March 23, 2007

International Reserves in Emerging Market Countries: Too Much of a Good Thing?[1]

Olivier Jeanne
IMF, Research Department
March 2007

PRELIMINARY. COMMENTS WELCOME

With international reserves four times as large as in the early 1990s in terms of their GDP, emerging market countries seem more protected than ever against shocks in their current and capital account (Figure 1). Some have pointed to the costs of carrying such large reserves holdings, and suggested that their level has become excessive (Summers, 2006). Others argue that this buildup in international reserves is warranted as an insurance against the increased volatility of capital flows associated with financial globalization (Aizenman and Marion, 2003; RBS, 2005).[2] Do emerging market countries hold too much international reserves?

This paper addresses this question by reviewing the evidence on the benefits and costs of reserves, and then comparing the two in the context of a simple model of the optimal level of reserves. The model assumes that international reserves insure a small open economy against current and capital account crises. This insurance role has two components: crisis prevention (reducing the probability of a crisis), and crisis mitigation (reducing the welfare cost of a crisis). I derive some formulas for the optimal level of reserves and compare them to

---

[1] This manuscript is a preliminary draft of a paper prepared for the March 2007 panel of the *Brookings Papers on Economic Activity*. I thank Ioannis Tokatlidis for excellent research assistance. I thank Eduardo Borensztein, Bill Brainard, Stijn Claessens, Nancy Marion, Jonathan Ostry, Larry Summers and Shang-Jin Wei for comments on an earlier draft. This paper benefited from discussions with Romain Rancière (who also generously shared his data with me) and Christian Mulder. The views expressed in this paper are those of the author and should not be attributed to the International Monetary Fund, its Executive Board, or its management.

[2] According to a survey of central bankers of developing and emerging market countries, the main reason for the recent buildup in reserves was to "secure protection from volatile capital flows" (RBS, 2005). In the words of Stiglitz (2006, p.248) "The East Asian countries that constitute the class of '97—the countries that learned the lessons of instability the hard way in the crises that began in that year—have boosted their reserves in part because they wanted to make sure that they don't need to borrow from the IMF again. Others, who saw their neighbors suffer, came to the same conclusion—it is imperative to have enough reserves to withstand the worst of the world's economic vicissitudes."

conventional rules of thumb, such as the Greenspan-Guidotti rule of full coverage of short-term debt.

Although it is impossible to pinpoint the optimal level of reserves because some underlying parameters are not directly observable and subject to uncertainty, the model nevertheless produces ranges of plausible estimates that can be compared to the data. One conclusion is that it is not difficult for the model to explain a reserves-to-GDP ratio of the order of 10 percent for the typical emerging market country—close to the historical average. The model can also predict higher reserves-to-GDP ratio (of the order of 25 or 30 percent) if one assumes that reserves have a significant role in terms of crisis prevention.

Ultimately, however, the model fails to account for the buildup in reserves in emerging market countries since 2000. The reason is that in most countries, especially in Asia, the vulnerability to a capital account crisis was too low in 2000 to justify the subsequent increase in reserves as an insurance against crises. This begs the question of why emerging market Asian countries accumulated so many reserves. I present some evidence on the "mercantilist" view of the recent reserves buildup—according to which reserves were accumulated as a way of resisting currency appreciation[3]—as well as the view that reserves accumulation resulted from deficient domestic financial intermediation.

The causes of excessive reserves accumulation notwithstanding, the authorities of emerging market Asian countries will have to manage unprecedented levels of foreign assets for some time to come. The paper concludes with a discussion of the policy challenges and opportunities implied by this situation. I discuss first, the impact of reserves diversification on global financial markets, and second, the implications of increased self-insurance against capital account crises for collective insurance arrangements.

The Buildup in International Reserves

Some facts

The buildup in the international reserves of emerging market countries is striking when compared to advanced countries (see Figure 1).[4] Whereas in advanced countries the level of

[3] See Dooley et al (2004) for an exposition of the mercantilist view.

[4] Our sample of emerging market countries is based on JP Morgan EMBIG and our sample of advanced countries includes all the countries that were members of the OECD in 1990. The list of countries is given in the Data Appendix. Note that it does not include three large reserves holders in Asia: Hong Kong, Singapore and Taiwan Province of China.

international reserves remained stable and below 10 percent of GDP, in emerging market countries it was multiplied by more than 4 in terms of GDP since 1990. A lot of the reserves accumulation in emerging market countries since 1990—more than half of the dollar amount— took place in Asia after the 1997-98 Asian crisis. China is now the country with the largest stock of international reserves in the world, and accounts for an important share of the buildup in emerging market reserves.[5] However, China is not very different from other the Asian emerging market countries if one looks at the ratio of reserves to GDP.

[Insert Figure 1]

This development is an important dimension of what Summers (2006) calls the "capital flows paradox" in the current world financial system, namely that capital flows flying upstream from developing and emerging markets towards the industrialized world and principally the United States. While claims flow in many directions, it is striking that the reserves accumulated in our sample of emerging market countries between 2000 and 2005 represent a significant fraction (40.4 percent) of the US current account deficit in the same period, and may thus have contributed to keep global interest rates low.

Table 1 gives some insights on the size and composition of the international capital flows associated with the emerging markets countries' buildup in reserves. In principle a country can accumulate reserves through the current account (by running current account surplus) or through the financial account (by issuing domestic liabilities to foreign investors). Table 1 shows how the buildup in reserves was financed in emerging market countries as a whole between 2000 and 2005. The first line gives the ratio of the cumulated capital inflows to the increase in reserves over the period 2000-05 for emerging market countries, and a breakdown for Asia and Latin America. About 40 percent of the reserves buildup was financed through the financial account on average. Whereas Asia relied more than the average on net exports to accumulate reserves, Latin America ran current account deficits so that its (relatively smaller) increase in reserves had to be financed more than one for one by capital inflows.

[Insert Table 1]

The lower part of Table 1 shows the types of external assets and liabilities that were traded in the financial account of emerging market countries between 2000 and 2005. More than 60 percent of the foreign assets accumulation consisted of reserves (more than 70 percent in Asia). By contrast, foreign direct investment accounted for almost 70 percent of the new liabilities accumulated by emerging market countries.

[5] China overtook Japan as the top reserves holder at the end of 2005.

This is consistent with the notion that emerging market countries tend to have assets that are more liquid than their liabilities. Whereas a large fraction of the claims that they acquire on the rest of the world are liquid and take the form of reserves, a large fraction of the liabilities that they sell to the rest of the world are illiquid and take the form of FDI. This pattern is confirmed by looking at the stocks rather than the flows. Figure 2 compares the structure of the external balance sheet of emerging market countries and advanced countries (taking the average over 2000-2005), using the IMF's data on International Investment Positions. The share of reserves in gross foreign assets is eight times as large in emerging market countries as in advanced countries, whereas the share of FDI in their liabilities is almost two times as large.

[Insert Figure 2]

Some questions

The level of reserves increased since the early 1990s, but so did the trade and financial integration of emerging market countries and the associated risks. How much of the increase in the insurance can be explained by an increase in the hazards of globalization? I look first at conventional rules of thumb in which the level of reserves is scaled by a measure of the risk in the balance of payments or in the domestic financial system, and then consider empirical models based on a larger range of risk measures.

Figure 3 shows the evolution of three conventional reserve adequacy ratios in emerging market countries: the ratio of reserves to import, which should be equal to 0.25 according to the three-months-of-import rule; the ratio of reserves to short-term external debt, which should be equal to 1 according to the Greenspan-Guidotti rule (the idea being that reserves should allow a country to live without foreign borrowing for up to one year); and the ratio of reserves to M2.[6]

As numerous studies have pointed out, the recent accumulation of reserves by emerging market countries seems difficult to explain using the conventional rules of thumb for reserves adequacy. Although imports, short-term debt and M2 increased all increased over time in emerging market countries, international reserves increased by much more.[7] The three reserves adequacy ratios increased markedly, especially since 1995 in Asia, and are now

[6] The rationale for this ratio is that broad money reflects a country's exposure to the withdrawal of assets (Calvo, 1996; De Beaufort Wijnholds and Kapteyn, 2001).

[7] Note, however, that the buildup in reserves is less striking if it is scaled by broad money. The ratio of reserves to short-term debt is much higher in Asia than in Latin America, but the two regions are close when their reserves are scaled by imports or by M2.

much higher than the levels prescribed by the conventional rules of thumb. In 2005 the level of reserves in emerging market countries was close to seven months of imports and five times the level of short-term debt. That the reserves deviate even more from the Greenspan-Guidotti rule than from the three-months of import rule is surprising since the latter was developed to better capture the risks stemming from the capital account after the crises of the 1990s.

[Insert Figure 3]

The reserves buildup is also difficult to explain using regression-based empirical models for precautionary reserves. There is a large empirical literature explaining the cross-country and time variation in the level of reserves by a few key variables: economic size, current and capital account vulnerability, and exchange rate flexibility (IMF, 2003; Lane and Burke, 2001; Lizondo and Mathieson, 1987; Aizenman and Marion, 2003). The studies by the IMF (2003) and Aizenman and Marion (2003) find that although such regressions do a good job of predicting reserve holdings over a long period, they significantly underpredict the reserves accumulation of emerging market countries after the Asian crisis, especially in Asia.[8]

It could be that such regressions fail to capture the impact that the "great" capital account crises of the 1990s had on the perception of the risks associated with their international financial integration. It has been argued that the Asian crisis marked a watershed, in that emerging market countries became painfully aware that even countries with apparently sound macroeconomic policies could be vulnerable to contagion and sharp reversals in capital flows. The buildup in reserves could be a rational adaptation to this new, more volatile world.

The concept that came to epitomize the capital account instability of the 1990s is that of "sudden stop" in capital inflows (Calvo, 1998). While sudden stops were not a total novelty for emerging market countries as a whole, it is true that they were a relatively new phenomenon in Asia. For the five Asian countries that were most affected by the 1997-98 crisis, furthermore, the size of the shock to the capital account and loss of reserves was unprecedented (Figure 4). It may not be a coincidence, from this point of view, that it is in Asia that most of the build-up in international reserves took place.

[Insert Figure 4]

In sum, the buildup in emerging market countries' international reserves cannot be explained by conventional adequacy ratios or by simple linear regressions. But it may be that neither

[8] Aizenman Lee and Rhee (2004) find evidence of a structural break in the patterns of hoarding and managing international reserves by the Korean central bank in 1997-8.

approach fully captures how the instability of the 1990s changed the perception of risks and the desire for insurance in the emerging market countries that were the most affected by the crises. As concluded by Bird and Rajan (2003), it may be time to "rethink the issue of reserve adequacy". For this, looking at the implications of a model that captures the recent evolutions in balance-of-payments risks might be more informative than regressions based on historical data—and this is the approach I will develop in this paper. Before the presentation of the model, I will now review the benefits and costs of international reserves for emerging market countries.

The benefits of international reserves

In line with the previous discussion, I now focus on how international reserves help countries deal with balance-of-payments crises.[9] I start with a simple accounting exercise that shows how international reserves can help a small open economy to smooth domestic absorption against balance-of-payments shocks, leading to a discussion of the benefits of reserves in terms of crisis mitigation (reducing the welfare cost of a crisis) and crisis prevention (reducing the probability of a crisis).

Crisis Accounting

In a small open economy domestic absorption can be written as the sum of domestic output, capital inflows, net income from abroad and reserves decumulation:[10]

$$A_t = Y_t + KA_t + IT_t - \Delta R_t. \qquad (1)$$

This decomposition is helpful in highlighting how balance-of-payment shocks can affect domestic absorption. Focusing on domestic absorption makes sense because it is the most proximate determinant of domestic welfare among the variables in equation (1).[11]

---

[9] My discussion will focus on crisis management and will not deal with some benefits that reserves may have in non-crisis times, such as limiting volatility in the exchange rate or providing liquidity to the foreign exchange market. A higher level of reserves has been found to reduce the portion of exchange rate volatility that is unrelated to macroeconomic fundamentals (Hviding and others, 2005). Reserves can also yield benefits if the government is able to invest them more wisely than the average citizen, or if they promote capital market integration and domestic financial development.

[10] This decomposition of domestic absorption results from two national accounting identities. First, domestic absorption (the sum of domestic private and public consumption and investment) is the difference between real output and the trade balance, $A_t = Y_t - TB_t$. Second, the balance-of-payments equation $CA_t + KA_t = \Delta R_t$, where $CA_t = TB_t + IT_t$ is the current account balance, can be used to substitute out the trade balance from the first identity.

[11] In an economy with a representative agent, domestic welfare is a function of the agent's consumption of private and public goods, which sum up to a large fraction of domestic absorption.

First, one could think of the balance-of-payments shock as a "sudden stop" in capital flows. A sudden stop is defined as a tightening of the external credit constraint which results in an abrupt fall in capital inflows, KA. This, other things equal, reduces domestic absorption. The impact of the sudden stop on domestic absorption could be amplified by a concomitant fall in domestic output, Y, or mitigated by a fall in reserves, ΔR. For example, reserves can be used to repay external lines of credit that are not rolled over in a sudden stop, alleviating the need to reduce domestic absorption.

Another way of defining the balance-of-payments shock is as a currency crisis. The empirical literature uses a number of definitions of currency crises that share in common that, by contrast with sudden stops, they all give a central role to the exchange rate. Some authors define a currency crisis simply as a large depreciation (Frankel and Rose, 1996), whereas others use an index of exchange rate pressure combining the exchange rate depreciation with the loss of reserves (Berg et al, 2005), and sometimes the increase in the interest rate. The main difference between the two approaches is that the pressure index counts as a crisis an unsuccessful speculative attack in which the authorities manage to defend the currency peg.

Although in theory a speculative attack on a fixed currency peg could occur without affecting any of the variables in equation (1),[12] real world currency crises are often associated with a capital flight as well as a fall in output and domestic absorption—more or less the same symptoms as sudden stops in capital flows. On can think of a number of mechanisms by which a sudden stop could lead to a currency crisis and conversely, a currency crisis could trigger a sudden stop. An abrupt tightening in a country's external credit constraint that drains the reserves and depresses domestic demand encourage speculation against the domestic currency. Conversely, if there are currency mismatches in domestic balance sheets an exchange rate depreciation could severely disrupt the financial and productive system and trigger a capital flight. Indeed, the many crisis dating exercises offered by the empirical literature tend to classify the famous balance-of-payments crises of the 1990s as both sudden stops and as currency crises.[13]

However, sudden stops and currency crises are not very closely correlated if one considers a larger sample of events (Hutchison and Noy, 2006; Eichengreen et al, 2006).[14] If I had to choose, the concept of sudden stop might seem more relevant to think about the optimal level

[12] This would be the case if the central bank ceded to speculation without resistance (i.e. , without spending any reserves in the defense of the currency). In the textbook model of Krugman-Flood-Garber, a speculative attack occurs without any real disturbance in the current account or domestic absorption—the capital outflow being perfectly offset by a fall in reserves of the same magnitude.

[13] For example, Frankel and Wei (2005) and Frankel and Cavallo (2004) find both a currency crisis and a sudden stop in Mexico, 1994; Indonesia, Korea, Thailand and the Philippines 1997.

[14] Eichengreen et al (2006) find that only about one-third of the sudden stops in their sample are associated with contemporaneous currency crises.

of reserves looking forward, given that the number of emerging market countries that defend formal fixed currency pegs has steadily gone down since the early 1990s. Having said this, I will consider both crisis definitions in what follows.

Another crisis concept that is often used in the literature is that of current account reversal (Edwards, 2004; Milesi-Ferretti and Razin, 2000). One problem with this measure is that it reflects both the balance-of-payments shock and the policy response to it. The reversal in the current account captures the part of the capital account shock that is not smoothed out by reserves. Thus, the current account reversal criterion leads to excludes the crises where the authorities have been able to effectively use their international reserves in order to avoid an abrupt and major reversal in the current account. Given that my focus is precisely on how reserves help to smooth the impact of capital account shocks, I will not use current account reversals to identify crises.

Crisis mitigation

There are two ways in which reserves can help to mitigate the impact of a balance-of-payments crisis on domestic welfare. First, the reserves can be used to mitigate the fall in domestic output. Second, the reserves can be used to buffer the impact of the balance-of-payments shock on domestic absorption. These two channels are conceptually distinct. In terms of equation (1), the first channel involves a fall in Y_t, whereas the second channel involves a fall in KA_t. To the extent that the capital that flows out of the country in a crisis comes back in tranquil times, the fall in KA_t disturbs the path of domestic absorption without changing its intertemporal value, whereas the fall in output decreases the intertemporal value of domestic absorption.

There are various ways in which the authorities can reduce the output cost of a crisis by using the international reserves. Reserves can mitigate the depreciation of the domestic currency, and thus the disruption induced by currency mismatches in balance sheets. They help the monetary authorities in providing liquidity to the domestic financial markets, the banking sector and even exporters, which is especially valuable if there is significant dollarization of bank deposits and other domestic liabilities (Jeanne and Wyplosz, 2003; Calvo, 2006).[15] Indeed, some authors have found a negative correlation between the pre-crisis level of reserves and the output cost of the crisis in emerging market countries (Rodrik and Velasco, 2000; De Gregorio and Lee, 2003).

[15] Both Jeanne and Wyplosz (2003) and Calvo (2006) emphasize that lending the reserves to domestic agents indebted in foreign currency is a more effective tool than blind foreign exchange interventions in preventing and mitigating crises. Calvo (2006) points to an interesting example of a non-standard way for disposing of international reserves: the operation carried out by Brazil in August 2002, when the central bank employed some of its international reserves to make loans to the export sector through commercial banks.

Reserves can also help in buffering domestic absorption against shocks to the balance of payments (the second channel). To illustrate, I now look how the components of equation (1) behave in observed sudden stop episodes. Sudden stops will be identified, in my sample of emerging market countries, as a year in which net capital inflows fall by more than 5 percent of GDP.[16]

Figure 5 shows the average behavior of domestic absorption and the contribution of the various components on the right-hand-side of equation (1) in a five-year event window centered around a sudden stop. Real output is normalized to 100 in the year prior to the sudden stop. The income and transfers from abroad are not shown because this term is small and does not vary much in a sudden stop. All the variables are converted from current US dollars into constant local currency units so as to track the changes in output and domestic absorption in volume.[17]

We observe a large fall in net capital inflows in the year of the sudden stop, amounting to almost 10 percent of the previous year's output. This is not surprising since a large fall in the financial account is the criterion that is used to identify sudden stops. More interestingly, we see that most of the negative impact of the financial account reversal on domestic absorption is offset by a fall in reserve accumulation. Thus, domestic absorption falls by only 3 percent of GDP on average in the year of the sudden stop—much less than the financial account. Figure 5 also shows that the contribution of output is relatively small: real growth merely falls to zero at the time of the sudden stop.

[Insert Figure 5]

This evidence is consistent with the view that emerging market countries accumulate reserves in good times so as to be able to decumulate them, thereby smoothing domestic absorption, in response to sudden stops. This smoothing effect is potentially large. To illustrate, if reserves accumulation were equal to zero in the year of the sudden stop, domestic absorption would fall by 9 percent of output on average instead of 3 percent, other things equal. This counterfactual experiment should be interpreted with caution because the magnitude of the capital flight could be in part endogenous to the fall in reserves.[18] It does suggest, however, that foreign exchange reserves may well provide a sizeable contribution to the smoothing of domestic absorption in response to sudden stops.

---

[16] I also exclude the sudden stops that occurred less than 2 years after the previous capital account event. The 5 percent threshold has been used to identify sudden stops by Rodrik and Velasco (2000), Guidotti et al (2004) and Jeanne and Rancière (2006). Calvo et al (2004) and Frankel and Wei (2005) use another identification criterion, which gives very similar results in the event study presented below.

[17] The dollar value of output and domestic absorption falls by a larger amount than indicated in Figure 5 because of the real depreciation of the domestic currency. The variables are converted from current US dollar to constant local currency units using the nominal exchange rate vis-à-vis the dollar and the local GDP deflator index. IMF loans are counted as reserves rather than capital inflows.

[18] This is the case in the speculative attacks a la Krugman-Flood-Garber, as mentioned above.

The case of Uruguay in 2002 provides a striking illustration of the role of reserves in a very severe sudden stop episode. Following the Argentine crisis, Uruguay experienced a capital account reversal amounting to 26 percentage points of GDP. The Uruguayan government used a large amount of foreign exchange reserves (a significant part of which was made available in the context of an IMF arrangement), largely in response to the withdrawal of dollar denominated deposits from the domestic banking system. As a result, the decline in domestic absorption, although quite substantial (14 percent of GDP), was much smaller than the shock to the capital account.

Crisis prevention

The international financial crises of the 1990s triggered a search for reserves adequacy ratios that would capture the vulnerability of emerging market countries' balance sheet and capital account in a world with highly mobile capital flows. One motivation was to develop leading indicators (or early warning signals) so as to help the domestic authorities and the official sector take early remedial action. Another objective was to develop new normative benchmarks of reserves adequacy that would capture the risks in the international financial environment of emerging market countries of the 1990s.

The staff of the International Monetary Fund presented its analysis of reserves adequacy in two documents: "Debt-and Reserve-Related Indicators of External Vulnerability" (IMF, 2000) and "Issues in Reserves Adequacy and Management" (IMF, 2001). It concluded that the ratio of reserves to short-term external debt was the "single most important indicator of reserves adequacy in countries with significant but uncertain access to capital markets", although this ratio should be taken only a "starting point" for an analysis that should also look at other reserves adequacy ratios in light of each country's specific conditions. [19]

This view was supported by a vast body of empirical research that showed that liability-based reserves adequacy ratios tended to be perform well as early indicators of currency crises.[20] By contrast, the (relatively smaller) empirical literature on *sudden stops* has been less conclusive, generally failing to detect a significant preventive role for reserves. Although Rodrik and Velasco (2000) found some evidence that applying the Greenspan-Guidotti rule

[19] One study that significantly contributed to crystallize the official sector's conventional wisdom about the importance of this ratio was Bussière and Mulder (1999).

[20] The literature on early warning signals and the empirical determinants of crisis in probit/logit regressions is too large to be reviewed here—the reader is referred to the reviews Kaminsky, Lizondo and Reinhart (1998), Berg et al (2005), and Frankel and Wei (2005). Another way in which reserves might stabilize the domestic economy is by lowering the interest rate on foreign debt (Levy-Yeyati, 2006). Evidence that larger reserves decrease the sovereign spread in Hauner (2005), Duffie et al (2003), and Eichengreen and Mody (2000) .

reduced the vulnerability of emerging market countries to sudden stops,[21] the probit regressions of Calvo et al (2004) and Frankel and Cavallo (2004) did not find that reserves had a statistically significant effect of reducing the probability of sudden stops.

In order to take a broad view of the preventive role of reserves with respect to both currency crises and sudden stops, I ran a number of univariate probit regressions using various crisis definitions and reserves adequacy ratios.[22] The regression results are based on four different definitions of currency crises (denoted by CC1 to CC4) and four different definitions of sudden stops (denoted by SS1 to SS4). For the currency crises I first use the Frankel and Rose (1996) criterion for a currency crash, i.e., a nominal depreciation of the currency of at least 25 percent relative to the previous year that is also at least a 10 percent increase in the rate of depreciation. The other three currency crisis definitions, taken from Frankel and Wei (2006), are based on a crisis pressure index adding the percentage nominal exchange rate depreciation to the percentage loss in foreign reserves (see the Data Appendix for details).

For sudden stops I first consider the simple criterion used by Rodrik and Velasco (2000), Guidotti et al (2004) and Jeanne and Rancière (2006) of a fall in net capital inflows amounting to more than 5 percent of GDP. This simple criterion has been criticized for various reasons, in particular because it captures some episodes in which capital net inflows slowed down but remained positive (such as Malaysia, 1994, following the imposition of controls on capital inflows). Thus, I also consider the three sudden stop measures of Frankel and Cavallo (2004), who apply the criteria of Calvo, Izquierdo and Mejia (2004) to a larger sample of countries and a longer time period.

Table 2 summarizes of the results of 128 univariate regressions using various reserves adequacy ratios, crisis definitions and probit specifications. For each crisis definition and reserves adequacy ratio I ran four probit regressions of the crisis dummy on the lagged reserves ratio and a constant: without fixed effects, with country fixed effects, with time fixed effects, and with both country and time fixed effects. Since currency crises and sudden stops each have four different definitions, each cell in the table is based on 16 probit regressions. The table reports the number of regressions in which the coefficient of reserves was both negative and significant at the 10 percent level.

[Insert Table 2]

[21] Another study that finds the level of international reserves to decrease the probability of sudden stop is Garcia and Soto (2004). However they identify sudden stops as current account reversals. As mentioned earlier, their result could reflect that countries with more reserves are more able to smooth the impact of the capital account shock on the current account (i.e., crisis mitigation rather than crisis prevention).

[22] I will present later in the paper the results of multivariate probit regressions that control for variables other than reserves—and broadly confirm the results of the univariate regressions.

Several facts stand out. First, the denominator of the reserves-adequacy ratio that "works" best to predict currency crisis is short-term debt.[23] This is consistent with the results obtained in the literature, such as Mulder (2000). The benefits of increasing reserves in terms of crisis prevention, furthermore, are economically significant. Based on the probit regressions for the first definition of currency crisis CC1 (without fixed effect) in Table 2, increasing the ratio of reserves to short-term debt from 1 to 2 decreases the probability of crisis by almost 4 percent. Because of the shape of the probit function there are diminishing returns to further increasing reserves: increasing the ratio of reserves to short-term debt from 5 to 6 decreases the probability of crisis by less than 1 percent.

Second, the reserve adequacy ratios do not perform as well when it comes to predict sudden stops instead of currency crises. The ratio that works best is based on M2, which seems to vindicate Calvo's (1996) analysis, but even this ratio is significant in only one fourth of the regressions. This result also seems consistent with the ambiguity of the empirical literature with regard to the benefits of reserves in terms of preventing sudden stops, rather than currency crises.

Overall, the evidence seems to support the idea that reserves help to prevent crises, but this conclusion should be accepted with some caveats. Most importantly, the existing empirical studies do not really distinguish whether high levels of reserves allow countries to *prevent* crises, or merely *postpone* them. This ambiguity is certainly present in the theoretical literature on crises and reserves. In some models, high reserves effectively reduce the probability of crisis by making the economy more resilient to bad shocks (Chang and Velasco, 2000; Aizenman and Lee, 2005) or to self-fulfilling changes in market sentiment (Morris and Shin, 1998). By contrast, in the Krugman-Flood-Garber model, a speculative attack made unavoidable by excessive money growth is merely delayed by a larger stock of reserves.[24] This problem is compounded by the fact that countries often shorten the maturity of their debt before a crisis, further reducing the Greenspan-Guidotti ratio from the denominator (Detragiache and Spilimbergo, 2001). Thus, the fact that the Greenspan-Guidotti ratio tends to fall before crises should not necessarily be interpreted as a causality from low reserves to high crisis risk.

This identification problem does not affect the rationale for using reserves as early warning indicators of crisis, but it may lead to an exaggeration of the benefits of reserves in terms of crisis prevention. In many cases, countries might have *hastened* the crisis, and not reduced its

[23] More precisely, the measure of short-term debt that works best is from the World Bank GDF database rather than the BIS data. This result is surprising because the BIS data should be a better measure of the denominator in the Greenspan-Guiddoti ratio than the World Bank data (the BIS reports the debt maturing in the following year whereas the World Bank data are based on maturity at issuance). However, the BIS debt measure might be less significant because it is available for a smaller number of countries in the regressions.

[24] In Flood and Jeanne (2005) the fiscal cost of carrying the reserves could actually hasten the attack.

probability, by trying to maintain a high level of reserves in the face of a loss of confidence in domestic policies.

The costs of international reserves

The cost of international reserves is usually defined as the opportunity cost of not consuming them, or not investing them in a more profitable way. In this section I provide some evidence on the costs of reserves in terms of foregone consumption and in terms of foregone investment.[25]

Foregone consumption

The reserves could be spent on the consumption of imported goods rather than accumulated in the central bank. The first cost of reserves accumulation is thus the welfare cost of postponing the consumption of tradable goods. This cost can be proxied by the difference between the interest rate at which the domestic consumers would be ready to borrow in order to increase their consumption of tradables and the rate of return on reserves. In a model with an infinitely-lived representative consumer the shadow interest rate on consumer loans, r_T, satisfies the Euler equation,

$$u'(C_{Tt}) = \frac{1+r_{Tt}}{1+r} u'(C_{Tt+1})$$

where $u(C_{Tt})$ is the utility that the representative consumer derives from consuming a quantity C_{Tt} of tradable goods in year t, and r is the rate at which the consumer discounts future consumption. The interest rate r_T is the shadow interest rate at which the central bank could lend the reserves to the domestic consumers in a frictionless consumer loan market.

One can estimate the shadow interest rate by making some assumptions on the form of the consumer's utility function. Let us assume, for example, that the consumer has a constant relative risk aversion σ. Then the shadow interest rate is given by,

$$1+r_{Tt} = (1+r)\left(\frac{C_{Tt+1}}{C_{Tt}}\right)^{\sigma} \simeq 1+r+\sigma g_t$$

[25] My discussion focuses on the opportunity cost of carrying the reserves, and does not deal with the challenges to monetary and financial stability posed by large-scale sterilization (see Mohanty and Turner, 2006, or ECB, 2006 for a discussion of those costs). Other costs that I will not discuss include the false sense of confidence instilled in foreign investors by reserves and allowing the domestic authorities to postpone necessary adjustments. Finally, large-scale reserves purchase and sales could induce exchange rate changes that cause valuation losses on the reserves.

where g_t is the growth rate in the consumption of tradables. If one further assumes that the return on reserves is close to the consumer's discount rate, the opportunity cost of reserves is measured by the differential $r_{Tt} - r \simeq \sigma g_t$.

The volume of imports (which can be taken as a proxy for the consumption of tradable goods) has grown by 4.1 percent per year on average in emerging market countries over the period 1980-2000. Thus the opportunity cost of reserves would exceed 8 percent if the risk aversion parameter σ were equal to 2. The results are obviously very sensitive to the consumer's level of risk aversion. If σ is equal to 8, as assumed by Caballero and Panageas (2005) in their model of optimal reserves, the marginal opportunity cost of reserves reaches a staggering level of 33 percent per year.

Foregone investment

This is the type of cost that is quantified most often in the literature on international reserves. The cost of holding reserves is usually measured as the difference between the return on the reserves and the return on more profitable alternative investment opportunities. One term of the comparison, the return on the reserves, is generally proxied as the return on short-term foreign currency assets. The appropriate definition of alternative investment opportunities, on the other hand, raises several thorny questions.

One approach that has been proposed very early in the literature is to consider higher-yielding investment opportunities in the domestic business sector or public infrastructure (Heller, 1966). The marginal product of capital is difficult to measure in a way that is comparable across a large number of countries, but Hauner (2005) suggested that one could use estimates from the development accounting literature. Caselli and Feyrer's (2007) recent estimates imply an average real return to capital of 7.9 percent in fifteen emerging market countries in my sample, which together with an estimate of 2 percent for the short-term real interest rate,[26] would lead to an opportunity cost of around 6 percent per year.

Given the difficulties involved in measuring the returns to physical investment, most measures in the literature assume that the alternative to holding international reserves is to invest in other financial assets or to repay financial liabilities. One approach defines the opportunity cost of reserves as the quasi-fiscal cost of sterilization by the central bank, i.e., the difference between the return on the central bank's domestic currency assets and the return on international reserves (Frenkel and Jovanovic, 1981; Flood and Marion, 2002). This differential is generally positive, but in countries where domestic interest rates are very

[26] This is close the average US real short-term interest rate over the period 1980-2005.

low—such as China recently—this approach leads to a negative opportunity cost of reserves (Mohanty and Turner, 2006).

There are two serious issues with measuring the opportunity cost of reserves in this way (Jeanne, 2007). First, it is not adjusted for the expected appreciation or depreciation of the domestic currency. For example, the fiscal cost of reserves could be found to be negative because the domestic currency is expected to appreciate relatively to the dollar—and interest rate parity applies—but this measure fails to take into account the expected valuation loss on the reserves. Second, the central bank's profit is not a measure of domestic welfare. Selling high-yielding domestic bonds for reserves may reduce the central bank's flow of profit but increases the income of the domestic investors who purchase the bonds. The opportunity cost of reserves should be measured by looking at the budget of the country as a whole rather than that of one part of the public sector. This might be a reason to measure the opportunity cost of reserves by reference to *external*—rather than domestic—assets and liabilities.

On the asset side, emerging market countries could also invest the reserves in a more fully diversified global portfolio with assets of longer maturity and higher yield (Summers, 2006). In fact there has been an increasing tendency for central banks to diversify their reserves (Knight, 2006; Wooldridge, 2006). As shown in Jeanne (2007) the optimal asset allocation of reserves can be viewed as a standard portfolio problem that is augmented to take into account the risk of a crisis. The optimal liquidity of the reserves is increasing with the probability that they will have to be used soon in a crisis. If the portfolio allocation is optimal, furthermore, the opportunity cost of reserves can be determined by reference to any margin of substitution between assets and liabilities—and there is a case for considering those margins of substitution that are the easiest to measure.

One margin of substitution that is relatively easy to measure is between foreign reserves and external debt. Reserves can be accumulated by issuing—or can be used to repay—external debt. This observation led Edwards (1985) to argue that the relevant opportunity cost should be measured by the spread between the interest rate on external debt and the return on reserves. Figure 6 shows a measure of this cost, for emerging markets as a whole as well as Asia and Latin America.[27] According to this measure, the opportunity cost of reserves was 7.4 percent in emerging market countries on average in 2000-05, but this figure masks important disparities between Asia (4 percent) and Latin America (11.4 percent).

[Insert Figure 6]

[27] The measure is constructed as the US term premium (the difference between the US long-term interest rate and the US short-term interest rate) plus the spread on emerging market countries' debt (the difference between the interest rate on those countries' long-term debt and the US long-term interest rate).

In Jeanne (2007), I argue that Edwards' (1985) measure might overstate the true opportunity cost of holding reserves because it includes the default risk premium on foreign debt. A welfare-based approach suggests that the default risk premium should not be included, because it is, on average, a fair reflection of the probability of non-full-repayment.[28] Pushed to its logical extreme, this approach suggests that the true opportunity cost of reserves is the US term premium, i.e., the opportunity cost of financing a stock of liquid dollar assets with default-free long-term dollar debt. This leads to a much lower measure of the opportunity cost of reserves. The differential between 10-year US Treasury bonds and 3-months US Treasury bills was 2 percent on average over 2000-05. Expectation-adjusted measures lead to even lower estimates of less than 1 percent (Rudebusch, Sack and Swanson, 2007).

Table 3 presents some measures of the average opportunity cost of reserves in terms of domestic GDP in our sample of emerging market countries over the period 2000-05. The measures are based on a uniform opportunity cost of 6 percent as well as the term premium, with and without spread. With an opportunity cost of 6 percent per year the average cost of reserves amounts to 1 percent of GDP, which is consistent with the estimates obtained by Rodrik (2006). The estimated cost of reserves is significantly lower if one considers the term premium, but larger if one includes the emerging markets spread. On average, the total cost of holding reserves was substantially lower in Latin America than in Asia if one uses the same opportunity cost per unit of reserves for both regions, but it was relatively similar in the two regions using the term premium plus the spread. This is explained by the fact that, while on average the reserves/GDP ratio is twice as high for Asian countries as for Latin American countries, the sovereign spread is substantially higher in Latin America than in Asia.

[Insert Table 3]

Summary

The different approaches to measuring the opportunity cost of reserves yield a large range of estimates, going from 1 percent per year (if it is based on the risk-free term premium) to more than 30 percent per year (if it is based on the opportunity cost of consumption assuming a risk aversion of 8). I would put more weight on the measures based on observable market interest rates than on estimates relying on assumptions about the intertemporal preferences of the domestic consumers. One to six percent per year seems a reasonable range of values for the real opportunity cost of reserves.

A Simple Theoretical Framework

There are diverging views on how the benefits and cost of holding reserves should be weighed against each other. Rodrik (2006) finds that his estimate of 1 percent of GDP for the opportunity cost of holding reserves is "a large number by any standard. It is a multiple of the budgetary cost of even the most aggressive anti-poverty programs implemented in

[28] However the default risk might be a determinant of the optimal level of reserves if defaulting is costly for the debtor country.

developing countries." By contrast, the supporters of large reserves holdings believe that "the costs linked to overcoming a currency crisis are astronomical while the gains to be made from the productive investment of the reserves will be quite small (Korea Times, January 17 2002, cited in Aizenman and Marion 2004).

Ideally, one would like to be able to compare the benefits and costs of reserves using the same welfare metric. There is unfortunately no well-established welfare-based model of the optimal level of reserves. I will thus present my own framework, after a brief review of the literature on cost-benefit analyses of international reserves.

Cost-benefit analyses of the optimal level of reserves

The idea of a cost-benefit approach to the optimal level of reserves has inspired a long line of literature that goes back at least to Heller (1966). In Heller's analysis the optimal of reserves was determined in the context of a trade-off between their opportunity cost and the risk of an external disequilibrium leading to a costly contraction in domestic absorption. Heller simply posited that the optimal level of reserves should minimize the sum of the expected cost of an external disequilibrium in terms of domestic absorption plus the opportunity cost of reserves.[29] The dynamic aspect of the authorities' optimization problem was treated more rigorously in the buffer stock models of international reserves of Hamada and Ueda (1977) and Frenkel and Jovanovic (1981).[30]

One problem with those models is that the objective function maximized by the optimal level of reserves is only loosely related to the welfare of the population of the country that is accumulating reserves. This is a source of confusion in several ways. For example, it is not clear whether cost of an external disequilibrium should be interpreted as a fall in domestic output (as in Ben Bassat and Gottlieb, 1992, or Garcia and Soto, 2004) or as a transitory fall in domestic absorption (as in Heller, 1966). The two are not equivalent for domestic welfare, as suggested by our discussion of crisis accounting. The lack of a rigorous welfare criterion also leads to ambiguity in the appropriate definition of the opportunity cost of reserves.

The theoretical literature on reserves adequacy has not fully incorporated the dynamic general equilibrium methodology used in modern macroeconomics. Stated in terms of modern macroeconomic theory, the problem is to determine the optimal level of precautionary savings in terms of tradable goods in a small open economy with limited and uncertain access to international financial markets. This class of problems does not have simple closed-form solutions, but can certainly be solved numerically using the techniques

[29] A similar loss function is used by Ben-Bassat and Gottlieb (1992) and Garcia and Soto (2004).

[30] The buffer stock approach is used by Flood and Marion (2002)

that have become standard in the closed-economy literature on precautionary savings. Although some recent papers have made steps in that direction,[31] as of today there is no off-the-shelf framework incorporating all the elements listed above that I could use to calibrate the optimal level of reserves.

I will thus rely instead on a model that makes a step in the right direction—in the sense that the optimal level of reserves will maximize the welfare of the representative consumer—but retains, in reduced form, the simplicity of the earlier models of Heller (1966) and Ben-Bassat and Gottlieb (1992). This section concludes with a brief summary of the main features and mechanisms in my analytical framework. After reading this summary, readers who are primarily interested in my predictions on the optimal level of reserves can skip the remainder of this section, which presents the model in more details, and proceed directly to the discussion of the numerical findings.

I will consider a small open economy populated by a representative consumer that can be hit by crises, defined as a loss of access to external credit associated with a fall in output.[32] The consumer benefits from accumulating reserves in two ways: a lower probability of a crisis (prevention), and a lower welfare cost of a crisis (mitigation). The optimal level of reserves will depend on the following parameters of the model:

- L and ΔY: the sizes of the capital flight and of output loss in a crisis, expressed in terms of potential output;
- δ: the opportunity cost of accumulating reserves through the financial account;
- σ: the relative risk aversion of the domestic consumer;
- π: the probability of a crisis (which is endogenous to the level of reserves if there is crisis prevention).

[31] Aizenman and Marion (2003) and Miller and Zhang (2007) present two-period precautionary savings models of reserves. Caballero and Panageas (2005) and Jeanne and Rancière (2006) present infinite-time optimizing models of reserves and sudden stops. In Caballero and Panageas (2005), the reserves are accumulated exclusively through the current account and do not reduce the probability of crisis, whereas in Jeanne and Rancière (2006) the reserves are accumulated exclusively through the financial account. Durdu, Mendoza and Terrones (2007) are developing an intertemporal optimizing framework in which reserves have benefits in terms of crisis prevention.

[32] The representative consumer assumption implies that we look at the optimal level of reserves from the point of view of the country as a whole, and do not distinguish between the private sector and the public sector. Models in which the public sector has a special role include Caballero and Krishnamurthy (2004)

Assumptions

I consider a small open economy in a world with one single homogeneous good.[33] The model has three periods $t = 0,1,2$. Period 2 represents the long term. Period 1 is the period in which a crisis could occur. The question is how the country optimally adjusts its reserves in period 0 to the risk of a crisis in period 1.

The economy is populated by a representative consumer. The consumer's welfare in period 0 is given by

$$U_0 = u(C_0) + \frac{1}{1+r}u(C_1) + \frac{W_2}{(1+r)^2}$$

where $u(\cdot)$ is an increasing and concave function of consumption, and W_2 is the consumer's net foreign wealth at the beginning of period 2. The term in W_2 is meant to represent the consumer's intertemporal welfare in period 2. In a full-fledged dynamic model (with an infinite number of periods after period 2) welfare would be a concave function of W_2. The linear approximation in (1) can be justified by the fact that welfare is a much less concave function of wealth than utility of consumption, as shown in the Appendix.

The linearity of the objective function (1) in final net wealth simplifies the consumption-saving problem a lot, since it implies that the consumer desire a level of consumption in periods 0 and 1 that does not depend on his intertemporal wealth. Assuming that foreign wealth can be traded intertemporally at rate r, the desired level of consumption C^* satisfies the first-order condition,

$$u'(C^*) = 1$$

In the absence of international financial friction, thus, domestic consumption is equal to C^* in period 0 and in period 1.

The consumer has access to the following menu of external assets and liabilities.[34] The consumer can hold one type of assets, short-term (one-period) bonds, and bears two types of liabilities, short-term debt and a long-term liability. The return on short-term bonds, denoted by r, is the same as the interest rate on short-term debt. The return on the long-term liability is higher than r, and the differential between the two will determine the cost of accumulating reserves through the capital account. The short-term bonds held by the consumer are interpreted as international reserves. The long-term external liability can be interpreted as long-term debt, equity or FDI.

---

[33] The model can be extended to include two goods and a real exchange rate (see the Appendix).

[34] See Jeanne (2007) for a model that incorporates a richer array of external assets and liabilities.

The sequence of events and actions is as follows.

- Period 0. The consumer inherits some net reserves $B_0 - L_0$ from the past. It receives the output Y_0 and issues some long-term debt D. The consumer chooses his consumption C_0 and the net reserves for the next period $B_1 - L_1$ subject to the budget constraint

$$B_0 - L_0 + D + Y_0 = C_0 + \frac{B_1 - L_1}{1+r}.$$

- Period 1. The consumer receives output Y_1 and there is no payment on long-term debt. He chooses again his consumption C_1 and net reserves $B_2 - L_2$ under the budget constraint,

$$B_1 - L_1 + Y_1 = C_1 + \frac{B_2 - L_2}{1+r}.$$

In period 1 the economy can be in two states that differ by the level of output and the access to external credit:

-the no-crisis state: output is at its potential level, $Y_1 = \overline{Y_1}$, and the representative consumer has complete access to external credit (i.e., there is no restriction on the sign of $B_2 - L_2$);

-the crisis state: output is below potential, $Y_1 = \overline{Y_1} - \Delta Y$, and the representative consumer has no access to external credit in period 1 (i.e., $B_2 - L_2$ must be positive).

- Period 2. The consumer's net foreign wealth is equal to the net reserves minus the repayment of long-term debt,

$$W_2 = B_2 - L_2 - (1+\rho)D.$$

In line with the evidence on sudden stops reviewed earlier, the crisis state thus consists in both an output drop and a fall in capital inflows (or capital flight). The period 1 budget constraint can be written in the same terms as the national accounting identity that we have used to study the impact of sudden stops on domestic absorption— equation (1). Here, domestic absorption is equal to consumption and is given by,

$$C_1 = Y_1 + \underbrace{\frac{L_2 - L_1}{1+r}}_{\text{capital inflows}} + \underbrace{r\frac{B_1 - L_1}{1+r}}_{\text{net income from abroad}} - \underbrace{\frac{B_2 - B_1}{1+r}}_{\text{change in reserves}}$$

There is a sudden stop if the representative consumer cannot roll over his short-term external debt ($L_2 = 0$). The negative impact on domestic consumption can then be mitigated by running down the reserves ($B_2 = 0$). Note that the consumer always repays the short-term

debt that is not rolled over, i.e., default is ruled out by assumption as a way of smoothing domestic consumption. I shall assume, as a matter of normalization, that $\overline{Y_1} = \overline{Y_2} = C^* = 1$, so that the output cost of a crisis ΔY and the size of the sudden stop L are expressed as shares of potential output.

What the model endogenizes is the level of net *usable* reserves, $B_1 - L_1$, not the levels of B_1 or L_1. Since I am interested in finding the optimal level of reserves given the level of short-term debt, I assume that $L_1 = L_0 = L$ and focus on the determinants of B_1. For convenience, the level of reserves at the beginning of period 1 (the main variable of interest) will be denoted by B, without time subscript.

Accumulating reserves through the financial account means increasing B by issuing the long-term liability D. I assume that this is costly because the return on this liability, ρ, is larger than the compounded short-term interest rate,

$$\frac{1+\rho}{(1+r)^2} = 1+\delta > 1$$

The premium δ can be interpreted as a term premium, or any transaction cost or illiquidity premium associated with the sale of long-term domestic liability to foreign investors. For example, if the long-term liability is FDI δ could be interpreted as the foreign investors' management cost in terms of monitoring.

The ex ante probability of a crisis is denoted by π. To capture the idea that reserves might have a benefit in terms of prevention I assume that the probability of crisis is a decreasing function of the ratio of reserves to short-term debt,

$$\pi = F\left(v - a\frac{B}{L}\right)$$

where v is a measure of the vulnerability to a crisis summarizing the fundamentals other than reserves, and function $F(\cdot)$ is increasing. The level of reserves could be scaled by short-term external debt or another liability measure. In the calibration of the model I will use a probit specification, implying that $F(\cdot)$ is the cumulative distribution of a normal function.

The interesting question is how the optimal level of reserves B depends on the relevant determinants: the country's vulnerability to a crisis, measured by *v*; the magnitude of the crisis, measured by the size of the shock to the capital account L and of the output loss ΔY, and the cost of financing the reserves through the capital account, δ.

The optimal level of reserves

As shown in the appendix, one can define the "full insurance" level of reserves as the sum of the capital flight and the output loss,

$$\overline{B} = L + \Delta Y .$$

This is the level of reserves that allows the consumer to maintain his consumption at the desired level in a crisis (i.e., the level that he would enjoy if there were no crisis). It is also the maximum amount of reserves that the consumer is ready to spend in a crisis. The consumer spends all the reserves in a crisis if he has less than the full insurance level. If the consumer has more reserves than the full insurance level, the surplus $B - \overline{B}$ is saved for future consumption.

One can also show that if $B \leq \overline{B}$ a crisis reduces domestic welfare by

$$f(B) = \underbrace{\Delta Y}_{\text{output cost}} + \underbrace{u(C^*) - u(C^* - (\overline{B} - B)) - (\overline{B} - B)}_{\text{consumption smoothing cost}}$$

The welfare cost of a crisis is the sum of two components: the output cost of the crisis, and the cost of distorting the path of domestic consumption away from the unconstrained equilibrium. The second component, which is decreasing with *B*, captures, the benefit of reserves in terms of crisis mitigation in my model.[35]

If the country finances a part of the reserves through the financial account ($D > 0$) then the opportunity cost of reserves is determined at the margin by the discount on domestic long-term liabilities. One can then show that the optimal level of reserves minimizes a loss function that is equal to the opportunity cost of reserves plus the expected welfare cost of a crisis

$$\text{Loss} = \delta B + \pi(B) f(B) \qquad (2)$$

This loss function is reminiscent of the one postulated by Heller (1966), Ben Bassat and Gottlieb (1992) or Garcia and Soto (2004). It captures in a simple way the trade-off between the opportunity cost of reserves (δB) and their benefits in terms of crisis prevention ($\pi(B)$) and mitigation ($f(B)$).

First, let us assume reserves have no benefits in terms of prevention, that is π is exogenous. For example, if the consumer has a constant relative risk aversion σ, then the optimal level of reserves is given by the formula:

$$B = \underbrace{L + \Delta Y}_{\text{full insurance}} - \underbrace{\left(1 - \left(1 + \frac{\delta}{\pi}\right)^{-1/\sigma}\right)}_{\text{opportunity cost}} \qquad (3)$$

The optimal level of reserves is equal to the full insurance level minus a term reflecting the opportunity cost of holding reserves. It is increasing with the probability of a crisis and the

[35] One could capture the idea that reserves help the country to reduce the output cost of a crisis by assuming that ΔY is a decreasing function of B.

consumer's risk aversion, and decreasing with the opportunity cost of holding reserves—as one would expect.[36]

Note that the optimal level of reserves could be higher than the Greenspan-Guidotti rule ($B = L$) because—in my model—reserves smooth the impact on consumption of the fall in output and not only that of the debt rollover crisis. The optimal level of reserves could also be lower than short-term debt because of the opportunity cost of holding reserves, which the Greenspan-Guidotti rule ignores.

Let us conclude this section with the general case where the probability of crisis is endogenous to the level of reserves. Then the optimal level of reserves minimizes,

$$\text{Loss}=F\left(v-a\frac{B}{L}\right)f(B)+\delta B. \quad (4)$$

Taking into account the benefits of crisis prevention leads to an increase in the optimal level of reserves, other things equal. In fact—and this is an important difference with the case where the probability of crisis was exogenous—the optimal level of reserves could now be larger than the full insurance level $\overline{B}$. In other terms, crisis prevention could make it optimal for a country to hold more reserves than it is willing to spend in a crisis. In the limit case where the opportunity cost of reserves is zero, the optimal level of reserves sets the probability of crisis to zero—"full insurance" in terms of crisis prevention.

Model Predictions

The model will be used to predict the optimal level of reserves in emerging market countries in two steps. First, I calibrate the model by reference to an average emerging market country, as a way of getting a broad sense of the quantitative implications of the model and their sensitivity on the parameters. Second, the model is calibrated by reference to country-specific data in 2000 to study how far the model can go in explaining the reserves buildup in emerging market countries.

Benchmark calibration and sensitivity analysis

The benchmark calibration is based on the parameter values given in Table 4. The size of the capital flight and of the output loss are both set to 10 percent of GDP, in line with the average behavior of the financial account and output in sudden stops. I assume that reserves have no benefits in terms of prevention, so that formula (3) applies. The probability of crisis was set to the unconditional frequency of sudden stops in my sample of emerging market countries,

---

[36] If $\delta = 0$ the optimal level of reserves is indeterminate and could take any value above $\overline{B}$. The nature of the indeterminacy is the same as for money demand in a liquidity trap.

which is close to 10 percent per year. The value for the opportunity cost of reserves, $\delta = 3$ percent, is at the low end of the range of estimates discussed earlier, but I will consider larger values in the sensitivity analysis. The benchmark risk-aversion and its range of variation are standard in the growth and real business cycle literature. The reader will find more detailed explanations for the benchmark calibration in the Appendix.

The benchmark calibration implies an optimal level of reserves of 7.7 percent of GDP, or 77 percent of the short-term external debt. This is slightly below the ratio of reserves to GDP observed in the data on average over 1980-2000, but significantly lower than the level observed in the most recent period, especially in Asia. It would be interesting to know what changes in the parameters are required to increase the optimal level of reserves toward the recently observed level.

Figure 7 shows how the optimal level of reserves depends on the size of the capital flight, the probability of crisis, the opportunity cost of reserves, the degree of risk-aversion, and the elasticity of the crisis probability to the level of reserves. In each case, the level of reserves computed using the sudden stop model is contrasted with the one implied by the Greenspan-Guidotti rule. Several interesting results emerge.

The optimal level of reserves is quite sensitive to the probability of crisis, the opportunity cost of reserves and the risk aversion parameter. This offers an interesting contrast with the Greenspan-Guidotti rule, which does not depend at all on these parameters. The optimal level of reserves is zero if the probability of crisis falls below 5 percent,[37] but almost doubles, from 7.7 percent to 13.3 percent of GDP, if the probability of crisis increases from 10 percent to 20 percent. Risk-aversion also has a first order impact on the optimal level of reserves. A shift in risk-aversion from 2 to 8 increases the optimal level of reserves from 7.7 percent to 16.8 percent of GDP. Note however that increasing risk aversion or decreasing the opportunity cost of reserves cannot put the optimal level of reserves above the full insurance level, equal to 20 percent of GDP under the benchmark calibration.

Figure 7 also shows how the optimal level of reserves varies with their benefits in terms of crisis prevention (parameter *a*).[38] The optimal level of reserves is quite sensitive to the benefits in terms of crisis prevention. If, in line with my univariate probit results for currency crises, parameter *a* is between 0.2 and 0.3, then the optimal level of reserves can reach 22.7 percent of GDP, about three times the optimal level in the absence of crisis prevention.

[Insert Figure 7]

[37] The optimal level of reserves is zero if the marginal cost of accumulating one dollar of reserves is larger than the marginal gain in terms of crisis mitigation.

[38] The probability of crisis is set at 10 percent conditional on a Greenspan-Guidotti ratio of 1.

To summarize, there are two ways that the model can potentially explain a level of reserves of the order of magnitude that we observe in Asia. The first one is to assume very large numbers for the probability of a crisis, the size of the capital flight or the output cost of a crisis. To illustrate, if the size of the sudden stop or of the output cost amounted to 40 percent of GDP—instead of 10 percent in the benchmark calibration—then the model would predict an optimal of reserves slightly in excess of 30 percent of GDP. Such an assumption, however, seems out of line with the historical record on currency crises and sudden stops. Second, and perhaps more plausibly, the model can predict a higher level of reserves if reserves have substantial benefits in terms of crisis prevention.

Can the model explain the buildup in emerging market reserves?

I now bring the model closer to the data by estimating the optimal level of reserves for each emerging market country in my sample. For each country *j* and year *t* I can estimate the level of reserves B_{jt}^{*} that minimizes (4), i.e., the sum of the opportunity cost of reserves and of the expected welfare cost of a crisis,

$$\text{Loss}_{\text{jt}} = \delta B_j + F\left(v_{jt} - a\frac{B_j}{L_{jt}}\right) f(B_{jt})$$

This loss function will be calibrated by reference to a probit estimation of the crisis probability for each country. The model indicates excess or insufficient reserves in year *t* depending on how the optimal level of reserves, B_{jt}^{*}, compares with the observed level, B_{jt}. Based on this information, one can also try to explain the subsequent change in reserves after year *t* as a catch-up toward the optimal level. I will run this numerical simulation for the emerging market countries in my sample for year *t*=2000.

The first step is to estimate an equation for the probability of a crisis. This is done by running a probit regression of the probability of crisis on the countries' economic fundamentals in my sample of emerging market countries over 1980-2000. The preferred specifications are reported in Table 5 for sudden stops, and in Table 6 for currency crises. The explanatory variables have been selected using a general-to-specific approach, starting from a set of 18 potential regressors.[39] All explanatory variables are lagged by at least one year, and are thus predetermined with respect to the crisis. The results are robust to the inclusion of time effects and fixed effects.

[Insert Tables 5 and 6]

I find that the main explanatory variables are the real exchange (more precisely, its deviation from a HP trend) and the ratio of the current account balance to GDP, which both appear

[39] The regressors are listed in the Appendix.

with the expected sign in three out of the four probit regressions. Consistently with the univariate evidence presented earlier, the ratio of reserves to short-term debt is significant for currency crises but not sudden stops. The GDP growth rate, the ratio of foreign liabilities to money (a measure of dollarization in the banking sector) and the level of total public debt are also significant for one definition of sudden stops. Finally, the probit estimations for currency crises find a role for inflation and trade openness.

Figure 8 shows the evolution of the estimated probability of crisis in my sample of emerging market countries.[40] The probability of crisis is significantly lower in Asia than in the other emerging market countries, especially at the end of the 1990s because of the real exchange rate levels, current account surplus and high growth that prevailed in that region. To illustrate, the probability of a currency crisis in China is estimated at less than 0.1 percent in 2000.

[Insert Figure 8]

In the second step, I compute the optimal level of reserves B^*_{j2000} for each country in 2000. The size the capital flight, of the output cost of the crisis, the opportunity cost of reserves and the risk aversion parameter remain the same as in the benchmark calibration given in Table 4. Finally, I also look at the extent to which the change in reserves between 2000 and 2005 can be explained as a catch-up toward the optimal level. For this, I compute the change in reserves that is required to achieve in 2005 the reserves-to-GDP ratio that was optimal in 2000.

The results of this exercise are reported in Table 7 for different parameter values. One important source of variation is whether reserves are assumed to have benefits in terms of crisis prevention or not. The case with prevention is obtained by using the currency crisis probit estimations given in Table 6. The case without prevention is obtained by using the sudden stop probit estimations given in Table 5. The table provides sum of the predicted levels of reserves for all emerging market countries, with a breakdown for Asia and Latin America.

[Insert Table 7]

Several facts stand out. First, the table shows that the model predictions are closer to the data when reserves are assumed to have benefits in terms of prevention. For example, the benchmark calibration explains close to three fourths of the reserves observed in 2000 ($479

[40] The figure shows the cross-country average of the estimated probability of crisis based on the probit regressions without fixed effects. The probability is averaged between the two crisis definitions (SS1 and SS2 for sudden stops; CC1 and CC2 for currency crises).

billion out of $651 billion) assuming prevention, against less than 7 percent of the observed level without prevention benefits ($144 billion out of $651 billion).

Second, it does not seem too difficult for the model to explain the aggregate level of reserves observed in 2000. If reserves have prevention benefits, this can be achieved, for example, by increasing the risk aversion parameter from 2 to 4, or the size of the sudden stop from 10 percent to 15 percent of GDP. It is more difficult for the model, however, to explain why Asia had almost three time more reserves than Latin America in 2000—the model tends to predict that the two regions have about the same level of reserves. To explain the difference between the two regions one would need to assume that Asia expected a bigger crisis, or was more risk-averse than Latin America.

Third, it is quite difficult for the model to explain why emerging market countries multiplied their reserves by two between 2000 and 2005. The benchmark calibration of the model predicts that reserves should have increased by 10 percent (with prevention benefits) or decreased by 40 percent (without prevention benefits). The only case that comes close to explaining the observed increase in reserves is when reserves have prevention benefits and the size of the sudden stop is set to 30 percent of GDP. In view of the historical record a sudden stop of 30 percent of GDP seems implausibly large—especially for a large country like China, which accounts for most of the reserves buildup in Asia. Even under those extreme assumptions the model explain only two thirds of the reserves buildup in Asia ($ 615 billions out of $ 937 billions).

To summarize, it seems impossible to explain the post-2000 reserves buildup in Asian emerging market countries as precautionary savings against the risk of a capital account crisis. Even if one assumes that reserves have susbtantial benefits in terms of crisis prevention and that future crises would be much more costly than in the past, the model fails to account for a resereves increase of the magnitude observed in Asia. This raise the question of the reasons that reserves have increased so much, which I take up in the following section.

Alternative explanations

Two main alternative explanations have been put forward for the reserves buildup in Asian emerging market countries. One (the mercantilist view) is that those countries have accumulated reserves to resist the appreciation of their currency. The other explanation relies on the lack of development of those countries' financial intermediation system, leading to capital outflows in the form of reserve accumulation. This section will make some points that may be useful in organizing one's thoughts on these two views—a rigorous testing of these views goes beyond the scope of this paper and is left for further research. The evidence presented in this section is suggestive at best, and is not meant as a test of one hypothesis or

the other. However, it does point to stylized facts that seem more difficult to explain with the precautionary view than with the alternatives.

Mercantilism

The main competitor of the precautionary view is the mercantilist view, which holds that reserves accumulation is the byproduct of exchange rates that are maintained competitive by authorities to expand employment in the export sector (Dooley et al, 2004). Although many commentators find this view very plausible, it is not obvious to nail down empirically. One approach is to look whether the countries that seem to follow mercantilist policies are also those that accumulate the most reserves. For example, Aizenman and Lee (2005) find that variables associated with the mercantilist motive (lagged export growth and deviations from predicted Purchasing Power Parity) explain very little of the cross-country difference in reserve accumulation, which leads them to conclude—by default—in favor of the precautionary view.

Identifying a mercantilist policy is not obvious, however. A competitive exchange rate and a trade surplus, per se, do not amount to mercantilism. Mercantilism supposes that the authorities implement *distortionary* policies to achieve those objectives. For example, the fact that in China wages are maintained low in the export sector by a reserve army of labor migrating from the traditional sector—as the advocates of the mercantilist view often point out— is not, per se, an indication of mercantilism. As long as the domestic authorities do not subsidize it, the migration of labor influences the real exchange rate but does not distort it away from its equilibrium level. The competitiveness of the real exchange rate, in this case, is a reflection of the equilibrium of the domestic labor market.

What are the policy distortions that underlie the mercantilist view, then? Most plausibly these distortions involve the capital account. Restrictions to the capital account are the most direct way that the authorities can distort the real exchange rate away from the equilibrium level for a long period of time.[41] To take an extreme but simple example, if the government has a monopoly over the management of foreign assets and liabilities and can set the stock of net foreign assets to an arbitrary level, it controls the current account (which is the change in net foreign assets) and so indirectly the real exchange rate.

If capital account restrictions are the policy tool of mercantilism, we should observe that the countries with the highest degree of capital account restrictions are also those that accumulate the most reserves, and that they do so mainly through current account surpluses. The first panel of Figure 9 shows the correlation between Edwards' (2001) measure of capital

[41] Nominal stickiness alone cannot explain very persistent deviations of the real exchange rate from its equilibrium value.

account openness and the accumulation of reserves between 2000 and 2005 in my sample of emerging market countries.[42] The relationship is negative and statistically significant at the 5 percent level, suggesting that indeed, the countries with a more restricted capital account do accumulate more reserves. The second panel of Figure 9 shows a negative correlation between capital account openness and current account surpluses, which is also consistent with the mercantilist hypothesis—but it is weaker and insignificant at the 10 percent level.

It is noteworthy that the correlations shown in Figure 9 are the opposite of those that one would expect based on the precautionary view of reserves accumulation. The countries with a more open capital account should be more vulnerable to the volatility of capital flows and accordingly should hold more precautionary reserves.

[Insert Figure 9]

Financial underdevelopment

According to this view, the buildup in reserves reflects a domestic inability to allocate household savings efficiently through the domestic financial sector. Thus emerging market countries export their savings in the form of reserves and import them back in the form of FDI or other forms of capital flows to finance domestic investment. The argument is captured by the models of Ju and Wei (2007) or Caballero Farhi and Gourinchas (2005).

If this view were correct we should observe that the emerging market countries that invest more accumulate more reserves, and this all the more than their domestic financial intermediation system is less efficient. To look into this hypothesis I construct the following indicator of *domestic demand for foreign intermediation*

$$(1-q)i$$

where q is an indicator of the quality of the domestic financial system, and i is the domestic investment rate. According to the financial underdevelopment view this indicator should be positively correlated with reserves accumulation.

Figure 10 shows the cross-country correlation—in my sample of emerging market countries—between reserves accumulation and domestic demand for foreign intermediation. The quality index q was constructed as the ratio of Ju and Wei's (2007) index of the quality of the domestic financial system to the US quality level. We observe that the correlation is positive and statistically significant at the 5 percent level.

One striking feature of the correlation in Figure 10 is that it is the opposite of the correlation that one would expect based on the textbook neoclassical model of capital flows (Gourinchas

[42] The results are similar if one uses Chinn and Ito's (2002) measure of capital account openness.

and Jeanne, 2006). The countries that invest more should import foreign capital rather than accumulate international reserves. This correlation is not inconsistent with the precautionary view (reserves could be held to deal with the risk of a domestic financial crisis in countries with bad quality financial systems). But the precautionary view does not explain why reserves should be positively correlated with domestic investment.

[Insert Figure 10]

Implications

To summarize, one justification for emerging market countries to hold international reserves—and to hold them in a liquid form—is to deal with the risk of capital account crises, but the evidence suggests that in most countries (especially in Asia) the level of international reserves is higher than the level that can be justified by this objective. This begs the question of how the reserves could be used differently.

First, a fraction of the reserves could be "spent" on imported consumption and investment goods. However it is unlikely that emerging market countries can spend the reserves in this way to a significant extent without compromising their macroeconomic objectives. Thus, even if the rate of accumulation of reserves abated in the future—and notwithstanding the good reasons that it should—the public sector of many emerging market countries, especially in Asia, will have to manage stocks of foreign assets of unprecedented size for some time.[43]

That the authorities of developing countries have to manage such large stocks of foreign assets creates policy challenges and opportunities. This section will discuss two implications of excess reserves in emerging market countries: first, the impact of reserves diversification on global financial markets, and second, the implications of increased self-insurance for collective insurance arrangements (such as the IMF).

Portfolio diversification

The reserves that are held to deal with the risk of a capital account crisis should be invested in liquid assets that can be sold quickly and at no loss in a crisis.[44] By contrast, the reserves

[43] According to the IMF World Economic Outlook (April 2006), reserves of developing countries are projected to increase by more than $500 billion in 2007.

[44] Those assets could have a risky return, provided that the return is positively correlated with a crisis. Caballero and Panageas (2005) argue that such a hedging strategy can be efficiently implemented by using options on the S&P500 implied Volatility Index (VIX).

that are in excess of the amount required for crisis insurance could be diversified into less liquid but higher-yielding assets.

There is evidence that emerging market countries have been diversifying the portfolio allocation of their foreign assets in the recent period. First, diversification can be achieved by granting a fraction of the reserves to a separate government fund that is mandated to invest in a diversified portfolio—not unlike the natural-resource-based stabilization funds that have been set up by a number of commodity exporters. For example a fraction of the Korean reserves started to be managed by an independent entity, the Korean Investment Corporation (KIC) in July 2005, with the aim of seeking higher yields.[45] China recently established the State Foreign Exchange Investment Corporation (SFEIC) to manage reserves outside of the central bank. This type of institutions is sometimes called "future generation" or "heritage" fund, because its main objective is to achieve higher long-term returns in order to preserve the value of the assets for future generations.[46]

Diversification has also been under way for the reserves that remain under the roof of the central bank, both across currencies and assets. The share of the US dollar in developing countries' foreign exchange holdings has decreased between 2000 and 2005, from around 70 percent to 60 percent. Second, the foreign official sector (from both advanced and developing countries) has diversified the allocation of its US assets, investing a little less in US Treasury Bills and a little more in long-term debt and equity (Knight, 2006).

However this diversification trend has been slow and central banks continue to allocate their portfolios in a way that is significantly different from private investors. Figure 11 compares the allocation of the U.S. financial portfolio of the foreign official sector with that of foreign private investors.[47] The foreign official sector invests much more in US government debt, and much less in equity or corporate debt, than private investors. Clearly, there remains significant scope for diversification (Truman and Wong, 2006).

[Insert Figure 11]

[45] The KIC partly resembles the model of the Government of Singapore Investment Corporation (GIC), which was established in the 1990s in response to the rapid growth of Singapore's foreign reserve holdings.

[46] Another approach would be to give the private sector a more direct control over the allocation of the country's foreign assets. Prasad and Rajan (2005) propose to set up closed-end mutual funds that purchase reserves from the central bank and invest the proceeds abroad. Presumably the optimal portfolio allocation should be close to the one that the average citizen would choose for himself, given the opportunity.

[47] The figure is based on US Treasury TIC data that do not provide a breakdown of the official sector between advanced countries and emerging market countries.

There have been concerns that the diversification of emerging market countries' reserves could lead to disruption in exchange rates and the relative prices of financial assets (Papaioannou, Portes and Siourounis, 2006). To shed light on this question I will consider, for the sake of the argument, the following experiment. The total stock of foreign exchange reserves in my sample of emerging market countries amounted to approximately 2,000 billion dollars in 2005. One could assume that 1,200 billion dollars (60 percent of the total) were invested in dollars assets, of which 900 billion dollars were invested in the asset classes recorded in Figure 11.[48] Let us further assume that the emerging market countries in my sample reinvest one half of this amount (450 billion dollars) in the global financial portfolio. What would be the impact on the net supply of financial assets for the rest of the global investor community?

The structure of the global portfolio of financial assets is presented in Table 8. It was constructed by aggregating World Bank cross-country data on stock and bond market capitalizations in advanced countries. The table also shows, for each asset class, the net demand from emerging market central banks induced by the portfolio re-allocation, in percentage points of the outstanding stock. For example, the demand for US bonds would decrease by 1.34 percent of the outstanding stock while the demand for Japanese equity would increase by 0.66 percent of the outstanding stock.

As one would expect, the selling pressure would play against the US dollar, especially fixed income dollar assets (the net demand for US equity would actually increase with the diversification). The net demand for US assets would decrease by 0.5 percent of the outstanding stock while the net demand for non-US assets would increase by 0.66 percent (the increase is the same for all asset classes because the net demand is allocated proportionately to the outstanding stocks).

[Insert Table 8]

Overall, this back-of-the-envelope calculation shows that the net demands amount to small fractions of the outstanding stocks. This suggests that moderate price (and exchange rate) changes would suffice to restore the equilibrium. This conclusion, however, comes with several caveats. First, the net supply is sizeable if one restricts the attention to marketable US Treasury debt (more than 7 percent of the outstanding stock). This results from the fact that the foreign official sector holds a significant fraction—about one third—of the outstanding US government debt (Parisi-Capone and Setser, 2006). The impact on the interest rate that

[48] Figure 11, which is based on TIC data, does not report foreign official investment in onshore or offshore dollar deposits and repos, which amount to about one fourth of the total (Knight, 2006, Table 2).

the US government pays on its debt may thus be non-negligible, depending on its substitutability with other forms of dollar debt in the portfolio of global investors.[49]

Second, the short-run price effects of the portfolio diversification might depend on the pace of the diversification and of the accompanying communication strategy. Whereas the literature on sterilized interventions suggests that they have a moderate and transitory effects on the exchange rate between the major currencies, the microstructure literature suggests that their impact might be large (at least in the short run), especially in markets that lack depth and in which information is fragmented. A change in the currency composition of a country's reserves, furthermore, might have a large effect if it is interpreted by the market as a change in the exchange rate objectives of the authorities.[50] So although it is unlikely that large price and exchange rate adjustments must result from increased diversification of emerging market countries' foreign assets *in the long run*, there certainly is a need to assess and monitor the risks in the transition.

Collective insurance

The risks associated with capital account crises are also addressed by collective insurance arrangements—the IMF at the global level, and pooling arrangements such as the Chiang Mai initiative or the Latin American Reserve Fund at the regional level. These arrangements reduce the need for self-insurance, implying that the excess level of reserves could be higher than the estimates derived earlier in the paper in a model without collective insurance. This bias should not be very large in aggregate, however, given that the resources of collective insurance arrangements are relatively small when compared to the reserves that emerging market countries have accumulated in the recent period.[51]

Other things equal, the buildup in emerging market countries' international reserves should reduce the demand for collective insurance. This effect is mitigated by the fact that the reserves buildup occurred mostly in emerging market Asia, where the vulnerability to a capital account crisis was already low in 2000. As a result the decrease in the crisis probability due to the post-2000 buildup in reserves is relatively small—based on the probit

[49] Warnock and Warnock (2006) find that foreign demand for Treasuries has a significant impact on Treasury yields. A study by the ECB (2006) finds that the interventions conducted by Asian central banks cannot be shown to be responsible for the low yield level in the US, although they have certainly played a role.

[50] For example, rumors regarding the possible diversification of reserves by the Bank of Korea in February 2005 triggered a 2 percent appreciation of the Korean won against the US dollar.

[51] The increase in reserves in emerging market Asian countries over 2000-2005 is more than 6 times larger than the IMF usable resources at the end of 2005. The bilateral swap agreements under the Chiang Mai Initiative signed over the period 2001-2005 amount to $ 50 bn, less than 4 percent of the reserves accumulation in the participating countries over the same period.

regressions reported in Table 6, I find that it amounts to only half of a percent on average in my sample of emerging market countries.

One might also think that the countries that have accumulated a large stock of reserves will be less dependent on the IMF if they come to be hit by a crisis. For example, among the five Asian countries that had a sudden stop in 1997, the only one who did not have an IMF program—Malaysia—also had the highest level of reserves before the crisis. This effect can be measured more systematically by looking at how the pre-crisis level of reserves affects the probability that a country borrows from the IMF in a crisis. I ran probit regressions of the probability of an IMF program conditional on a crisis in my sample of emerging market countries over the period 1980-2000, using the pre-crisis reserves-to-short-term-debt ratio as the explanatory variable. The coefficient of reserves is negative and highly significant (Table 9). There is evidence, thus, that higher reserves reduce the demand for IMF crisis lending.

[Insert Table 9]

This effect, however, is quantitatively not very large. I find that a result of the buildup in reserves between 2000 and 2005 the probability of borrowing from the IMF conditional on a crisis decreased from 39.7 percent to 33.2 percent on average for the emerging market countries in my sample.[52] One interpretation of this result is that IMF programs do more than just filling a liquidity gap in a crisis, they could play a role in restoring confidence through conditionality.

Looking forward, one important question is whether the large accumulated stocks of reserves could be used to collective insure risks other than capital account crises. Emerging market countries face other risks that are largely uninsured: natural disasters, epidemies, terms of trade shocks,[53] or severe output drops (Becker et al, 2007). Although some of these shocks may be uninsurable because of moral hazard problems, the range of risks against which emerging market countries could be expanded by appropriate policy intervention.

Summary and conclusions

This paper argued that reserves accumulation in emerging market Asian countries is difficult to justify—at least after 2000—in terms of self-insurance against capital flow volatility and capital account crises. The main piece of evidence behind this claim was the failure of a simple cost-benefit model of optimal reserves to account for the reserves buildup in emerging

[52] These are average predicted probabilities, where the average is taken over all the regressions in Table 9.

[53] Commodity funds insure the exporter against fluctuations in the price of the commodity, not the importer.

market Asian countries after 2000. The vulnerability of those countries to a capital account crisis was too low, in 2000, to justify the cost of accumulating the reserves. Another piece of evidence is the fact that the emerging market countries that accumulated the most reserves were also those who were the most protected from capital flow volatility by capital account restrictions. Finally, that reserves were excessive from the point of view of crisis insurance is also suggested by recent moves to re-allocate reserves to government funds invested in less liquid and higher-yielding assets.

Even if the rate of accumulation of reserves abated, the public sector of a number of emerging market countries, especially in Asia, will have to manage stocks of foreign financial assets of unprecendented size for some time to come. This generates policy challenges and opportunities for the international community. One challenge is to ensure that the diversification of those assets is conducted in an orderly manner so as to avoid large or abrupt changes in the relative price of financial assets or exchange rates. As an example of opportunity, the large stock of foreign assets could provide the basis for cross-country insurance arrangements against a wide range of risks (demographic shocks, natural disasters, epidemies, etc.) that may be currently underinsured.

Bibliography

Aizenman, Joshua, and Jaewoo Lee, 2005, "International Reserves: Precautionary Vs. Mercantilist Views, Theory, and Evidence," IMF Working Paper 05/198 (Washington: International Monetary Fund).

Aizenman, Joshua, Lee, Yeonho and Yeongseop Rhee, 2004, "International Reserves Management and Capital Mobility in a Volatile World: Policy Considerations and a Case Study of Korea," NBER Working Paper 10534.

Aizenman, Joshua,, and Nancy Marion, 2004, "International Reserve Holdings With Sovereign Risk and Costly Tax Collection," *Economic Journal* 114, 569-591.

Aizenman, Joshua,, and Nancy Marion, 2003, "The High Demand For International Reserves In the Far East: What is Going On?," *Journal of The Japanese and International Economies*, Vol. 17, pp. 370–400.

Beck Thorsten and Ross Levine, 2005, "Financial Structure Database," The World Bank, Washington, D.C.

Becker, Torbjörn and Paolo Mauro, 2006, "Output Drops and the Shocks That Matter," IMF Working Paper 06/172.

Becker, Torbjörn, Jeanne, Olivier, Mauro, Paolo, Ostry, Jonathan D. and Romain Rancière, 2007, "Country Insurance—The Role of Domestic Policies," Occasional Paper, forthcoming IMF.

Ben Bassat, Avraham and Daniel Gottlieb, 1992, "Optimal International Reserves and Soereign Risk," *Journal of International Economics* 33, 345-362.

Berg, Andrew, Borensztein, Eduardo and Catherine Pattillo, 2005, "Assessing Early Warning Systems: How Have They Worked in Practice?" *IMF Staff Papers* 52(3), 462-502.

Bird, Graham, and Ramkishen Rajan, 2003, "Too Much of a Good Thing? The Adequacy of International Reserves in the Aftermath of Crises," *The World Economy* 26(6), 873-891.

Bussière, Matthieu and Christian Mulder, 1999, "External Vulnerability in Emerging Market Economies: How High Liquidity Can Offset Weak Fundamentals and the Effects of Contagion," IMF Working Paper 99/88 (Washington: International Monetary Fund).

Bussière, Matthieu and Christian Mulder, 2000, "Which Short-term Debt over Reserves Ratio Works Best?: Operationalising the Greenspan Guidotti Rule," in Dipak Dasgupta, Marc Uzan and Dominic Wilson eds., *Capital Flows Without Crisis?*, Routledge.

Caballero, Ricardo and Arvind Krishnamurthy, 2004, "Smoothing Sudden Stops", *Journal of Economic Theory* 119(1), 104-127.

Caballero, Ricardo and Stavros Panageas, 2005, "A Quantitative Model of Sudden Stops and External Liquidity Management," NBER Working Paper 11293.

Caballero, Ricardo, Farhi, Emanuel and Pierre-Olivier Gourincahs, 2006, "An Equilibrium Model of 'Global Imbalances' and Low Interest Rates," MIT Working Paper.

Calvo, Guillermo, 1996, "Capital Flows and Macroeconomic Management: Tequilla Lessons," *International Journal of Finance and Economics*.

Calvo, Guillermo, 1998, "Capital Flows and Capital-market Crises: the Simple Economics of Sudden Stops," *Journal of Applied Economics* 1(1), 35-54.

Calvo, Guillermo, 2006, "Monetary Policy Challenges in Emerging Markets: Sudden Stop, Liability Dollarization and Lender of Last Resort," NBER Working Paper 12788.

Calvo, Guillermo A., Izquierdo, Aljandro, and Luis F. Mejía, 2004, "On the Empirics of Sudden Stops: The Relevance of Balance-Sheet Effects," NBER Working Paper 10520.

Caselli, Francesco and James Feyrer, 2007, "The Marginal Product of Capital," *Quarterly Journal of Economics*, forthcoming.

Chang, Roberto, and Andres Velasco, 2000, "Liquidity Crises in Emerging Markets: Theory and Policy," *NBER Macroeconomics Annual 1999*, 11-58.

De Gregorio, Jose and J. Lee, 2003, "Growth and Adjustment in East Asia and Latin America," Central Bank of Chile Working Paper 245.

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

Dooley, Michael P., Folkerts-Landau, David, and Peter Garber, 2004, "The Revived Bretton Woods System: The Effects of Periphery Intervention and Reserve Management on Interest Rates and Exchange Rates in Center Countries, "NBER Working Paper 10332 (Cambridge, Massachusetts: National Bureau of Economic Research).

Duffie, Darrell, Pedersen, Lasse Heje and Kenneth J. Singleton, 2003, "Modeling Sovereign Yield Spreads: A Case Study of Russian Debt," *The Journal of Finance* 63(1), 119-159.

Durdu, C. Bora, Mendoza, Enrique G. and Marco E. Terrones, 2007, "Precautionary Demand of Foreign Assets in Globalized Emerging Market Economies," in progress.

Edwards, Sebastian, 1985, "On the Interest-Rate Elasticity of the Demand for International Reserves: Some Evidence from Developing Countries," *Journal of International Money and Finance* 4, 287-295.

Edwards, Sebastian, 2004, "Thirty Years Of Current Account Imbalances, Current Account Reversals and Sudden Stops," *IMF Staff Papers* Vol. 51(10), pp.1-49.

Eichengreen, Barry and Ashoka Mody, 2000, "What Explains Spreads on Emerging Market Debt?", in Sebastian Edwards, ed., *Capital Flows and the Emerging Economies: Theory, Evidence and Controversies*, Chicago: the University of Chicago Press.

Eichengreen, Barry, Gupta, Poonam and Ashoka Mody, 2006, "Sudden Stops and IMF-Supported Programs," IMF Working Paper 2006/101.

European Central Bank, 2006, "The Accumulation of Foreign Reserves," Occasional Paper No.43 (February).

Flood, Robert and Olivier Jeanne, 2005, "An Interest Rate Defense of a Fixed Exchange Rate?", *Journal of International Economics* 66, 471-484.

Flood, Robert, and Nancy Marion, 2002, "Holding International Reserves In an Era of High Capital Mobility," in Susan M. Collins and Dani Rodrik eds., *Brookings Trade Forum 2001*, 1-47 (Brookings Institution Press, Washington DC).

Frankel, Jeffrey and Eduardo Cavallo, 2004, "Does Openness to Trade Make Countries More Vulnerable to Sudden Stops or Less? Using Gravity to Establish Causality", NBER Working Paper 10957.

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

Frankel, Jeffrey and Shang-Jin Wei, 2005, "Managing Macroeconomic Crises: Policy Lessons," in J. Aizenman and B. Pinto, eds, Managing Economic Volatility and Crises, *Cambridge University Press*.

Frenkel, Jacob and Boyan Jovanovic, 1981, "Optimal International Reserves: A Stochastic Framework," *Economic Journal*, Vol. 91, pp. 507–14.

Garcia, Pablo S., and Claudio Soto, 2004, "Large Hoarding of International Reserves: Are they worth it?" Central Bank of Chile Working Paper No.299.

Gourinchas, Pierre-Olivier and Olivier Jeanne, 2006, "Capital Flows to Developing Countries: The Allocation Puzzle," mimeo, UC Berkeley, Department of Economics.

Gourinchas, Pierre-Olivier and Hélène Rey, 2005, "From World Banker to World Venture

Capitalist: US External Adjustment and the Exorbitant Privilege," NBER Working Paper 11563.

Guidotti, Pablo, Sturzenegger, Federico, and Agustin Villar, 2004, "On the Consequences of Sudden Stops," *Economia*, Vol. 4, No. 2, pp.171–203.

Gupta, P., Mishra, D. and Ratna Sahay, 2003, ""Output Responses to Currency Crises," IMF Working Paper 03/230.

Hamada, Koichi and Kazuo Ueda, 1977, "Random Walks and the Theory of Optimal International Reserves," *Economic Journal 87,* 722-42.

Hauner, David, 2005, "A Fiscal Price Tag for International Reserves," IMF Working Paper 05/81 (Washington: International Monetary Fund).

Heller, Robert H, 1966, "Optimal International Reserves," *Economic Journal* 76, 296-311.

Hutchison, Michael M., and Ilan Noy, 2006, "Sudden Stops and the Mexican Wave: Currency Crises, Capital Flow Reversals and Output Loss in Emerging Markets," *Journal of Development Economics* 79, 225-248.

Hviding, Nowak, Michael and Luca Ricci, 2004, "Can Higher Reserves Help Reduce Exchange Rate Volatilit?", IMF Working Paper 04/189.

IMF, 2000, "Debt- and Reserve-Related Indicators of External Vulnerability," IMF Board Paper, http://www.imf.org/external/np/pdr/debtres/index.htm

IMF, 2001, "Issues in Reserves Adequacy and Management," IMF Board Paper, http://www.imf.org/external/np/pdr/resad/2001/reserve.htm

International Monetary Fund, 2003, "Are Foreign Exchange Reserves in Asia Too High?" *World Economic Outlook*, September, 2003, Chapter II, pp. 78–92.

Jeanne, Olivier, 2007, "Benefits and Costs of International Reserves: the Balance Sheet Approach," manuscript, in progress.

Jeanne, Olivier and Romain Rancière, 2006, "The Optimal Level of International Reserves for Emerging Market Countries: Formulas and Applications," IMF Working Paper 06/229 (Washington: International Monetary Fund).

Jeanne, Olivier and Charles Wyplosz, 2003, "The International Lender of Last Resort: How Large Is Large Enough?" in M. Dooley and J. Frankel, efds., *Managing Currency Crises in Emerging Markets*, University of Chicago Press.

Ju, Jiandong, and Shang-Jin Wei, 2007, "Domestic Institutions and the Bypass Effect of International Capital Flows," manuscript, IMF.

Kaminsky, Graciela, Lizondo, Saul and Carmen Reinhart, 1998, "Leading Indicators of Currency Crises," *IMF Staff Papers* 5(1), 1-48.

Knight, Malcolm, 2006, "International Reserve Diversification and Disclosure," speech at the Swiss National Bank/Institute for International Economics Conference, Zurich, 8 September 2006, http://www.bis.org/speeches/sp060908.htm

Lane, Philip R. and Gian Maria Milesi-Ferretti, 2006, "The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970–2004," IMF Working Paper 06/69 (Washington: International Monetary Fund).

Lane, Philip, and Dominic Burke, 2001, "The Empirics of Foreign Reserves," *Open Economies Review* 12, 423-434.

Levy-Yeyati, Eduardo, 2006, "The Cost of Reserves," CIF Working Paper 10/2006 (Centro de Investigación en Finanzas, Di Tella University).

Lizondo, José Saùl, and Donald J. Mathieson, 1987, "The Stability of the Demand for International Reserves," *Journal of International Money and Finance* 6, 251-282.

Milesi-Ferretti, Gian Maria and Assaf Razin, 2000, "Current Account Reversals and Currency Crises: Empirical Regularities," in Paul Krugman ed., *Currency Crises*, University of Chicago Press.

Miller, Marcus, and Lei Zhang, 2006, "Fear and Market Failure: Global Imbalances and 'Self-Insurance'", CEPR Discussion Paper N0.6000.

Mohanty, M.S. and Philip Turner, 2006, "Foreign Exchange Reserve Accumulation in Emerging Markets: What Are the Domestic Implications?" *BIS Quarterly Review* (September), 39-52.

Morris, Stephen and Hyun Song Shin, 1998, "Unique Equilibrium in a Model of Self-Fulfilling Currency Attacks", *American Economic Review*, Vol. 88(3), pp. 587–97.

Mulder, Christian, 2000, "The Adequacy of International Reserve Level: A New Approach," in S.F. Frowen, Robert Pringle and Benedict Weller eds., *Risk Management for Central Bankers*, Central Bank Publications (London UK).

Papaioannou, Elias, Portes, Richard and Gregorio Siourounis, 2006, "Optimal Currency Shares in International Reserves: the Impact of the Euro and the Prospects for the Dollar," CEPR Discussion Paper N0. 5734.

Prasad, Eswar and Raghuram Rajan, 2005, "Controlled Capital Account Liberalization: A Proposal," IMF Policy Discussion Paper.

Prasad, Eswar, Rajan, Raghuram and Arvind Subramanian, 2006, "Foreign Capital and Economic Growth," manuscript, IMF.

Quinn, Dennis, 2000, "Democracy and International Financial Liberalization", manuscript, McDonough School of Business, Georgetown University.

RBS (The Royal Bank of Scotland), 2005, *RBS Reserve Management Trends 2005*, edited by Robert Pringle and Nick Carver, Central Banking Publications (London UK).

Rodrik, Daniel, 2006, "The Social Cost of Foreign Exchange Reserves," *International Economic Journal* Vol.20(3), 253-266.

———, and Andrés Velasco, 2000, "Short-Term Capital Flows," Annual World Bank Conference on Development Economics 1999.

Rudebusch, Glenn D., Sack, Brian, and Eric T. Swanson, 2007, "Macroeconomic Implications of Changes in the Term Premium," manuscript, Federal Reserve Bank of San Francisco.

Stiglitz, Joseph, 2006, *Making Globalization Work*, W.W. Norton.

Summers, Lawrence H., 2006, "Reflections on Global Account Imbalances and Emerging Markets Reserves Accumulation", L.K. Jha Memorial Lecture at http://www.president.harvard.edu/speeches/2006/0324_rbi.html

Truman, E.M. and A. Wong, 2006, "The Case for an International Reserve Diversification Standard," Institute for International Economics, Working Paper 06-2.

Warnock, Francis and Veronica Cacdac Warnock, 2006, "International Capital Flows and U.S. Interest Rates," NBER Working Paper 12560.

Woolridge, Philip D., 2006, "The Changing Composition of Official Reserves," *BIS QuarterlyRreview* (September 2006), 25-38.

DATA APPENDIX

A. List of countries.

Emerging Market Countries	Advanced Economies
Argentina	Australia
Brazil	Austria
Bulgaria	Belgium
Chile	Canada
China	Denmark
Colombia	Finland
Cote d'Ivoire	France
Dominican Republic	Germany
Ecuador	Greece
Egypt	Iceland
El Salvador	Ireland
Hungary	Italy
India	Japan
Indonesia	Luxembourg
Korea	Netherlands
Malaysia	New Zealand
Mexico	Norway
Morocco	Portugal
Nigeria	Spain
Pakistan	Sweden
Panama	Switzerland
Peru	United Kingdom
Philippines	United States
Poland	
Russia	
South Africa	
Thailand	
Tunisia	
Turkey	
Ukraine	
Uruguay	
Venezuela	

The group of emerging market countries include all the countries in JP Morgan Emerging Market Bond Index Global (EMBIG) as of August 31, 2005, excluding Serbia and Montenegro and Lebanon because of data availability, and adding India and Korea. The group of advanced countries includes the countries that were members of the OECD in 1990 and are not in the emerging market countries list.

B. Crisis definitions:

1) Currency crises

CC1: criterion of Frankel and Rose (1996), nominal depreciation of the currency of at least 25 percent relative to the previous year that is also at least a 10 percent increase in the rate of depreciation.

CC2: Frankel and Wei (2006) with a threshold of 15%

CC3: Frankel and Wei (2006) with a threshold of 25%

CC4: Frankel and Wei (2006) with a threshold of 35%

2) Sudden stops

SS1: the ratio of the financial account to GDP falls by more than 5 % relative to the previous year.

SS2: Frankel and Cavallo's (2004) Sudden Stop 1

SS3: Frankel and Cavallo's (2004) Sudden Stop 2

SS4: Frankel and Cavallo's (2004) Sudden Stop 3

C. Benchmark calibration

For our benchmark calibration we assume that reserves yield no benefits in terms of prevention, i.e., that π is exogenous. The behavior of the model economy is then determined by 5 parameters: the size of a sudden stop L, the size of the output loss ΔY, the probability of a sudden stop π, the opportunity cost of reserves δ, and the risk-aversion parameter σ.

Three parameters (L, ΔY and π) have been calibrated by using the same sample of sudden stops as for Figure 5 (i.e., the years in which net capital inflows decreased by more than 5 percent of GDP). Parameter π was set to the unconditional frequency of sudden stops in my sample, which is close to 10 percent per year. Parameter L was calibrated as the average fall of the financial account in terms of GDP over our sample of sudden stops, which is close to 10 percent. The reversal in capital flows in a crisis is a more direct measure of *L* than the size of short-term debt. Looking at the ratio of short-term external debt to GDP would give similar values. This ratio is equal to 8.2 percent on average in our sample according to the World Bank's *Global Development Finance* (GDF) data set, and to 11.7 percent according to the Bank of International Settlements (BIS) database.

The output cost of a crisis is calibrated to 10 percent of the pre-crisis GDP. This figure was obtained by cumulating the average output gap in the year of a sudden stop and the following year, under the assumption that output would have grown at the same rate as before the crisis in the absence of a sudden stop. An output loss of 10 percent of GDP is in the ballpark of the estimates obtained in the literature on currency crises and sudden stops. The IMF World Economic Outlook (1998) estimates that a currency crisis reduces output by 7.6 percent on average in emerging market countries (including only those crises with an output loss). Hutchison and Noy (2006) find that the cumulative output loss of a sudden stop is around 13-15 percent over a 3-year period. Becker and Mauro (2006) find an expected output cost of 11.6 percent for currency crises and 10.2 percent for sudden stops.[54]

The value for the opportunity cost of reserves, $\delta = 3$ percent, is toward the middle of the range of estimates [1.5%, 6%] resulting from our discussion of the cost of reserves. The low side the range corresponds to the average U.S. term premium over 1987—2005, whereas the higher bound is calibrated by reference to the average return on capital or sovereign spread in emerging market countries. The benchmark risk-aversion and its range of variation are standard in the growth and real business cycle literature.

[54] The estimates of the output cost of a crisis can be significantly larger if the output gap is cumulated until output has gone back to its potential level, which typically takes longer than two or three years. On the other hand, using the pre-crisis growth rate to estimate post-crisis potential output may exaggerate the size of the output gap if there was an unsustainable economic boom before the crisis. What matters for the optimal level of reserves, furthermore, is only the output loss that occurs while the country is cut off from external credit.

C. List of variables considered in the probit analysis

Variables	Source
Debt	
Lag of Real Public Debt to Real GDP	GDF/WDI (2005)
Lag of Short Term Debt to Real GDP	GDF/WDI (2005)
Exchange Rate	
Second Lag Exchange Rate Regime Dummies	Reinhart & Rogoff (2004)
Lag of Real Effective Exchange Rate Deviation from HP trend	IFS (2005)
Trade	
Lag of Openness to Trade, (X+M)/GDP	WDI (2005)
Lag of Term of Trade Growth	IFS (2005)
Index of Current Account Openness	Quinn (2000)
US Interest Rate	
Interest Rate of T-bill	IFS (2005)
Change in the Interest Rate of T-bill	IFS (2005)
Business Cycles	
Average of First and Second Lags of Real GDP Growth	WDI (2005)
Financial Account Openness	
Lag of Absolute Gross Inflows / GDP	IFS (2005)
Lag of Sum of Absolute Gross Inflows and Absolute Gross Outlows / GDP	IFS (2005)
Stocks of Foreign Assets and Foreign Liabilities	
Lag of Net Foreign Assets / GDP	Lane and Milesi-Ferretti (2006)
Lag of Stock of Foreign Liabilities / GDP	
Lag of Stock of Debt Liabilities / Stock of Liabilities	
Lag of Stock of FDI / Stock of Liabilities	Lane and Milesi-Ferretti (2006)
Others	
Ratio of Foreign Liabilities to Money in the Financial Sector	IFS (2005)
Inflation Rate (CPI)	IFS

TECHNICAL APPENDIX

A. Derivations

1) Justification of equation (1). Let us assume that then model has an infinite number of periods, and that from period 2 onwards the economy is in a steady state with

$$C_t = \overline{Y} + \frac{r}{1+r} W_2$$

Period 2 welfare is the discounted sum of a sequence of constant utility flows,

$$U_2 = \sum_{t=0}^{+\infty} \frac{1}{(1+r)^t} u\left(\overline{Y} + \frac{r}{1+r} W_2\right) = \frac{1+r}{r} u\left(\overline{Y} + \frac{r}{1+r} W_2\right)$$

This defines an indirect utility function of wealth, $V(W_2)$. If $u(\cdot)$ is CRRA, given by $u(C) = C^{1-\sigma}$, then the concavity in $V(\cdot)$ can be measured by

$$-\frac{V''(W)W}{V'(W)} = \sigma \frac{1}{1 + \frac{(1+r)\overline{Y}}{rW}}$$

This smaller than σ, and much smaller if the net income from abroad is a small fraction of domestic output.

2) Reserves management in a crisis. How does the country use the reserves in period 1? If there is no crisis, the consumer achieves his desired level of consumption C^* and saves his residual wealth (which could be positive or negative) as net reserves. By contrast, if there is a crisis the consumer may be unable to consume C^*. Then period-1 consumption is given by

$$C_1 = \overline{Y}_1 - \Delta Y - L + B - \frac{B_2}{1+r}$$

The question is whether the consumer can achieve his desired level of consumption $C_1 = C^*$ by running down the reserves ($B_2 = 0$). This is the case if the level of reserves B_1 is larger than the following threshold,

$$\overline{B} = L + \Delta Y + (C^* - \overline{Y}_1)$$

$\overline{B}$ is the "full insurance" level of reserves allowing the consumer to maintain his consumption at the same level as if there were no crisis. In the following I will normalize the desired trade deficit $C^* - \overline{Y}_1$ to zero, so that the "full insurance" level of reserves is equal to the capital outflow plus the output cost of a crisis.

3) Expression for the welfare cost of crisis. Using the period 1 budget constraint to substitute out $B_2 - L_2$ from the expression for W_2, we can write period-1 welfare as

$$U_1 = u(C_1) + \frac{W_2}{1+r}$$
$$= u(C_1) + (B - L) + (Y_1 - C_1) - (1+r)(1+\delta)D$$

If there is no crisis $Y_1 = \overline{Y}_1$ and $C_1 = C^*$. If there is a crisis $Y_1 = \overline{Y}_1 - \Delta Y$ and $C_1 = \overline{Y}_1 - \Delta Y - L + B = C^* - (\overline{B} - B)$ (assuming $B \le \overline{B}$). It follows that welfare conditional on no crisis and conditional on a crisis is respectively given by

$$U_1^n = u(C^*) + (B - L) + (\overline{Y}_1 - C^*) - (1+r)(1+\delta)D$$
$$U_1^c = u(C^* - (\overline{B} - B)) + (B - L) + (\overline{Y}_1 - \Delta Y - C^* + \overline{B} - B) - (1+r)(1+\delta)D$$

Taking the difference one obtains $U_1^n - U_1^c = f(B)$.

4) Expression for total loss. Period-0 welfare is given by

$$U_0 = u(C_0) + \frac{1}{1+r}\left((1-\pi)U_1^n + \pi U_1^c\right)$$
$$= u(C_0) + \frac{1}{1+r}\left(U_1^n - \pi f(B)\right)$$

Leaving aside all the exogenous terms (which are irrelevant for the maximization) and using the expression for U_1^n above and the period-0 budget constraint to substitute out D one obtains

$$U_0 = u(C_0) + \frac{B}{1+r} - (1+\delta)D - \frac{\pi f(B)}{1+r}$$
$$= u(C_0) - (1+\delta)C_0 - \frac{1}{1+r}\left(\delta B + \pi f(B)\right)$$

If $D > 0$ then C_0 satisfies the first-order condition $u'(C_0) = 1+\delta$ and B must minimize the last term on the right-hand side.

5) Equation (3). The first-order condition for minimizing the loss is

$$u'\left(C^* - (\overline{B} - B)\right) = 1 + \frac{\delta}{\pi}.$$

Then use $C^* = 1$ and $u'(C) = C^{-\sigma}$.

B. A two-goods extension with a real exchange rate.

Let us introduce a distinction between tradables and non-tradables in domestic consumption. If utility is separable in the two types of consumption, our model applies to the "tradable part" of the economy. An interesting implication is that the model will also make predictions about the real exchange rate.

Ex post, the real exchange rate will depreciate in a crisis, an effect that can be mitigated by spending the reserves. Ex ante, larger reserves accumulation is associated with a depreciation of the real exchange rate. This result is interesting in view of the debate between the precautionary and mercantilist views. A real depreciation is sometimes interpreted as a sign in favor of the mercantilist view (Aizenman and Lee, 2005). But it is only a sign that the reserves have been accumulated through the current account rather than the capital account. The difference between the two views relates to the authorities' intent, not to their methods of accumulation.

In the calibration we will look at the sensitivity of the results to assuming non-separability in the consumption of tradables and non-tradables. Assume that domestic consumption is the following CES index of the consumption of non-tradables and tradables:

$$C = \left[aC_N^{-\mu} + (1-a)C_T^{-\mu} \right]^{-1/\mu}$$

The country has exogenous endowments of tradables and non-tradables Y_{Tt}, Y_{Nt}.

[to be completed]

TABLES

Table 1. Reserves Accumulation and the Financial Account

	Emerging Markets	Asia	Latin America
Financial Account/Change in Reserves	40.6	36.6	137.0
Gross Foreign Assets (increase 2000-2005)			
Direct Investment (%)	8.8	5.6	20.9
Portfolio Investment (%)	8.7	8.7	13.0
Other Investment (%)	22.3	11.7	36.0
Reserve Assets (%)	60.2	73.9	30.0
Gross Foreign Liabilities			
Direct Investment (%)	67.9	63.3	104.0
Portfolio Investment (%)	20.9	28.2	6.8
Other Investment (%)	11.2	8.5	-10.8

Source: IMF, Balance of Payments Statistics

Table 2

Reserves and crisis prevention

	Dependent Variable	
Measure of Reserve Adequacy	Currency Crisis	Sudden Stop
Reserves to imports	9/16	1/16
Reserves to short term debt (WB)	16/16	0/16
Reserves to short term debt (BIS)	4/16	1/16
Reserves to M2	0/16	4/16
Reserves to GDP	12/16	1/16

The table reports the number of regressions in which the reserve adequacy ratio coefficient is negative and significant at the 10% level or less

Table 3. The Opportunity Cost of Reserves
(group averages for 2000-2005, in percent of GDP)

	All Emerging Markets	Asia	Latin America
6%	1.00%	1.67%	0.65%
term premium (2%)	0.33%	0.56%	0.22%
term premium+spread	1.23%	1.10%	1.23%

Table 4. Calibration Parameters

Parameters	Baseline	Range of Variation
Size of Sudden Stop	L=0.10	[0,0.3]
Probability of a Sudden Stop	π=0.10	[0,0.25]
Output Loss	ΔY=0.10	[0,0.2]
Opportunity Cost	δ=0.03	[0.01,0.06]
Risk Aversion	σ=2	[1,10]
Prevention benefit	a=0	[0,0.3]

Table 5. Panel A

Dependent Variable: SS1

	1	2	3	4
		Country Effects	Year Effects	Country and Year Effects
Real Exchange Rate -Deviation from HP tendency	-1.240***	-1.295**	-1.102**	-1.192**
(Average of values at (t-1) and (t-2))	[0.438]	[0.521]	[0.442]	[0.519]
GDP Growth	-2.047***	-2.028**	-2.511***	-2.856***
(Average of values at (t-1) and (t-2))	[0.749]	[0.830]	[0.884]	[1.038]
Foreign Liabilities to Money at (t-1)	0.025***	0.031**	0.028***	0.037***
	[0.008]	[0.014]	[0.008]	[0.014]
Current Account to GDP at (t-1)	-0.045**	-0.053***	-0.044**	-0.056***
	[0.019]	[0.019]	[0.021]	[0.021]
Total Public Debt to GDP at (t-1)	0.544**	0.333	0.578**	0.324
	[0.220]	[0.415]	[0.234]	[0.464]
Constant	-1.712***	-1.834***	-2.276***	-1.724***
	[0.168]	[0.495]	[0.629]	[0.575]
Observations	511	394	511	394
Pseudo R-sq	0.12	0.16	0.14	0.19

Table 5. Panel B

Dependent Variable: SS2

	1	2	3	4
		Country Effects	Year Effects	Country and Year Effects
Real Exchange Rate -Deviation from HP tendency	-2.278***	-4.955***	-2.638***	-10.460***
(Average of values at (t-1) and (t-2))	[0.489]	[1.046]	[0.790]	[2.629]
Current Account to GDP at (t-1)	-0.080***	-0.125***	-0.174***	-0.475***
	[0.019]	[0.029]	[0.037]	[0.099]
Constant	-2.196***	-1.391***	-9.526***	-11.189***
	[0.146]	[0.420]	[0.539]	[1.238]
Observations	544	331	284	173
Pseudo R-sq	0.17	0.31	0.29	0.6

Note: Robust standard errors are given in brackets below the estimated coefficients.

One, two, or three asterisks denote significance at the 10%, 5% and 1% levels respectively.

Table 6. Panel A

Dependent Variable: CC1

	1	2	3	4
		Country Effects	Year Effects	Country and Year Effects
Reserves to Short Term Debt at (t-1)	-0.162**	-0.261**	-0.130**	-0.201*
	[0.065]	[0.104]	[0.064]	[0.108]
Real Exchange Rate -Deviation from HP tendency	-1.441***	-1.332***	-1.598***	-1.547***
Average of values at (t-1) and (t-2)	[0.463]	[0.496]	[0.504]	[0.528]
Consumer Price Inflation at (t-1)	0.331**	0.134	0.392***	0.161
	[0.134]	[0.210]	[0.141]	[0.231]
Constant	-1.148***	-0.571*	-2.109***	-1.019*
	[0.111]	[0.324]	[0.404]	[0.585]
Observations	560	483	560	483
Pseudo R-sq	0.07	0.12	0.13	0.18

Table 6. Panel B

Dependent Variable: CC4

	1	2	3	4
		Country Effects	Year Effects	Country and Year Effects
Reserves to Short Term Debt at (t-1)	-0.234**	-0.205*	-0.210**	-0.157
	[0.106]	[0.108]	[0.098]	[0.097]
Trade Openness at (t-1)	-0.612**	-1.772**	-0.598*	-1.299
	[0.307]	[0.754]	[0.333]	[0.907]
Current Account to GDP at (t-1)	-0.039**	-0.041**	-0.042**	-0.057**
	[0.018]	[0.020]	[0.021]	[0.023]
Constant	-0.751***	-0.459	-0.627*	-0.518
	[0.196]	[0.437]	[0.364]	[0.569]
Observations	546	477	466	408
Pseudo R-sq	0.07	0.1	0.12	0.16

Note: Robust standard errors are given in brackets below the estimated coefficients.

One, two, or three asterisks denote significance at the 10%, 5% and 1% levels respectively.

Table 7. Observed and model-predicted levels of reserves (in billion USD)

	Observed	Predicted Benchmark		Predicted $\sigma = 8$		Predicted L = 0.3	
Prevention benefits		no	yes	no	yes	no	yes
Level of Reserves in 2000							
All emerging	651	144	479	592	871	777	1167
Asia	406	12	200	200	402	210	589
Latin America	145	100	203	283	339	419	403
Change in Reserves 2000-05							
All emerging	1133	-455	62	218	672	455	1153
Asia	937	-386	-72	-68	280	-55	615
Latin America	88.5	-26	-106	199	271	357	329

Source: author's computations

Table 8. Impact of reserves diversification in emerging market countries on global financial portfolio (in billion US dollar)

	United States	Euro area	Japan	United Kingdom
Equity	16,800 (+0.40%)	6,000 (+0.66%)	4,200 (+0.66%)	3,000 -0.66%
Bonds	19,800 (-1.34%)	8,400 (+0.66%)	8,700 (+0.66%)	1,000 (+0.66%)
of which US Treasury marketable debt	4000 (-7.1%)			

Source: Beck and Levine (2005), author's computations

Table 9. Demand for IMF Lending

Dependent Variable: Probability of Starting New IMF Program Conditional on a Crisis

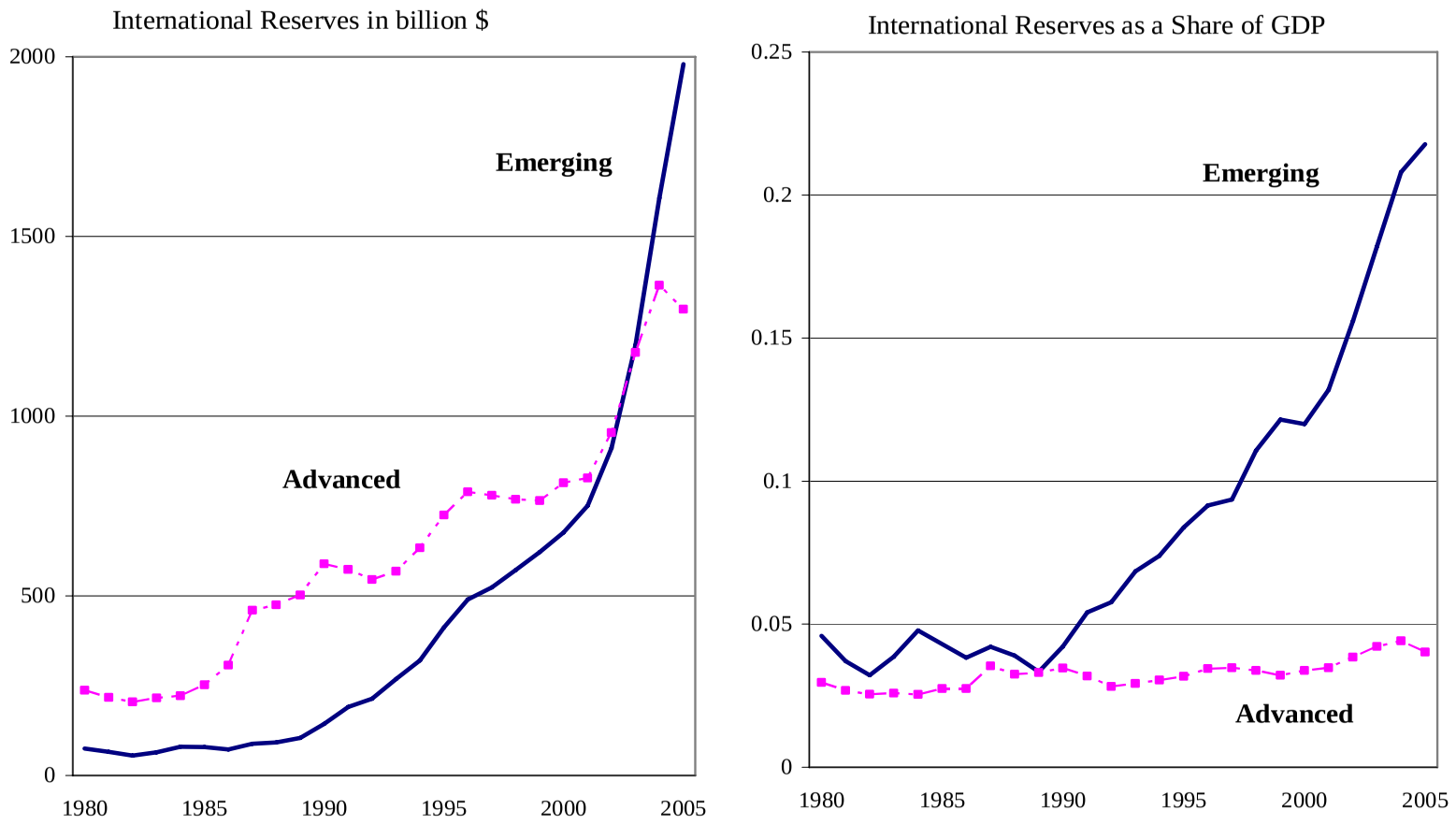
Explanatory Variable: Pre-Crisis Ratio of Reserves-to-ShortTerm Debt

	1 SS1	2 SS2	3 SS3	4 SS4	5 CC1	6 CC2	7 CC3	8 CC4
Reserves to Short Term Debt	-0.126*	-0.787	-0.196***	-0.161***	-0.372	-0.423*	-0.400*	-0.42
	[0.065]	[0.493]	[0.061]	[0.053]	[0.278]	[0.254]	[0.223]	[0.281]
Constant	0.3	0.778	0.973**	0.575	0.08	0.09	0.132	0.273
	[0.216]	[0.527]	[0.487]	[0.459]	[0.291]	[0.253]	[0.243]	[0.309]
Observations	46	21	13	12	46	59	47	33

Note: Robust standard errors in brackets. One, two and three asterisks denote significance at the 1%, 5% and 10% level or less.

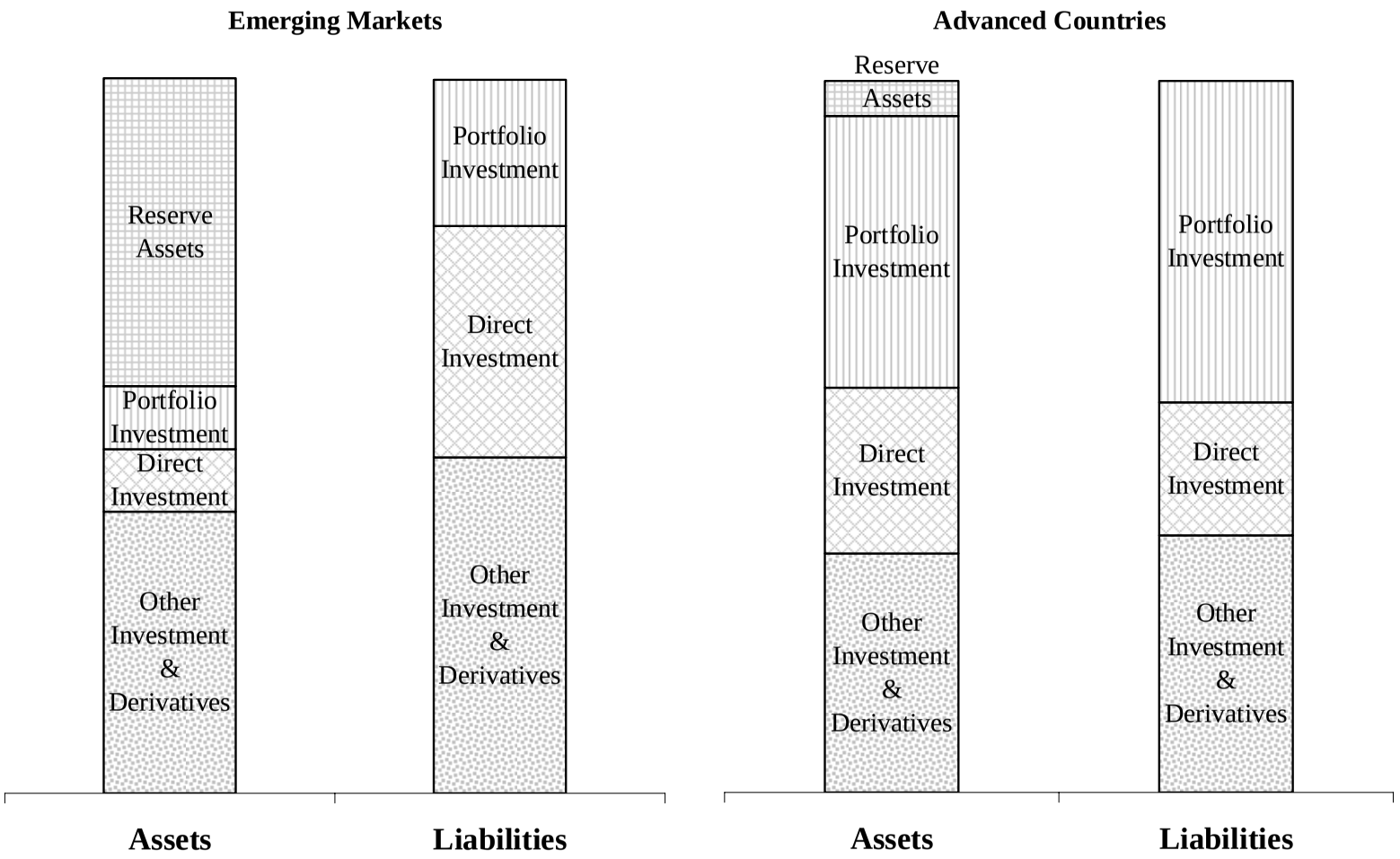
FIGURES

Figure 1. The Buildup in International Reserves



Source: Total reserves minus gold: IMF, International Financial Statistics; GDP: World Bank, World Development Indicators.

Figure 2. Country Balance Sheet Structure, 2000-2005

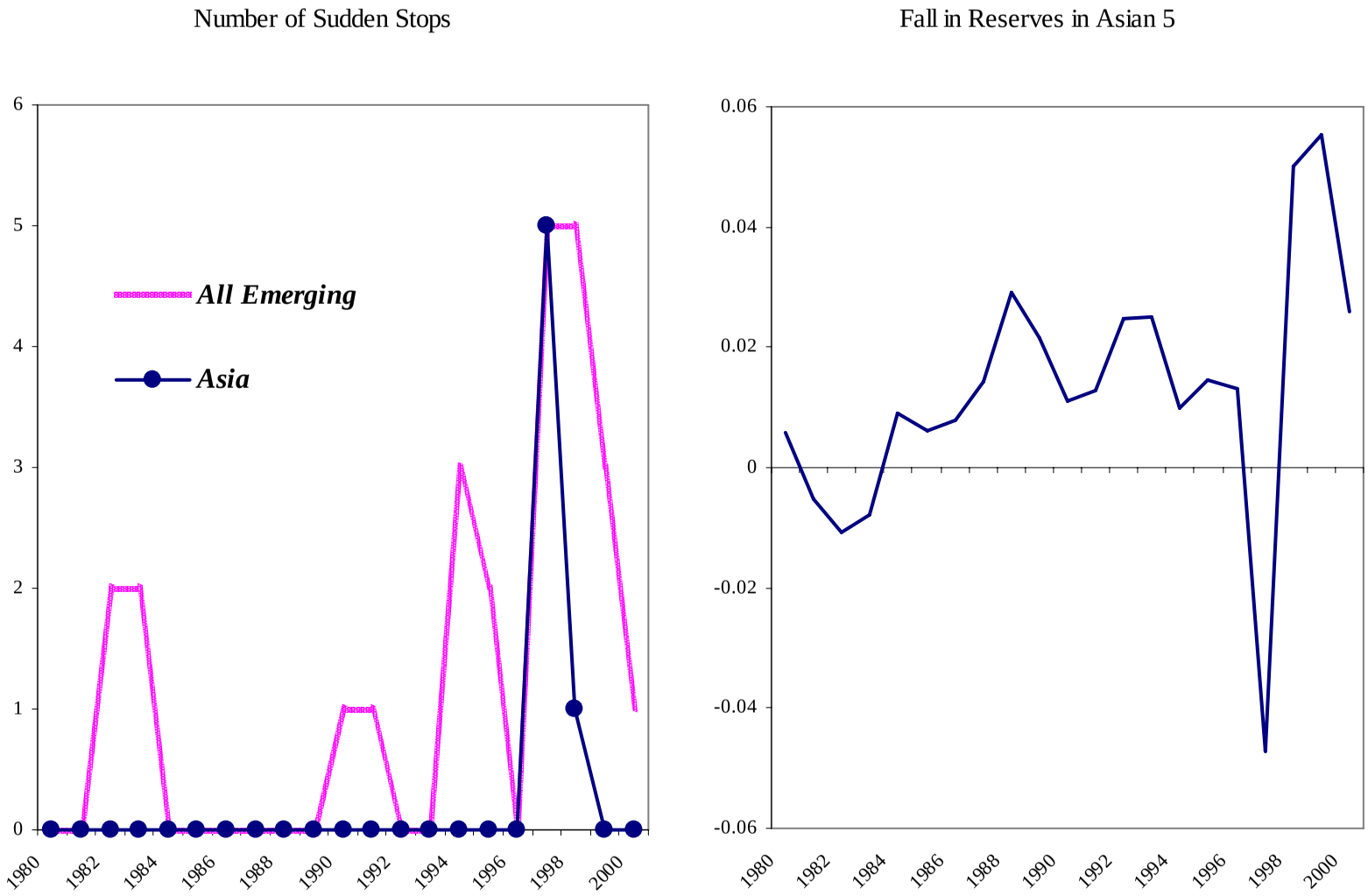


Source: IMF, International Investment Position in Balance of Payments Statistics

Figure 3. Reserve Adequacy Ratios in Emerging Market Countries, 1980-2005

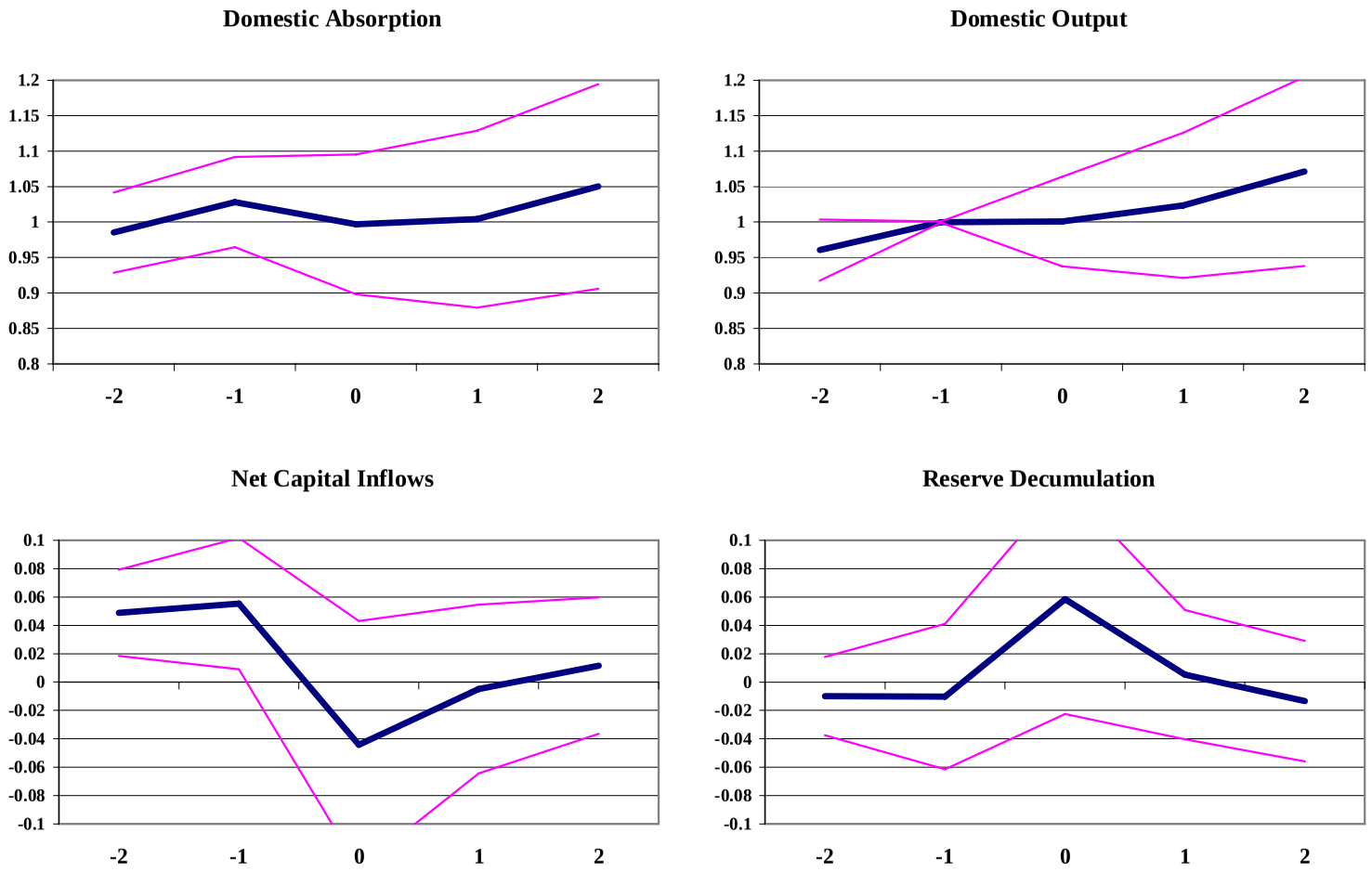
Source: IMF, International Financial Statistics and World Bank, Global Development Finance

Figure 4. Sudden Stops



Source: Frankel and Cavallo (2004) for the number of sudden stops in all emerging and Asian countries. IMF, International Financial Statistics and World Bank, World Development Indicators for the ratio of reserves to GDP in Indonesia, Korea, Malaysia, Philippines and Thailand combined in panel B. The fall in reserves include

Figure 5. Domestic Absorption and International Reserves in Sudden Stops



Note: The five year event window is centered around a sudden stop occurring at time zero. The list of emerging market countries is given in the Data Appendix. The events that occurred before 1980, or inside the five-year window of the previous sudden stop were excluded. All variables are expressed as a fraction of GDP in the year before the sudden stop.

Figure 6. The Opportunity Cost of Reserves

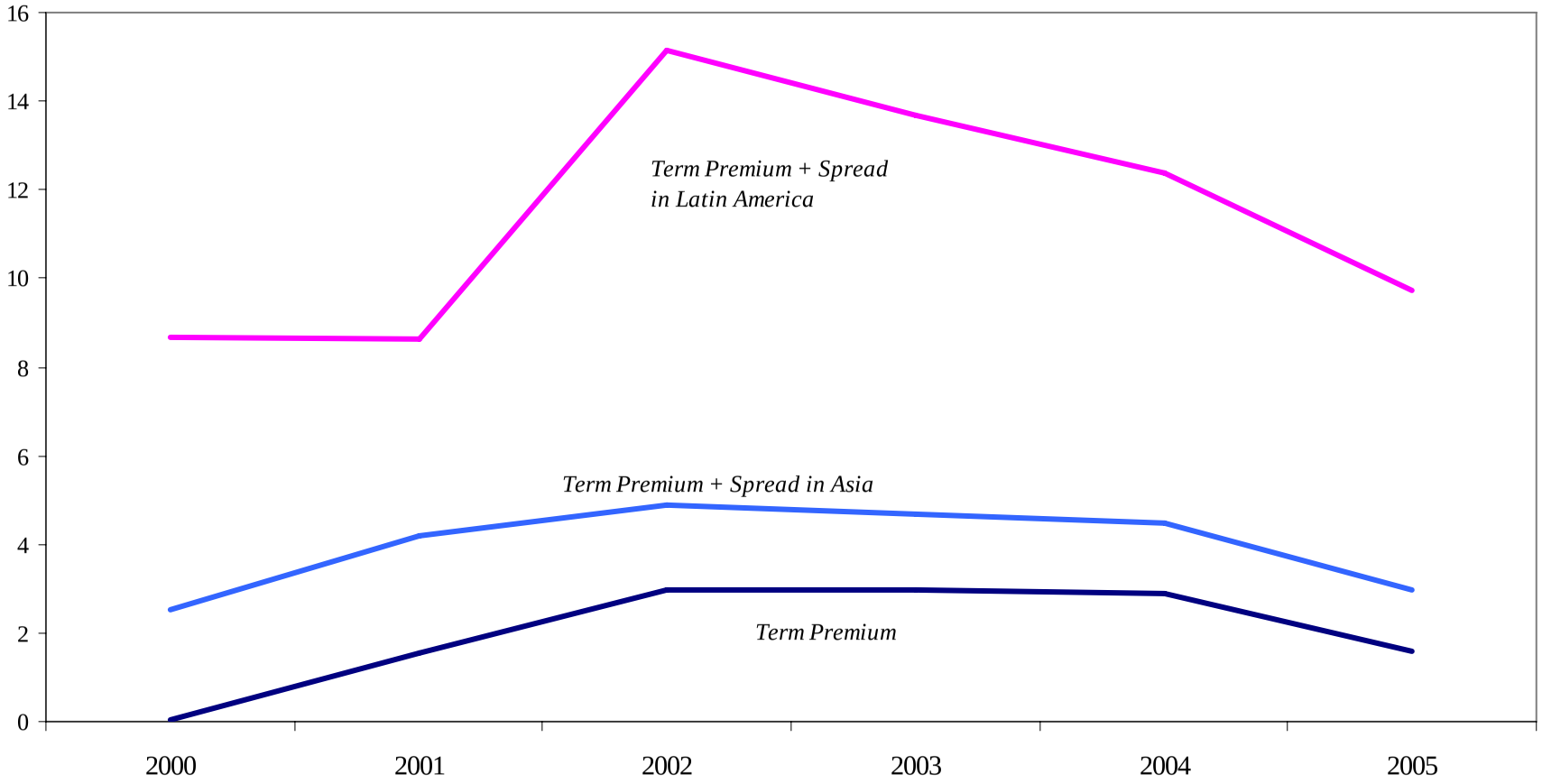
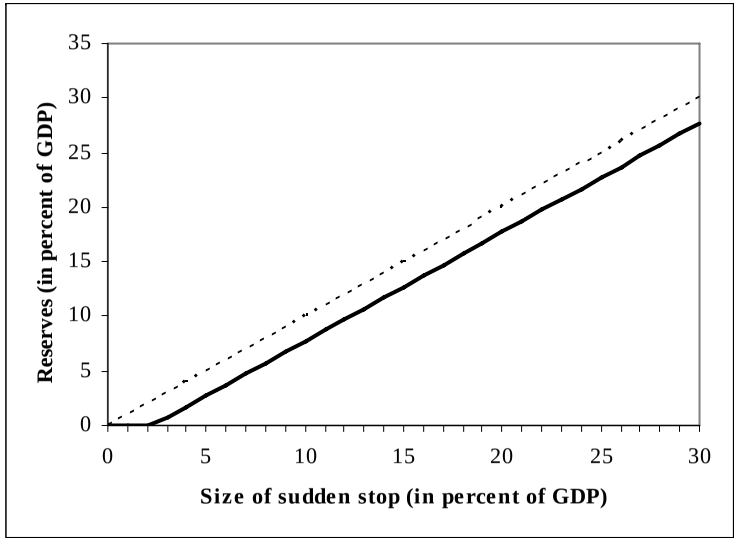
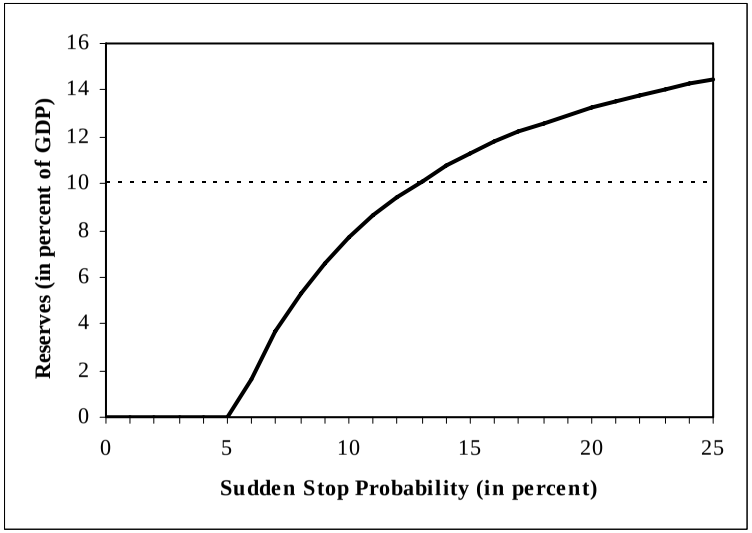
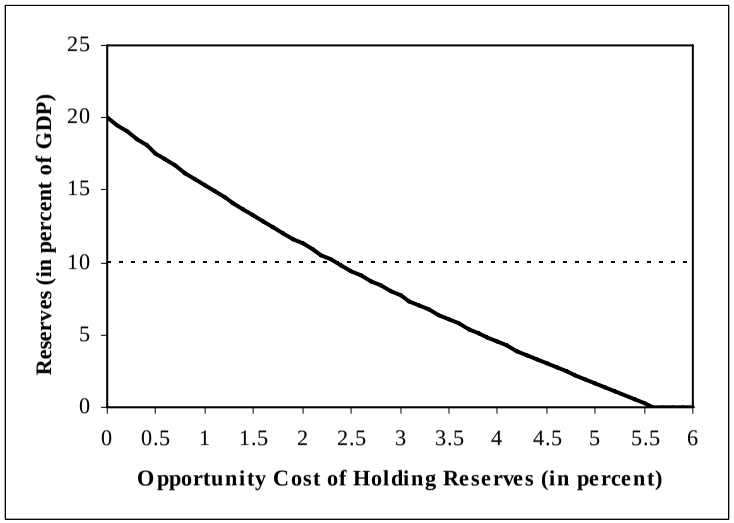


Figure 7. The Optimal Level of Reserves: Sensitivity Analysis







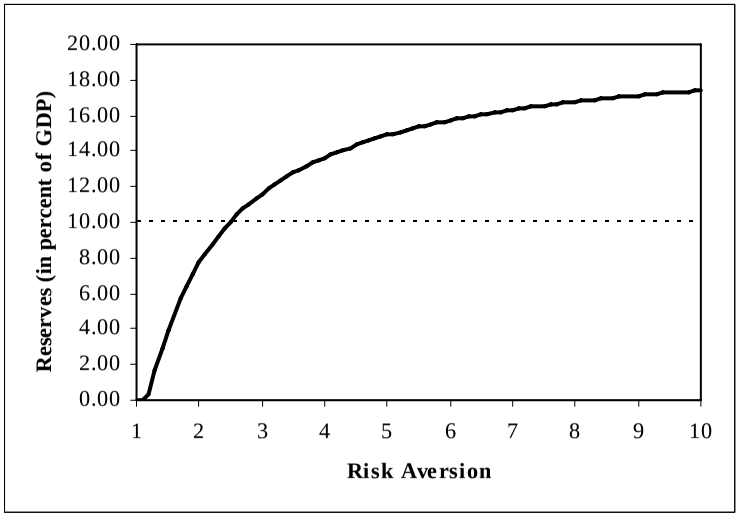


Figure 7 (continued). Crisis prevention and the optimal level of reserves

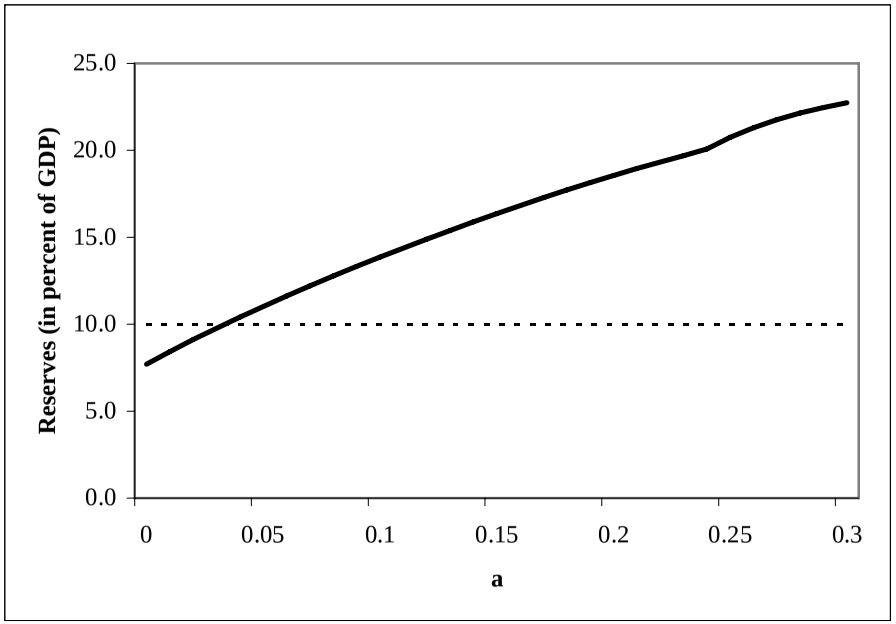
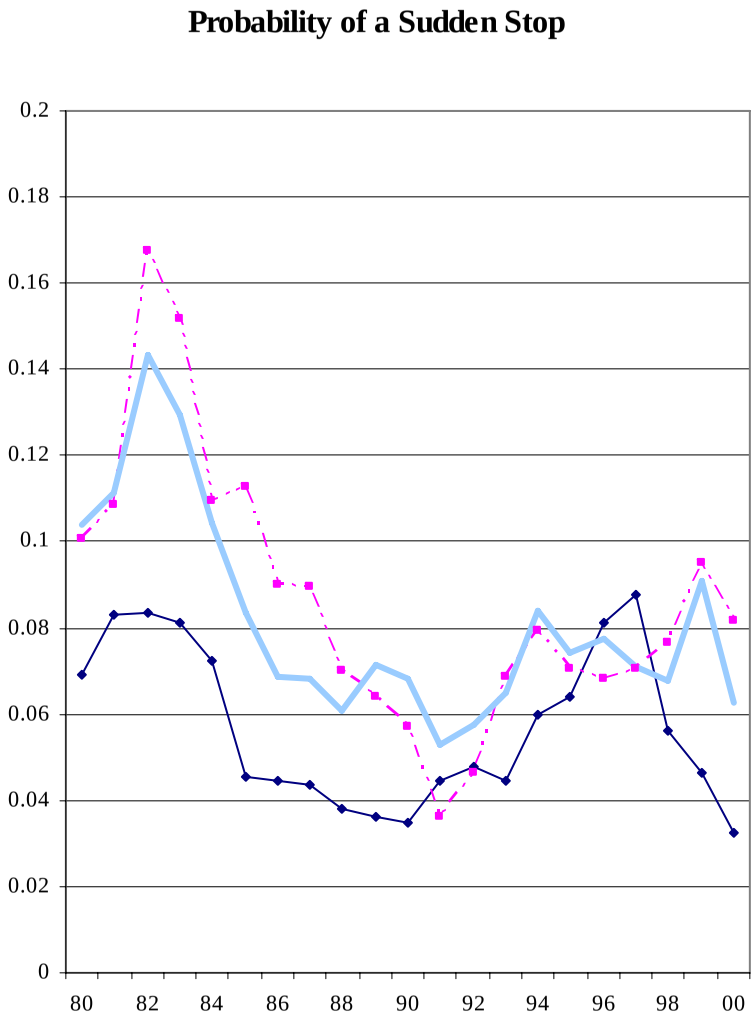
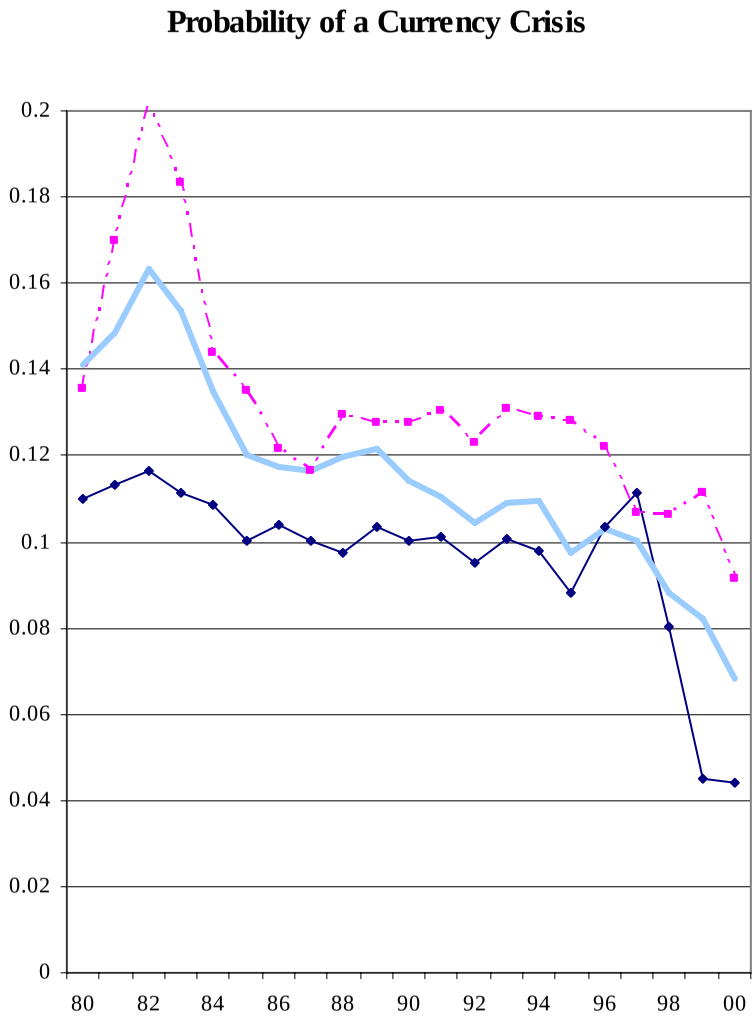


Figure 8. Probabilities of Currency Crises and Sudden Stops





Note: For each country in the sample the probability of a sudden stop in a year is the average of the probability of a sudden stop according to the Jeanne and Ranciere (2006) definition and the probability of a sudden stop according to the Frankel and Cavallo (2004) definition. Similarly, the probability of a currency crisis is the average of the probability of a currency crisis for the Frankel and Rose (1996) definition and the probability of a currency crisis for the Frankel and Wei (2005) definition. The figure depicts averages over regional groups. Asia includes China, India, Indonesia, Korea, Malaysia, Pakistan, Philippines and Thailand; Latin America includes Argentina, Brazil, Chile, Colombia, Dominican Republic, Ecuador, El Salvador, Mexico, Panama, Peru,

Figure 9

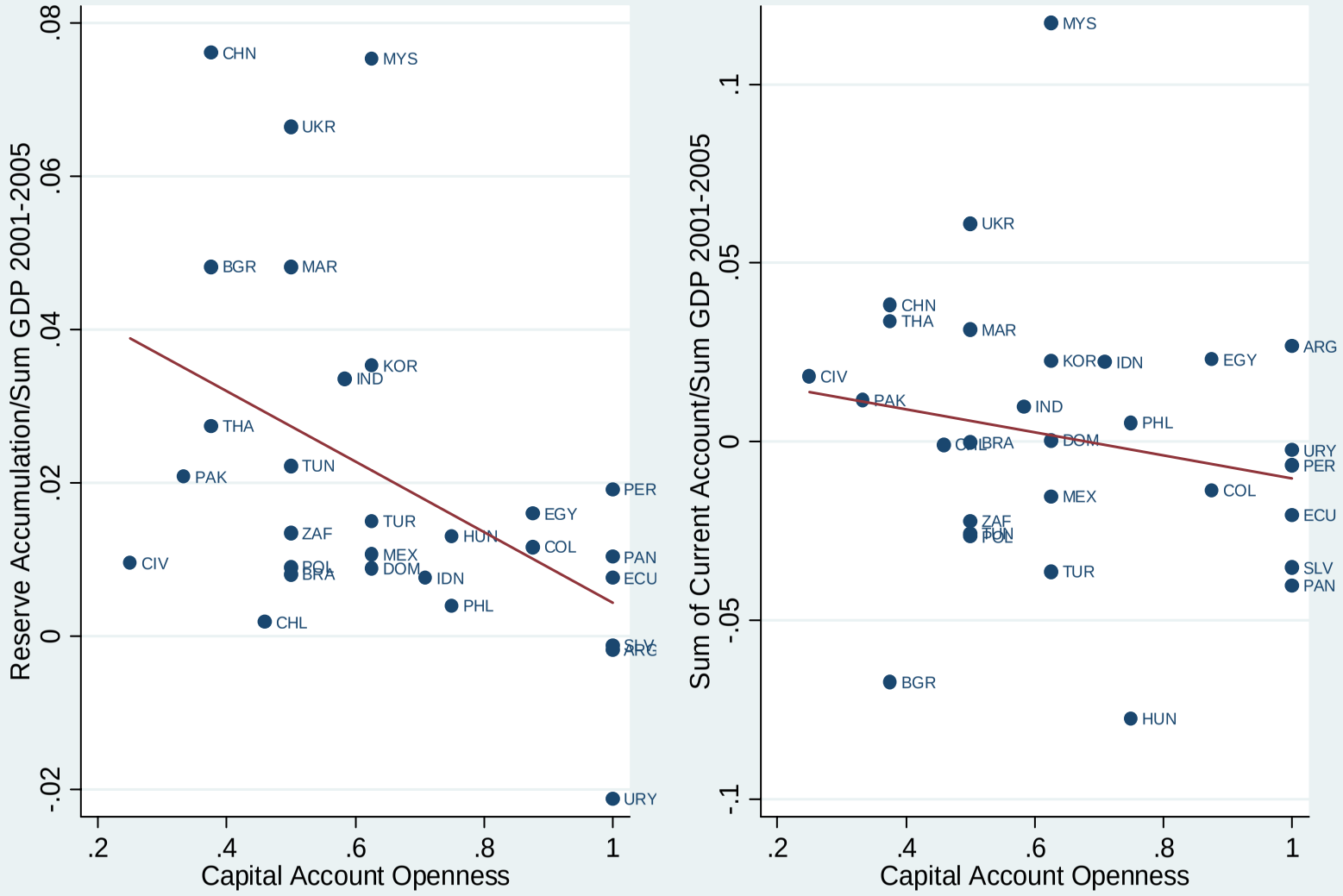

Reserve Accumulation/Sum GDP 2001-2005
-.02
0
.02
.04
.06
.08
CHN
MYS
UKR
BGR
MAR
KOR
IND
THA
TUN
PAK
PER
EGY
ZAF
TUR
HUN
COL
MEX
CIV
DOM
PAN
IDN
ECU
PHL
CHL
URY
.2
.4
.6
.8
1
Capital Account Openness
Sum of Current Account/Sum GDP 2001-2005
-.1
-.05
0
.05
.1
MYS
UKR
CHN
THA
MAR
KOR
IDN
EGY
ARG
CIV
PAK
IND
PHL
DOM
URY
PER
COL
MEX
ECU
ZAF
TUR
SLV
PAN
BGR
HUN
.2
.4
.6
.8
1
Capital Account Openness

Figure 10

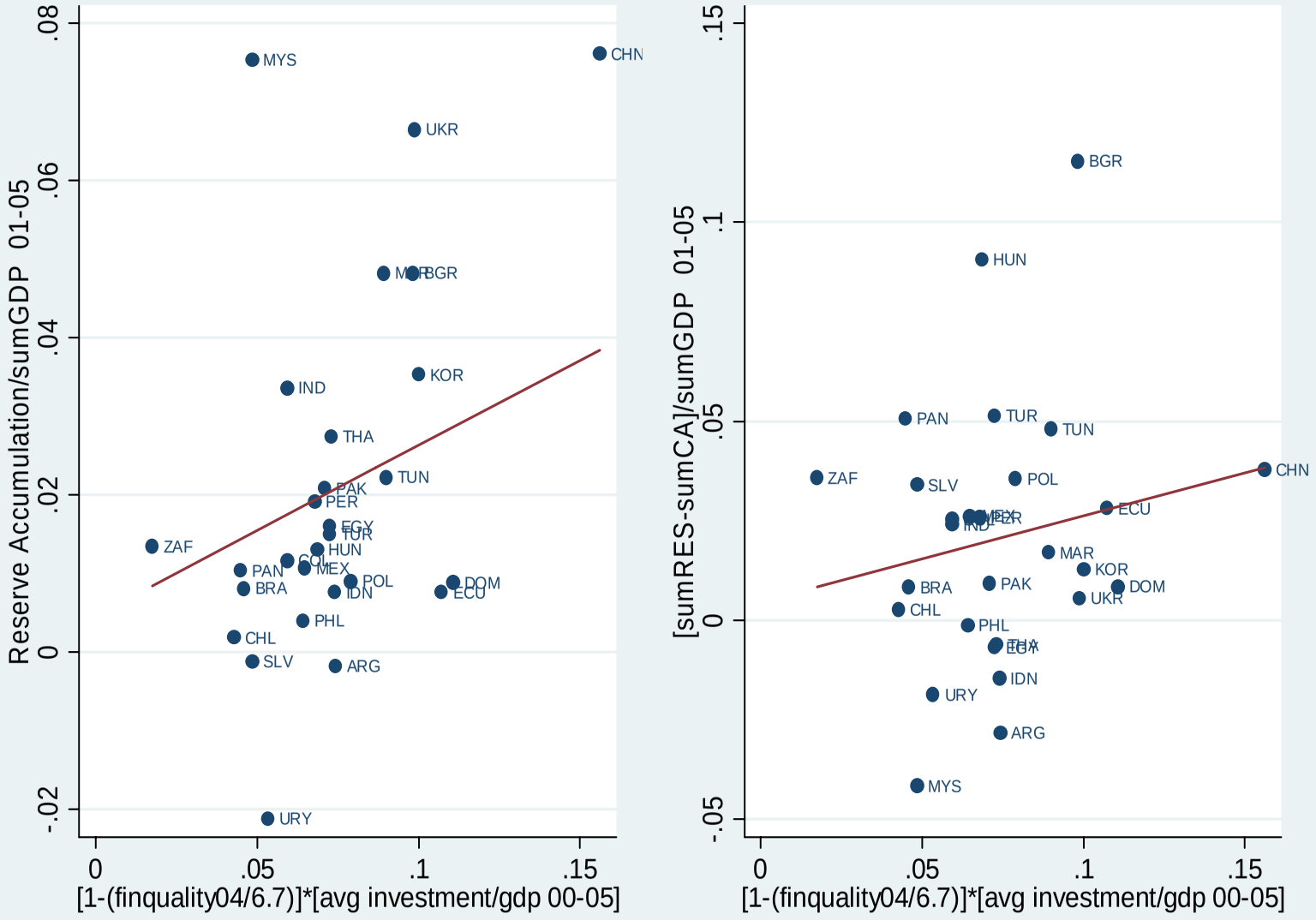

Reserve Accumulation/sumGDP 01-05
-.02
0
.02
.04
.06
.08
MYS
CHN
UKR
BGR
IND
KOR
THA
TUN
PAK
PER
ZAF
HUN
PAN
BRA
POL
IDN
DOM
ECU
PHL
CHL
SLV
ARG
URY
0
.05
.1
.15
[1-(finquality04/6.7)]*[avg investment/gdp 00-05]
[sumRES-sumCA]/sumGDP 01-05
-.05
0
.05
.1
.15
BGR
HUN
PAN
TUR
TUN
ZAF
SLV
POL
CHN
ECU
MAR
KOR
BRA
PAK
DOM
UKR
CHL
PHL
IDN
URY
ARG
MYS
0
.05
.1
.15
[1-(finquality04/6.7)]*[avg investment/gdp 00-05]

Figure 11. Foreign investors' cross-assets allocation of US financial portfolio