARCH specifications yields far best forecasts of variance. This result is not surprising, as discussed above[6]. The mean of Brazilian international reserves changes is clearly related to its variance, which is not constant over any period of time and this feature indicates the use of GARCH models.

We tested different GARCH and EGARCH models, according to the following specifications:

$$\Delta R_t = \gamma_0 + \sqrt{h_t} \cdot \upsilon_t \qquad (6)$$

where γ_0 is a constant, h_t is the conditional variance and υ_t is a random variable.

Assuming that the conditional variance depends on an infinite number of lags of reserves changes, it follows a GARCH (p, q) specification:

$$h_t = \kappa + \delta_1 h_{t-1} + \delta_2 h_{t-2} + \cdots \delta_p h_{t-p} + \alpha_1 \Delta R_{t-1}^2 + \alpha_2 \Delta R_{t-2}^2 + \cdots + \alpha_q \Delta R_{t-q}^2 \qquad (7)$$

The EGARCH specification is an exponential variation of the above equation, proposed by Nelson (1991). The main departure from the traditional model is the parameter Ψ, that allows for asymmetries in the volatility in response to deviations of the mean (innovations).

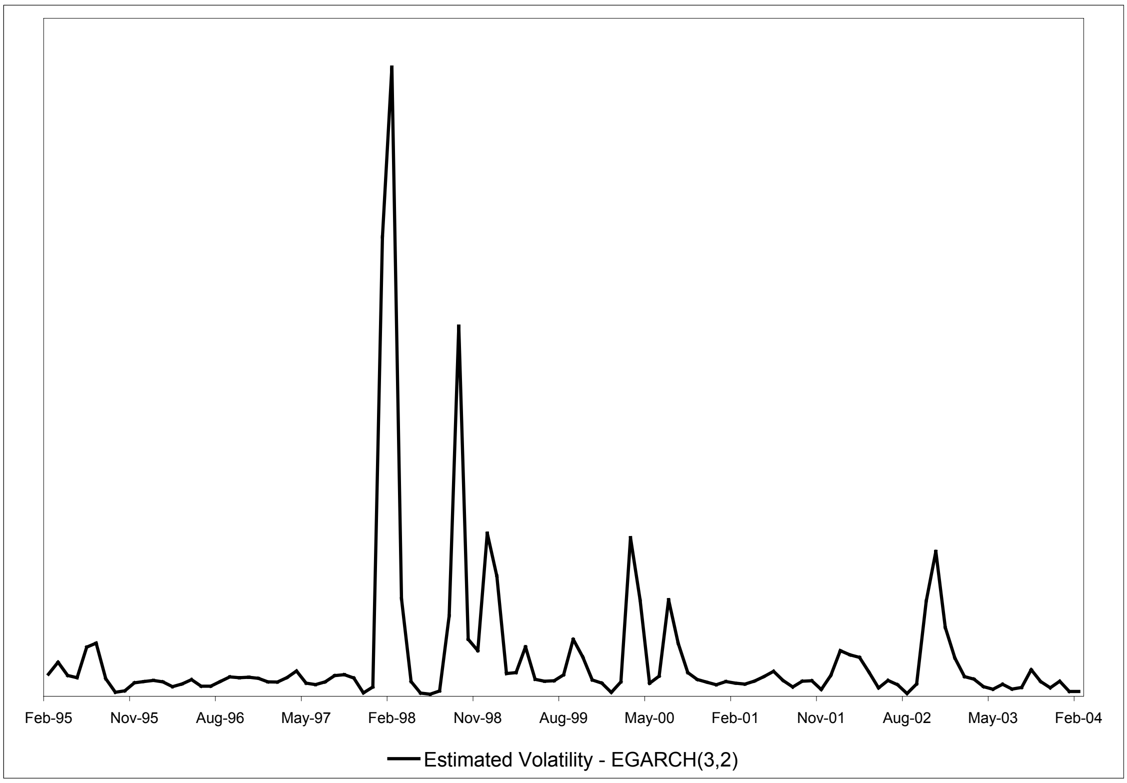
$$\ln(h_t) = \zeta + \sum_{j=1}^{\infty} \pi_j \cdot \left\{ \left|\upsilon_{t-j}\right| - E\left|\upsilon_{t-j}\right| + \Psi \upsilon_{t-j} \right\} \qquad (8)$$

Many authors suggest that this specification is better suited to capture the volatility of financial time series, given that negative innovations generally yields bigger effects on the volatility than positive innovations, the so called "leverage effect" (Brandt and Jones, 2002).

Using the standard AIC criterion to select the better model we chose the EGARCH (3, 2) as the generating process for the volatility of the change in international reserves. Figure 6 shows the volatility estimated with the chosen model. One can easily identify the crisis points listed in Table 1 as the points with big volatilities in Figure 6.

[6] We also did the statistical ARCH-LM test to detect the conditional structure of the process, and the null hypothesis of no ARCH was strongly rejected.

Figure 5 - Estimated Volatility of Changes in Reserves



We proceeded with the estimation of the buffer stock model, using monthly data for the period from January/1995 to March/2004. The start point was equation (4), as estimated by FJ. The proxy used for the opportunity cost is SELIC effective annual rate, shown in Figure 5. We found rather disappointing results, as the expected signs were wrong and t-statistics low. That was no surprise, considering the change in currency regime and high payments volatility of Brazil, which are a general characteristic of emerging economies.

Trying to capture the effect of the regime switch in January/99 we included a dummy variable pointing to the period of floating exchange rate. The estimated equation was:

$$\ln R = b_0 + b_1 \ln \sigma + b_2 \ln r + dummy + u \tag{9}$$

The inclusion of the dummy variable improved the estimation significantly, and its sign was negative, in line with the theory, indicating that a country needs to hold less international reserves in a floating exchange rate framework. The new estimation presents all parameters signs in line with FJ's theoretical proposal, despite differences in magnitudes. The b_0 estimative, that represents country specific fixed adjustment costs, is very similar to those found by Salman and Salih (1999) and Ramachandran (2004), which is important to note, since both studies were pointed to emerging economies.

One of the most difficult features of the buffer stock model is to find a correct measure of the opportunity cost of holding international reserves, as pointed out by FJ and FM. This cost is defined as the difference between the yield earned investing the international reserves and the yield paid to finance the government debt. For an emerging economy we suggest that this cost be considered as a mix of the costs of internal and external finance, since both rates differ significantly from the yield of international reserves investments. So we considered the following specification to entail both foreign and domestic opportunity costs:

$$\ln R = b_0 + b_1 \ln \sigma + b_2 \ln r + b_3 \ln s + dummy + u \qquad (10)$$

where s is the cost of external debt finance, measured by C-bond spread over US Treasuries, considering that it is a good proxy of country risk. Estimation results are consistent with theory, and all coefficients are statistically significant (see table 2). The negative effect of opportunity cost estimated with (10) is higher than the effect estimated by (9) but the effect of the adjustment costs also increases. This leads to a hypothesis of some kind of market expectation effect that is associated with the decrease of total reserves holdings[7].

Table 2 - Estimation Results[8]

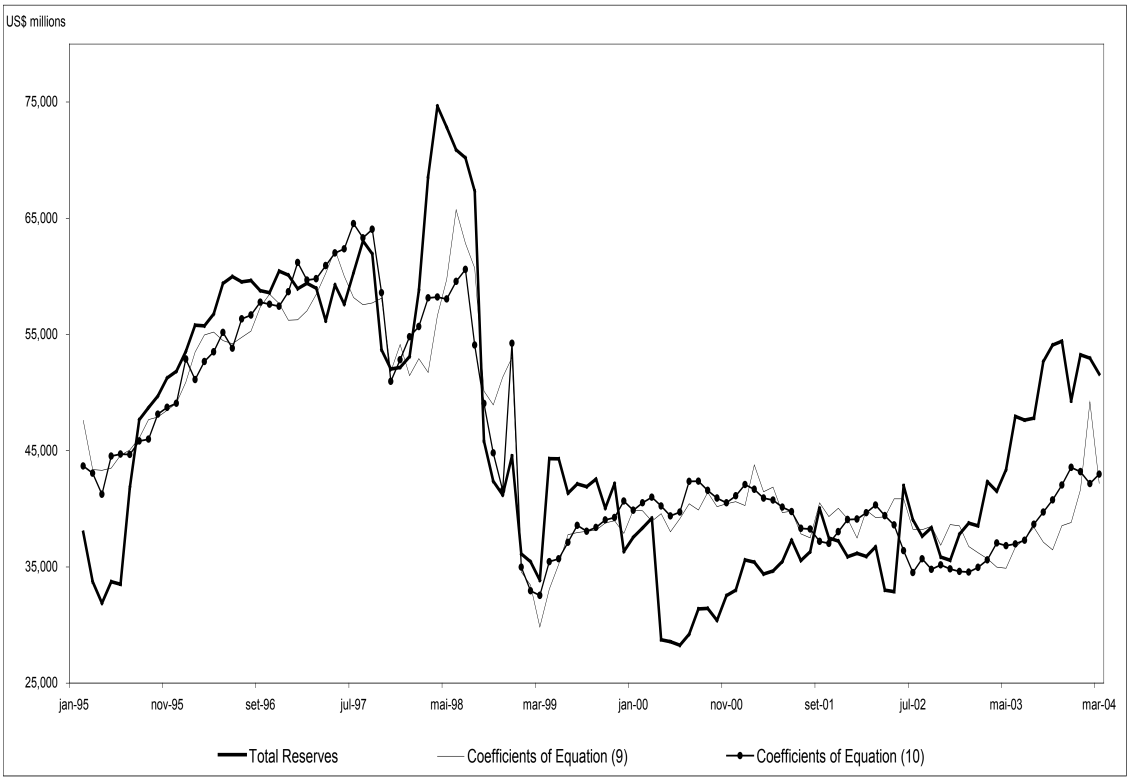
Equation	Coefficient	b_0	b_1	b_2	b_3	*dummy*	*F-stat*
(4)	value	9.994	0.054	0.079	-	-	
	std error	0.938	0.091	0.126	-	-	0.842
(9)	value	10.805	0.125	-0.278	-	-0.457	
	std error	0.613	0.057	0.103	-	0.063	46.401
(10)	value	11.366	0.143	-0.192	-0.153	-0.382	
	std error	0.718	0.0543	0.108	0.077	0.087	39.467

Figure 6 shows actual reserves holdings and optimal reserves as estimated by equations (9) and (10). We notice that, just before Russian crisis, in a fixed exchange rate regime, Brazilian reserves holdings were above the buffer stock optimal. That was an era of high FDI and 'hot-money' inflows attracted by high domestic interest rates.

Another notable period was April/2000 where Brazil paid a high amount of external debt to IMF. So reserves stayed below optimal level calculated by the model. In 2001, due to Argentina's crisis, reserves also stayed below optimal level. Otherwise, even with Brazilian's election crisis in the second half of 2002, reserves stayed above the optimal level.

[7] As the purpose of this paper is evaluating the buffer stock model using a time series analysis for Brazilian data, we suggest this issue for further studies.
[8] All standard errors were computed using the Newey-West HAC covariance matrix estimator.

Figure 6 – Actual vs. 'Optimal' Reserves



There is a trouble with time series approach to estimate buffer stock model: optimal reserves holdings will depend upon historical data rather than on future current and capital accounts of balance of payments. Indeed, this is also a problem on estimation of buffer stock model based on cross section analysis. The optimal reserves level depends on future costs of reserves holdings; future outflows and inflows of investments; roll over of external debt; current account results etc. Furthermore, it depends on future international environment, liquidity etc.

Even with the above limitations, one may argue that buffer stock model is a good forecast of optimal reserves holdings based on historical information. Looking again to table 1 we can see that Russian's crisis demanded approximately US$ 34 billion of reserves, but Brazil was in a fixed foreign exchange rate regime. So, the recent past experience of Brazil, since 1990s, evidences that US$ 10 billion would cover outflows due to financial crisis if we exclude Russian's crisis event.

Actually, in June 2004 Brazil had US$ 49.8 billion of total international reserves and US$ 25 billion of this total are due to IMF accord. Renew of IMF accord implies in access to new money and it is interesting to evaluate needs based on the difference between optimal and real international reserves holdings. Using this criteria and the buffer stock model we may conclude that actually Brazil does not need access to new money by IMF. Indeed, as we stated above this analysis do not take in account expectations about future inflows and outflows.

5. Conclusions

We evaluate the buffer stock model considering an analysis of time series to a specific country rather than a cross section analysis. It allows us to take in account particular issues of an emerging country as its behavior in a currency crisis event. Traditional approaches look to optimal international reserves model in a general view. Our work captures the differences in the demand for international reserves due to fixed or floating foreign exchange rate regimes, as it covers a range where Brazil has changed its policy. Furthermore, it captures the experience of crisis 'events' in both periods.

Another feature of this paper is that it shows volatility modeling as a capital point in the buffer stock model evaluation, as best results were attained when we use a GARCH model. This is a relevant point to consider, supporting the idea of a time series analysis rather than a cross section approach.

The C-bond spread over US Treasuries was used as an additional indicator of the opportunity costs of holding reserves, and the estimation result supports our choice. We observed that addition of C-bond spread had two effects in the regression coefficients. It increases the opportunity cost of holding reserves but also it increases the effect of volatility, the adjustment cost. It reflects a kind of market expectation effect that must be better understood and it is a task for further studies.

The model may be used for evaluate the need for new money from IMF accords. A topic for further studies is the effects of drifts in the payments and receipts balances, which modifies the function of demand for international reserves and may have significant impacts in the buffer stock model.

References

Aizenman, Joshua and Nancy Marion (2002), "International Reserve Holdings with Sovereign Risk and Costly Tax Collection", *NBER Working Paper, nº w9154.*

Bar-Ilan, Avner and Marion, Nancy and Perry, David (2004), "Drift Control of International Reserves", *University of Haifa Working Paper*.

Bilson, John and Jacob Frenkel (1979), "Dynamic Adjustment and the Demand for International Reserves", NBER Working Paper, nº 403.

Brandt, Michael W. and Christopher S. Jones (2002), "Volatility Forecasting with Range-Based EGARCH models".

Edwards, Sebastian (1983), "The Demand for International Reserves and Exchange Rate Adjustments: The Case of LDCs, 1964-1972, Economica, New Series, Vol. 50, Nº 199, pp. 269-280.

Flood, Robert and Nancy Marion (2002), "Holding International Reserves in an Era of High Capital Mobility", IMF *working paper – WP/02/62*.

Frankel, Jeffrey and Andrew Rose (1996), "Currency Crashes in Emerging Markets: An Empirical Treatment", *Journal of International Economics, 41, pp. 351-366.*

Frenkel, Jacob and Boyan Jovanovic (1981), "Optimal International Resreves: A Stochastic Framework", *Economic Journal, 91 (June), pp. 507-514.*

Grimes, Arthur (1993), "International Reserves under Floating Exchange Rates: Two Paradoxes Explained", *The Economic Record, vol. 69, nº 207, pp. 411-415.*

Horne, Jocelyn and Daehoon Nahm (2000), "International Reserves and Liquidity: A Reassessment", *Macquarie University research paper.*

Kohlscheen, Emanuel and Stephen O'Connell (2004), "Sovereign Debt Recontracting: The Role of Trade Credit and Reserves", Stockholms Universitet - doctoral thesis.

Lichtbuer, Pierre C. (1994), "Overview of Reserve Management by Central Banks", in *Administración de Reservas Internacionales en la Banca Central*, org. by CEMLA.

Nelson, D.B., (1991), "Conditional Heteroskedasticity in Asset Pricing: A New Approach", *Econometrica, 59, pp. 347-370.*

Ramachandran, M. (2004), "The Optimal Level of International Reserves: Evidence for India", *Economics Letters, 83*, pp. 365-370.

Salman, Ferhan and Aslihan Salih (1999), "Modeling the Volatility in the Central Bank Reserves", *Research paper of Central Bank of Turkey*.