Foreign Reserves Accumulation in Emerging Economies: Determinants and Sustainability Case of Mexico

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Abstract

Foreign reserves have been growing rapidly since the mid 1990s in emerging economies hit by Sudden Stops (SS). For policy makers and researchers, this large buildup of reserves reflects a new policy that emerging economies have taken to insure against the risk of future SS. In this paper we have argue that the observed increase in foreign exchange holdings in Mexico is the result of more favorable global conditions and NOT a policy shift. We show that the long run demand for international reserves can be replicated using a linear combination of a set of exogenous shocks.We argue that using a set of asset returns and the oil price to investigate the determinants of reserves holdings is both conceptually appealing and quantitatively superior to traditional methods. We show that it is possible to approximate the reserves accumulation process in Mexico as a stationary function of these shocks without an abrupt regime shift after the Tequila crisis. Our results suggest that the rise in reserves holdings experienced by Mexico was the result of a series of positive shocks in the post crisis period. The strong and stable correlation between the foreign exchange and the exogenous shocks provides a basis for a flexible and simple method for determining the implicit market assessment of the sustainability of the current target of reserves to GDP ratio. Our findings suggest that the Mexican current policy is sustainable.

JEL Classification: C22, F31, G15

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1 Introduction

The 1990s financial crisis has led to a rethinking of policy design in developing countries. Several countries have reacted by more active management of international reserves and external debt positions, and a large build up of international liquidity. As a result, the global reserves increased from about 1 trillion US dollar in 1990, to more than 5 trillion US dollar in 2006. Two thirds of the global international reserves are held by developing countries, with emerging economies hit by Sudden Stops (SS) accounting for much of the increase.[1] According to Durdu, Mendoza and Terrones (2007), DMT (2007), the median increase in reserves after the year of SS in these countries was 7.7% of GDP. Many econometric evaluations confirmed these facts and suggested several structural changes in the patterns of reserves hoarded by developing countries. A notable change occurred in the 1990s, a decade when the international reserves to GDP ratios shifted upwards; a trend that intensified shortly after the Tequila crisis of 1994 and the East Asian crisis of 1997-8, but subsided by 2000.[2,3]

The level of reserves in emerging market countries has thus increased since the early 1990s, but so has their trade and financial integration-and with it the associated risks. IDB (1995) and Hausmann et al. (2006) show that developing countries are exposed to terms of trade (TOT) volatility that is 3 times the volatility of industrial countries, resulting in income shocks that are 3.5 times as volatile as those affecting industrial countries. Dealing with TOT volatility is a challenge, in particular, for natural resources exporters, exposed to TOT volatility that is 3 times the volatility of manufacturing countries. TOT shocks impose a daunting challenge for developing countries.

For policy makers and researchers, this large buildup of reserves represents a form of self-insurance that emerging economies have taken against the risk of future SS. They argue that while not a panacea, international reserves help by providing self insurance against capital flows reversal; mitigating effects of terms of trade (TOT) shocks; smoothing overtime the adjustment to shocks by allowing more persistent current account patterns; and possibly even export promotion. In the absence of a lender of last resort and the big exposure to external shocks (as a result of the financial and trade globalization), emerging economies in general, and SS countries in particular, opted for, what DMT (2007) call, a "New Mercantilism" in which large holdings of reserves are a war-chest for defense against SS.

In short, the episodes of financial crises experienced by many developing countries illustrated the downside risk of financial and trade integrations and

[1]In 2006, while the International reserves/GDP ratio of industrial countries was overall stable, hovering around 4%, the reserves/GDP of developing countries increased dramatically, from about 5% to about 27%.

[2]Another structural change have taken place in early 2000s, mostly driven by an unprecedented increase in the hoarding of international reserves in China, from close to zero during 1998-2000 to more than $ 300 billion in 2006.

[3]See Aizenman and Marion (2003), Bird and Rajan (2003), Aizenman and Lee (2007), Jeanne (2007), and Cheung and Ito (2007) for econometric evaluation dealing with the emerging patterns of hoarding reserves.

the costs of exposure to exogenous shocks. The main question in this study is to investigate to what extend the increase in reserves can be explained as response to an increase in the hazards of globalization? To mitigate the effects of shocks, emerging markets opt for new *policy*: accumulate highly liquid reserves. This raises two important questions: do exogenous shocks really explain the high demand for reserves? and, what level of reserves is needed to insure against liquidity problems? We discuss both issues in section 2, and 3, respectively, pointing out that *exogenous* shocks to current and capital accounts account for most of the variation of the reserves to GDP ratio, and that the process driving reserves is a key element in assessing the sustainability of the current policy.

A key novelty of our analysis is that, using Mexico as a study case, we consider a new set of macroeconomic determinants to identify exogenous shocks to the demand of foreign reserves: internationally traded financial assets and oil variables. We argue that it is conceptually more appealing to use internationally traded asset returns and oil variables as instruments to identify the shocks to the Mexican long-run demand for reserves. We demonstrate that this approach does better job than the use of the traditional (i.e., commonly used in the literature) determinants. The approach to shock adjustment developed in section 2 also makes possible a simple and flexible way to assess the *sustainability* of reserves holding strategies.

The self-insurance against external liquidity problems cannot be simply judged by the reserves to GDP ratio. Central banks cannot accumulate reserves indefinitely, however. How far is the current level of reserves from that given by the standard macroeconomic determinants? Clearly the degree to which the reserves to GDP ratio is sustainable depends on an assessment of the country's external net debt position and the present value of it's future incomes. This in turn depends on current targets of reserves to GDP and net debt to GDP ratios, current forecast of economic growth and interest rates, and the correlation of the reserves (i.e., the shocks driving them) with the rate at which future cash flows are discounted. In section 3 we describe how to use the balance of payment equations, a cash flow model as well as a calibrated asset pricing model to compute the present value of future incomes. Computing this with the net debt position, we provide a flexible and easily applied measure of sustainability.

Finally, the recent buildup in emerging market countries' international reserves cannot be explained by conventional adequacy ratios or by a traditional set of macroeconomic variables. But it may be that neither approach fully captures how the instability of the 1990s changed the perception of risks and the desire for insurance on the part of the countries most affected. For this reason, the decomposition of the recent buildup of reserves into a policy component and a set of exogenous shocks might be more informative and more meaningful to assess the sustainability of the current targets of reserves holding than the analysis of the optimal level of reserves. This is the approach that we take in the rest of the paper.

2 Literature Review

In addressing this new waves of demand for foreign reserves by emerging countries, the literature considers key macroeconomic determinants. Empirical research on international reserves (Heller and Khan 1978; Edwards 1985; Lizondo and Mathieson 1987; Landell-Mills 1989; Lane and Burke 2001, IMF 2003, Gosselin and Parent 2005; among others) establishes a relatively stable long-run demand for reserves based on a limited set of explanatory variables. The determinants of reserve holdings reported in the literature can be grouped into five categories: economic size, current account vulnerability, capital account vulnerability, exchange rate flexibility, and opportunity cost.

In theory, the volume of international financial transactions, and therefore reserve holdings, should increase with economic size. In the literature, GDP and GDP per capita are used as indicators of economic size. The vulnerability of the current account can be captured by such measures as imports to GDP, trade openness and export volatility. In the long run, central banks will increase their reserves in response to a greater exposure to external shocks. For this reason, the level of reserves should be positively correlated with an increase in both exports and imports.[4] Capital account vulnerability increases with financial openness and potential for resident-based capital flight from the domestic currency. Consequently, reserves should be positively correlated with such variables as the ratio of capital flows to GDP and the ratio of broad money to GDP (which signals the potential demand for foreign assets from domestic sources). Exchange rate flexibility is usually important: it reduces the demand for reserves, since central banks no longer need a large stockpile of reserves to manage a pegged exchange rate. Because there is a "fear of floating", flexibility is generally measured by the actual volatility of the exchange rate. There is an opportunity cost of holding reserves, because the monetary authority swaps high-yield domestic assets for low-yield foreign ones. It corresponds to the difference between the yield on reserves and the marginal productivity of an alternative investment. This variable is, however, often insignificant in the empirical literature, likely reflecting measurement problems (Edwards 1985).

The IMF (2003) studies a simple empirical model that incorporates various determinants of reserve holdings. The model is estimated using a large panel that covers 122 emerging-market economies with annual data from 1980 to 1996. In the study, real GDP per capita, the population level, the ratio of imports to GDP, and the volatility of the exchange rate are found to be statistically significant determinants of real reserves, while measures of capital account vulnerability and opportunity cost were insignificant. Predicted values from this model over the 1997-2002 period reveal that international reserves in many emerging markets have increased more than warranted by the determinants since 2001. The IMF concludes that foreign exchange reserves in these countries have reached a point where some slowdown in the rate of accumulation is needed.

[4] In the shorter run, however, foreign exchange intervention may be required to maintain a currency peg so that reserves are positively correlated with the trade balance (i.e., positively correlated with exports but negatively correlated with imports).

Overall, many studies find that although such variables do a good job of predicting reserve holdings over a long period, they significantly underpredict the reserves accumulation of emerging market countries after the 1990s crises, especially in Asia.[5] It could be, however, that the regressions considered fail to capture the impact that the severe capital account crises of the 1990s had on how these countries perceived the risks associated with their international financial integration.

To evaluate whether reserve holdings are sufficient to cope with financial crises, several indicators have been used in the literature. The ratio of reserves to short-term external debt measures the capacity of a country to service its external liabilities in the forthcoming year, should external financing conditions deteriorate sharply. The idea being that reserves should allow a country to live without foreign borrowing for up to one year. According to the Greenspan-Guidotti rule, a ratio above one signals that a country holds an adequate level of reserves to face the risk of a financial crisis, while a ratio below one may suggest a vulnerable capital account.[6] If reserves exceed short-term debt, then a country can be expected to meet its obligations in the coming year and thus avoid rollover problems stemming from liquidity concerns. The ratio of reserves to imports is considered as a proxy for a country's current account vulnerability. The ratio measures the number of months a country is able to finance its current level of imports. Normally, a ratio of 3 and 4 would be considered adequate (Fisher 2001).[7] Lastly, an indicator that is commonly used is the ratio of reserves to broad money. A conventional range for the ratio of reserves to broad money is 5 to 20 percent. The rationale for this ratio is that broad money reflects a country's exposure to the withdrawal of assets from domestic sources(Calvo, 1996; De Beaufort-Wijnholds, Onno, and Kapteyn, 2001).

While the key macroeconomic determinants discussed above is getting extensive and increasing attention, the relevance of external *shocks* to these determinants and their implications for foreign reserves accumulations get little attention in the literature. In the new area of globalization the current and capital accounts are more exposed to external factors and driven mostly by shocks to these factors. For example, the capital account liberalizations adopted by most emerging market economies exposed them to the global financial market shocks. The surge and change in the composition of foreign capital into emerging economies motivate the importance of understanding the determinants of such flows and the implications of *shocks* to these flows for the composition and the level of foreign reserves. Much of the literature rationalizes the large capital flows as a key macroeconomic variable explaining the foreign reserves. However, the analysis ignores the nature and the composition of these flows and the implications of shocks to these flows for foreign reserves accumulation strategies. To capture this idea we introduce a set of internationally traded financial assets and investigate the implications of shocks to these variables to the long run demand for foreign reserves.

[5]See IMF (2003), Aizenman and Marion (2003), and Aizenman, Lee, and Rhee (2004).

[6]See Greenspan (1999) and BIS (2000)

[7]The ratio of reserves to imports should equal 0.25 according to the three-months-of-imports rule.

Relevance of oil sector to Mexico

The literature also ignores the fact that key determinants of the current account variables are driven by exogenous factors and *shocks* to these factors have important implications for reserves accumulation strategies. In our case study, Mexico, we introduce some country-specific variables (crude oil price and U.S. imports of crude oil from Mexico) that are important determinants of reserves accumulations but are driven by exogenous factors. In fact, in many countries while the macroeconomic determinants widely discussed continue to be of interest other sources appear to be more relevant for the reserves building (oil, natural gas, raw material like copper for Chile, etc.). Therefore, the level of production and the change in prices of exported commodities (whether natural resources or industrial products) motivate the importance of understanding the way these commodities are managed and their contribution in the overall reserves buildup.

To clarify this idea we examine the relevance of the oil industry to our case study, Mexico. According to the 2006 annual report of the International Energy Agency, IEA, Mexico is the sixth-largest producer of oil in the world. Mexico produced an average of 3.7 million barrels per day.Of Mexico's oil production, about 88 percent was crude oil and condensate, the rest consisting of natural gas liquids (NGL) and refinery gain. The oil sector is a crucial component of Mexico's economy. While its importance to the general Mexican economy has declined, the oil sector still generates over 10 percent of the country's export earnings and one-third of government revenues.[8] According to the Oil and Gas Journal (OGJ), Mexico had 12.9 billion barrels of proven oil reserves as of January 1, 2006, the third-largest amount of conventional crude oil reserves in the Western Hemisphere. Most reserves consist of heavy crude oil varieties.

Relevance of capital flows to emerging economies

Jeanne (2007) provides some insights on whether the reserves buildup has tended to be financed by current account surpluses or through capital inflows. He finds that About 40 percent of the reserves buildup has been financed by capital inflows on average. Whereas Asia has relied more than the average on net exports to accumulate reserves, Latin America has run current account deficits, so that its (relatively smaller) increase in reserves has had to be financed more than one for one by capital inflows. Second, he examines the reserves in the broader context of the country's external balance sheet. He analyzes the composition of the increase in both external assets and external liabilities that were traded in the financial accounts of emerging market countries between 2000 and 2005. More than 60 percent of their foreign asset accumulation consisted of reserves. By contrast, foreign direct investment (FDI) accounted for almost 70 percent of the new liabilities accumulated by these countries. To confirm the fact that emerging market countries tend to have external assets that are more liquid than their external liabilities Jeanne (2007) looks at stocks rather than flows. By comparing the external balance sheets of emerging markets and in-

[8] Again, according to the IEA, Mexico is the tenth largest oil net exporter of oil in the world.

dustrial countries (taking the average over 2000-05),[9] he finds that the share of reserves in gross foreign assets is almost nine times as large in the emerging market countries as in the industrial countries, whereas the share of FDI in their liabilities is almost twice as large.

3 Determinants of International Reserves

The empirical literature focuses on examining equations for foreign exchange reserves from either very large panels or sample of countries. We estimate a long-run equation that applies to a single country, Mexico. Focusing on a single country is of greater relevance to the issue of reserves accumulation. Since the buildup in reserves is driven by country specific as well as exogenous factors, identifying the domestic versus external components of reserves is a key element in assessing the sustainability of the observed levels. This focus also addresses the question of reserve accumulation more thoroughly than by studying a sample of countries with fundamentally different policy regimes, as the IMF (2003) and Gosselin and Parent (2005), among others, do. We Consider the case of Mexico, but the analysis applies to other countries with close economic fundamentals. The data are quarterly and span from 1981:1 to 2006:4. The estimated model is:

$$y_t = \alpha + \sum_{k=1}^{K} \beta_k x_{k,t} + e_t \qquad (1)$$

where y_t is the dependent variable, $x_{k,t}$ contains the explanatory variables, K is the number of regressors, and e_t a stationary disturbance term.

We revisit the explanatory variables commonly used in the literature and introduce a set of new variables that we consider key to our analysis.

The dependent variable is the log of (nominal) reserves divided by GDP, FX. As Figure 1 shows, controlling for economic size (i.e divide by GDP) is not sufficient to remove the upward trend in reserves. One potential reason for this is increasing openness to trade and more integrated global financial markets, which render the economy more vulnerable to external shocks, since imbalances in payments can be more substantial. As such, we consider imports propensity, LIMP (log of imports divided by GDP) and the volatility of export receipts, EXPV (10-quarter backward moving standard deviation of exports) as explanatory variables that capture current account vulnerability. In the capital account vulnerability, we consider the ratio of broad money to GDP (in log), LM2, and the financial openness, FO (ratio of capital flows to GDP). The other potential explanatory variables we consider exchange rate volatility, EXRV (12-month backward moving standard deviation of exchange rate), opportunity cost, OPPC (domestic deposit rate minus the interest rate on U.S treasury bills), log of crude oil price, LCOP, and a set of asset return variables.

The asset return variables are 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

[9] Using the International Monetary Fund (IMF) data on international investment positions

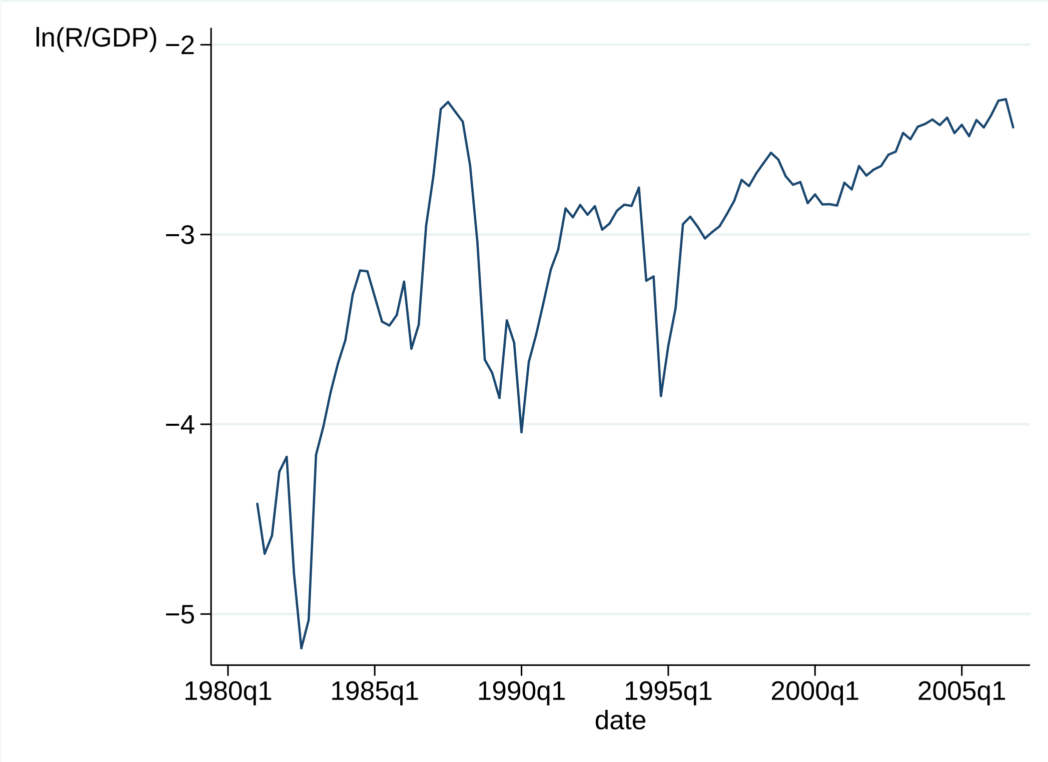


Figure 1: Foreign Exchange to GDP, Mexico

first month of the quarter), the 3-month Treasury bill rate TBILL, 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).

Next, we determine the quantitative importance of the exogenous shocks to the variation of the foreign exchange. To do so, we run multiple simple linear regressions of the log of (nominal) reserves to GDP on different sets of variables.

3.1 Decomposition of International Reserves

In order to evaluate the Mexican reserves accumulation's strategy, one would like to decompose the demand for reserves into those resulting from exogenous factors (e.g. business cycle fluctuations, capital flows reversal, unanticipated growth slowdowns), which we consider them as *shocks*; and those induced by the permanent components of the government's policy variables (it could be time-varying and may change in response to the debt level and political as well as economic and financial events). In this section we discuss a decomposition method that was introduced in Lloyd-Ellis and Zhu (2001, 2006). Lloyd-Ellis and Zhu use a set of international financial assets to identify shocks to the Canadian fiscal policy, assess the fiscal risk management, and enhance Canadian fiscal policy. These financial assets have been used extensively in the finance literature to represent underlying factors in stock market returns and to capture cyclical activity in the U.S. economy. We use these variables to identify the *financial market shocks* driving the Mexican demand for international reserves. We also consider *oil shocks* to capture some of the variation in the demand for reserves. As we outlined in the introduction, the oil sector is a crucial component of the Mexican economy. While its importance to the general Mexican economy has declined, the oil sector still generates over 10 percent of the country's export earnings and one-third of government revenues. So it is not unrealistic to consider crude oil prices as shock driving the reserves accumulation. Since Mexico is a small open economy it is save to assume that the international financial assets and oil price are not influenced by the Mexican government. Moreover, if the financial markets and oil markets are relatively complete, then it should be possible to replicate a large portion of the precautionary demand for reserves using some combination of the asset returns and oil variables.

Let z_t be the state vector that summarizes the exogenous shocks in period t. We assume that the Mexican demand for foreign reserves in period t, FX_t, can be decomposed as follow:

$$FX_t = \Lambda_t + F_t(z_t) \tag{2}$$

The term Λ_t is a key component in our analysis. It summarizes the permanent components of the government's policy variables. It could be time-varying and may change in response to the debt level and political events. In other words, it represents the non-shock related components of the foreign exchange. We interpret significant and persistent changes in Λ_t as being associated with changes in the government reserves accumulation policy (i.e., reserves to GDP target). $F(z_t)$ components of the demand for reserves are shock-related. In general, the state vector z_t may contain variables that are difficult to identify or not directly observable. Let X_t be a vector of observable variables that are correlated with the state vector z_t. Using linear approximation we can express $F_t(z_t)$ as follows:

$$F_t(z_t) = \lambda' X_t + \epsilon_t$$

where ϵ_t is the residual that represents the shocks that are not captured by the observable variables. The vector λ measures the marginal impact of the exogenous shocks. Thus, the demand for reserves can be expressed as

$$FX_t = \Lambda_t + \lambda' X_t + \epsilon_t \tag{3}$$

So, the first step in our decomposition method is to identify the vector of observable variables, X_t. Once these variables are identified, we can then use regression to estimate the shock dependence vector λ. Finally, given the estimated λ, we adjust the reserves for shocks by simply subtracting $\lambda' X_t$ from the actual foreign exchange, FX_t.

Note that we demeaned the X_t variables. This exercise gives a particular interpretation to the constant term in the regression. In fact, demeaning the explanatory variables implies that Λ captures the permanent component of the government policy variable. That is, Λ reflects the curent policy of reserves to GDP ratio.

3.1.1 The Traditional Demand for International Reserves

The traditional demand for international reserves is a special case of the shock-adjusted demand that we defined above when the variables in X_t are identified as the *traditional variables* commonly used in the literature; that is, the current account and capital account variables. Column of Table 1 presents the results from a regression of the demand for foreign exchange (log of reserves to GDP ratio) on LIMP, log of imports to GDP; LM2, log of broad money to GDP; EXPV, exports volatility (10 quarters backward moving standard deviation of exports receipts), FO, financial openness (Capital flows to GDP ratio), and EXRV, the exchange rate volatility. The regression uses quarterly data over the period 1985:4-2006:4.

Except for LM2 (and the constant), all the other variables are not significant.. LM2, the potential for resident-based capital flight from the domestic currency, which is an indicator of capital account vulnerability, is statistically significant and correctly signed. This is consistent with an increasing role for the self-insurance motive against potential internal drain.[10] As expected, foreign reserves are positively correlated with export volatility. The ratio of imports to GDP, however, is negatively correlated with the demand for reserves, a result we expected it to be otherwise.[11] Financial openness is positively correlated with foreign exchanges confirming the importance of capital flows in the accumulation of reserves. As the result in column 1 shows, while these variables account for 38% of the variation in the demand for reserves they are individually statistically insignificant. This suggests that perhaps, as Figure 2 illustrates, the demand for reserves does not capture what we might a priori believe to be important determinants of reserves accumulations.

The failure of the traditional variables in capturing the variation in demand for international reserves is not unexpected. For the decomposition method to work well, the observable vector X_t should satisfy at least two conditions: (1) it contains variables that can capture a significant portion of exogenous shocks that affect the reserves accumulation, and (2) it only contains variables that are exogenous to monetary policy so that any policy changes will be captured in the shock-adjusted demand for reserves. The current account and capital account variables used in the traditional demand for foreign exchange do not satisfy either of these conditions. As we pointed out, the traditional variables do not capture much of the variation in the reserves accumulations. It is likely that shifts in imports and exports are sometimes induced by changes in trade policy, so that they cannot be thought as exogenous. Moreover, restrictions on capital outflows (e.g., capital controls) are induced by changes in the monetary policy and cannot be thought as exogenous.

[10] Rothenberg and Warnock (2006) find that almost half of the episodes of sudden stops are actually episodes of sudden flights.

[11] In the shorter run, however, foreign exchange intervention may be required to maintain a currency peg so that reserves are positively correlated with the trade balance (i.e., positively correlated with exports but negatively correlated with imports).

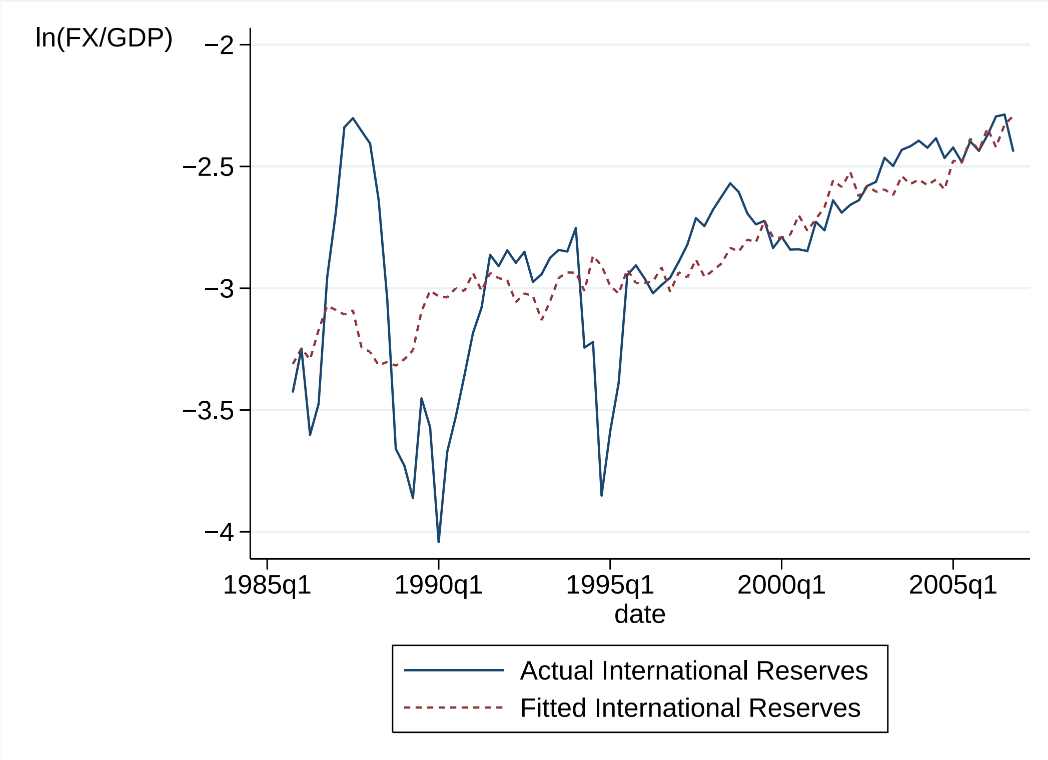


Figure 2: Current Account and Capital Account Variables

3.1.2 The Contribution of the Exogenous Shocks to the Demand for International Reserves

Here we consider an alternative approach to adjusting the demand of international reserves for exogenous shocks. We use two types of exogenous shocks (i) Indices of the market returns on a set of internationally traded financial assets, and (ii) the crude oil price; to identify shocks to the demand for reserves. If global asset markets were complete, then it would be possible to replicate the impact of all global economic shocks using some combination of market returns. This is sometimes referred to in the finance literature as the "spanning" property (see Duffie, 1986), and is analogous to the use of relative prices to infer sectoral productivity shocks under the assumption of competitive markets (e.g. investment-specific technical change). While, in reality, such markets are unlikely to be complete, we take this as a first approximation. The market return indices that we consider have been used extensively in the finance literature to represent underlying factors in stock market returns and to capture cyclical activity in the U.S. economy. As for the oil price, it is not unrealistic to consider it as key variable driving the international reserves accumulation in Mexico. Like many oil exporting countries, Mexican's business cycle is correlated with the price of oil, its main export good; so much so that this price has become a signal of aggregate conditions to (foreign and domestic) investors and policy-makers alike in these countries. As a result of the many internal and external reactions to this signal, the change in Mexican government revenue (and then

Table 1: Decomposition of International Reserves

Variables	Traditional	Shocks	Dummy	Stability
$\Delta LCOP$		-.14	-.13	-.16
		(.26)	(.26)	(.42)
DIV		-2.39***	-2.49***	-2.90**
		(.67)	(.76)	(1.17)
TBILL		-9.66***	-9.32***	-16.33***
		(3.10)	(3.35)	(6.0)
LONG		-1.79	-2.27	6.73
		(4.08)	(4.45)	(6.69)
CONSTANT	-2.87***	-3.08***	-3.06***	-3.09***
	(.037)	(.035)	(.07)	(.09)
LIMP	.21			
	(.28)			
LM2	1.65***			
	(.39)			
EXPV	$5.99e-06$			
	$(9.52e-06)$			
FO	.13			
	(1.87)			
EXRV	.048			
	(.21)			
DUMMY			-.03	
			(.13)	
NOBS	85	103	103	56
R^2	0.38	.70	.70	.57
	[0.000]	[0.000]	[0.000]	[0.000]

the reserves accumulation in this country) is correlated with changes in the crude oil price. Since Mexico is a small open economy, it is not unreasonable to assume that these international variables are not influenced by the Mexican monetary policy.

We introduced these variables and discussed them in the previous section. For our purposes, we view these variables as picking up key components of the shocks affecting the world economy. To determine their quantitative importance to the variation of the foreign exchange, we run a simple linear regression of the log of (nominal) reserves to GDP ratio on these shock variables[12] over the period 1981:1 - 2006:4. The result is reported in the second column of Table 1.[13] This regression suggests that 70% of the demand for reserves can be replicated by a simple linear combination of the exogenous shocks to the Mexican economy.

[12] We use the change in the crude oil price instead of the level because LCOP is I(1) process.

[13] Notes: (1) Standard errors are given in parentheses, (2)* denotes significance at 10 percent; ** significance at 5 percent; and *** significance at 1 percent.

The simple correlations between (log of) reserves (to GDP) and each of the explanatory variables, are consistent with the theoretical predictions. We expected the change in the crude oil price, $\Delta LCOP$,to be positively correlated with the foreign reserves accumulation to reflect the increasing role of oil industry in the Mexican government revenue. One would interpret this counter intuitive result as follow: an increase in the oil price is an indicator of high demand for oil in the world and then favorable conditions to invest in the U.S economy and probably investment opportunity elsewhere for foreign capital (mainly U.S. investors). Thus, the increase of the oil revenue to the Mexican government is off set by the forgone capital inflows (and outflows) might be interested investing in the U.S instead, and that would result in a negative effect on the capital inflows to the Mexican economy. As for the asset return variables, the dividend, DIV, the treasury bill rate, TBILL, and the yield on 10-year U.S. bond, LONG, are negatively correlated with foreign reserves. The treasury bill rate is viewed as an indicator of short run opportunities in the U.S economy. Then, an increase in TBILL results in capital outflows and then affects negatively the stock of foreign exchange. Dividends in the finance literature are used to forecast the future U.S. growth. An increase of DIV will result in capital outflows to the U.S and consequently the stock of reserves is negatively affected. The yields on 10-years U.S. government bonds, LONG, is considered in the RBC literature as a good indicator of the U.S. RBC, is negatively correlated with the foreign reserves. An increase in LONG reflects good expectation about the U.S RBC and then we should expect capital outflows, a result confirmed by the sign of the coefficient on LONG. Figure 3 shows the actual and fitted foreign exchange implied by this relationship.

The above exercise shows that exogenous shocks represent a good approximation of the factors driving the reserves accumulation in Mexico. This is an interesting finding and supports our fundamental assumption that reserves in Mexico are not subject to policy change after the Tequila Crisis.

To explore this interpretation further, we ran the same regression but included a dummy variable which took on the value 1 after 1994 and zero otherwise. As the results in column 3 of Table 1 indicate the coefficient on this dummy is statistically not significant and suggests that the long run reserves to GDP ratio did not change at all. In fact, as discussed in our decomposition method, the constant term in this regression captures the permanent component of the government's policy variable, Λ. The model suggests that over the period 1981-2006, the long run policy target (i.e., foreign exchange to GDP) is 4.6%. By accounting for the structural break (i.e., introducing a dummy variable) the long run policy policy component remains unchanged, 4.6%. Recall that the dependent variable is $FX = ln(\frac{R}{GDP}) = \Lambda_t + \lambda' X_t + \epsilon_t$, so the long run reserves to GDP ratio, $\frac{R}{GDP}$ (the constant term in this regression) is

$$e^{\hat{\Lambda}} = 4.6\%$$

when we do not account for a structural break, and

$$e^{\hat{\Lambda}+\hat{\lambda}_0} = 4.6\%$$

Although there is no evidence for a structural break we find it useful to address the following question: is this relationship stable over time? In Column

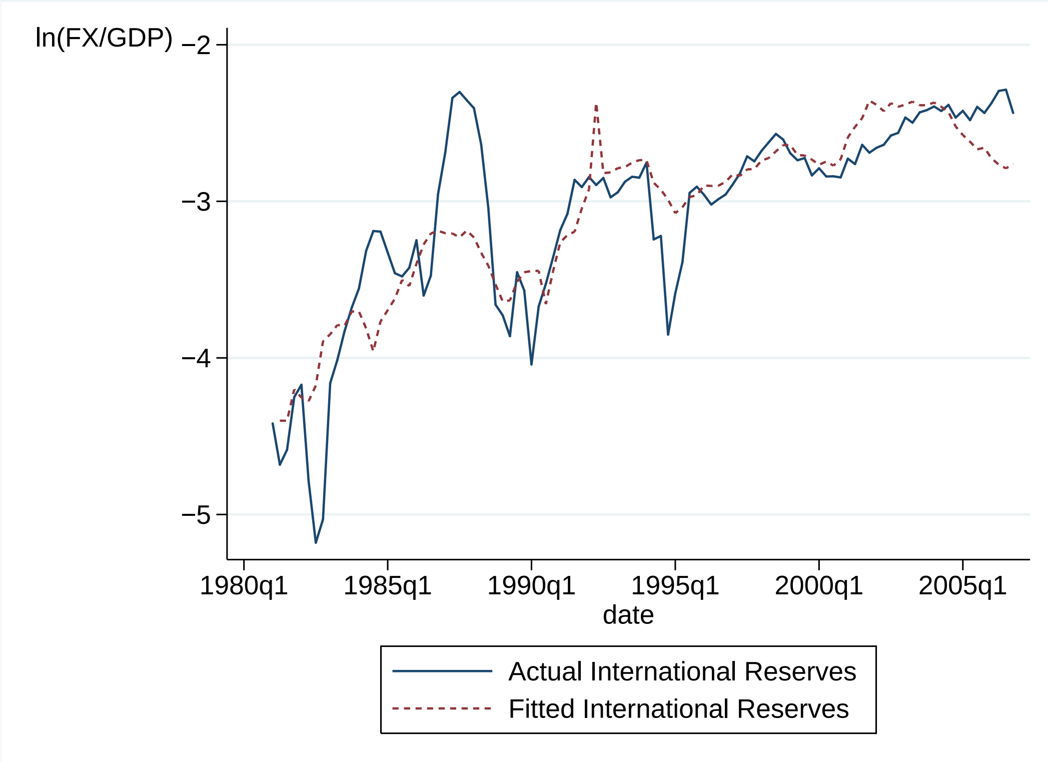


Figure 3: Shocks Adjusted with Asset Returns and Oil Price

4 of Table 1 we report the results of estimating the model over the pre crisis period 1981:1- 1995:2. Except for the yield on 10-year U.S bonds, LONG, the coefficients are robust to this truncation of the sample period.[14] The fact that we are able to identify these parameters ex ante suggests that our empirical specification should provide a *useful* basis for a conditional forecast of the demand for reserves.

Based on these empirical results, we interpret the Mexican's reserves accumulation process as follows: Under the policy regimes that were in place up to the mid-1990s, exogenous global shocks accounted for 70% of the variation in the demand for international reserves. In the mid1990s, however, although the exogenous shocks caused a period of liquidity problems it did not result in high demand of foreign exchange as the reserves literature suggests. Instead of adjusting its reserves policy immediately in response to the liquidity problem and accumulate more reserves (as the literature suggests) the Mexican economy adopted the same long run target of reserves to GDP. It is likely that more favorable shocks that accounts for the increase in level of international reserves and not a policy shift.

[14]The shortness of the sample suggests that one should not expect stable results that would be robust across possible specifications, as indeed we find in our empirical results.

4 Assessing the Sustainability of Reserves

> What policy measures can developing countries take to improve their institutional capacity to analyze the links between trade, finance, investment and debt? ... Debt is not sustainable unless the[se] wider development strategies lead to an increase in foreign exchange earnings that can be used as repayment. This is why trade plays such a critical role.[15]

What level of the reserves should the monetary authorities hold? As discussed in the introduction, several indicators have been used to evaluate whether reserve holdings are sufficient (see Bird and Rajan, 2003, for a more detailed discussion). The heyday of the reserve adequacy literature dates back to the 1960s and the 1970s, when the focus was mainly on the current account. The main framework of this literature has been the Baumol-Tobin inventory model with fixed costs of depleting and replenishing reserves (see Frenkel and Jovanovic, 1981, and Flood and Marion, 2002 for recent review). The main prediction of the model is a positive correlation between the volatility and the level of international reserves, and it has been found to hold very robustly in the data. However, the model has not been used normatively to estimate the optimal level of reserves. Policymakers have often used an old rule of thumb of maintaining reserves equal to the short-term debt or equivalent to three months of imports (see introduction for discussion). Although these ratios provide a good measure of reserve adequacy in terms of a country's resiliency when facing a potential financial crisis, they do not provide an upper bound for reserve holdings.

In recent years (i.e., following the mid-1990s crises), a few recent papers attempt to estimate the optimal level of reserves for emerging market countries that face the risk of sudden stops. Alfaro and Kanczuk (2006) study the joint decision of holding sovereign debt and reserves. They construct a stochastic dynamic equilibrium model calibrated to a sample of emerging economies. Their results suggest that the optimal policy is not to hold reserves at all. Aizenman and Lee (2005) present a three-period stylized model of the optimal level of international reserves based on the Diamond-Dybvig model of banks runs. Garcia and Soto (2004) construct estimates of the optimal level of reserves based on the assumption that the authorities are risk-neutral and accumulate reserves in order to reduce the probability of a sudden stop. 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. He finds that it is not difficult for the model to explain a reserves-GDP ratio on the order of 10 percent for the typical emerging market country (close to the long-run historical average), and that even higher ratios can be justified if one assumes that reserves have a significant role in crisis prevention. He concludes that levels of reserves observed in many countries in the recent period, in particular in Latin America, are within the range of the models predictions.

In sum, according to the literature, the self-insurance motive against potential drain of foreign capital is the key element in addressing the optimal level of reserves. The financial crises of the 1990s showed that sudden loss of access

[15] United Nations Conference on Trade and Development, UNCTAD, 2006.

to capital markets might occur if the country is not able to fulfil its existent external obligations. As a result rollover problems take place and the economy fall into a crisis.

In the present study we deviate from this literature by addressing the sustainability of reserves holding, instead.

4.1 Future Incomes of an Open Economy

In an open economy , the tarde balance, TB_t, can be written as the difference of output, Y_t, and domestic absorption[16], DA_t:

$$TB_t = Y_t - DA_t. \tag{4}$$

This representation of trade balance refers to the net income that an economy has after subtracting all costs and expenses and can be interpreted as earnings of the country. Net income can be positive or negative.

Clearly, the reserves accumulation and the external debt that an economy can afford depend on its future incomes, which are function of the macroeconomic fundamentals of the country, and other exogenous factors. It turns out, as we will show below, that the set of exogenous shocks introduced in the previous section are good approximation of the process driving the country's net incomes.

In an open economy, the balance of payment equation is

$$CA_t + KA_t = \Delta R_t, \tag{5}$$

where KA_t is the financial account, CA_t is the current account, and $\Delta R_t = R_t - R_{t-1}$, is the change in reserves.[17] The capital account, in turn, can be written as,

$$CA_t = TB_t + IT_t \tag{6}$$

where IT_t is the net income transfers. Combining (5) and (6) we get

$$TB_t + IT_t + KA_t = \Delta R_t. \tag{7}$$

"*The financial account records, by type of financial instrument, the changes in the financial assets and liabilities that compose net lending or borrowing.*"[18] Using this definition, we can think of the financial account, KA_t, as the change in the *net liabilities* position of the country. That is,

$$KA_t = L_t - L_{t-1} \tag{8}$$

where,

[16] Domestic absorption, DA_t, is the sum of private consumption, C, general government consumption, G, and gross domestic investment, I: $DA = C + I + G$. Trade Balance is the difference between exports, X, and imports, M: $TB = X - M$.

[17] The financial account was formally called the capital account. We will use the two terms interchangeably

[18] OECD (2001): Glossary of Statistical Terms. Source of Publication ESA 8.50-8.51 [III.2]. http://stats.oecd.org/glossary/detail.asp?ID=960

$$L_t = \text{All Liabilities - All Assets.}$$

Combining equations (5)-(8) we can write trade balance, using (7), as follow

$$TB_t = \Delta R_t - KA_t - IT_t$$

or,

$$TB_t = \underbrace{(R_t - R_{t-1})}_{\Delta R_t} - \underbrace{(L_t - L_{t-1})}_{\Delta L_t} - IT_t \tag{9}$$

which represents the net income of the whole economy.

Clearly, to assess whether a certain level of international reserves is viewed sustainable, given the country's net liability position, depends crucially on what its expected future incomes are. In fact, as the state of an economy evolves, expectation of future incomes may change too. Therefore, it is not meaningful to ask what level of international reserves can the economy accumulate independent of the state of the global and domestic economy. A more useful way to pose the question is: *conditional* on ***current*** forecasts of future incomes, what reserves level will be considered as sustainable? We address this question by computing the market valuation of expected future incomes under the current targets of reserves to GDP and comparing it to the current *net liabilities* position.

To be able to compute the future incomes we first need to specify the processes driving period t net income defined by (9),R_t, L_t and IT_t. We use our specification in the previous section to infer R_t. Next, we adopt similar specifications to derive the process driving the L_t and IT_t

4.1.1 Reserves Process

In section 2, we estimated the model

$$ln(\frac{R_t}{Y_t}) = \beta_0 + \beta^T X_t + \epsilon_t, \tag{10}$$

where β is 4×1 vector of parameters, and X_t is a 4×1 vector of variables. ϵ_t is i.i.d. and $\epsilon_t \sim N(0, \sigma_\epsilon^2)$. It follows that

$$\frac{R_t}{Y_t} = e^{\beta_0 + \beta^T X_t + \epsilon_t}, \tag{11}$$

or,

$$R_t = Y_t e^{\beta_0 + \beta^T X_t + \epsilon_t} \tag{12}$$

It follows that

$$\Delta R_t = e^{\beta_0} \left[Y_t e^{\beta^T X_t + \epsilon_t} - Y_{t-1} e^{\beta^T X_{t-1} + \epsilon_{t-1}} \right] \tag{13}$$

4.1.2 Liabilities Process

The increasing indebtedness of many emerging economies during the last three decades have created serious concerns about the ability of these economies to pay back their debt and have become a major topic of policy debate. Mach of the economic literature on this subject rationalizes these large indebtedness of all economic agents as the consequence of the increasing openness of financial markets in these economies, and the abundance of capital. However, the analysis fails to explain why the indebtedness problem of developing countries emerged in the mid-eighties and not before[19]. In addressing the public debt, some authors have started to consider the role of exogenous fiscal shocks as a source of the rising public debt. However, their attention has largely been focused on how political and fiscal institutions affect the government's response to fiscal shocks,[20] rather than on the shocks themselves. One exception is Lloyd-Ellis and Zhu (2001) who explored the contribution of exogenous factors to the primary surplus and measure their importance to the rising public debt.

In what follow we investigate the actual contribution of financial and oil shocks discussed in the previous section to both public and private debt. Moreover, to capture the increasing effect of capital (in and out) flows we focus on the net liability position. We estimate the contribution of exogenous factors to the variations in the net liability position of Mexico and measure their relative importance to the net income.

We estimate the model

$$ln(\frac{L_t}{Y_t}) = \alpha_0 + \alpha^T X_t + \mu_t, \tag{14}$$

where μ is i.i.d. and $\mu \sim (0, \sigma_\mu^2)$. Column 1 of Table 2 reports the results. This regression illustrates the striking fact that 82% of the net liabilities position of Mexico can be replicated by a simple linear combination of the asset returns and the oil price. We can rewrite (14) as

$$L_t = Y_t e^{\alpha_0 + \alpha^T X_t + \mu_t} \tag{15}$$

it follows that

$$\Delta L_t = e^{\alpha_0} \left[Y_t e^{\alpha^T X_t + \mu_t} - Y_{t-1} e^{\alpha^T X_{t-1} + \mu_{t-1}} \right] \tag{16}$$

Figure 5 shows that accounting for the structural break improves the direction of movements in the net liability position and adds a bit to the explanatory power. However, the parameters of the model are not quite robust to the inclusion of the dummy variable.

4.1.3 Income Transfers Process

Interest payments by domestic agents on their external debt and interests received by domestic agents on loans to foreign agents as well as the interests

[19]Alesina and Perotti (1995) ask similar question but regarding the public debt issues that emerged in the mid-seventies and not before.

[20]See Von Hagen (1991), Poterba (1994), Bayoumi and Eichengreen (1996), Bohn and Inman (1996), and Alesina and Perotti (1996).

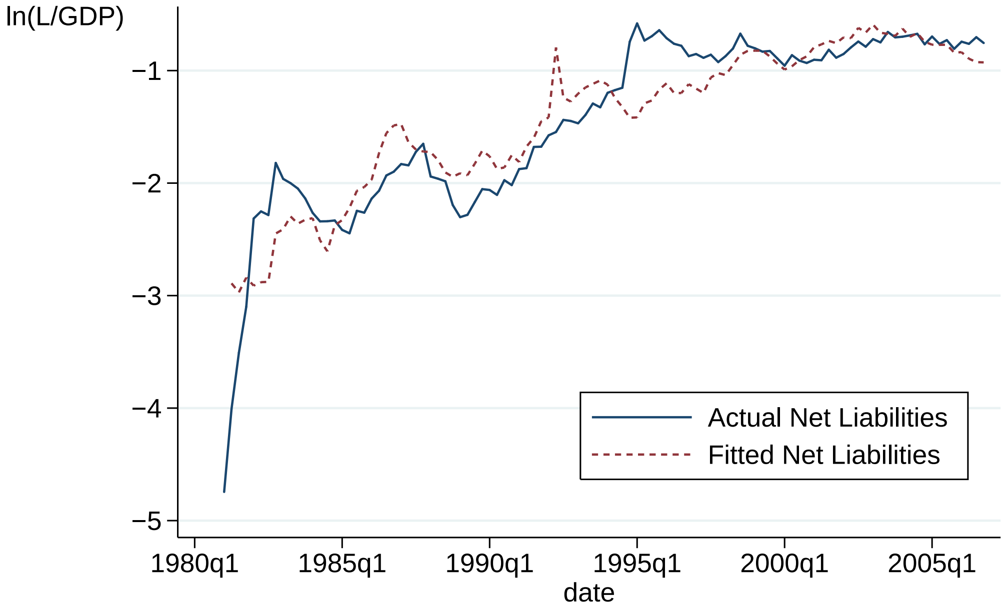
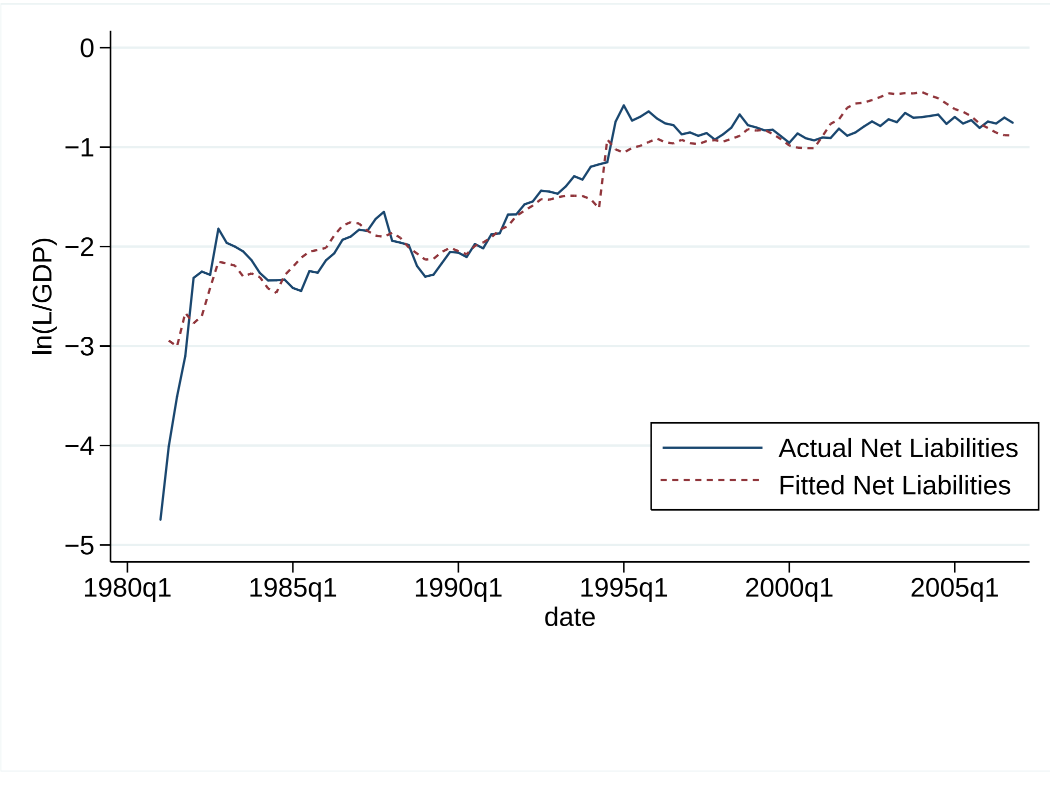


Figure 4: Shocks Adjusted Net Liabilities



[!h]

Figure 5: Shocks Adjusted Net Liabilities with Dummy

on the reserves holdings by domestic agents are the main components of the income transfers recorded in the balance of payments. Since external debt as well as foreign reserves processes were explained by the exogenous shocks to the economy we expect these same factors to explain the income transfers.

We assume that the income transfers, IT_t, are driven by the following process,

$$ln(\frac{-IT_t}{Y_t}) = \gamma_0 + \gamma^T X_t + \varsigma_t, \tag{17}$$

where ς is i.i.d. and $\varsigma \sim (0, \sigma^2_\varsigma)$. Results of this exercise are reported in colunm 3 of Table 2.

Figure 6 shows that while the model replicates the direction of movements in the income transfers, it does not capture their volatile pattern. Moreover, the shock variables accounts for only 55% of the variation in the income transfers. One reason for this, is that many transfers are one-sided transaction (e.g., donations for foreign aid) and might not be affected by the exogenous shocks. Another reason is that reserves are highly liquid risk-free assets and thus the interests they generate are not affected by the shocks describing the state of the world. Note, however, that the parameter estimates are correctly signed and DIV and LONG are statistically significant.

(17) can be rewritten as

$$IT_t = -Y_t e^{\gamma_0 + \gamma^T X_t + \varsigma_t} = -e^{\gamma_0} Y_t e^{\gamma^T X_t + \varsigma_t} \tag{18}$$

Table 2: Decomposition of Net Liabilities and Income Transfers

Variables	Liab. Shocks	Liab. Dummy	IT Shocks
$\Delta LCOP$	.22	.09	-.07
	(.23)	(.17)	(.26)
DIV	-2.39***	-.05	1.32*
	(.59)	(.49)	(.67)
TBILL	-3.58	-9.90***	.50
	(2.75)	(2.11)	(3.11)
LONG	-12.14***	-3.43	9.09**
	(3.62)	(2.78)	(4.09)
CONSTANT	-1.44***	-1.80***	-4.82***
	(.03)	(.045)	(.035)
DUMMY		.76***	
		(.08)	
NOBS	103	103	103
R^2	.82	.90	.55
p-value	[0.000]	[0.000]	[0.000]

Although the model for income transfers we consider does not fit very well the data, we think it is very important to keep its present specification. First, we want to be consistent with our specification of the reserves and the net liabilities specifications. Second, we want to investigate the effect of exogenous shocks in computing the net income of the overall economy.

Figure 6: Shocks Adjusted Income Transfers

In order to determine the market valuation of the future net incomes (net present value of the trade balance), however, we choose a valuation method, which is based on several assumptions.

4.2 Assumptions for Valuation of Future Income

We assume that there is a complete world financial market in which all contingent claims with payoffs that are functions of the set of the exogenous shocks, z_t, can be traded. Under this assumption and the assumption of no-arbitrage, there exists a unique sequence of stochastic discount factors, $\{M_t\}_{t \succeq 0}$, such that the time t price of a contingent claim pays $q(z_t)$ units of the consumption good in period $t + j$ is

$$\Pi(t, j) = E_t \left[\frac{M_{t+j}}{M_t} q(z_{t+j}) \right] \tag{19}$$

We assume that Mexico is a small open economy, so that the stochastic discount factors are exogenous with respect to domestic agents' actions. In particular, changes in the liability position has no effect on them.

Given our specification for and reserves in (3) and for the trade balance (i.e., net incomes) in (9), if the government's reserves policy continues to be Λ in the future, the present value of the country's net incomes can be expressed as

$$V_t(\Lambda) = E_t\Big[\sum_{j=1}^{\infty} \frac{M_{t+j}}{M_t}\Big(\underbrace{[R_{t+j} - R_{t+j-1}]}_{\Delta R_{t+j}} - \underbrace{[L_t - L_{t+j-1}]}_{\Delta L_{t+j}} - IT_{t+j}\Big)\Big] \qquad (20)$$

To compute the market valuation, $V_t(\Lambda)$, in addition to the three processes R_t, L_t, and IT_t discussed above, we need to specify a process for the the stochastic discount rate applied by the market in valuing future cashflows.

Since movements in the discount rate will also reflect global shocks, an important determinant of the present value is its covariance with the net incomes. We take "the market" to be a representative US investor and assume that the "state of the world" is captured by the asset return indices and the oil price discussed in the previous section. Specifically, we assume that the vector

$$X_t = (X_{1,t}, X_{2,t}, X_{3,t}, X_{4,t}) = (\Delta LCOP_t, DIV_t, TBILL_t, LONG_t),$$

follows a vector autoregressive process:

$$X_t = AX_{t-1} + \mathbf{u}_t \qquad (21)$$

where $\mathbf{A}$ is 4×4 matrix of parameters, and $\mathbf{u}_t$ is a 4×1 vector, $\mathbf{u}_t$ is i.i.d., and $\mathbf{u}_t \sim N(0, \Sigma)$. Table 3 provides the estimated process using quarterly data from 1981:q1 to 2006:q4.

Table 3: VAR Estimates

	$\Delta LCOP$	DIV	TBILL	LONG
$\Delta LCOP(-1)$	.14	.020	.006	.0005
	(.10)	(.03)	(.004)	(.004)
DIV(-1)	-.019	.68	.015	.007
	(.25)	(.063)	(.01)	(.01)
TBILL(-1)	.09	-.32	.92	.06
	(1.19)	(.30)	(.05)	(.05)
LONG(-1)	-.65	1.36	-.03	.88
	(1.56)	(.39)	(.07)	(.06)

4.3 Asset Pricing Model

To calibrate our model for the stochastic discount factor we use the approach of lloyd-Ellis and Zhu (2006). Let r_t^n be the interest rate on the 3-month Treasury bills, r_t^L to be the yield on 10-year Treasury bonds, and R^m to be the nominal return on the market portfolio. Then, the following no-arbitrage conditions should hold for any asset pricing model:

$$E_t\big[\frac{M_{t+1}}{M_t} exp(r_t^n)\big] = 1, \qquad (22)$$

$$E_t\Big[\frac{\frac{1}{2}\Big(\sum_{j=1}^{20} M_{t+2j} r_t^L\Big) + M_{t+40}}{M_t}\Big] = 1, \quad (23)$$

$$E_t\big[\frac{M_{t+1}}{M_t} R_{t+1}^m\big] = 1. \quad (24)$$

where $r_t^n = E[r_t^n] + \frac{1}{3}X_{3,t}$, $r_t^L = E[r_t^L] + X_{4,t}$, and $R^m = exp(X_{2,t})$.

Since we use the stochastic discount factors to value cash-flows that are functions of X_t; it is important to model the covariance between the stochastic discount factors and X_t: Here, we adopt the following linear specification for the growth rate of the nominal stochastic discount factor:

$$-ln(\frac{M_t}{M_{t-1}}) = \varpi + \mathbf{b}' X_{t-1} + \omega_t \quad (25)$$

where ω_t is i.i.d., $\omega_t \sim N(0, \sigma_\omega^2)$, and $E[\omega_t \mathbf{u}_t] = \mathbf{v}$.

In our calculations, we focus on a special case of this specification. We extend the term structure model discussed in Campbell and Viceira (1998) and Campbell, Lo and MacKinlay (1997) by allowing the innovation in the stochastic discount factor to be correlated with the innovations in the shock variables. Specifically we adopt the following specification for the growth in the discount factor:

$$-ln(\frac{M_t}{M_{t-1}}) = r_{t-1}^n + \frac{1}{2}\sigma_\omega^2 + \omega_t, \quad (26)$$

where r_{t-1}^n is the 3-month risk-free nominal interest rate. By definition, $X_{3,t-1} = 4(r_{t-1}^n - E[r_t^n])$. So, the above equation is a special case of (25) with $\varpi = E[r_{t-1}^n] + \frac{1}{2}\sigma_\omega^2$, and $\mathbf{b}' = (0, 0, 1/4, 0)$. We further assume that

$$\omega_t = \rho_2 \mathbf{u}_{1,t} + \rho_3 \mathbf{u}_{3,t}. \quad (27)$$

That is, the the innovation in the stochastic discount factor is a linear combination of the innovation in the return on market portfolio and the innovation in the 3-month interest rate. Then, we have

$$\sigma_\omega^2 = \rho_2^2 \sigma_{2,u}^2 + \rho_3^2 \sigma_{3,u}^2 + 2\rho_2\rho_3\sigma_{23,u}, \quad (28)$$

$$\mathbf{v}' = (0, 0, \rho_3, \rho_4, 0, 0)'\Sigma \quad (29)$$

We calibrate the parameters ρ_2 and ρ_3 so that the other two moment conditions, (23) and (24), hold on average over the sample period 1981:1-2006:4. For more details on calibration and present value calculation, see Appendix.

Let $L_t(\Lambda)$ be the net liability position of the Mexican economy at the end of period t, when the current policy of reserves accumulation is Λ. *Under the existing reserves policy* (i.e. current target of reserves to GDP ratio), sustainability requires that

$$L_t(\Lambda) \leq R_t + V_t(\Lambda) \quad (30)$$

Figure 7 illustrates the evolution of our estimate of the present value of future surpluses as a percentage of GNP in comparison with the liabilities-GNP ratio.

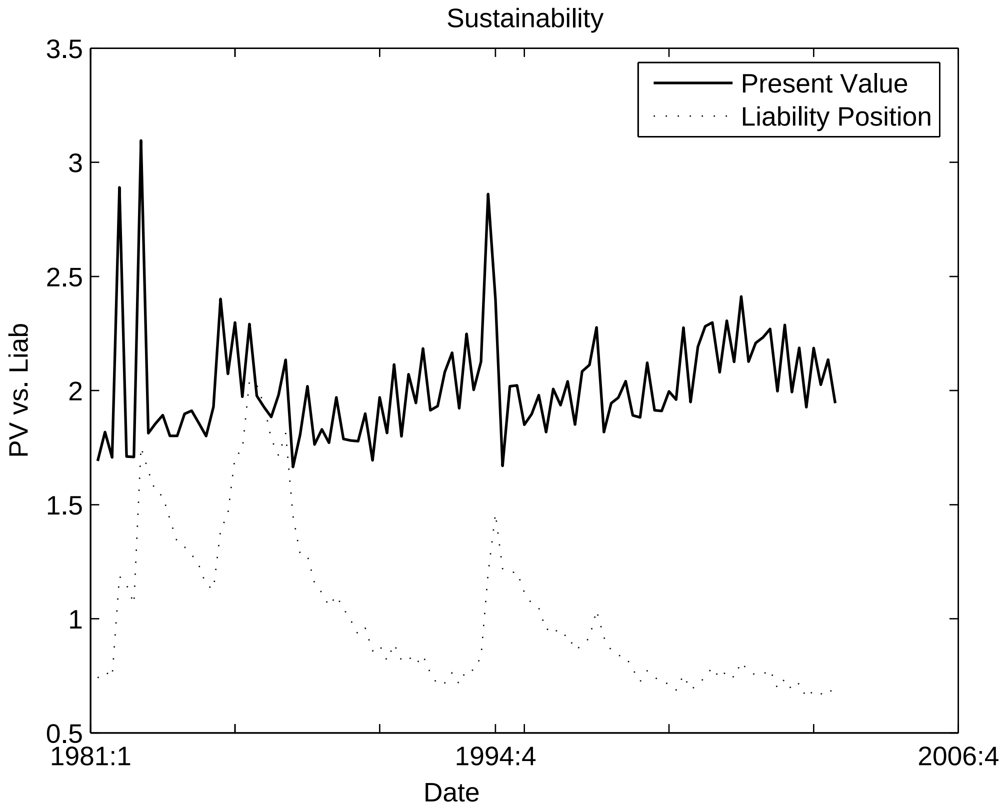


Figure 7: Liabilities and the Value of Future Incomes Under the Current Policy

As can be seen, while the liabilities-GDP ratio fell throughout the period, the present value floats around a constant but at a higher level than the liabilities-GDP ratio. Note, however, that in the mid-1980s liabilities reached the same level as the present value of future incomes suggesting that during that sustainability condition above was violated. In 1994, the gap between liabilities-GDP increased and became closer but never reached the present value of future incomes as percentage of GDP. This reflects that although Mexico experienced a financial crisis in 1990s it was able to pay its liabilities under the policy regime in place and that's why it did not opt for a policy change. In other words, Mexico did not need to increase its reserves holdings to fulfil its external liabilities.

5 Concluding Remarks

Increasing financial and trade openness exposes emerging market economies to unavoidable shocks that are outside the control of the local authorities. As a result many countries experienced liquidity problems and financial distress during the 1990s. The international finance literature has provide evidence that these countries opted for new policy consist: increase the international reserve holdings. In this paper we have argued that the observed increase in foreign exchange holdings in Mexico is the result of more favorable global conditions. We show that many of the shocks to the Mexican reserves can be replicated using a linear combination of internationally traded asset returns and the oil price. We argue that using these asset returns and the oil price to investigate the determinants of reserves holdings is both conceptually appealing and quantitatively superior to traditional methods. We also show that it is possible to approximate the reserves accumulation process over the last three decades as a stationary function of these shocks without an abrupt regime shift after the Tequila crisis. Our results are consistent with the hypothesis that the rise in reserves holdings experienced by Mexico was the result of a series of positive shocks in the post crisis period.

The strong and stable correlation between the foreign exchange and these asset return indices and the oil price also provides a basis for a flexible and simple method for determining the implicit market assessment of the sustainability of the current target of reserves to GDP ratio. Using the trade balance as an approximation of the country's net income we infer that the Mexican current policy is sustainable.

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Appendix

Net Liability Position

Only few observations of the international investment position are available in the IFS database. For Mexico, there are 6 annual observations, 2001 through 2006. To infer the quarterly data we use some identities from the balance of payments. To outline our approach we first need to define our variables. Define,

- L_t: Net Liability Position in period t,
- R_t: Stock of International Reserves the country holds in period t,
- IT_t: Net Income Transfers in period t. It is equal to Income Credit - Income Debt.
- TB_t: Trade balance in period t.

From the balance of payment equations we have

$$R_{t+1} - L_{t+1} = R_t - L_t + IT_t + TB_t$$

or

$$L_{t+1} = \Delta R_t + L_t - IT_t - TB_t$$

where $\Delta R_t = R_{t+1} - R_t$. Since we have only few observations of L_t which they are annual (end of period) and refer to the last 6 years only we infer the quarterly data starting from the last observation, i.e. 2006, which is also the observation relative to the last quarter of the year 2006, i.e. 2006:4 and then work our way backward using the quarterly flow variables we have (ΔR_t, IT_t, and TB_t). That is,

$$L_t = L_{t+1} - \Delta R_t + IT_t + TB_t$$

Details Related to Calculation of the Present Value

To compute the present value of Mexico net income we proceed as follow: for each date, we computed the change in reserves, $\Delta R_t = R_t - R_{t-1}$, the change in net liabilities position, $\Delta L_t = L_t - L_{t-1}$, and the income transfers, IT_t and then we discount at rate M_t/M_{t-1}.

We need to calculate present value of nominal cash-flows of the following form:

$$B(t,j) = \frac{1}{M_t} E_t \left[M_{t+j} \left(\underbrace{(R_{t+j} - R_{t+j-1})}_{\Delta R_{t+j}} - \underbrace{(L_{t+j} - L_{t+j-1})}_{\Delta L_{t+j}} - IT_{t+j} \right) \right] \quad (31)$$

Let $Z(t,j) = -ln(M_{t+j})$. Then[21]

$$Z(t,j) = Z(t,j-1) + \mathbf{b}^T X_{t+j-1} + w_{t+j}, \quad (32)$$

[21] This is the general form. As outlined in the paper, in our case we use the following specification

$$-ln(\frac{M_t}{M_{t-1}}) = r_{t-1} + \frac{1}{2}\sigma^2 + \omega_t$$

where $Z(t,0) = -lnM_t$ and ω_t is i.i.d, and $\omega_t \sim N(0, \sigma_\omega^2)$. It follows that

$$B(t,j) = \frac{1}{M_t} E_t\left[e^{-Z(t,j)}\left(\Delta R_{t+j} - \Delta L_{t+j} - IT_{t+j}\right)\right] \tag{33}$$

or

$$B(t,j) = \frac{1}{M_t}\left\{\underbrace{E_t[e^{-Z(t,j)}\Delta R_{t+j}]}_{(I)} - \underbrace{E_t[e^{-Z(t,j)}\Delta L_{t+j}]}_{(II)} - \underbrace{E_t[e^{-Z(t,j)} IT_{t+j}]}_{(III)}\right\} \tag{34}$$

To calculate this present value we need to calculate its three components, (I), (II), and (III). Recall that in section 2 we derived the processes driving R_t, L_t, and IT_t. Using section 2, we have

$$R_t = Y_t e^{\beta_0} e^{\beta^T X_t + \epsilon_t} = e^{\beta_0} e^{\beta^T X_t + \epsilon_t} Y_0 \prod_{s=0}^{t}(1+g_s) \tag{35}$$

where Y_0 stands for the output in 0, g_s is the growth rate of output between periods s and $s-1$, and $\prod_{s=0}^{t}(1+g_s)$ is the output growth between periods 0 and t. It follows that

$$\Delta R_t = Y_0 e^{\beta_0}\left[e^{\beta^T X_t + \epsilon_t}\prod_{s=0}^{t}(1+g_s) - e^{\beta^T X_{t-1} + \epsilon_{t-1}}\prod_{s=0}^{t-1}(1+g_s)\right] \tag{36}$$

Similarly, we have

$$L_t = Y_t e^{\alpha_0 + \alpha^T X_t + \mu_t} = e^{\alpha_0 + \alpha^T X_t + \mu_t} Y_0 \prod_{s=0}^{t}(1+g_s) \tag{37}$$

it follows that

$$\Delta L_t = Y_0 e^{\alpha_0}\left[e^{\alpha^T X_t + \mu_t}\prod_{s=0}^{t}(1+g_s) - e^{\alpha^T X_{t-1} + \mu_{t-1}}\prod_{s=0}^{t-1}(1+g_s)\right] \tag{38}$$

The income transfers, IT_t, process is,

$$IT_t = -Y_t e^{\gamma_0 + \gamma^T X_t + \varsigma_t} = -Y_0 e^{\gamma_0} e^{\gamma^T X_t + \varsigma_t} \prod_{s=0}^{t}(1+g_s) \tag{39}$$

Note that $1 + g_t$ can be approximated by e^{g_t}; that is,

$$1 + g_t \approx e^{g_t} \tag{40}$$

We further assume that the growth rate of GDP evolves according to the following process

$$g_t = \bar{g} - \frac{1}{2}\sigma_\eta^2 + \eta_t, \tag{41}$$

That is $\mathbf{b}^T = (0, 0, 1/4, 0)$. Which can be rewritten this as follow

$$-logM_t = -lnM_{t-1} + r_{t-1} + \frac{1}{2}\sigma^2 + \omega_t$$

where $\bar{g}$ is a constant and η_t is i.i.d, and $\eta_t \sim N(0, \sigma_\eta^2)$.

Let

$$\Gamma(t,j) = \prod_{s=0}^{t+j} e^{g_s} \tag{42}$$

Using (32), (36), (38), and (40)-(42) we can rewrite (I), (II), and (III) as follow

$$(I): E_t[e^{-Z(t,j)}\Delta R_{t+j}] = Y_0 e^{\beta_0} E_0\Bigg[e^{-Z(t,j)}\Bigg(e^{\beta^T X_{t+j}+\epsilon_{t+j}}\Gamma(t,j) - e^{\beta^T X_{t+j-1}+\epsilon_{t+j-1}}\Gamma(t,j-1)\Bigg)\Bigg]$$

or,

$$(I): E_t[e^{-Z(t,j)}\Delta R_{t+j}] = Y_0 e^{\beta_0}\Bigg\{\underbrace{E_0\Big[e^{-Z(t,j)+\beta^T X_{t+j}+\epsilon_{t+j}}\Gamma(t,j)\Big]}_{(Ia)} - \underbrace{E_0\Big[e^{-Z(t,j)+\beta^T X_{t+j-1}+\epsilon_{t+j-1}}\Gamma(t,j-1)\Big]}_{(Ib)}\Bigg\} \tag{43}$$

$$(II): E_t[e^{-Z(t,j)}\Delta L_{t+j}] = Y_0 e^{\alpha_0}\Bigg\{\underbrace{E_0\Big[e^{-Z(t,j)+\alpha^T X_{t+j}+\mu_{t+j}}\Gamma(t,j)\Big]}_{(IIa)} - \underbrace{E_0\Big[e^{-Z(t,j)+\alpha^T X_{t+j-1}+\mu_{t+j-1}}\Gamma(t,j-1)\Big]}_{(IIb)}\Bigg\} \tag{44}$$

$$(III): E_t[e^{-Z(t,j)}IT_{t+j}] = -Y_0 e^{\gamma_0}\underbrace{E_0\Big[e^{-Z(t,j)+\gamma^T X_{t+j}+\varsigma_{t+j}}\Gamma(t,j)\Big]}_{(IIIa)} \tag{45}$$

So,

$$B(t,j) = \frac{1}{M_t}\Big[(I)-(II)-(III)\Big] = \frac{1}{M_t}Y_0\Big[e^{\beta_0}\big[(Ia)-(Ib)\big]-e^{\alpha_0}\big[(IIa)-(IIb)\big]+e^{\gamma_0}(IIIa)\Big] \tag{46}$$

The next exercise is to calculate (Ia), (Ib), (IIa), (IIb), and (IIIa) in or der to get the present value of cash-flows.

$$(Ia): E_0\Big[e^{-Z(t,j)+\beta^T X_{t+j}+\epsilon_{t+j}}\Gamma(t,j)\Big] = E_0\big[e^{-Z(t,j)+\beta^T X_{t+j}+\epsilon_{t+j}}\big]E_0\big[\Gamma(t,j)\big] + COV\big(e^{-Z(t,j)+\beta^T X_{t+j}+\epsilon_{t+j}}, \Gamma(t,j)\big) \tag{47}$$

Note that $COV\big(e^{-Z(t,j)+\beta^T X_{t+j}+\epsilon_{t+j}}, \Gamma(t,j)\big) = 0$. Recall that

$$\Gamma(t,j) = \prod_{s=0}^{t+j} e^{g_s},$$

and using the process driving the growth rate described above, (38), we have that $E[e^{g_s}] = e^{\bar{g}}$, and

$$E[\Gamma(t,j)] = e^{\bar{g}(t+j)} \tag{48}$$

$$E_0\big[e^{-Z(t,j)+\beta X_{t+j}+\epsilon_{t+j}}\big] \quad = \quad e^{-m_z(t,j)+\beta^T m_x(t,j)+E[\epsilon_{t+j}]+\frac{1}{2}V(-Z(t,j)+\beta X_{t+j}+\epsilon_{t+j})}$$

where $m_z(t,j) = E[Z(t,j)]$ and $m_x(t,j) = E[X_{t+j}]$. Note that $E[\epsilon_{t+j}] = 0$. So,

$$E_0\big[e^{-Z(t,j)+\beta X_{t+j}+\epsilon_{t+j}}\big] = e^{-m_z(t,j)+\beta^T m_x(t,j)+\frac{1}{2}V(-Z(t,j)+\beta^T X_{t+j}+\epsilon_{t+j})} \tag{49}$$

Let $V(-Z(t,j) + \beta X_{t+j} + \epsilon_{t+j}) = V_{\beta,\epsilon}(j)$. Then,

$$\begin{aligned}
V_{\beta,\epsilon}(j) = \; & V(-Z(t,j) + X_{t+j}\beta) + V(\epsilon_{t+j}) + 2COV(-Z(t,j) + X_{t+j}\beta, \epsilon_{t+j}) \\
= \; & V(Z(t,j)) + \beta^T V(X_{t+j})\beta + 2COV(-Z(t,j), X_{t+j}\beta) + V(\epsilon_{t+j}) \\
& +2COV(-Z(t,j) + \beta X_{t+j}, \epsilon_{t+j}) \\
= \; & V(Z(t,j)) + \beta^T V(X_{t+j})\beta - 2COV(Z(t,j), X_{t+j})\beta + V(\epsilon_{t+j}) \\
& +2\big[-COV(Z(t,j), \epsilon_{t+j}) + \beta^T COV(X_{t+j}, \epsilon_{t+j})\big]
\end{aligned} \tag{50}$$

We have that $COV(Z(t,j), \epsilon_{t+j}) = 0$ and $COV(X_{t+j}, \epsilon_{t+j}) = 0$. So it follows that

$$V_{\beta,\epsilon}(j) = V(Z(t,j)) + \beta^T V(X_{t+j})\beta - 2\beta^T COV(X_{t+j}, Z(t,j))^T + V(\epsilon_{t+j}) \tag{51}$$

Let $V_{xx}(j) = V(X_{t+j})$, $V_{zz}(j) = V(Z(t,j))$, $V_{xz}(j) = COV(Z(t,j), X_{t+j})$.

Then (51) can be written as

$$V_{\beta,\epsilon}(j) = V_{zz}(j) + \beta^T V_{xx}(j)\beta - 2V_{xz}(j)\beta + \sigma_\epsilon^2 \tag{52}$$

To iterate on this moment we need to calculate $V_{xx}(j)$, $V_{zz}(j)$, and $V_{xz}(j)$. These moments can be calculated recursively as follows:

$$\mathbf{m}_x(t,j) = \mathbf{A}\mathbf{m}_x(t,j-1), \tag{53}$$

$$\mathbf{m}_z(t,j) = \mathbf{m}_z(t,j-1) + \mathbf{b}^T\mathbf{m}_x(t,j-1), \tag{54}$$

$$\mathbf{V}_{xx}(j) = \mathbf{A}\mathbf{V}_{xx}(j-1)\mathbf{A}^T + \Sigma, \tag{55}$$

$$\mathbf{V}_{xz}(j) = \mathbf{A}\mathbf{V}_{xz}(j-1) + \mathbf{A}\mathbf{V}_{xx}(j-1)\mathbf{b} + \mathbf{v}, \tag{56}$$

$$\mathbf{V}_{zz}(j) = \mathbf{V}_{zz}(j-1) + 2\mathbf{b}^T\mathbf{V}_{xz}(j-1) + \mathbf{b}^T\mathbf{V}_{xx}(j-1)\mathbf{b} + \sigma_\omega^2. \tag{57}$$

where $\mathbf{m}_z(t,1) = \mathbf{b}^T\mathbf{X}_t - lnM_t$, $\mathbf{m}_x(t,1) = \mathbf{A}\mathbf{X}_t$, $\mathbf{V}_{xx}(1) = \Sigma$, $\mathbf{V}_{xz} = \mathbf{v}$, and $V_{zz} = \sigma_\omega^2$.

We can rewrite (49) as follows

$$E_0\big[e^{-Z(t,j)+\beta X_{t+j}+\epsilon_{t+j}}\big] = e^{-m_z(t,j)+\beta^T m_x(t,j)+\frac{1}{2}V_{\beta,\epsilon}(j)} \tag{58}$$

Using (48) and (58) we have that

$$(Ia) = exp\bigg\{ - m_z(t,j) + \beta^T m_x(t,j) + \frac{1}{2}V_{\beta,\epsilon}(j) + \bar{g}(t+j)\bigg\} \tag{59}$$

Similar calculations lead to the derivation of (Ib),

$$(Ib) = exp\bigg\{ - m_z(t,j) + \beta^T m_x(t,j-1) + \frac{1}{2}Q_{\beta,\epsilon}(j-1) + \bar{g}(t+j-1)\bigg\} \tag{60}$$

where,

$$Q_{\beta,\epsilon} = \mathbf{V}_{zz}(j) + \beta^T V_{xx}(j-1)\beta - 2\beta^T\big[\mathbf{V}_{xz}(j-1) + \mathbf{V}_{xx}(j-1)\mathbf{b}\big] + \sigma_\epsilon^2 \tag{61}$$

Following the same steps we can calculate, (IIa), (IIb), and $(IIIa)$

$$(IIa) = exp\bigg\{ - m_z(t,j) + \alpha^T m_x(t,j) + \frac{1}{2}V_{\alpha,\mu}(j) + \bar{g}(t+j)\bigg\} \tag{62}$$

$$(IIb) = exp\bigg\{ - m_z(t,j) + \alpha^T m_x(t,j-1) + \frac{1}{2}Q_{\alpha,\mu}(j) + \bar{g}(t+j-1)\bigg\} \tag{63}$$

$$(IIIa) = exp\bigg\{ - m_z(t,j) + \gamma^T m_x(t,j) + \frac{1}{2}V_{\gamma,\varsigma}(j) + \bar{g}(t+j)\bigg\} \tag{64}$$

where,

$$V_{\alpha,\mu}(j) = V_{zz}(j) + \alpha^T V_{xx}(j)\alpha - 2V_{xz}(j)\alpha + \sigma_\mu^2, \tag{65}$$

$$Q_{\alpha,\mu} = \mathbf{V}_{zz}(j) + \alpha^T V_{xx}(j-1)\alpha - 2\alpha^T\big[\mathbf{V}_{xz}(j-1) + \mathbf{V}_{xx}(j-1)\mathbf{b}\big] + \sigma_\mu^2, \tag{66}$$

$$V_{\gamma,\varsigma}(j) = V_{zz}(j) + \gamma^T V_{xx}(j)\gamma - 2V_{xz}(j)\gamma + \sigma_\varsigma^2 \tag{67}$$

Recall from (46) we have

$$B(t,j) = \frac{1}{M_t}\Big[(I)-(II)-(III)\Big] = \frac{1}{M_t}Y_0\Big[e^{\beta_0}\big[(Ia)-(Ib)\big]-e^{\alpha_0}\big[(IIa)-(IIb)\big]+e^{\gamma_0}(IIIa)\Big]$$

So, the present value of the trade balance (i.e., country's future net income) is equal to

$$V(TB) = \frac{1}{M_t}\sum_{j=1}^{\infty} B(t,j) \tag{68}$$