Working Paper

INTERNATIONAL MONETARY FUND

WP/07/265

IMF Working Paper

The Optimal Level of Foreign Reserves in Financially Dollarized Economies: The Case of Uruguay

Fernando M. Gonçalves

INTERNATIONAL MONETARY FUND

 WP/07/265

IMF Working Paper

Western Hemisphere Department

The Optimal Level of Foreign Reserves in Financially Dollarized Economies: The Case of Uruguay[1]

Prepared by Fernando M. Gonçalves

Authorized for distribution by Marco Piñón

November 2007

Abstract

This paper extends the framework derived by Jeanne and Rancière (2006) by explicitly incorporating the dollarization of bank deposits into the analysis of the optimal level of foreign reserves for prudential purposes. In the extended model, a sudden stop in capital flows occurs in tandem with a run on dollar deposits. Reserves can smooth consumption in a crisis but are costly to carry. The resulting expression for the optimal level of reserves is calibrated for Uruguay, a country with high dollarization of bank deposits. The baseline calibration indicates that the gap between actual and optimal reserves has declined sharply since the 2002 crisis due to a substantial reduction in vulnerabilities. While the results suggest that reserves are now near optimal levels, further accumulation may be desirable going forward, partly because banks' currently high liquidity levels are likely to decline as the credit recovery matures.

JEL Classification Numbers: F31, F32, F37, F41

Keywords: Foreign Reserves, Balance of Payments Crises, Sudden Stops, Bank Runs, Financial Dollarization.

Author's email: fgoncalves@imf.org

[1] This paper greatly benefited from discussions with Gustavo Adler, Marco Piñón, and Alejandro López Mejía. The author also would like to thank useful comments by Gaston Gelos, Ana Ibarra, Olivier Jeanne, Rafael Romeu, Herman Kamil, Marcos Rietti Souto, and participants of WHD's departmental seminar and workshop on reserve adequacy, of *Banco Central del Uruguay*'s seminar, and of a presentation in the 2007 LACEA meeting. Pablo Bazerque, Silvia Cabrera, Adriana Induni, Leonardo Vicente, Romain Rancière and Carolina Saizar kindly provided data. Remaining errors are the sole responsibility of the author.

Contents

Tables

Figures

I. Introduction

The large accumulation of foreign reserves by several central banks in recent years has stimulated an extensive literature on the motives and adequacy of this practice. One often cited reason is to self-insure against costly crises.[2] Even though reserves may be expensive to carry, they can help mitigate a fall in domestic consumption in the event of a sudden stop in external credit. Such insurance role is even more pronounced in dollarized economies, where financial account reversals may be accompanied by a large withdrawal of foreign currency deposits.

This paper focuses on the role of reserves as insurance against balance-of-payments and banking crises in financially dollarized economies. It extends Jeanne and Rancière (2006) (henceforth, JR) by explicitly incorporating into their framework the dollarization of bank deposits. The extended model is then calibrated for the case of Uruguay, a highly dollarized economy.

The scope of this paper is limited to the assessment of reserve optimality from a crisis mitigation self-insurance perspective[3]. The model does not contemplate a role for reserves in reducing the likelihood of a crisis. There are other potentially relevant issues not addressed. First, moral hazard consequences of reserve accumulation—i.e., the fact that larger official reserves may decrease the propensity of banks to hold liquid foreign assets. While important, the problems associated with moral hazard can be reduced by proper banking regulation, as discussed in further detail later. Second, reserve accumulation may adversely affect the credibility of monetary policy if, for example, official acquisitions in the foreign exchange market are perceived as signals of exchange rate targeting. However, this problem may also be substantially limited by improving the transparency and independence of monetary policy.

The remainder of this paper is as follows. Section II presents basic accounting relations that illustrate the role of foreign reserves to help smooth domestic consumption in the face of adverse shocks and in the mitigation of the currency and banking crisis in Uruguay in 2002. Section III discusses the evolution of vulnerabilities that can potentially lead to large requirements of foreign reserves in the event of a crisis in Uruguay. Section IV discusses the closed-form solution of the model of optimal prudential reserves in financially dollarized economies and calibrates it for the Uruguayan economy for the years 1999-2006. It also presents a simulation of the impact that a shock of the magnitude of the 2002 crisis would have on reserves today. Section V provides an assessment of the sensitivity of the optimal level of reserves to key parameters in the model. Section VI discusses in further detail a number of caveats of the analysis. The conclusions and policy implications of the study are provided in section VII.

---

[2] Countries may accumulate foreign reserves to achieve a range of objectives, not restricted to self-insurance, including: (1) making exchange rate markets more efficient by providing liquidity when needed; (2) limiting exchange rate volatility (“leaning against the wind”); and (3) pursuing export-led growth maintaining de facto fixed or undervalued exchange rate (see Becker et al., 2007, and European Central Bank, 2006).

[3] In a forethoughtful work, Licandro (1997) provided an early assessment of the adequacy reserve levels in Uruguay from a self-insurance point of view. At the time, in addition to their role as insurance against possible banking and debt rollover crises, reserves were seen as important for the sustainability of a fixed exchange rate regime.

II. Reserves as Insurance and the 2002 Crisis in Uruguay

As in JR's work, the role of reserves in smoothing domestic absorption in the event of large capital outflows can be seen through basic accounting relations. First, domestic absorption is defined as:

(1) A=Y-TB,

where A is domestic absorption, Y is output, and TB is the trade balance.

The balance of payments identity is given by

(2) TB = -FA-IT-ΔR,

where FA is the financial account, IT is net income and transfers from abroad, and ΔR is the drop in (or, if negative, accumulation of) central bank reserves.

Combining the equations we have:

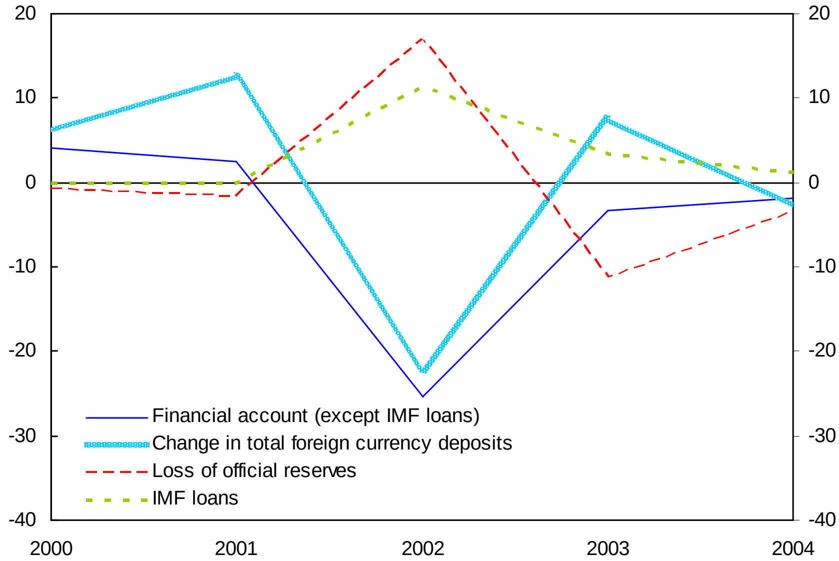
(3) A=Y+FA+IT+ΔR.

Equation (3) shows that the effect of a sudden stop (defined as an abrupt fall in the financial account, FA) on absorption can be mitigated by an injection of central bank reserves (implying ΔR>0) in the economy. For example, reserves can be used to repay foreign currency lines of credit that are not rolled over. If the financial account reversal is accompanied by a drop in output, as typically occurs, reserves have a further role in mitigating the effect on absorption (equation (3)). Other things being equal, the drop in output during a crisis could be larger in economies with dollarized deposits, as sudden stops may be accompanied by runs on dollar deposits, exacerbating the drop in credit. Therefore, under high bank deposit dollarization, the prudential role of reserves is larger as the monetary authority may need to provide liquidity in dollars to the banking sector.

Central bank reserves played a significant role in mitigating the effects of the 2002 crisis in Uruguay. Following the Argentine crisis in 2001, Uruguay experienced a sudden stop of external credit and a banking crisis, resulting in a large credit crunch.[4] Figure 1 shows the resulting large capital outflow and withdrawal of dollar deposits. It also shows the large amount of reserves—a significant part of which made available through an IMF arrangement—used to offset the outflows. While output dropped significantly, the use of reserves helped offset a potentially larger fall in economic activity.

[4] See De la Plaza and Sirtaine (2005) for a detailed analysis of the 2002 crisis in Uruguay.

Figure 1. Financial account reversal, dollar deposits and reserves in Uruguay
(percent of 2001's GDP)



Source: International Financial Statistics; author's calculations.

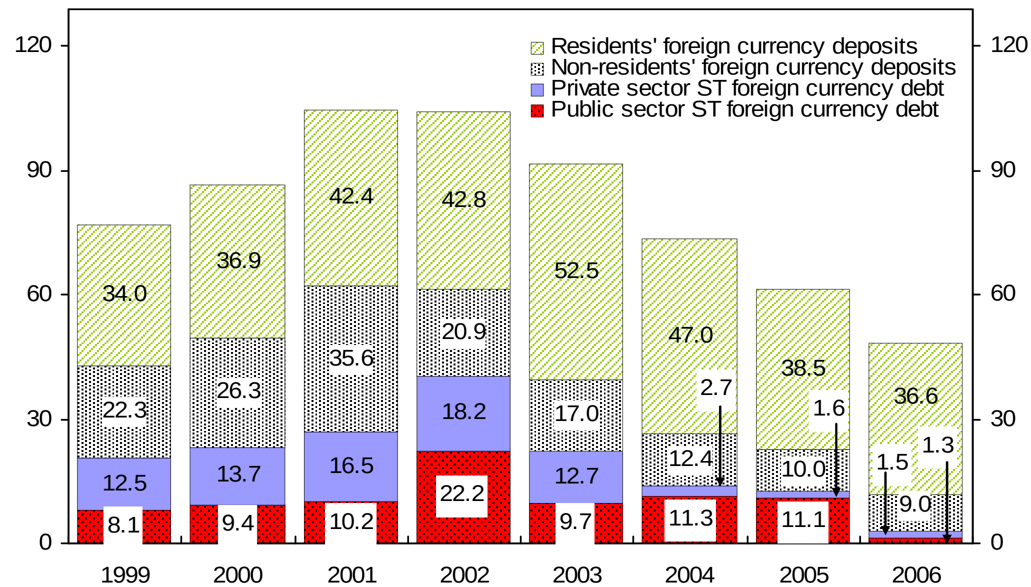
III. Vulnerabilities of The Uruguayan Economy

Foreign reserves may be useful to insure against various kinds of financial vulnerabilities. However, the literature typically emphasizes the fragility stemming from short-term foreign currency debt, which may precipitate a debt rollover crisis if external credit dries out. As argued in the previous section, another source of fragility is the existence of bank dollar deposits. In fact, a banking crisis may unfold in parallel to a debt rollover crisis if, concurrent with a sudden stop, there is a withdrawal of dollar deposits as occurred in Uruguay in 2002.

Figure 2 shows that sources of financial vulnerabilities in Uruguay increased from 1999 until the crisis in 2002, but have significantly dropped since then. Short-term foreign currency debt is now at historically low levels.[5] Private short-term foreign currency debt was 12.5 percent of GDP in 1999, increasing to 18.2 percent of GDP in 2002. Since then, it has declined (with a major drop in 2004), reaching 1.5 percent of GDP in 2006. Public short-term external debt, on the other hand, was 8.1 percent of GDP in 1999, but jumped to 22.2 percent in 2002, before dropping to 11.1 percent in 2005. As the government bought back large amounts of its short term liabilities in 2006, this ratio dropped to 1.3 percent of GDP.

[5] The definition of public and private short-term debt is in a remaining maturity basis. Public foreign currency debt includes both domestic and external debt.

Figure 2. Short-term foreign currency debt and foreign currency deposits in Uruguay
(percent of GDP)

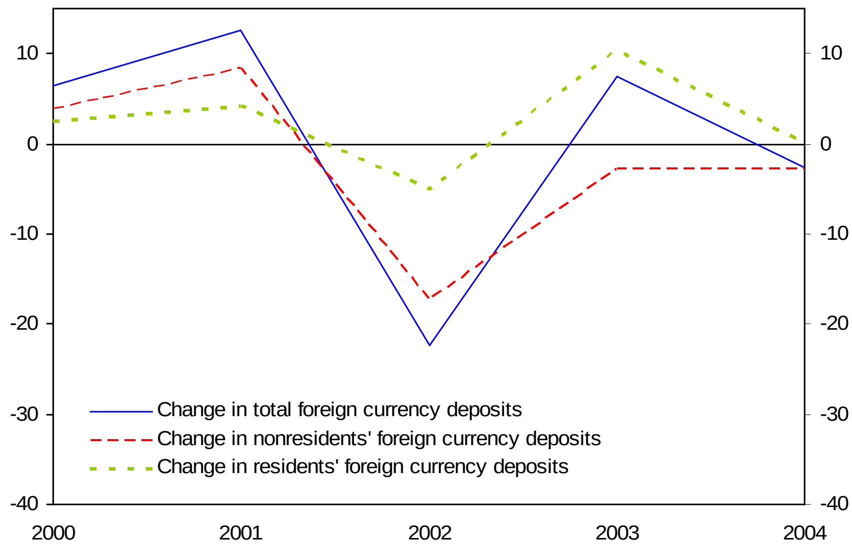


Source: Central Bank of Uruguay; International Financial Statistics; and author's calculations.

Despite progress, high deposit dollarization remains a key vulnerability. Non-residents' foreign currency deposits peaked at 35.6 percent of GDP in 2001, when deposits from Argentinean citizens increased as a result of the crisis in that country. Since then, non-residents' foreign currency deposits have decreased sharply, reaching 9 percent of GDP at end-2006, a significant reduction in the vulnerability of the banking system. However, residents' foreign currency deposits remained at 36.6 percent of GDP at end-2006, a relatively small drop from 42.4 percent of GDP in end-2001. Thus, while risks have been reduced considerably since the 2002 crisis, dollarization of deposits remains one of the highest in the world and a major vulnerability for the Uruguayan economy.

As illustrated by the 2002 crisis experience, non-residents' deposits can be more susceptible to large withdrawals than residents' deposits (figure 3). While the drop in residents' deposits in 2002 was about 5 percent of GDP, the drop in non-residents' deposits reached 17 percent of GDP. Furthermore, residents' deposits increased in the year just after the crisis, while non-residents' deposits continued to drop even two years after the crisis (in part a consequence of improvements in the regulation of such deposits). Importantly, the 2002 experience shows that non-residents' deposits can be more volatile than residents' deposits, a feature that will be taken into account when assessing the optimal prudential level of reserves in Uruguay.

Figure 3. Withdrawal of foreign currency deposits in 2002
(percent of 2001's GDP)



Source: Central Bank of Uruguay; International Financial Statistics; and author's calculations.

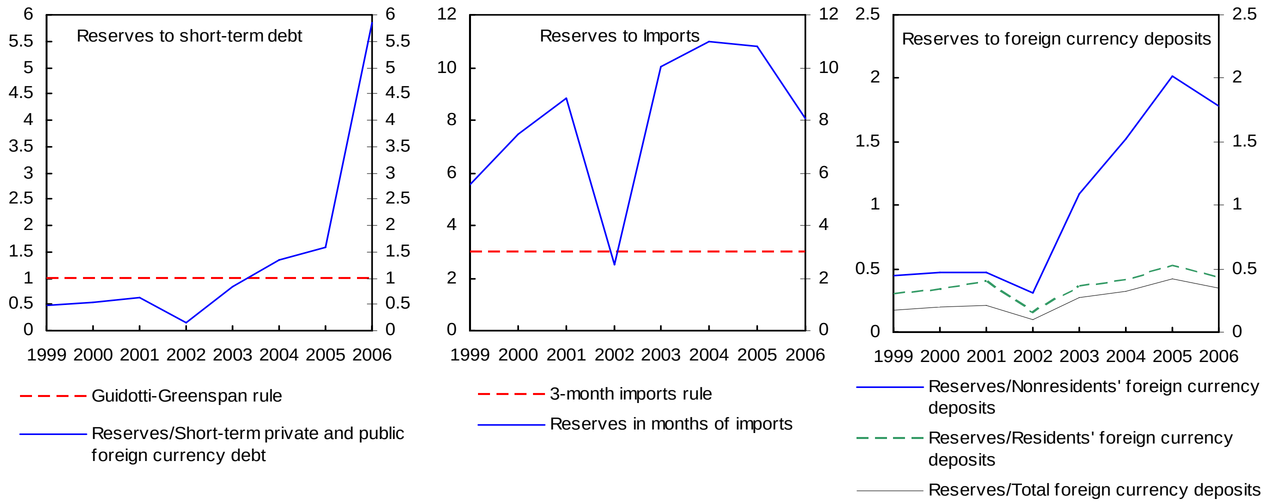
Given Uruguay's low short term debt at present, the usefulness of reserves for self-insurance purposes is more related to the high degree of deposit dollarization. Therefore, a proper assessment of reserve adequacy should take this into account. Traditional benchmark measures of reserve adequacy, such as the ratio of reserves to short-term debt and the ratio of reserves to imports, do not satisfy this criterion.[6] The most well-known ad-hoc measure of reserve adequacy is the so-called Guidotti-Greenspan rule, which prescribes reserves coverage of 100 percent of short-term foreign currency debt, to allow the central bank to fully counteract any debt rollover crisis, at least in the short run. Another typical rule is to have a coverage of at least three months of imports, to smooth shocks to the current account and avoid large swings in domestic consumption.

Although the ratio of reserves to short-term foreign currency debt provides some evidence of reserve inadequacy prior to the crisis, traditional benchmark measures do not appear sufficiently informative for the case of Uruguay. Figure 4 shows that the ratio of reserves to short-term foreign currency debt was about 62 percent in 2001, before dropping to 15 percent in 2002, as reserves were used to mitigate the crisis. Since then, the coverage of reserves has been increasing, reaching almost 100 percent of short-term debt in 2003 and a sharply higher coverage during the following years as short-term debt was being repaid. The ratio of reserves to imports has also been consistently above the three-months-of-imports rule, except for 2002, the year of the crisis.

---

[6] For a discussion of these and other benchmark measures of reserve adequacy, see Wijnholds and Kapteyn (2001).

Figure 4. Benchmark Measures of Reserve Adequacy



Source: International Financial Statistics; Central Bank of Uruguay; and author's calculations.

In contrast, the ratio of reserves to dollar deposits suggests that the Uruguayan economy was particularly vulnerable to a bank run prior to the 2002 crisis:. reserves covered only 18-21 percent of dollar deposits during 1999-2001. The coverage of dollar deposits by reserves has increased substantially since then, and is currently sufficient to cover about 35 percent of total dollar deposits and more than 100 percent of non-residents' deposits. Despite this increase, further analysis is needed to establish whether reserves now provide an appropriate balance between costs and protection against major withdrawal of dollar deposits, an issue pursued in the next sections.

IV. The Optimal Level of Reserves in Uruguay

What is the optimal level of foreign reserves for self-insurance purposes in a financially dollarized economy? To address this question, an extended version of JR's framework that explicitly takes into account dollar-denominated deposits is derived. Consider a small open economy in discrete time which may face a 'sudden stop', defined as an exogenous loss of external credit. We assume that when this occurs:

(i) short-term foreign currency debt is not rolled over;
(ii) a significant fraction of foreign currency deposits is withdrawn from the banking sector;
(iii) output falls;
(iv) the real exchange rate depreciates.

The resulting closed-form solution for the optimal level of reserves is shown in equation (4) below (a full derivation of the model is in appendix 1). The description of each parameter and the baseline calibration for the case of Uruguay is shown in tables 1 and 2. Parameters computed from actual data are shown in table 1, while parameters that need judgment to be calibrated are in table 2 (the latter are assumed to be fixed during the sample period).

(4) $$\rho = \lambda + \gamma + \frac{(1-\gamma)p^{1/\sigma}\Delta q}{1+[p^{1/\sigma}(1+\Delta q)-1](1-\pi-\delta)}$$

$$-\frac{p^{1/\sigma}(1+\Delta q)-1}{1+[p^{1/\sigma}(1+\Delta q)-1](1-\pi-\delta)}\left\{1-\frac{r-g}{1+g}\left[\lambda+(1-\phi)\lambda_D\right]-(\pi+\delta)\left(\lambda+\gamma\right)\right\},$$

where $\lambda = (\phi - \alpha)\lambda_D + \lambda_P + \lambda_G$, $\phi = s_R C_R + s_{NR} C_{NR}$, and $p = \frac{(1-\pi)(\delta+\pi)}{\pi(1-\delta-\pi)(1+\Delta q)}$.

The formula balances consumption-smoothing benefits with quasi-fiscal costs of holding reserves. It states that optimal reserves are increasing in the magnitude of deposit withdrawals ($\phi\lambda_D$), private (λ_P) and public (λ_G) short-term foreign currency debt, the output cost (γ) and the likelihood of a crisis (π). Intuitively, reserves are more useful as a buffer the larger the drop in consumption (caused by the withdrawal of dollar deposits and sudden stop in foreign currency credit) and the bigger the probability of such drop. A larger coverage of dollar deposits by banks' own reserve holdings (i.e., by banks' liquid foreign assets[7]—$\alpha\lambda_D$) implies that less official reserves are needed, as such coverage also provides cushions to face dollar deposits withdrawals in a crisis.[8] In addition, a real exchange rate depreciation (Δq) increases the burden of foreign currency liabilities, leading to further drops in consumption and, thus, a need for larger reserves. Finally, the optimal level of reserves is decreasing in the cost of holding reserves, which is captured by the interest rate differential between long-term debt issued to finance reserves and the return on reserves (δ).

The model needs to be adjusted to take into account that, in the Uruguayan context, the drop in non-residents' deposits during a crisis was larger than for residents' deposits (figure 3). While the ratio of liquid foreign assets of banks to foreign currency deposits has been relatively stable in Uruguay, the composition of foreign currency deposits has shifted from non-residents to residents in recent years. Thus, in the event of a 2002-like crisis, the current coverage of deposits by banks' liquid foreign assets could be considered stronger than in 2002. In order to reflect this

[7] Banks' liquid foreign assets comprise cash, bonds, and deposits with maturity of less than one year.

[8] A shortcoming of our analysis is that, by looking at the banking sector as a whole, we may miss the fact that some banks can have better coverage than others. However, even if disaggregated data by banks were available, the proper way of aggregating such data is unclear.

in the calibration, the ratio of banks' liquid foreign assets to dollar deposits takes into account the change in residents/non-residents composition of deposits over time.[9]

Table 1. Variable Parameters
(in percent)

	1999	2000	2001	2002	2003	2004	2005	2006
Public sector short-term foreign currency debt/GDP (λ_G)	8.1	9.4	10.2	22.2	9.7	11.3	11.1	1.3
Private sector short-term foreign currency debt/GDP (λ_P)	12.5	13.7	16.5	18.2	12.7	2.7	1.6	1.5
Total foreign currency deposits/GDP (λ_D)	56.3	63.3	78.0	63.7	69.4	59.4	48.5	45.7
Non-residents' foreign currency deposits/ Total foreign currency deposits (S_{NR})	39.6	41.6	45.6	32.8	24.4	20.9	20.6	19.8
Residents' foreign currency deposits/ Total foreign currency deposits (S_R)	60.4	58.4	54.4	67.2	75.6	79.1	79.4	80.2
Banks' liquid foreign assets as a share of foreign currency deposits—corrected (α^C)	16.2	17.3	13.9	21.4	28.9	41.0	42.8	37.3

Table 2. Fixed Parameters

Coverage of non-residents' deposits (C_{NR})	100%
Coverage of residents' deposits (C_R)	30%
Accumulated output loss (γ)	14%
Probability of sudden stop (π)	7.5%
Term premium (δ)	1.5%
Risk-free rate (r)	5%
Risk aversion (σ)	2
Real exchange rate depreciation (Δq)	30%
Long-run GDP growth rate (g)	3%

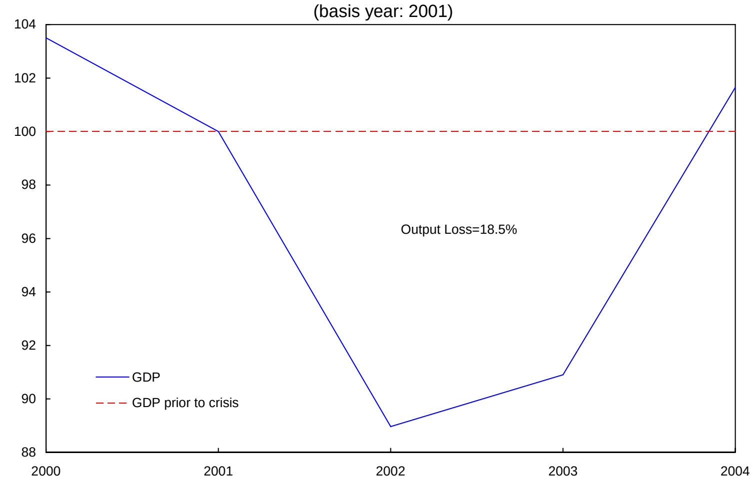
[9] In the model, α is defined as the ratio of banks' liquid foreign assets (BLFA) to total dollar deposits (residents – R – and non-residents – NR), $\alpha = \frac{BLFA}{R+NR}$. Note that α can be rewritten as follows: $\alpha = \frac{BLFA}{R+NR} = \frac{BLFA}{NR} \times \frac{NR}{R+NR}$. The first term, the coverage of non-residents' deposits by banks' liquid foreign assets, has increased since the 2002 crisis, while the second term, the share of non-residents' deposits, has decreased. The reduction of the later term implies a reduction in the risk of large deposit withdrawals. For comparability purposes, it is sensible to maintain the same "level of risk" in all years of the sample. This is done by assuming that in previous years the composition of residents'/non-residents' deposits was the same as in 2006, yielding the corrected measure $\alpha_y^C = \frac{BLFA}{R+NR} = \left(\frac{BLFA}{NR}\right)_y \times \left(\frac{NR}{R+NR}\right)_{2006}$, where y is the year under consideration.

The parameters were generally calibrated following standard assumptions. The risk aversion parameter is set at 2, a number typically used in the business cycle literature. The risk free short-term dollar interest rate (the return on reserves) is set to 5 percent, about the average U.S. 3-month T-bill rates in the last 10 years. The term premium is assumed to be 1.5 percent, close to the average difference between the yield on 10-year U.S. treasury bonds and the federal fund rate in the last 20 years. The growth of potential output in Uruguay is calibrated at 3 percent. The real exchange rate depreciation following a crisis is calibrated at 30 percent, slightly less than the 33 percent depreciation that took place between March and September of 2002.

Coverage of foreign currency deposits by official reserves and banks' liquid foreign assets was set at 100 percent for non-residents and 30 percent for residents. The full coverage for non-residents deposits, which broadly matches the current practice by banks in Uruguay, would fully insulate the domestic economy from sudden withdrawals by non-residents, which can be large as evidenced by the 2002 crisis. Since residents' deposits have been less volatile than non-residents', a smaller coverage seems appropriate.

The output loss due to a crisis was calibrated at 7 percent of GDP per year during 2 years—i.e., 14 percent total. The accumulated output loss of the Uruguayan economy as a result of the 2002 crisis was about 18 ½ percent, taking roughly two years for output to recover to its pre-crisis levels (figure 5). This implied an average loss of 9¼ percent of GDP per year during two years. Given improved external conditions, particularly compared with 2002 (when the devaluation in Brazil was followed by a severe crisis in Argentina), it seems reasonable to assume a less pronounced output loss. In addition, the choice of a 14 percent loss in output is consistent with estimates found in the literature on currency crisis and sudden stops for a typical emerging market country.[10]

Figure 5. Output Loss due to the 2002 crisis in Uruguay
(basis year: 2001)



[10] Hutchison and Noy (2006) find that the cumulative output loss of a sudden stop (defined as a simultaneous occurrence of a currency/balance-of-payments crisis with a reversal in capital inflows) is around 13–15 percent of GDP.

The probability of a crisis was calibrated at 7.5 percent a year, or an average of one crisis every 15 years. JR's estimation, based on a cross-country Probit model, yields a probability of 10 percent for a typical emerging market country. Nonetheless, Uruguay track record of one major crisis every 20 years (1982 and 2002) implies an observed crises frequency of 5 percent. The model was calibrated using an intermediate probability between these results, given potential specification problems of the Probit estimation[11] and the very few data points on Uruguay's crisis episodes.

The calibrated model suggests that reserve coverage has increased since 2002 from well below optimal to near optimal levels. Figure 6 shows that, while reserves have increased significantly in the last few years, they have remained relatively stable with respect to GDP. At the same time, short-term foreign currency indebtedness and deposit dollarization (specially non-residents' deposits) have declined and banks' own liquidity has increased. With a reduced need for central bank reserves for prudential purposes, the estimated optimal level of reserves declined from almost 80 percent of GDP (or US$14.7 billion) 2001 to below 20 percent of GDP (or around US$3.8 billion) by mid-2007. Actual reserve levels are about 1.7 percent of GDP (or US$300 million) below the estimated optimal level.

An alternative way to evaluate reserve adequacy is to simulate the impact of a (hypothetical) crisis on the level of reserves. Figure 7 presents the results of a 2002-like crisis, i.e. drops in non-residents' and residents' deposits, and short term debt of 63 percent, 36 percent, and 26 percent, respectively. While in 2002 reserves were clearly insufficient to deal with the shocks, the simulation illustrates that current reserve levels would be nearly sufficient to deal with a similar shock. In other words, the gap in 2002 had to be filled with substantial external support, but a similar scenario in 2006 would require significantly less foreign assistance.[12] This is not only a consequence of higher reserve levels, but also and more importantly, of sharply reduced vulnerabilities.

Nonetheless, further reserve accumulation will likely be desirable going forward. In particular, the optimal level of central bank reserves is likely to increase in the next few years, as the ongoing credit recovery matures and banks' reduce their currently high holdings of liquid external assets. As an illustration, Figure 6 shows that the optimal level of reserves as of June 2007 would increase to almost 30 percent of GDP (or about US$5.7 billion) if banks' coverage of deposits by own foreign liquid assets were to return to pre-crisis levels.[13] This highlights the importance of banking regulations to address the vulnerabilities caused by dollar deposits, thereby

[11] Using Uruguay's macroeconomic variables in JR's Probit equation generates unrealistically high probabilities of crisis in Uruguay in recent years resulting perhaps from misspecification problems.

[12] See appendix 2 for an explanation of how simulation results were obtained.

[13] The dashed line in Figure 6 assumes that the corrected ratio of banks' liquid assets to deposits is at pre-crisis level (the later is obtained by the 1999-2001 average of the ratio of banks' liquid assets to deposits).

limiting the need for central bank reserve accumulation (see section VI.B for further discussions on banking sector regulation and reserve adequacy).

Figure 6. Optimal versus actual level of reserves in Uruguay
(in percent of GDP)

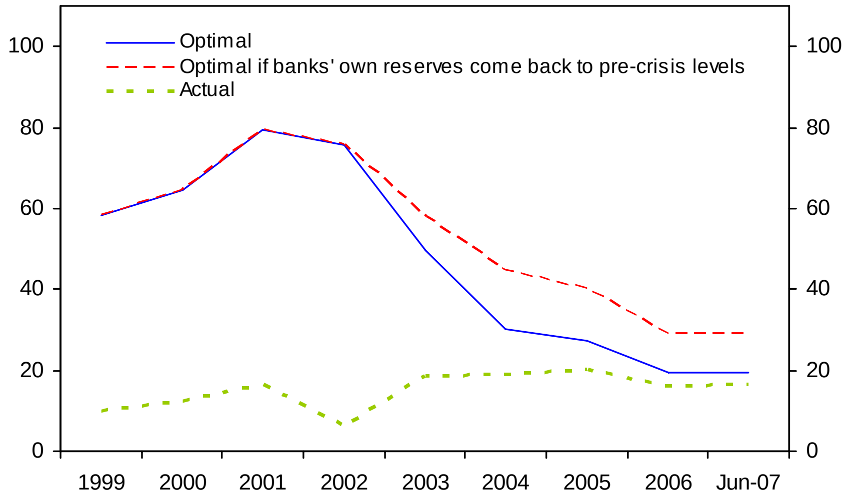
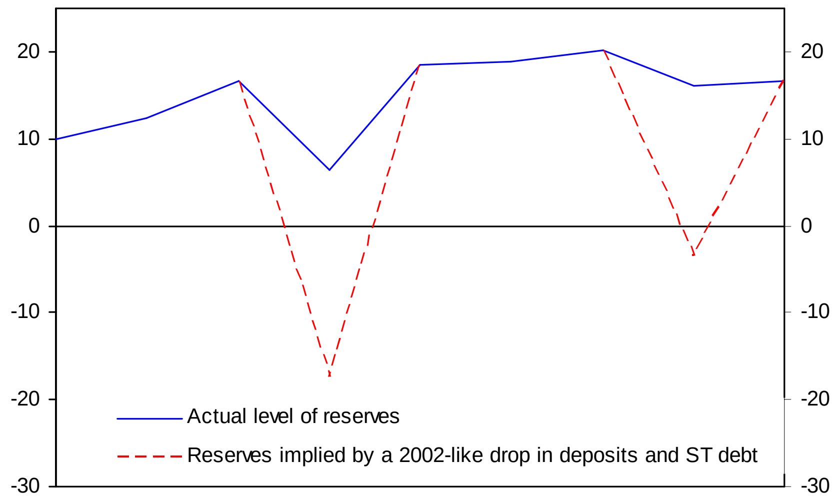


Figure 7. Actual and Implied Reserves
(percent of GDP)

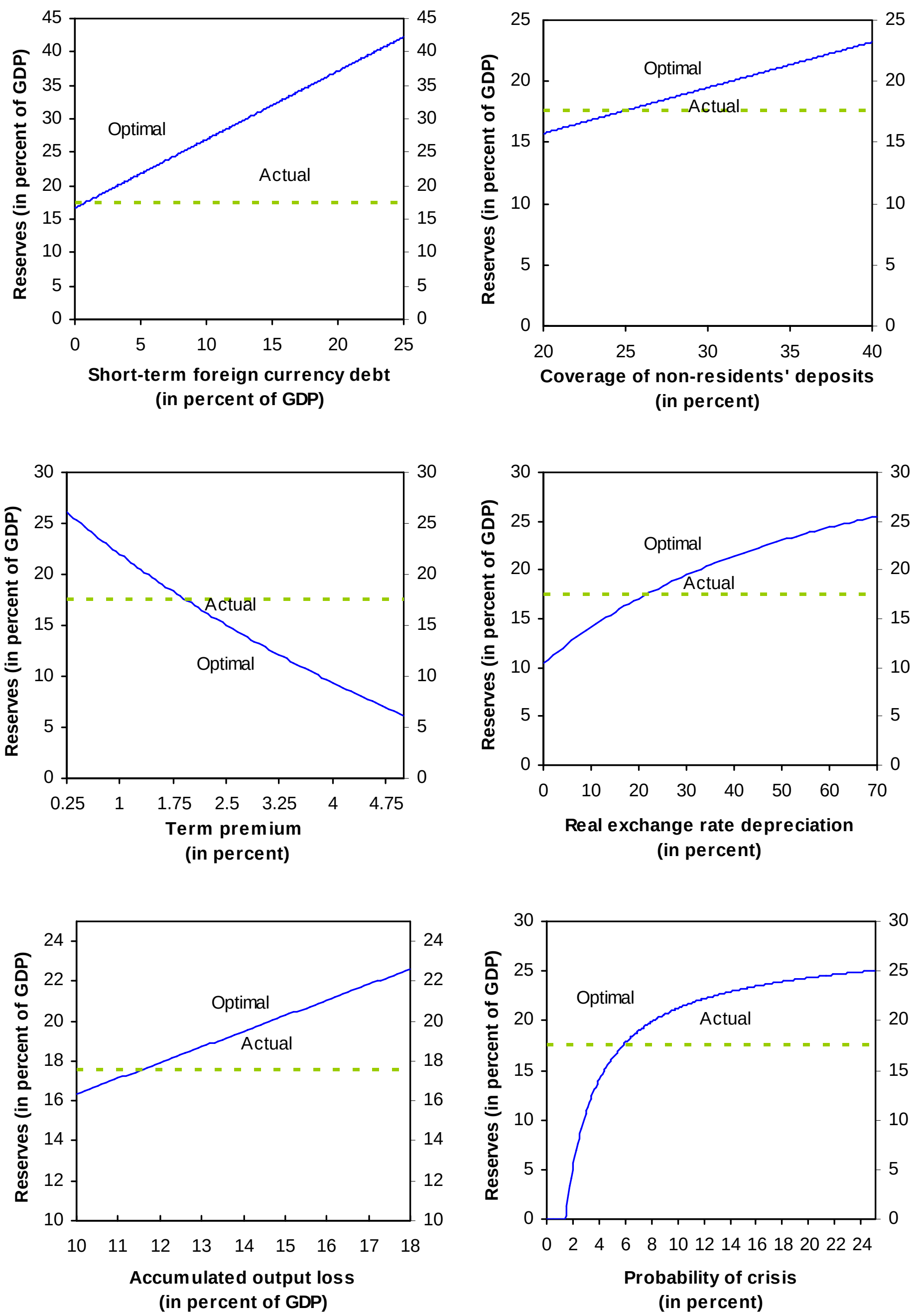


V. Sensitivity Analysis

To investigate the sensitivity to calibration choices, Figure 8 presents the impact that changes in parameters would have on the results. The optimal level of reserves is particularly sensitive to the level of short term foreign currency debt, where a debt to GDP ratio of 25 percent, as in end-2001, would result in optimal reserves of over 40 percent of GDP. Coverage of residents' deposits in the range 10–40 percent would imply reserve levels between 15–25 percent

of GDP; an increase in the term premium from 1.5 to 2.5 percent would reduce optimal reserves to less than 16 percent of GDP; and a real exchange rate depreciation of 50 percent results in optimal reserve levels of about 23 percent of GDP. Interestingly, an output loss of 18.5 percent of GDP, as in 2002, or a 10 percent probability of crisis (as assumed by JR) would only increase optimal reserve moderately to about 21-22 percent of GDP.

Figure 8. Sensitivity Analysis



Source: Author's calculations

Table 3 shows which assumptions would lead to conclude that current reserves are optimal. For example, reserves would be optimal if short-term foreign currency debt dropped below 1 percent of GDP from its current historic low level of 2.8 percent of GDP, or if coverage of residents' foreign currency deposits were reduced from 30 percent to 25 percent of deposits; or, if the probability of a crisis decreased to about 6 percent. To obtain an equivalent result, larger changes in other parameters would be needed: a significant decline in output loss to11-12 percent (much smaller than 2002's experience); an increase in the term premium of 2 percent (higher than historical averages); or a real exchange rate depreciation of only 22 percent (much smaller than observed in the last crisis).

Table 3. Implicit Parameters
(In percent)

Short-term foreign currency debt/GDP (λ_G+λ_P)	0.9
Coverage of residents' deposits (C_R)	24.8
Accumulated output loss (γ)	11.6
Probability of sudden stop (π)	5.8
Term premium (δ)	2.0
Real exchange rate depreciation (Δq)	21.8

VI. Some Caveats

A. Caveat on the Model: Crisis Prevention and the Optimal Level of Reserves

The results of the calibration above could be seen as a lower bound for the optimal level of reserves. In fact, the analytical model derived in this paper captures the role of reserves in the mitigation of balance-of-payments and banking crises, but not its role in reducing the likelihood of a crisis. To capture this, the model could be extended by allowing the probability of a crisis to be a negative function of the level of reserves,

(5) $$\pi = \pi(R), \text{ with } \pi'(R) < 0 .$$

Empirical evidence on the preventive role of reserves is mixed. The ratio of reserves to short-term debt has been found to be negatively associated with currency crisis and sudden stops (Bussière and Mulder, 1999; Garcia and Soto, 2006). However, the direction of causality is unclear as the negative association may reflect optimal default decisions (Detragiache and Spilimbergo, 2001). Also, empirical studies typically fail to identify whether high levels of reserves help to prevent crises, or simply postpone the crises (Jeanne, 2007). This methodological issue may lead to an exaggeration of the role of reserves in preventing crises.

From a theoretical modeling perspective, there are also reasons for not incorporating the crises prevention role of reserves. First, endogenizing the likelihood of a crisis comes at the cost of no longer obtaining closed-form expressions for the optimal level of reserves, implying that

numerical simulations need to be used to obtain the solution of the maximization problem.[14] This would undermine a key objective of the model, i.e. to provide a framework that can be easily used for the assessment of reserve levels in dollarized economies. Second, the inclusion of the crises prevention role of reserves may obscure the assessment of the usefulness of reserves for the mitigation of crises. Finally, it also complicates the assessment of the sensitivity of the optimal level of reserves to underlying parameters.

B. Caveats on the Policy of Reserve Accumulation

Moral Hazard and Reserve Accumulation

The model assumed that central bank reserves and commercial banks' reserves (liquid assets in dollars) are close substitutes. In other words, lower banks' liquid dollar assets imply a higher need for central bank reserves in order to provide liquidity to banks in the event of a crisis. An important moral hazard consideration not captured by the model is that reserve accumulation could intensify perceptions of government guarantees. As a result, increases in official reserves may lead banks to hold less reserves themselves or to become more dollarized.

How can moral hazard be incorporated in the model? The optimal level of official reserves is derived as the residual of the consolidated (banks plus central bank) optimal level of reserves minus banks' liquid foreign assets. The resulting expression—equation (4)—is increasing in the mismatch between dollar deposits and banks' liquid foreign assets (captured by the parameter α). Therefore, moral hazard could be incorporated into the model by assuming that mismatches increase as reserves are accumulated,

(6) $\alpha = \alpha(R)$, with $\alpha'(R) < 0$.

How can moral hazard concerns be contained? Levy-Yeyati (2006) studies the optimal composition of "decentralized reserves" (liquid assets held by banks) and "centralized reserves" (official reserves). He concludes that higher liquid asset requirements on banks—i.e., a regulatory shift from centralized to decentralized reserves—could limit moral hazard concerns. In terms of the model of this paper, Levy-Yeyati's argument implies an α that is constant (i.e., independent of the level of official reserves), as we have assumed, and sufficiently large. By assuming that banks' balance sheet mismatches are not a function of the level of reserves, we implicitly assumed that banks in Uruguay are properly regulated.[15]

[14] See, for example, Garcia and Soto (2006), Chami et al. (2007), Jeanne (2007).

[15] Note that, as in the case of peso deposits, increasing liquidity requirements (or reducing deposits) induce disintermediation. To limit this problem, Levy-Yeyati defends the use of "circuit breakers" (ex-ante suspension-of-convertibility clauses) and analyzes their application in two recent crisis: Argentina in 2001 and Uruguay in 2002.

Monetary Policy and Reserve Accumulation

The credibility of monetary policy may also be affected by the accumulation of reserves. Lopez-Mejia et al. (2007) have shown that financial dollarization and credibility of monetary policy are closely associated in Uruguay. Thus, to the extent that moral hazard effects are economically important, the accumulation of reserves may induce further dollarization, indirectly affecting monetary policy credibility. Similarly, foreign exchange intervention to accumulate reserves may signal exchange rate targeting, which may also hinder the credibility of other monetary policy goals, such as inflation targets. Nevertheless, these problems can be addressed to a great extent through proper regulation of banks and by improving the transparency and independence of monetary policy.

VII. Conclusions

This paper derives a model of optimal reserves from a prudential perspective that explicitly takes into account the possibility of large withdrawals of foreign currency deposits in the event of a crisis. The model extends the more typical approach that focuses on the risk and potential magnitude of financial account reversals. The resulting expression for the optimal level of reserves was calibrated for Uruguay, a country that has a highly dollarized financial sector.

The results show that, with the sharp reduction in short term foreign currency debt and non-residents' deposits since the 2002 crisis, and the high holdings of liquid foreign assets by banks, the prudential benefit of holding official reserves has diminished. In the model, this is reflected in the significant drop of the optimal level of reserves since 2002 which, together with the accumulation of reserves by the central bank, has nearly closed the gap between optimal and actual reserve levels.

Nonetheless, further reserve accumulation may be needed going forward. In particular, with banks' currently high liquidity levels likely to decline as the credit recovery matures, the optimal level of official reserves is expected to increase in the years ahead. Also, the analysis shows that the optimal reserve levels are highly sensitive to a possible increase in short-term foreign currency indebtedness. Finally, with the model focusing on crisis mitigation and not on crisis prevention, the calculated optimal level of reserves could be seen as a lower bound.

APPENDIX 1. A MODEL OF OPTIMAL RESERVES IN FINANCIALLY DOLLARIZED ECONOMIES

Consider a small open economy in discrete time which may be hit by a ‘sudden stop’, defined as an exogenous loss of external credit. When a sudden stop hits the economy,

(i) short-term foreign currency debt is not rolled over;
(ii) a significant fraction of foreign currency deposits is withdrawn from the banking sector;
(iii) output falls;
(iv) a real exchange rate depreciation occurs.

The (non-financial) private sector is subject to the following budget constraint:

$$\text{(A.1)}\quad C_t = Y_t + q_t\left[B_t - (1+r_B)B_{t-1} + P_t - (1+r)P_{t-1} + Z_t\right],$$

where C_t is domestic consumption, Y_t is domestic output, q_t is the real exchange rate, B_t is the dollar short-term lending by banks to the private sector, P_t is the short-term external debt of the private sector, and Z_t is a transfer from the government. The interest rates r_B and r are constant. Consumers do not default on short-term external debt, so r is a risk free interest rate.

Banks are subject to the following budget constraint:

$$\text{(A.2)}\quad B_t - (1+r_B)B_{t-1} + RB_t - (1+r)RB_{t-1} = D_t - (1+r_D)D_{t-1},$$

where RB_t is the amount of dollar deposits that banks invest in risk free short-term foreign assets (in dollars) at an interest rate of r, and D_t are dollar deposits for which banks pay an interest rate of r_D. RB_t can be interpreted as reserves retained by banks as a precautionary measure against sudden withdrawals of dollar deposits. As we shall see below, because RB_t represents self-insurance by banks against crises, the larger its amount the less reserves the central bank will need to hold for insurance purposes.

Note that the model abstracts from short term peso securities, as the central bank always has the ability to generate extra liquidity in pesos on demand. In fact, it has been argued in the literature that peso deposits and dollar deposits differ fundamentally in that the former do not require the central bank to accumulate reserves in advance, while the later do (Levy-Yeyati, 2006).[16]

[16] In practice, central banks retain reserves in pesos as well to reduce the likelihood of runs, providing confidence to the banking sector. This, however, can be seen as a separate problem from the one on smoothing the effects of a sudden stop and capital flight, which is the focus in this paper.

RB_t is assumed to be a constant fraction of short-term foreign currency deposits: $RB_t = \alpha D_t$, $0 < \alpha < 1$. Furthermore, it is assumed for simplicity that $r_D = r$ (introducing a premium in domestic foreign currency deposits would not fundamentally alter the results). Hence, equation (A.2) can be rewritten as follows,

$$\text{(A.3)} \quad B_t - (1+r_B)B_{t-1} = (1-\alpha)\left[D_t - (1+r)D_{t-1}\right].$$

By (A.1) and (A.3), a consolidation of the banking sector and non-financial private sector yields,

$$\text{(A.4)} \quad C_t = Y_t + q_t\left\{(1-\alpha)\left[D_t - (1+r)D_{t-1}\right] + P_t - (1+r)P_{t-1} + Z_t\right\}.$$

As in JR, the government issues a long-term security that is sold by the price P (assumed constant), and yields one unit of good every period until the sudden stop occurs, after which it stops yielding any income. Therefore, the price of this security before the sudden stop occurs is given by the present discounted value of its expected future returns,

$$\mathrm{P} = \frac{1}{1+r+\delta}[1+(1-\pi)\mathrm{P}],$$

where π is the probability that a sudden stop occurs, *r* is the interest rate on short-term external debt, and δ is the term premium (so the interest rate paid on long-term debt is $r+\delta > r$). Solving the expression above for P yields

$$\mathrm{P} = \frac{1}{r+\delta+\pi}.$$

The long-term security is issued to finance a stock R_t of official reserves, implying that

$$R_t = \mathrm{P}N_t,$$

where N_t is the number of long-term securities issued by the government in period *t*.

The government may also issue short-term foreign debt in non-sudden-stop periods. Therefore, before the sudden stop, government's budget constraint is given by:

$$\text{(A.5)} \quad \mathrm{P}(N_t - N_{t-1}) - N_{t-1} + G_t - (1+r)G_{t-1} = Z_t + R_t - (1+r)R_{t-1},$$

where G_t is the short-term foreign debt of the government. The government does not default, implying that the interest rate on this debt is the risk free interest rate, *r*.

Following JR's notation, the subscripts *b* and *d* denote the periods before and during a sudden stop. Substituting out P, N_t and N_{t-1} from government's budget constraint yields the expression for the government transfer to the private sector before the sudden stop,

$$\text{(A.6)} \quad Z_t^b = G_t - (1+r)G_{t-1} - (\delta + \pi)R_{t-1}.$$

This expression shows that, before the sudden stop, government transfers can be increased by the issuance of short-term external public debt by the government. The second term in (A.6) corresponds to the cost of carrying reserves, which is proportional to the term premium plus a default risk premium, captured by the sudden stop probability. To pay for this cost, the government taxes the consumer, reducing the government transfer.

When a sudden stop occurs, private and public short-term external debt can no longer be issued. In order to smooth the effects on consumption of the sudden stop of external credit, the government transfers its official reserves to consumers, except for the amount $(\delta + \pi)R_{t-1}$, which it has to pay on its long-run security for the last time. Therefore, transfers during a sudden stop are given by

$$\text{(A.7)} \quad Z_t^d = -(1+r)G_{t-1} + (1 - \delta - \pi)R_{t-1}.$$

Assuming that $\delta + \pi < 1$, the term $(1 - \delta - \pi)R_{t-1}$ will be positive. This is what characterizes the insurance role of reserves in the model: in non-sudden-stop states, consumers pay $(\delta + \pi)R_{t-1}$ so that government carries reserves and, in exchange for that, consumers receive $(1 - \delta - \pi)R_{t-1}$ when a sudden stop occurs. Note that the issuance of short-term external debt by the government reduces the insurance provided by reserves since it increases the transfer that consumers receive in good states of nature and reduces the transfers in bad states of nature.

When the balance of payments crisis unfolds, a fraction of output γ is lost, and a fraction of dollar deposits ϕ is withdrawn from banks. Furthermore, the real exchange rate is constant and normalized to 1 before the crisis, and depreciates by Δq during the crisis. In the long run output grows at a rate *g*. With these assumptions and the equations for the transfer in (A.6) and (A.7), the expressions for domestic consumption before and during the crisis are, respectively,

$$\text{(A.8)} \quad C_t^b = Y_t^b + (1-\alpha)D_t^b + P_t^b + G_t^b - (1+r)\left[(1-\alpha)D_{t-1}^b + P_{t-1}^b + G_{t-1}^b\right] - (\delta + \pi)R_{t-1};$$

$$\text{(A.9)} \quad C_t^d = (1-\gamma)Y_t^b + (1+\Delta q)\left\{(1-\phi)D_{t-1}^b - (1+r)\left[(1-\alpha)D_{t-1}^b + P_{t-1}^b + G_{t-1}^b\right] + (1-\delta-\pi)R_{t-1}\right\}.$$

The government chooses the amount of reserves to maximize the expected welfare of consumers,

$$\text{(A.10)} \quad E(U_t) = E\left[\sum_{s=0}^{\infty}(1+r)^s u(C_{t+s})\right], \text{ where } u(C) = \frac{C^{1-\sigma} - 1}{1-\sigma}.$$

Since reserves at *t* only matter for the level of consumption in *t+1*, the government's problem in period *t* is simply

(A.11) $\max_{R_t}(1-\pi)\cdot u(C_{t+1}^b)+\pi\cdot u(C_{t+1}^d)$.

The first order condition of this problem is

(A.12) $\pi\cdot(1-\delta-\pi)\cdot(1+\Delta q)\cdot u'(C_{t+1}^d)=(1-\pi)\cdot(\delta+\pi)\cdot u'(C_{t+1}^b)$,

which basically states that, in the optimum, the probability of a sudden stop times the marginal utility of reserves in a sudden stop equals the probability of no sudden stop times the marginal cost of carrying reserves. Denoting by *p* the marginal rate of substitution between consumption in the sudden-stop state and consumption in the non-sudden-stop state,

(A.13) $p_t\equiv\dfrac{u'(C_t^d)}{u'(C_t^b)}$,

equation (A.12) shows that, in the optimum,

(A.14) $p_t\equiv p=\dfrac{(1-\pi)(\delta+\pi)}{\pi(1-\delta-\pi)(1+\Delta q)}$,

where *p* can be interpreted as the price of a sudden-stop dollar relative to the price of a non-sudden-stop dollar, which is a measure of the liquidity premium generated by a sudden stop.

Denote by λ_D, λ_P, and λ_G respectively, dollar deposits, private short-term foreign currency debt, and public short-term foreign currency debt as shares of output before the sudden stop:

(A.15) $\lambda_i=\dfrac{i_t^b}{Y_t}$, where $i=D,P,G.$

From equation (A.12), it can be shown that the optimal level of reserves before the sudden stop is a constant fraction of the level of output,

(A.16) $R_t=\rho Y_{t+1}^b$,

where the optimal ratio of reserves to output ρ is given by equation (4) in the text.

APPENDIX 2. LEVEL OF RESERVES REQUIRED TO COVER A 2002-LIKE CRISIS

The total drop in short-term foreign currency deposits is the sum of the drop in non-residents' deposits (ΔNR) and residents' deposits (ΔR) and can be written as follows:

$$\Delta D = \Delta NR + \Delta R = (NR + R)\left(\frac{NR}{NR+R}\frac{\Delta NR}{NR} + \frac{R}{NR+R}\frac{\Delta R}{R}\right) = D\left(\frac{NR}{NR+R}\frac{\Delta NR}{NR} + \frac{R}{NR+R}\frac{\Delta R}{R}\right)$$

The drop in *NR* and *R* is calibrated based on the 2002 crisis, whereas the composition of deposits in terms of *NR* and *R* is obtained from actual data in each year. In other words, the drop in deposits in a particular year *y* is given by:

$$\text{(A.17)} \quad \Delta D_y = D_y\left[\left(\frac{NR}{NR+R}\right)_y\left(\frac{\Delta NR}{NR}\right)_{2002} + \left(\frac{R}{NR+R}\right)_y\left(\frac{\Delta R}{R}\right)_{2002}\right].$$

Similarly, the drop in short-term foreign currency debt (ΔL) can be written as $\Delta L = L(\Delta L / L)$ and the size of the drop is calibrated based on the 2002 crisis:

$$\text{(A.18)} \quad \Delta L_y = L_y\left(\Delta L / L\right)_{2002}.$$

The implied level of reserves is simply the level that would result if reserves were used to cover the fall in deposits and debt implied by equations (A.17) and (A.18). As a share of GDP, this would be

$$\text{(A.19)} \quad \rho_y - \frac{\left(\Delta D_y + \Delta L_y\right)}{GDP_y},$$

where ρ_y is the actual level of reserves in year *y*.

References

Becker, Torbjorn, Olivier Jeanne, Paolo Mauro, Jonathan D. Ostry, and Romain Rancière, 2007, *Country Insurance: the Role of Domestic Policies*, Occasional Paper No. 254 (Washington: International Monetary Fund).

Bussière, Matthieu, and Christian Mulder, 1999, "External vulnerability in emerging market economies: how high liquidity can offset weak fundamentals and the effect of contagion," IMF Working Paper 99/88.

Chami, Saade, Donal McGettigan, and Stanley Watt, 2007, "Jordan's International Reserve Position: Justifiably Strong," IMF Working Paper 07/103 (Washington: International Monetary Fund).

De la Plaza, Luis, and Sophie Sirtaine, 2005, "An Analysis of the 2002 Uruguayan Banking Crisis," World Bank Policy Research Paper 3780 (Washington: World Bank).

Detragiache, Enrica and Antonio Spilimbergo, 2001, "Crises and Liquidity—Evidence and Interpretation," IMF Working Paper 01/2.

European Central Bank, 2006, *The accumulation of foreign reserves*, Occasional Paper No. 43 (Washington: International Monetary Fund).

Garcia, Pablo S., and Claudio Soto, 2006, "Large Hoarding of International Reserves: Are They Worth It?" in *External Financial Vulnerability and Preventive Policies*, ed. by Ricardo Caballero, César Calderón and Luis Céspedes, Eight Annual Conference of the Central Bank of Chile (Santiago, Chile).

Hutchison, Michael M., and Ilan Noy, 2005, "How Bad Are Twins? Output Costs of Currency and Banking Crises," *Journal of Money, Credit, and Banking*, Vol. 37, No.4.

Jeanne, Olivier, and Romain Rancière, 2006, "The optimal level of international reserves in emerging market countries: formulas and applications," IMF Working Paper 06/229 (Washington: International Monetary Fund).

Jeanne, Olivier, 2007, "International Reserves in Emerging Market Countries: Too Much of a Good Thing?" *Brookings Papers on Economic Activity*.

Levy-Yeyati, Eduardo, 2006, "Liquidity Insurance in a Financially Dollarized Economy," NBER Working Paper No. 12345 (Cambridge, Massachusetts: National Bureau of Economic Research).

Licandro, José Antonio, 1997, "Una evaluación de las reservas internacionales del banco central del Uruguay," *Revista de Economía*, Segunda Época Vol. IV, No. 2, Banco Central del Uruguay.

Lopez-Mejia, Alejandro, Alessandro Rebucci, and Carolina Saizar, 2007, "Pass-Through, Dollarization, and Credibility in Uruguay," in *Uruguay—Selected Issues*, SM/07/787, chapter II, IMF (Washington: International Monetary Fund)..

Wijnholds, J. Onno de Beaufort, and Arend Kapteyn, 2001, "Reserve Adequacy in Emerging Market Economies," IMF Working Paper 01/143 (Washington: International Monetary Fund).