Balance of Payments Sustainability and Optimal International Reserves

Salem Nechi*
This version, December 2010

Abstract

In this paper we explore the consequences of bailout packages for the long run international reserves policy in emerging market economies. We develop a model that looks at the intertemporal optimization problem of a small open economy that accumulates international reserves at a cost to insure itself against the risk of a balance of payments crisis associated with a fall in output. The analysis is applied to the Mexican case. Without the possibility of bailout, the model predicts an optimal reserves policy considerably higher than the current long run international reserves policy. When the model accounts for the bailout package that Mexico received after its 1994 Tequila crisis and the possibility of similar rescue packages in the future, the current reserves policy is in the range of the model’s predictions. A key feature of the model is that it explicitly links the optimal level of reserves not only to local policy rules, such as the trade policy and the net liability position, but also to the notion of sustainable BOP, which is, in turn, linked to global factors such as U.S. interest rates and oil prices.

*Assistant Professor of Economics, College of Business, American University of the Middle East. P.O.BOX: 220 Dasman, 15453 Kuwait. Phone: (+965)222 51 400 ext. 1114. E-mail: nechi.salem@gmail.com
1 Introduction

Recent studies argue that the accumulation of international reserves as insurance mechanism against the adverse output effects of Balance of Payments (BOP) crises has become excessive in many emerging market economies hit by the 1990s’ financial crises. In addition to using the stock of reserves to cope with their liquidity problems, many of these countries received substantial support (bailout) from the international financial community, resulting in less incentives to undertake costly economic adjustments.

In this paper we explore the consequences of bailout packages for the long run reserves policy in emerging market economies. Our model looks at the intertemporal optimization problem of a small open economy that accumulates international reserves at a cost to insure itself against the risk of a BOP crisis associated with a fall in output. We consider this problem with and without the possibility of bailouts. The analysis is applied to the Mexican case. Without the possibility of bailout, the model predicts an optimal reserves policy considerably higher than the current long-run reserves policy. When the model accounts for the bailout package that Mexico received after its 1994 Tequila crisis and the possibility of similar rescue packages in the future, the current reserves policy is in the range of the model’s predictions.

The appropriate level of reserves a country should accumulate has generated a large literature on optimal reserves. This literature has two strands. The focus of the first is on a set of rules of thumb, providing indicators that can be used to evaluate the sufficiency of reserves based on a set of macroeconomic variables such as the external short-term debt, imports, and money demand. The second strand emphasizes optimal level of reserves based on cost-benefit analysis. This paper contributes to this debate by developing a novel but practical method of estimating a country’s optimal level of international reserves based on a dynamic cost-benefit approach. We add to the existing literature by including the sustainability of the BOP as a constraint in the analysis of the trade-off between the desire to control for the costs of crises and the opportunity cost of holding reserves. We argue that this approach is more meaningful and more intuitive than the static cost-benefit analysis and the rules of thumb.

---

1 See, for example, Summers (2006).
2 See for example Vásquez (2002)
We assume that, under any reserves policy (i.e., target level of the reserves-GDP ratio), a country faces a risk of BOP crisis. Whenever the sum of current reserves and the present value of the economy’s expected future trade balance surpluses falls below its net liabilities (i.e., the BOP is not sustainable), the economy experiences a BOP crisis and incurs the cost associated with it, in addition to the opportunity cost of holding reserves. If, under the current reserves policy, no crisis occurs, the economy only incurs the opportunity cost of holding reserves. The opportunity cost of holding reserves in safe, low-return assets is not having those funds channeled to capital formation, a higher return activity. This cost has been estimated by Rodrik (2006) at close to 1 percent of GDP annually for all developing countries.\(^3\) Thus, the optimal reserves policy reflects a trade-off between the opportunity costs of holding reserves and the cost of BOP crisis. After calibrating the costs of BOP crises and the opportunity costs of holding reserves, we compute the present value of the expected total costs incurred under a target level of the reserves-GDP ratio. The target value of the reserves-GDP ratio associated with the lowest expected discounted total cost is the optimum.

In the aftermath of the 1990s’ financial crises, many emerging market economies have been bailed out either by other countries or by international financial institutions. For instance, in 1995, the United States committed up to $20 billion in repayable support, part of a nearly $50 billion international package to stem Mexico’s difficulties. In the following years, the IMF responded to the increased frequency and severity of financial crises by providing bailouts to Thailand, South Korea, Indonesia, Russia, Brazil, Turkey, and Argentina. This emergency aid, together with increasing financial and trade integrations, have created a conviction among many policymakers that rescue packages will be provided should a crisis hit (Vásquez, 2002).

The existent literature on optimal reserves policy, to our knowledge, does not quantify the level of reserves that can be rationalized in the presence of a bailout scenario like the one described above. Moreover, the literature does not explicitly address the contribution of external factors to the shaping of reserves policy in emerging economies. In this paper we bring together these

\(^3\)Rodrik (2006) estimates the cost of reserves as the spread between the private sector’s cost of short-term borrowing abroad and the yield the Central Bank earns on its liquid foreign assets.
two questions in a model of optimal reserves in the face of shocks experienced by emerging market countries and consider the possibility of external rescue plans and bailout options if the country faces a crisis.

Our starting point in optimal reserves determination is the reserves adequacy approach discussed in Nechi (2009). This approach is based on a numerical assessment of BOP sustainability given any reserves policy. In this paper we refine the adequacy rule by adding a dynamic cost-benefit analysis. The refinement exercise is addressed numerically, too. The first step in our analysis is to estimate the current reserves policy on the basis of a decomposition method that separates out movements in reserves process that are attributed to policy adjustments from movement resulting from external factors. Next, we discuss our approach to optimal reserves determination which includes the concept of sustainable BOP that allows the stock of reserves to influence the likelihood of crisis and the overall cost of holding reserves. Next we introduce the policymakers' perceptions of the possibility of a potential bailout into the derivation of the optimal reserves. We then calibrate the model to Mexico, simulate the optimal reserves policy and compare the model's predictions with our estimate of the current reserves policy.

The model predicts an optimal target level of the reserves-GDP ratio on the order of 9 percent for Mexico, which is considerably higher than the (estimated) long-run target of reserves-GDP ratio of 4.64 percent. This result raises the question of why Mexico holds lower reserves-to-GDP ratio than it should, even though it went through a severe crisis in 1994. One possible explanation is the international aid package it got at the time of the crisis and its strong conviction that it will get a similar rescue package should a crisis hit. When we account for this scenario the current reserves policy is in the range of the model's predictions. In fact, the bailout scenario produces an optimal level of reserves-GDP ratio of 5 percent (close to the estimated long-run level).

Heller (1966) was the first to derive the optimal level of reserves from a model using a cost-benefit approach. The benefit of holding reserves stems from the ability to avoid a reduction in output in the case of a deficit in the balance of payments. The opportunity cost of hold-
ing reserves is the difference between the return on capital and on reserves. Heller’s solution links the optimal level of reserves to three variables: the propensity to import, the interest rate, and the stability of international accounts as reflected in the average yearly imbalances experienced in the past. Heller’s analysis, however, only takes into account of the situations of unfavorable deficits that lead to the minimum level of international reserves; it does not consider the situations of mixed deficits and surpluses that lead to the minimum. Moreover, Heller does not explicitly consider the economic situation after the international reserves reach the minimum level. Hamada and Ueda (1977) correct Heller’s shortcomings by elaborating the random walk behavior for the exhaustion of reserves, which eventually leads to adjustment costs, and by taking into account the state of affairs after the exhaustion of reserves. Frenkel and Jovanovic (1981) and Flood and Marion (2002) replace the discrete random walk assumption of the reserve behavior with the continuous counterpart, i.e., a Wiener process, and introduce uncertainty to the cost of reserves holding. They derive formally an explicit solution for optimal reserve holdings as a function of the rate of interest, the variance of the stochastic process governing international payments and receipts, and the mean rate of net payments.

The studies discussed above assume that the economy initially holds an optimal level of reserves. Any deviation from that initial level requires costly adjustments to restore the reserves to their initial level. Moreover, any simulated time path of the international reserves starting from the initial point of the optimal level does not incorporate any deterministic behavior into the reserve movements and is characterized by a random walk behavior with upper and lower bounds. Accordingly, any observed deterministic behavior in the actual reserves should be interpreted as an adjustment toward attaining the initial optimal level. In our framework, we relax the assumption that the initial level of reserves is optimal. Moreover, the decomposition of reserves process into a policy component (i.e. target level of the reserves-GDP ratio) and stochastic component driven by external shocks suggests that movements in reserves should be interpreted as variation around the target level of reserves-GDP ratio not adjustment toward the optimal level. A key ingredient of this conclusion of our analysis is that we model the reserves process.
The issue of cost benefit analysis has also been discussed by Ben-Bassat and Gottlieb (1992). They develop a model that stresses the importance of the potential cost of default (on external debt) as a major determinant of optimal reserves. They assume that the cost of reserves depletion is the cost of default on loans by the country rather than the adjustment cost. Studying the case of Israel, their simulated results show that, in each year of the sample period, the optimal level of reserves depends on the estimates of GNP foregone in case of default (i.e., the opportunity cost of holding reserves), and the determinants of the default probability. Note that although Ben-Bassat and Gottlieb’s (1992) model does not assume the initial level of reserves to be optimal and accounts for some structural problems in the BOP, it restricts, however, the cost to a finite number of periods and ignores any dynamics in the balance of payments. In our model, we correct for these shortcomings by using an infinite time horizon in the optimization problem and allowing the dynamics of the BOP. In contrast to Ben-Bassat and Gottlieb’s (1992) model, in which the optimal level of reserves depends on the state of the economy (described by the subjective probabilities associated with the reserve depletion), the optimal level of reserves in our model depends on the state of the world economy which is represented by global factors and their implications for the BOP sustainability.

The reminder of this paper is as follow. Section 2 discusses a decomposition method introduced by Nechi (2009) which estimates the policy component of the reserves process, and describes the use of the concept of sustainable BOP to assess the adequacy of the reserves policy. Discussion of the cost-benefit analysis is presented in section 3. Details of the calibration and simulation, as well as the results, are discussed in section 4. Section 6 concludes this paper.
2 Reserves Policy and Balance of Payments Sustainability

2.1 Reserves Policy

In order to evaluate different reserve policies (i.e., target levels of reserves-GDP ratios), one would like to separate movements in reserves process resulting from policy components from movements resulting from external factors. In this section we discuss a decomposition method that have been introduced in Nechi (2009). We adopt the following specification of reserves process

\[ R_t = T_t + \beta' X_t + \epsilon_t, \]

where \( R_t \) is the (log of) nominal reserves to nominal GDP, and \( T_t \) is (log of) the target level of the reserves-GDP ratio. \( T_t \) could be time-varying and may change in response to the net liability position of the economy and political events. \( X_t \) is a vector of observable variables (shocks) that are exogenous to the economy but correlated with the unobservable variables driving the reserves process. \( \epsilon_t \) is the residual that represents the shocks that are not captured by \( X_t \) and uncorrelated to it. \( \epsilon_t \sim N(0, \sigma_\epsilon) \).

To identify \( X_t \), we define two sets of shock variables that best fit the Mexican economic environment. The first set of variables consists of internationally traded financial securities. These asset return variables are the value weighted return (excluding dividend) on the New York Stock Exchanges, VWR (from the CRSP tape), the dividend yield, DIV, on the CRSP value-weighted index (measured as a 1-year backward moving average of dividends divided by the S&P500 Composite Price Index-stock market price index at the first month of the quarter), the 3-month Treasury bill rate TBILL, and the yield on 10 years U.S. government bonds, LONG. These asset return variables (in addition to the 1-year moving average of the 3-month treasury bill rate TBMA), or linear combinations of them, have been found to forecast asset returns and are discussed in more detail in Campbell (1996). The second set of variables are related to the oil industry. We consider the change in the (log of) crude oil price, \( \Delta LCOPO \), and the change in the (log of) U.S imports of crude oil from Mexico, \( \Delta LUSMCO \). Since Mexico is a small open economy, it is reasonable to assume that the above two sets of variables
Table 1: Shocks-Adjusted Trade Balance

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta LCOP)</td>
<td>-.14 (\pm .26)</td>
<td>-.12 (\pm .27)</td>
<td>-.14 (\pm .43)</td>
<td>.27 (\pm .24)</td>
<td>.10 (\pm .19)</td>
<td>-.05 (\pm .27)</td>
</tr>
<tr>
<td>(\Delta LUSMCO)</td>
<td>-.67** (\pm .33)</td>
<td>-.65** (\pm .33)</td>
<td>-1.77*** (\pm .40)</td>
<td>-.015 (\pm .29)</td>
<td>-.15 (\pm .24)</td>
<td>-.26 (\pm .33)</td>
</tr>
<tr>
<td>DIV</td>
<td>-2.31*** (\pm .70)</td>
<td>-2.54*** (\pm .81)</td>
<td>-2.45* (\pm 1.29)</td>
<td>-2.64*** (\pm .63)</td>
<td>-.50 (\pm .59)</td>
<td>1.29* (\pm .71)</td>
</tr>
<tr>
<td>TBILL</td>
<td>-9.97*** (\pm 3.07)</td>
<td>-9.25*** (\pm 3.33)</td>
<td>-17.36*** (\pm 6.04)</td>
<td>-3.61 (\pm 2.76)</td>
<td>-10.20*** (\pm 2.41)</td>
<td>.37 (\pm 3.14)</td>
</tr>
<tr>
<td>LONG</td>
<td>-1.54 (\pm 4.12)</td>
<td>-2.46 (\pm 4.44)</td>
<td>6.91 (\pm 6.96)</td>
<td>-11.21*** (\pm 3.71)</td>
<td>-2.83 (\pm 3.21)</td>
<td>9.42** (\pm 4.22)</td>
</tr>
<tr>
<td>VWR</td>
<td>-.11 (\pm .46)</td>
<td>-.06 (\pm .47)</td>
<td>-.47 (\pm .87)</td>
<td>.51 (\pm .41)</td>
<td>.05 (\pm .34)</td>
<td>.09 (\pm .47)</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>-3.07*** (\pm .03)</td>
<td>-3.04*** (\pm .07)</td>
<td>-3.11*** (\pm .09)</td>
<td>-1.44*** (\pm .03)</td>
<td>-1.75*** (\pm .05)</td>
<td>-4.82*** (\pm .04)</td>
</tr>
<tr>
<td>DUMMY</td>
<td>(\pm .07) (\pm 1.13)</td>
<td>(\pm .09) (\pm 1.13)</td>
<td>(\pm .09) (\pm 1.13)</td>
<td>(\pm .09) (\pm 1.13)</td>
<td>(\pm .67*** (\pm .09)</td>
<td>(\pm .09) (\pm 1.13)</td>
</tr>
</tbody>
</table>

Notes: (1) standard errors are given in parentheses. (2) P-values are in square brackets. Significance at 10%, 5% and 1% is referred to by *, **, and ***, respectively.

are not influenced by the Mexican policy. For our purposes, we view these variables as picking up key components of the shocks affecting the world economy. Note that all the variables are demeaned.

Once these variables are identified, we can then estimate the target level of the reserves-GDP ratio, \(T_t\), and the contribution of the shock variables, \(X_t\), to the reserves process. Column 1 of Table 1 presents the results from OLS estimation of model (1) over the period 1981:1-2006:4. The results illustrate the striking fact that 70 percent of the variation in the reserves can be replicated by a simple linear combination of the shock variables. According to our model, the
estimated long-run target level of reserves-GDP is 5.64 percent.\(^4\)

Next, we test the argument, widely discussed in the literature, claiming that Mexico has adjusted its reserves policy (i.e. increased its long-run target level of reserves-GDP ratio) in the aftermath of the Tequila crisis. To do so, we run the same regression but include a dummy variable which takes on the value of zero before the crisis (during the period 1981:1-1994:4), and the value of 1 afterwards (during the period 1995:1-2006:4). As the results in Column 2 of Table 1 indicate, the coefficient on this dummy is statistically insignificant, a result confirmed with a Chow test. This implies that Mexico did not adjust its long-run target level of the reserves-GDP ratio. In fact, by accounting for the possibility of a policy adjustment (i.e., by including a dummy) the long-run target level of reserves-GDP ratio became 4.46 percent.\(^5\) That is, a decrease of the target level of the reserves-GDP ratio of .18 percentage point. Given the magnitude of the crisis and the economic consequences that followed it, one would expect a much bigger adjustment. In fact, when the Tequila crisis hit, Mexico experienced a reduction of net private capital flows of almost 4 percent of the GDP in 1994 and a drop of more than 5 percent in 1995. Output dropped of 6 percent in the crisis year and the economy plunged into a systemic banking crisis until 1997.

According to our interpretations there are at least two reasons that there was not change in Mexico’s reserves policy (as compared to other emerging market economies, who doubled and even tripled their reserves-GDP ratios). First, there is a cost of adjustment, which stems from the need to reduce expenditures relative to income so as to yield the desired balance of payments surplus that is necessary for the accumulation of reserves.\(^6\) Second, it is likely that

\(^4\) recall that \(T_t\) in model (1) refers to log of reserves-GDP. So, the estimated target is
\[
\hat{t} = e^{\hat{T}_t} = e^{-3.07} = 4.64 \%
\]

\(^5\)
\[
\hat{t}_{\text{post}} = e^{\hat{T}_t + \hat{\beta}_\text{dummy}} = e^{(-3.04 - 0.07)} = 4.46 \%
\]

\(^6\) In principle the stock of reserves could be built up by international borrowing. However, during a period of financial distress, borrowing opportunities are limited and very costly; thus, by and large, adjustment requires a current account surplus.
the U.S. (and international) bailout of the Mexican economy during the crisis gave the Mexican government less incentive to adopt a new reserves policy. Indeed, the U.S committed up to $20 billion in repayable support, part of a nearly $50 billion international package to stem Mexico’s difficulties. A few months after the support started, the stage was set for Mexican recovery. Mexico all but eliminated the short-term debt instruments that spawned the crisis. It seems that this rescue package from the international financial community and the high likelihood of similar international intervention may have discouraged Mexico from changing its international reserves policy.

2.2 Adequacy of Reserves Policy

The framework we discuss here is in the spirit of the reserves adequacy model discussed in Nechi (2009). The model developed there introduced a concept of sustainable balance of payments that allows the stock of reserves to influence the likelihood of balance of payments crises. If a continuation of the current reserves policy is going to require a drastic policy shift or lead to a crisis (unless bailed out), then it is not adequate. This approach provides a basis for a flexible and simple method of determining the implicit market assessment of a country’s external position and serves as an effective and practical tool to evaluate the adequacy of reserves policy. The reserves policy is adequate if the following condition is satisfied:

\[ RES_t + \tilde{PV}_t(TB_t) - NL_t \geq \phi Y_t, \]  

(2)

where, \( RES_t \) is the stock of reserves, \( \tilde{PV}_t(TB_t) \) is the present discounted value of the trade balance, under a given policy stance, \( NL_t \) is the net liability (all liabilities minus all non-reserves assets) position of the economy at time \( t \), and \( Y_t \) is the GDP. The parameter \( \phi \) captures foreign investors perception about the country’s inability or unwillingness to meet its external obligations. \( \phi \) is calibrated as the critical value of the net asset position that triggered the 1994 Mexican crisis. Under a target value of the reserves-GDP ratio, if the above condition is violated, the country experiences a BOP crisis of capital flows and incurs a social cost. In addition to the social cost of a crisis, there is an opportunity cost of holding reserves, which is associated with the entire stock of reserves, regardless of whether they are used to cope with
The evaluation of condition (2) requires, in addition to the process driving the reserves, a specification of the processes driving net liabilities, \( NL_t \), and the trade balance, \( TB_t \); and calculation of the discounted present value of the country’s future incomes, \( \tilde{PV}_t(TB_t) \), under the current reserves policy. So the next step in our analysis is to (i) specify and estimate processes driving the net liabilities and the trade balance, and (ii) calculate the discounted present value of the trade balance.

### 2.2.1 Trade Balance

Using the balance of payments equation we have that

\[
TB_t = DR_t - DN_L_t - IT_t
\]

where \( DR_t \) is the change in reserves, \( DN_L_t \) is the change in the net liabilities position, and \( IT_t \) refers to income transfers. We assume that the components of the trade balance are governed with processes similar to the one driving the reserves. That is, each component (i.e. \( NL_t \) and \( IT_t \)) is evolving around a constant part (policy component) and subject to external shocks. So, we adopt the same decomposition used in the previous section to approximate the processes driving net liabilities \( NL_t \), and income transfers, \( IT_t \). That is,

\[
L_t = \bar{L} + \alpha'X_t + \mu_t, \tag{4}
\]

and

\[
I_t = \bar{I} + \theta'X_t + \xi_t \tag{5}
\]

where \( L_t \) is log of net liabilities to GDP, \( I_t \) is log of (the negative of) income transfers to GDP.\(^8\) \( \mu_t \) and \( \xi_t \) are the residuals for net liabilities and income transfers, respectively, that are not captured by the shock variables. Table 1 summarizes the results of OLS estimations of models (4) and (5).

---

7Standard models of optimal reserves assume that, when the crisis hits, reserves are exhausted (i.e., reach the lower bound of zero). Consequently, there is no opportunity cost of holding reserves at the time of a crisis in these models.

8Because \( IT_t \) is negative we estimate model (5) with \( I_t = \ln\left(\frac{-IT_t}{Y_t}\right) \) as dependent variable.
2.2.2 Calculation of the Present Discounted Value of Trade Balance

To calculate the present discounted value of trade balance surpluses, \( \overline{PV}(TB_t) \) we assume that there is a complete world financial (and real) markets in which all contingent claims with payoffs that are a measurable function of \( X_t \) can be traded. Under this assumption and the assumption of non-arbitrage, there exists a unique sequence of stochastic discount factors, \( \{M_t\}_0^\infty \), such that the time \( t \) price of a contingent claim that pays \( q(Z_t) \) units of the consumption good in period \( t + j \) is

\[
P(t, j) = E_t \left[ \frac{M_{t+j}}{M_t} q(Z_{t+j}) \right]
\]

Since Mexico is a small open economy, the stochastic discount factors are exogenous with respect to domestic agents’ actions. It follows that the present discounted value of trade balance, under the current reserves policy, can be written as

\[
\overline{PV}_t(TB_t) = \frac{1}{M_t} E_t \left[ \sum_{j=1}^{\infty} M_{t+j} \left( \frac{[R_{t+j} - R_{t+j-1}]}{\Delta R_{t+j}} - \frac{[NL_{t+j} - NL_{t+j-1}]}{\Delta NL_{t+j}} - IT_{t+j} \right) \right]
\]

In order to calculate (7), we need to specify a process for the shock variables \( X_t \), and the stochastic discount factor \( M_t \). Moreover, since movements in the discount factor will also reflect global shocks, an important determinant of the present value is its covariance with the trade surpluses. We take “the market” to be a representative U.S. investor and assume that the “state of the world” is captured by the asset return indices and the oil variables discussed in the previous section. Specifically, we assume that the vector

\[
X_t = (X_{1,t}, X_{2,t}, X_{3,t}, X_{4,t}, X_{5,t}, X_{6,t}) = (\Delta LCOP_t, \Delta LUSMCO_t, DIV_t, TBILL_t, LONG_t, VWR_t)
\]

follows a vector autoregressive process

\[
X_t = AX_{t-1} + u_t
\]

where \( A \) is a \( 6 \times 6 \) matrix of parameters, and \( u_t \) is a \( 6 \times 1 \) vector, \( u_t \) is i.i.d., and \( u_t \sim N(0, \Sigma) \).

For the stochastic discount factor we adopt the following specification,

\[
-ln(\frac{M_t}{M_{t-1}}) = r_{t-1}^{TBILL} + \frac{1}{2} \sigma_\omega^2 + \omega_t,
\]

where \( \omega_t \) is i.i.d., \( \omega_t \sim N(0, \sigma_\omega^2) \), and \( E[\omega_t u_t] = v \) (See Nechi (2009) for calibration and calculation details).
3 Total Cost of Holding Reserves

In this section, we present a simple framework for a cost-benefit analysis of the optimal level of reserves to cope with the risk of BOP crises. For our purposes, we define “BOP crisis” as a violation of condition (2). Reserves are useful both in terms of crisis prevention (reducing the likelihood of balance of payments crisis) and in terms of crisis mitigation (reducing the cost of a crisis, once it has occurred). However, this self-insurance comes at a price because of the opportunity cost of accumulating low-yield securities such as U.S. government bonds.

We assume that the central bank chooses a target level of reserves-GDP ratio that minimizes the expected total costs of holding reserves. In accordance with standard procedures, we further assume that, at every period, these total costs, $TC_t$, consist of an opportunity cost of holding reserves (i.e. forgone earnings), $OC_t$, plus a social cost of a BOP crisis (i.e., output loss), $SC_t$, if crisis occurs; that is,

$$TC_t = \chi_t SC_t + OC_t,$$

where $\chi_t = 1$ if crisis hits, and 0 otherwise.

3.1 The Social Cost of BOP crisis

In Heller (1966) and Clark (1970), when the BOP experiences problems (i.e., reserves reach a lower bound), policymakers need to cut imports in order to restore the reserves. This cost is inversely related to the economy’s openness or import propensity. Ben-Bassat and Gottlied (1992) consider costs of a different nature—that is, the cost of default (or cost of reserve depletion) incurred by a borrowing country. A default on the external debt (which happens at the time of crisis) will disturb the orderly flow of raw materials imports, implying a negative output effect. Furthermore, the economy will also lose the possibility of consumption smoothing over time, by means of temporary debt accumulation. The more specialized the economy at the time of default, the stronger is the chain reaction caused by a shock such as a cut in the supply of inputs. Therefore, in Ben-Bassat and Gottlied’s (1992) model, the effect of openness on the cost of reserve depletion is positive, unlike in Heller (1966).
In this paper, we do not investigate the effect of the degree of openness on the magnitude of the cost incurred if a balance of payments crisis hits. Rather, like Jeanne and Rancière (2006), we assume that, when a crisis hits, output falls by a constant fraction, $\gamma$, below its long-run growth path.\(^9\) However, unlike Jeanne and Rancière (2006), who assume that there is only one sudden stop, we allow for multiple sudden stops. Each time a crisis hits, the economy incurs a cost equivalent to a fraction $\gamma$ of its output, and, in the subsequent period, the economy (whether bailed out or not) faces a new risk of crisis. We then write

$$SC_t = \gamma Y_t,$$

where $\gamma < 1$.

### 3.2 The Opportunity Cost of Reserve Holdings

Holding low-yield reserves presents an opportunity cost to the country. This opportunity cost, $OC_t$, has been widely discussed in the literature on optimal reserves. It depends on the on the level of reserves, and one the difference between the economy’s marginal productivity of capital and the interest rate on reserves. The cost can then be written as

$$OC_t = \Delta r_t R_t,$$

where $\Delta r_t$ represents the difference between the economy’s marginal productivity of capital and the interest rate on (low-yield) reserves. It could be time-varying and may change in response to the debt level, global conditions, and political events. For simplicity, and in line with many studies, we consider that $\Delta r_t$ is constant and use $\Delta r$ instead.

Edwards (1985) argues that the relevant opportunity cost for the borrowing country can be measured by the spread between the interest rate on the debt and the reserves. Ben-Bassat and Gottlied (1992) define the opportunity cost as the difference between the rate of return on capital, calculated as the ratio of profits to gross capital stock, and the yield on reserves, calculated as the average of real interest on short-term deposits in dollars and marks. Barni-

---

\(^9\)Jeanne and Rancière (2006) model sudden stop as a debt rollover crisis associated with a fall in output. When the sudden stop occurs, two things happen: the representative consumer is unable to roll over her external debt, and output falls below its long-run growth path by a fraction.
Chon (2008) calculates the opportunity cost as the difference between nominal interest rates and low-yield securities such as U.S. government bonds.

3.3 The Expected Total Cost

The object of the policymaker is to choose a target level of the reserves-GDP ratio that minimizes the expected total cost (under that target). Substituting conditions (11) and (12) into (10), the optimization problem is given by

$$\min_{R} E_t \sum_{j=1}^{\infty} \frac{M_{t+j}}{M_t} TC_{t+j}$$

subject to condition (2).

If a solution exists, it can be written as

$$R^* = R(Y_t, \gamma, PV(\cdot), \Delta r, \phi).$$

(14)

However, it is not possible to solve for equation (14) analytically. The method we consider here is based on the assessment of the balance of payments sustainability condition, (2), for multiple hypothetical policy rules. For every possible policy rule (i.e. target level of the reserves-GDP ratio), we evaluate condition (2) using the estimated parameters of models (1), (4), and (5) (summarized in Table 1), and the calculated present discounted value of the trade balance, defined by equation (9). It is important to recall that a given reserves policy rule is defined by the (exponential of the) constant term of model (1). This means that, in my evaluation of the sustainability condition (2), both the reserves process and future trade surpluses will be affected by the change of the policy rule, which is captured by the constant term of model (1).

Under a given reserves policy, in every period the total cost of holding reserves is calculated based on the outcome of the evaluation of condition (2) and the calibrated parameters $\gamma$, $\Delta r$, and $\phi$. If condition (2) is violated, then the economy incurs both the social cost, $SC_t$, and the opportunity cost, $OC_t$. If condition (2) is satisfied, only the opportunity cost, $OC_t$, is incurred. The expected total cost for a target value of the reserves-GDP ratio is the simulated present discounted value of total costs.
The target value of the reserves-GDP ratio associated with the lowest expected total cost is the optimal reserves policy, and it is equivalent to the solution $R^*$ defined by equation (14). As discussed above, our approach consists of solving for $R^*$ numerically. To solve for $R^*$ numerically, we simulate the economy, under a candidate policy rule, using Monte Carlo techniques; evaluate condition (2); and calculate the expected total costs associated with outcome of the evaluation of condition (2).

### 3.4 Present Discounted Value of Total Costs

We set the number of paths, $N$, to 1000 and the number of periods, $T$, to 300. For every path, $i$, and at each date, $t + j$, we evaluate condition (2), given the current target level of the reserves-GDP ratio and the risk coming from global conditions. If it is violated, then the economy incurs a social cost $SC^i_{t+j} = \gamma Y^i_{t+j}$ at that date (i.e., $\chi^i_{t+j} = 1$). If condition (2) is satisfied, then $SC^i_{t+j} = 0$. Next, whether the economy is bailed out (by receiving rescue package) or not, we evaluate condition (2) for all the subsequent dates (i.e., $t + j + 1$, $t + j + 2$, $t + j + 3$, ..., $T$) along the same path, $i$. If condition (2) is violated again, then the social cost applies again; if not, no social cost is incurred, and so on. We do the same calculation at all dates for all paths until we investigate the social cost at date $T$ of path $N$. Note that at every date, $t + j$, and along every path, $i$, the economy incurs the opportunity cost, $OC^i_{t+j}$. After calculating and discounting the total costs at all dates along every path, we add them up to get the expected total cost of every path. In other words, the expected total cost of path $i$ is calculated as the sum of the total costs at dates 1 through $T$, discounted with the sequence of discount factors $\{M_t\}_{t=0}^T$. We then average the expected total costs of all paths, $i = 1, 2, ..., N$, in order to find the discounted total cost under a given policy rule. The following equation summarizes the procedure:

$$
EVC(\hat{R}) = \frac{1}{N} \sum_{i=1}^{N} \frac{1}{M^i_{t+j}} \sum_{j=1}^{T} M^i_{t+j} [\chi^i_{t+j} SC^i_{t+j} + OC^i_{t+j}] 
$$

where $EVC(\hat{R})$ is the present discounted value of the total costs incurred if the target value of the reserves-GDP ratio continues to be $\hat{R}$ in the future. $M^i_{t+j}$ is the stochastic discount factor between dates $(t + j)$ and $(t + j - 1)$. $\chi^i_{t+j}$ is an indicator function that takes the value of 1 if
condition (2) is violated at date \( t + j \) and 0 otherwise.

4 Estimation of Optimal Reserves

4.1 Benchmark Calibration

For the social cost of sudden stop, we use the calibration of Jeanne and Rancière (2006). They look for sudden stops (i.e., BOP crises) in a set of 34 middle-income countries between 1975 and 2003.\(^{10}\) The output cost of a sudden stop is estimated by looking at the average difference between the GDP growth rate in normal years and the growth rate in sudden stop years. Jeanne and Rancière (2006) find that the growth rate in a sudden stop year falls by 4.5 percent on average relative to a normal year and falls by 2.2 percent in the year following the sudden stop year. Thus, in their model \( \gamma \) is set to 6.5 percent per year.\(^{11}\) In our model, because we are using quarterly data, \( \gamma \) is set to 1.63 percent.

As far as the measurement of the opportunity cost of holding liquid international reserves is concerned, much depends on the form in which these reserves are held. Heller (1966) discusses reserves composition in developing and developed countries. He argues that less developed countries seem to have a tendency to hold a larger proportion of their reserves in the form of interest-yielding dollar or sterling balances, while the more developed countries tend to hold a larger fraction in the form of non-interest-yielding assets, such as gold or foreign-demand deposits. He concludes that the opportunity cost of holding reserves should be roughly equal for most countries, and he makes, in his own words the “heroic assumption” that the opportunity cost of holding liquid international reserves is 5 percent. Barnichon (2008) calibrates the opportunity cost at 4 percent. Jeanne (2007), using data for all Latin American countries,

---
\(^{10}\)They identify a sudden stop in year \( t \) if the ratio of capital inflows to GDP falls by more than 5 percent of GDP relative to the previous year. See Table 1 of their paper for the countries they consider and the years in which they had a sudden stop.

\(^{11}\)To see how \( \gamma \) is calculated, let \( \Delta g \) be the change in the growth rate \( g \). According to Jeanne and Rancière’s (2006) model, \( \Delta g = -4.5\% \) in the first year following the sudden stop and \( \Delta g = -2.2\% \) in the second year following the sudden stop. Thus, the overall change in the growth rate is \( \Delta g = -6.7\% \). The output drop is then

\[
\gamma = 1 - e^{-\Delta g} = 1 - e^{-0.067} = 6.48\%.
\]

This is consistent with the output cost of currency crises as estimated, for example, by Rancière and others (2003).
calibrated the opportunity cost of holding reserves at 6.5 percent. For our purposes, we set the opportunity cost of holding reserves at 5 percent per year. The quarterly opportunity cost is then 1.25 percent.

4.2 Optimal Reserves

The expected total costs of reserve policies are calculated by summing and discounting the simulated values of GDP foregone in case of crisis, $SC$, and the opportunity cost of holding reserves, $OC$. The optimal reserves policy corresponds to the level of the reserves-GDP ratio associated with the lowest expected total cost.

In the introduction, we discussed some historical arrangements that Mexico had when it was hit by the Tequila crisis. One renowned (and very controversial) example is the $50 billion international aid package, including the $20 billion U.S. bailout. The bailout certainly helped the Mexican economy to recover quickly, but that came, as the opponents of the bailout claim, at high costs–namely in the form of moral hazard–to the world economy. More importantly, policymakers in Mexico have not seriously considered market-oriented alternatives to official bailouts. For our purposes, we consider this issue further and emphasize whether the bailout in Mexico in the aftermath of the Tequila crisis might have affected its optimal reserves policy.

In what follows, we investigate the optimal reserves determination under two scenarios: (i) no bailout, then (ii) bailout. Note that, with the 1995 bailout, Mexico all but eliminated the short-term debt instruments that spawned the crisis. So, when we consider the bailout scenario, we assume that the money (or, more generally, the aid) received was used to pay external liabilities. This means that, in our simulation of the bailout scenario, the mean (or the target) of net liabilities to GDP ratio is reduced each time condition (2) is violated. In other words, the estimated constant term in model (4) needs to be reduced following a crisis, in order to reflect the bailout in our simulations.

---

12 His benchmark calibration for all emerging market economies is 3 percent.
13 See, for example, Chari and Kehoe (1998), and Hoskins and Coons (1995) for a discussion of the consequences of the international intervention, especially that of the IMF, during the financial crises of the 1990s.
4.2.1 No Bailout

In determining the optimal target level of the reserves-GDP ratio without bailout, we use the long-run level of net liabilities to GDP reported in Table 1 (i.e. 23.7 percent). We consider a grid of 20 points, in which each point corresponds to a candidate policy rule. The grid starts at the lowest possible value, zero, and ends at 20 percent, a less likely scenario given the current target. Figure 1 illustrates how the expected total cost varies with the target level of the reserves-GDP ratio in the absence of bailouts.

Figure 1: Optimal Reserves Without Bailout.

According to our simulation results, the optimal reserves-GDP ratio for Mexico is 9 percent. This is considerably higher than the estimated long-run target level of the reserves-GDP ratio of 4.64 percent over the whole sample period (1981:Q1-2006:Q4), and the adjusted target level of 4.46 percent in the post-crisis period (1995:Q1-2006:Q4). Note that the estimated rate of 4.64 percent represents only 51.6 percent of the calculated optimal reserves policy, while the
post-crisis rate represents only 49.6 percent of the calculated optimum. This suggests that the current reserves policy in Mexico is sub-optimal. In other words, the current reserves policy falls short of optimal policy by almost 50 percent. This result represents a key contribution to the literature on optimal reserves in Mexico because no other study, to our knowledge, concluded that Mexico holds reserves less than it should.

Ben-Bassat and Gottlieb (1992), studying the case of Israel over the period 1964-88, find that, while optimal and actual reserves are highly correlated, optimal reserves instead fell short of actual reserves by an average of 6 percent. Kim (2008) presents a model that builds upon the global games framework of Morris and Shin to establish a unique relationship between the probability of a sudden stop (i.e., BOP crisis) and the level of reserves. He calibrates his model to 15 emerging market countries, including Mexico, over the sample period of 1993-2006. Over the full sample period, calibrated optimal reserves average between 10 and 30 percent of GDP for most countries in the sample. As for Mexico, Kim (2008) finds an optimal level of the reserves-GDP ratio of 9.1 percent, which is the same as my estimate, over his full sample (1993-2006), and 12.2 percent over the period 1993-99.

Jeanne (2007) develops a simple welfare-based model of the optimal level of reserves to deal with the risk of capital account crises or of sudden stops in capital flows. His benchmark calibration (the probability of a sudden stop of 10 percent) implies an optimal level of reserves of 7.7 percent of GDP (or 77 percent of short-term external debt). He argues that this is close to the ratio of reserves to GDP observed in the data on average over 1980-2000, but significantly below the level that has been observed in the most recent period, especially in Asia. Jeanne’s (2007) model also finds that, the optimal level of reserves is zero if the probability of crisis falls below 5 percent, but it almost doubles, from 7.7 percent to 13.3 percent of GDP, if the probability of crisis increases from 10 to 20 percent. Jeanne concludes that levels of reserves observed in many countries, particularly in Latin America, in the recent years are within the range of his model’s predictions.
4.2.2 Bailout

To address the effect of a bailout in Mexico on optimal reserves policy, we calibrate the bailout Mexico gets every time it experiences a sudden stop to 40 percent of its net liability position. This calibration is based on the 1994 experience. As discussed previously, after the Tequila crisis, Mexico received a $50 billion international aid package, which represents about 40 percent of its net liabilities position (i.e., $128 billion) at the time of crisis. Within 7 months, Mexico managed to decrease its overall liabilities, and, in particular, eliminated the short-term debt instruments that spawned the crisis. This means that Mexico has used the funds mainly to reduce its liabilities. Based on this experience, we make the assumption that 40 percent of the Mexican net liability position will be bailed out every time a crisis hits. Figure 2 illustrates how the expected total cost varies with the target level of the reserves-GDP ratio under the bailout scenario.

As we can see, the bailout scenario resulted in a lower target level of the reserves-GDP ratio. In fact, the optimal target level of the reserves-GDP ratio is now 5 percent, a decrease of 4 percentage points with respect to the no bailout case. Note that this level is very close to the estimated long-run target of 4.64 percent over the whole sample period as well as the estimated adjusted long-run level of 4.46 percent. This result implies, that when accounting for the possibility of bailout, current reserves policy in Mexico is within the model’s predictions. This, however, is not an unexpected result. Mexico realizes that it is an important partner of the U.S. and the world economy in general and that the international community will not let it down in case of a crisis. Moreover, the strong conviction of policymakers in Mexico (based on the 1982 and 1995 experiences) that their economy will be rescued should a crisis hit gave them reason to consider bailouts in their optimization problem. Accounting for this bailout scenario, the current reserves policy is within my model’s predictions. Thus, the reserves policy in Mexico is not sub-optimal as it was in the no bailout scenario.

---

14Mexico is the third-largest export market for U.S. products, and hundreds of thousands of American jobs depend on trade with Mexico. See Summers and D’Amato (1996) for a discussion of the economic and social costs to the U.S. economy in the aftermath of the Tequila crisis.
This approach to investigating the quantitative impact of a bailout on optimal reserves policy is, to our knowledge, a new contribution to the optimal reserves literature. In fact, the current literature excludes bailout scenarios in addressing optimal reserves determination. Given the recent developments in international financial architecture, in particular the new role played by the IMF, as well as the emergence of new regional institutions such as the Chiang Mai Initiative or the Latin American Reserve Fund, the bailout scenario seems to be even more likely to occur.

An interesting and implicitly related work is worth mentioning here. Dhasmana and Drummond (2008) look at the optimal level of reserves in sub-Saharan African countries in light of the shocks faced by these nations. Using a two-good endowment economy model facing terms of trade and aid shocks, which might be interpreted as bailout shocks, they find that the optimal level of reserves in these economies is equal to 11 to 12 percent of total output.
They also find that there were a few countries whose reserve levels were significantly below the optimal level.

4.2.3 Sensitivity of Optimal Reserves to Changes in Parameters

Figure 3 shows the sensitivity of the optimal target level of the reserves-GDP ratio to an increase in the social cost of a sudden stop crisis. As we can see, the optimal level of reserves is quite sensitive to welfare cost (output loss) resulting from a sudden stop. An increase in the social cost (i.e., parameter $\gamma$) from 6.5 percent (benchmark model, Figure 1) to 10 percent results in a new optimal level of reserves of 11 percent, an increase of 2 percentage points. Not surprisingly, this exercise suggests that a higher cost of crisis would motivate policymakers to insure themselves even more by accumulating more reserves.

Figure 4 shows that the optimal level of the reserves-GDP ratio is also very sensitive to
a change in the opportunity cost of holding reserves. In fact, a decrease of the opportunity cost (i.e., $\Delta r \downarrow$) from 5 percent to 3 percent increases the optimal level of reserves to 15 percent. This is not an unexpected result either, since a decrease in the opportunity cost is equivalent to small forgone earnings related to a higher stock of reserves. So, it is less costly to accumulate reserves, which implies that it is optimal to accumulate more reserves.

5 Conclusion

The model developed in this paper has several advantages compared to other studies in the literature on optimal reserves. Most importantly, the model explicitly links the optimal level of reserves not only to local policy rules, such as the current target level of the reserves-GDP ratios and the net liability position, but also to the notion of sustainable balance of payments, which is, in turn, linked to global factors such as U.S. interest rates and oil prices. A key
contribution of our framework is that the model accounts for bailout possibilities that the country may get in periods of crises. Incorporating these possibilities into the model tends to lower the level of optimal reserves. As a consequence, our estimates of the no-bailout scenario should be viewed as an upper bound on optimal reserves.

The calibration results are broadly consistent with two key facts: (i) current reserves policy in Mexico is below the predicted optimal level, reflecting, most likely, Mexico’s perceptions of a potential bailout in the case of crisis, and (ii) by considering a target level of 4.64 percent, which is close to the present average level of the reserves-GDP in developed economies, suggests that, although Mexico is highly exposed to external shocks, its fundamentals have improved substantially.\textsuperscript{15} If this is the case, Mexico might be better insured in recent years than it was in the 1990s.

A common result in the international reserves literature suggests that emerging market countries holdings of international reserves as means of dealing with capital flow volatility and the risk of capital account crisis are more than can be justified by this objective. But the evidence from our model suggests that Mexico holds less international reserves than can be justified. This raises an important question: what factors might account for the gap between the model’s predictions and the observed actual hoarding of reserves? One plausible explanation is the Mexican government’s strong conviction that it will be bailed out should a crisis hit. Another explanation (which is related to the previous one) is that the emergence of collective insurance–such as that provided by the IMF at the global level or the Latin American Reserve Fund at the regional level– gave less incentive to Mexico to undertake costly adjustment policies in order to increase its reserve holdings.

\textsuperscript{15}According to Alfaro and Kanczuk (2007), in 2006, reserve accumulation amounted to 20 percent of GDP in low- and middle-income countries, whereas this number was close to 5 percent in high-income countries.
References


