Large Hoardings of International Reserves: Are They Worth It?

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Several Asian economies have accumulated large stocks of international reserves over the last few years. This motivates the question we address in this paper from an empirical point of view. Are these large increases in reserves an efficient crisis-prevention strategy? Or are they second-best to other options, such as improving governance and developing better institutions in the financial markets? The current literature does not reach a firm consensus. A number of studies argue that reserve accumulation reduces the likelihood of self-fulfilling speculative attacks.[1] Others, however, stress that reserve accumulation is a relatively costly self-insurance strategy. Moreover, reserve accumulation could also be a counterproductive strategy, while crises are likely to be deeper in the presence of weak financial systems.[2]

In this paper, we estimate a model to quantify the impact of international liquidity on the probability of a crisis. Our goal is to evaluate how robust reserves (or the lack thereof) are in explaining crises, in particular, after we control for the quality of political institutions and the soundness of the financial system. We then use our estimates to evaluate the optimal level of reserves from a cost-benefit analysis for a group of East Asian economies and for Chile.[3]

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1. See, for example, Sachs, Tornell and Velasco (1996); Chang and Velasco (1999); Jeanne and Wyplosz (2001).

2. These points are noted particularly in Caballero and Krishnamurthy (1999, (2000, 2001).

3. Recent research on related topics can be found in Aizenman and Lee (2005).

External Vulnerability and Preventive Policies, edited by Ricardo Caballero, César Calderón, and Luis Felipe Céspedes, Santiago, Chile.

Our results lead us to the conclusion that recent trends in reserve accumulation by some Asian economies seem a sensible approach to dealing with the current macroeconomic conditions in the world economy. The empirical evidence we present indicates that the probability of crisis is still strongly related to the ratio of reserves to short-term debt, even when we control for political and financial system variables. At the same time, the actual size of the reserve stock observed today is not far from what would be implied by the usual cost of a crisis.

Our work is framed around two existing strands of the literature on international reserves. The first strand is the role of reserves as an indicator for financial or currency crisis in the context of the early-warning-system literature.[4] Typically in this literature, an exchange market pressure variable is constructed combining increases in interest rates, the exchange rate, and rapid reserve depletion. This variable attempts to summarize the magnitude of speculative behavior over a wide range of possible policy responses and regimes, and it is therefore not restricted to specific circumstances, such as depreciations after periods of fixed exchange rates. An indicator variable is created that takes the value of one if exchange market pressure is above a specified crisis threshold. The second step in this procedure is to regress this indicator on a set of right-hand-side variables, which typically include the ratio of reserves to short-term debt and the misalignment of the real exchange rate. This framework should thus allow an observer of these variables to assess the likelihood of a currency crisis.

Although we follow the logic of this basic approach in our work, we extend the empirical methodology in two directions. First, we include different variables to capture the effect of financial depth on the likelihood of a crisis. We test whether a deeper, more liquid domestic financial system is related to a lower probability of crisis. Second, we include governance variables. Weak political institutions are prone to deal feebly with financial stress, as they do not have the correct incentives (because of corruption), they lack technical expertise, or their policy actions are not credible to market participants. Our results indicate that the effect of the ratio of reserves to short-term debt on crisis probability is robust to the inclusion of these two sets of variables, and the selected financial and political variables have an empirically ambiguous or weak relation with the probability of a crisis.

4. See Frankel and Rose (1996); Berg and Pattillo (1999); Sachs, Tornell, and Velasco (1996); Berg and others (1999). See also Kaminsky and Reinhart (1999).

The second strand of the literature on which we base our work is the standard model of reserves demand. We use a simple model that relates the optimal level of reserves to its opportunity cost and the expected cost of a crisis. By assuming reasonable values for the latter, we compute theoretical optimal levels for reserves and compare them to actual recent stocks held by a number of Asian countries and Chile. We find that for a crisis cost of between 5 and 15 percent of gross domestic product (GDP), the actual ratio of reserves to short-term debt in some of these Asian countries is below the optimal level derived from the model. At the same time, the implicit cost of a crisis that is consistent with the actual level of reserves held by those countries is in the range of a soft to mild crisis. These results, however, turn out to be very sensitive to the data used and the specification of the model for the crisis probability.

Our approach to explain reserve accumulation emphasizes the role of international liquidity as a tool for self-insuring against external shocks. Dooley, Folkerts-Landau, and Garber (2003, 2004) put forward an alternative explanation for the large reserve accumulation by East Asian economies. According to these authors, this large reserve accumulation—in particular, by China—corresponds, in part, to an export-oriented development strategy, by which governments attempt to systematically keep the real exchange rate undervalued by accumulating reserves. We do not explore this hypothesis in this paper.

The paper is organized as follows. The next section describes some recent trends in reserve accumulation by emerging economies. Section two then presents the empirical methodology used to estimate the probability of a crisis and discusses the main results. Section three computes the optimal level of reserves for a selected group of Asian countries and for Chile. Finally, section four concludes.

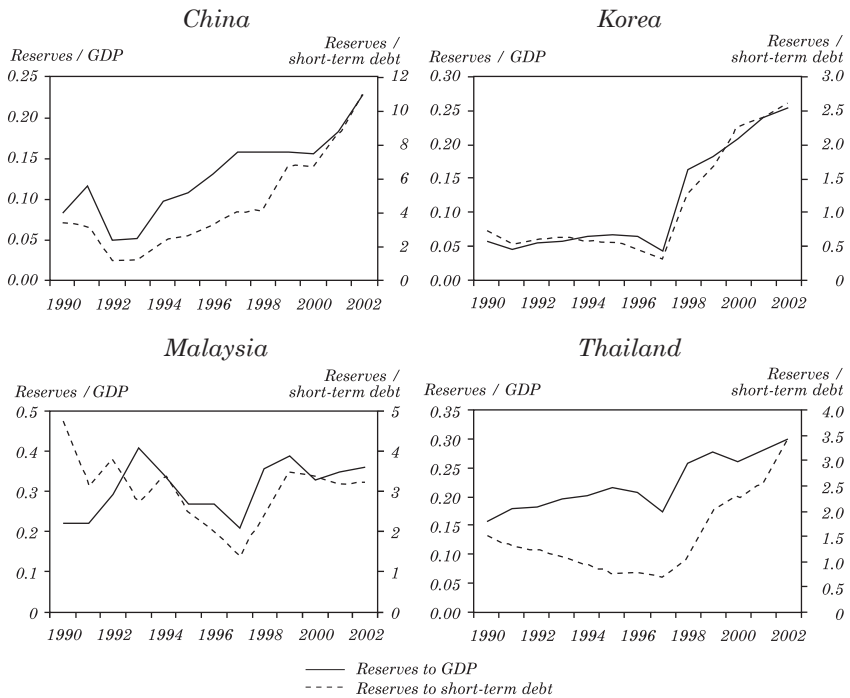
1. Recent Trends in Reserve Accumulation

One of the most remarkable features of the recent trend in reserves is the large accumulation by East Asian economies. By the end of 2003, four East Asian economies (namely, China, Korea, Malaysia, and Thailand) held roughly 25 percent of world's total international reserves. These countries have systematically increased their reserve holdings over the last several years. Measured as a percentage of GDP, reserves in these four East Asian economies on average grew from roughly 10 percent at the end of the 1980s to nearly 30 percent in 2002. Reserves have increased not

only relative to the size of those economies, but also relative to short-term external debt: the ratio of reserves to short-term external debt rose from 2.5, on average, for those four countries in 1990 to 5 by 2002.

These figures are heavily influenced by the trend followed by reserves in China, which increased from less than 10 percent of GDP in 1990 to more than 25 percent of GDP in 2002, and to a lesser extent by the trend in Korea and Thailand (see figure 1). Korea held a relatively constant fraction of GDP in reserves (about 5 percent) until the Asian crisis. After 1998, it dramatically increased its reserve holdings to 25 percent of GDP in 2002. Thailand systematically increased its reserves as a fraction of GDP throughout the 1990s. However, this country also received large capital inflows over these years—until the Asian crisis—so its ratio of reserves to short-term external debt actually felt from 1990 to 1998. After that year, reserves increased systematically, measured both as a fraction of GDP and relative to short-term external debt .

Figure 1. Reserves in four East Asian economies, 1990–2002

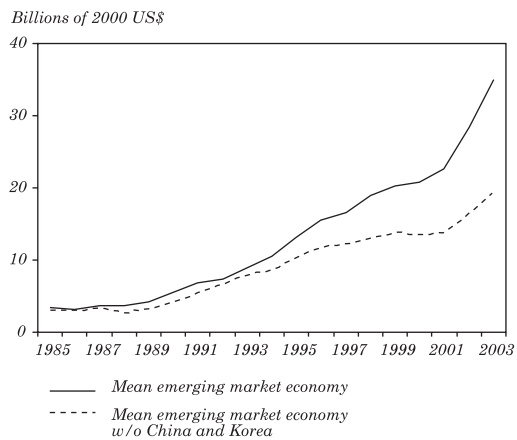


Source: Authors' calculation based on IFS/BIS data.

Malaysia held a relative large stockpile of reserves in the 1990s, measured both as a fraction of GDP (30 percent on average) and relative to short-term external debt (more than twice its stock of short-term external debt, on average). Both ratios fell before the Asian crisis but have grown since.

East Asian economies are not the only countries to have accumulated large amounts of international liquidity. Emerging market economies, in general, have followed a similar pattern, though to a lesser extent (figure 2). Reserves in emerging market economies grew from approximately 5 percent of GDP at the end of the 1980s to 16 percent in 2002 (figure 3).[5] When measured with respect to short-term external liabilities, reserves in emerging market economies also increased systematically after the early 1990s, despite the large capital inflows to those economies during this period. The ratio of reserves to short-term debt in emerging market economies rose, on average, from approximately 1 in 1990 to 2.4 in 2002 (see figure 4).

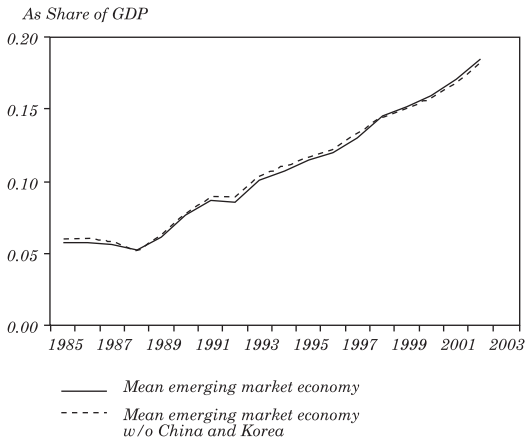
Figure 2. Real Reserves in Emerging Market Economies



Source: Authors' calculations based on IFS data.

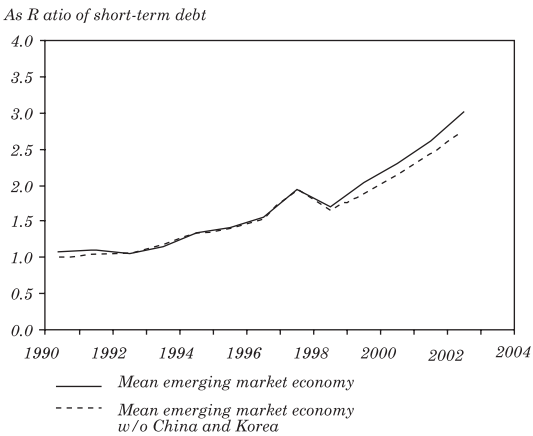
5. In contrast, developed economies have maintained a relatively constant ratio of reserves to GDP of about 6 percent since the mid-1980s.

Figure 3. Reserves in Emerging Market Economies as a Share of GDP



Source: Authors' calculations based on IFS data.

Figure 4. Reserves in Emerging Market Economies as Ratio of Short-Term Debt



Source: Authors' calculations based on IFS/BIS data.

2. Reserve Accumulation and Crisis Probability

Recent literature on international crises emphasizes the role of international reserves in preventing financial or currency crisis.[6] Rather than serving as a buffer to absorb transitory current account shocks—(as was emphasized in the literature on reserve adequacy in the 1950s and 1960s), reserves are now perceived as a tool for reducing both the frequency and the impact of international crisis. This role of international reserves has been widely analyzed, both theoretically and empirically. However, the quantitative contribution of reserves to reducing the risk of a crisis has only recently been addressed. Bussière and Mulder (1999), for example, find that the ratio of short-term debt to reserves is significant in predicting a crisis. They also quantify how much liquidity (reserves) countries should have to counteract weak fundamentals and avoid a crisis. In this section, we follow the early-warning-system literature to quantitatively estimate the robustness of the contribution of reserves in reducing the probability of an international crises.

2.1 Empirical Approach

The literature usually posits a specification that relates the probability of a crisis to the ratio of reserves to a selected scaling variable and a number of other controls. Consistent with recent theoretical emphasis on liquidity to explain crisis, we consider as a scaling variable the short-term debt of the country.

For the sake of simplicity, we denominate $p_{i,t}$ the probability of a crisis in country i at time t, and we assume that it is a function of a linear combination of the ratio of reserves to short-term debt at the beginning of period t, $R_{i,t} / S_{i,t}$, the total debt to GDP ratio, $D_{i,t} / Y_{i,t}$, another set of variables contained in vector $\mathbf{Z}_{i,t}$, and a crisis shock, $\varepsilon_{i,t}$:

$$p_{i,t} = p\left(\beta_0 \frac{R_{i,t}}{S_{i,t}} + \beta_1 \frac{D_{i,t}}{Y_{i,t}} + \mathbf{Z}_{i,t}\gamma - \varepsilon_{i,t} \right). \tag{1}$$

In this formulation the ratio of reserves to short-term debt is a measure of the liquidity of the economy, and the ratio of total debt to GDP is a proxy for solvency. Therefore, $\beta_0 < 0$ and $\beta_1 > 0$.

6. The theoretical literature includes, for example, Calvo (1996), Chang and Velasco (1999), and Jeanne and Wyplosz (2001).

We estimate the crisis probability based on a panel of countries with yearly observations. To define a crisis episode, we use the standard measure of exchange market pressure (EMP), by constructing a weighted average of the first differences in the real exchange rate, and the level of reserves,[7]

$$\mathrm{EMP}_{i,t} = \omega_{rer} \frac{\mathrm{RER}_{i,t} - \mathrm{RER}_{i,t-1}}{\mathrm{RER}_{i,t-1}} + \omega_R \frac{R_{i,t} - R_{i,t-1}}{R_{i,t-1}}, \tag{2}$$

where $\mathrm{RER}_{i,t}$ is the average real exchange rate of country i in year t, and $R_{i,t}$ is the level of reserves (real) at the end of year t. Weights correspond to the inverse of the variance of each variable for all countries over the full sample. A crisis episode occurs in period t in country i if $\mathrm{EMP}_{i,t}$ exceeds a predetermined threshold value, $\bar{X}$. In particular, we define a crisis index as follows:

$$Y_{i,t} = \begin{cases} 1 & \text{if } \mathrm{EMP}_{i,t} > \overline{\mathrm{EMP}}_i + 2\mathrm{SD}(\mathrm{EMP}_i) \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

In this framework, the crisis probability corresponds to the probability of the event $Y_{i,t} = 1$. This probability cannot be measured ex ante, as only the effective ex post occurrence of crises can be observed. Moreover, the latter hinges on the particular definition of the threshold value, $\bar{X}$. For the sake of our main argument, we abstract from these considerations for now, and assume that a well-defined function relates macroeconomic variables to this probability of crisis for country i in period t:

$$\Pr(Y_{i,t} = 1) = F\left(\beta_0 \frac{R_{i,t}}{S_{i,t}} + \beta_1 \frac{D_{i,t}}{Y_{i,t}} + \mathbf{Z}_{i,t}\gamma - \varepsilon_{i,t}\right). \tag{4}$$

Equation 4 indicates that the probability of a crisis occurring in period t is a nonlinear function, F, of a linear combination of the ratio of reserves to short-term debt and other variables included in vector $\mathbf{Z}_{i,t}$, such as the deviation of the real exchange rate from its fundamental or long-run value, GDP growth, and the exchange rate regime.

7. Bussière and Fratzscher (2002) use a similar measure, but they also consider pressures absorbed by interest rate movements. In our case, we cover a longer time span, and incorporating interest rate movements would have decreased the data significantly. Other works that use a similar crisis indicator are Kamin and Babson (1999) and Kruger, Osakwe, and Page (1998).

For the empirical application, we assume that F is a logistic function. In other words,

$$p_{i,t} = \frac{\exp\left(\beta_0 \frac{R_{i,t}}{S_{i,t}} + \beta_1 \frac{D_{i,t}}{Y_{i,t}} + \mathbf{Z}_{i,t}\gamma - \varepsilon_{i,t}\right)}{1 + \exp\left(\beta_0 \frac{R_{i,t}}{S_{i,t}} + \beta_1 \frac{D_{i,t}}{Y_{i,t}} + \mathbf{Z}_{i,t}\gamma - \varepsilon_{i,t}\right)}. \quad (5)$$

2.2 Quantifying the Effect of Reserves on Crisis Probability

This subsection presents benchmark estimates of crisis probability. Estimations were made using a logit model with yearly observations for the period 1975–2003. These estimates clearly highlight two of the results found in the literature, despite the lower frequency of our data and the longer time span. First, a low ratio of reserves to, among other measures of liabilities, short-term external debt, by the end of a year, increases the probability of a crisis in the subsequent year. Second, a large deviation of the real exchange rate from trend in a given year increases the probability of crisis in the subsequent year. The magnitudes involved are large.

Tables 1 through 3 present the results of a number of estimates using three scaling variables for reserves. Tables 1 and 2 present the results using short-term debt from different sources, while table 3 uses total external debt.[8]

Short-term debt is usually chosen as the scaling variable for reserves in crisis models. In circumstances of financial stress, however, a liquidation of assets held by investors (both local and foreign) need not be constrained to their holdings of short-term external debt. Domestic agents can liquidate their own holdings of money (a central bank liability), while holders of external debt can attempt to shift their portfolio away from all external liabilities. This justifies trying other definitions of the relevant scaling variables for reserves.

8. The data on short-term debt are from the Bank for International Settlements (BIS) and the World Bank's *World Development Indicators* database. The main difference between the two sources is that the BIS data include not only debt with maturity of up to one year, but also amortizations due within the year. Unfortunately, this database starts in the 1990s and is available only for emerging economies.

Table 1. Benchmark Estimation of Crisis Probability, with Liquidity Measured as Reserves to Short-Term Debt: BIS Data[a]

Explanatory variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
REER MIS	–5.389	–5.638	–9.107	–8.91	–5.458	–5.763	–9.159	–8.97
	(3.88)**	(3.89)**	(4.69)**	(4.65)**	(3.82)**	(3.84)**	(4.56)**	(4.44)**
OPEN	1.584	2.603	3.192	3.592	2.148	3.317	3.461	4.015
	(0.90)	(1.55)	(1.77)*	(2.03)*	(1.18)	(1.88)*	(1.89)*	(2.21)*
R/STD	–0.391	–0.438	–0.504	–0.573	–0.468	–0.55	–0.529	–0.62
	(1.90)*	(1.88)*	(2.01)*	(1.97)*	(2.07)*	(2.11)*	(2.07)*	(2.04)*
TD/GDP	–0.336		–1.609		–0.416		–1.57	
	(0.42)		(1.91)*		(0.52)		(1.89)*	
CRED	0.313	0.318	0.512	0.528	0.438	0.478	0.572	0.611
	(1.08)	(1.08)	(1.24)	(1.26)	(1.42)	(1.50)	(1.34)	(1.39)
PUB. DEBT		–1.206		–2.153		–1.32		–2.102
		(1.22)		(2.21)*		(1.31)		(2.18)*
Growth			–14.83	–13.593			–14.332	–12.858
			(4.07)**	(3.85)**			(3.86)**	(3.55)**
Exports					–3.17	–3.885	–1.915	–2.583
					(1.69)*	(1.97)*	(0.98)	(1.25)
FIX	1.688	0.928	2.348	1.595	1.767	1.029	2.299	1.54
	(1.69)*	(0.85)	(2.23)*	(1.39)	(1.74)*	(0.93)	(2.21)*	(1.35)
MANAGED	0.737	0.557	0.888	0.792	0.697	0.534	0.761	0.656
	(0.90)	(0.68)	(1.06)	(0.94)	(0.84)	(0.65)	(0.91)	(0.78)
FLOAT	0.828	0.78	0.829	0.783	0.791	0.736	0.778	0.736
	(0.99)	(0.93)	(0.94)	(0.88)	(0.94)	(0.87)	(0.89)	(0.84)
Constant	–3.946	–3.771	–3.436	–3.445	–3.799	–3.626	–3.34	–3.348
	(4.25)**	(4.17)**	(3.71)**	(3.78)**	(4.02)**	(3.91)**	(3.60)**	(3.64)**
Summary statistic								
Pseudo R^2	0.13	0.14	0.24	0.24	0.15	0.16	0.24	0.24
No. observations	512	480	511	479	506	474	505	473
No. crisis	24	23	24	23	24	23	24	23

Source: Authors' calculations, based on data from the Bank for International Settlements (BIS).
** Statistically significant at 1 percent.
a. Absolute value of z statistics are in parentheses. See appendix for definition of explanatory variables.

Table 2. Benchmark Estimation of Crisis Probability, with Liquidity Measured as Reserves to Short-Term Debt: World Bank Data[a]

Explanatory variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
REER MIS	–5.09	–5.095	–5.686	–5.722	–5.104	–5.101	–5.662	–5.684
	(5.99)**	(5.98)**	(6.12)**	(6.12)**	(5.84)**	(5.82)**	(6.02)**	(6.01)**
OPEN	0.278	0.639	0.026	0.287	0.427	0.757	0.107	0.35
	(0.21)	(0.48)	(0.02)	(0.21)	(0.31)	(0.57)	(0.08)	(0.26)
R/STD	–0.267	–0.291	–0.245	–0.257	–0.271	–0.291	–0.245	–0.256
	(1.89)*	(2.03)*	(1.78)*	(1.84)*	(1.91)*	(2.03)*	(1.76)*	(1.82)*
TD/GDP	–0.013		–0.362		–0.01		–0.303	
	(0.02)		(0.69)		(0.02)		(0.58)	
CRED	0.143	0.152	0.339	0.36	0.239	0.248	0.383	0.4
	(0.55)	(0.58)	(1.24)	(1.31)	(0.90)	(0.93)	(1.39)	(1.44)
PUB. DEBT		–0.499		–0.881		–0.464		–0.781
		(0.77)		(1.34)		(0.72)		(1.19)
Growth			–5.918	–6.154			–5.368	–5.597
			(3.20)**	(3.30)**			(2.86)**	(2.95)**
Exports					–2.197	–2.183	–1.452	–1.379
					(2.10)*	(2.10)*	(1.36)	(1.28)
FIX	0.771	0.692	0.914	0.849	1.002	0.927	1.035	0.969
	(1.21)	(1.08)	(1.43)	(1.32)	(1.54)	(1.42)	(1.59)	(1.48)
MANAGED	–0.002	–0.014	–0.103	–0.1	0.048	0.033	–0.082	–0.083
	(0.00)	(0.04)	(0.25)	(0.24)	(0.12)	(0.08)	(0.20)	(0.20)
FLOAT	0.513	0.531	0.286	0.306	0.524	0.538	0.309	0.327
	(1.24)	(1.28)	(0.67)	(0.71)	(1.25)	(1.29)	(0.72)	(0.76)
Constant	–3.133	–3.006	–2.608	–2.517	–3.137	–3.015	–2.657	–2.566
	(6.04)**	(6.10)**	(4.89)**	(4.99)**	(5.93)**	(5.99)**	(4.90)**	(5.01)**
Summary statistic								
Pseudo R^2	0.17	0.17	0.2	0.2	0.18	0.18	0.2	0.2
No. observations	897	897	874	874	891	891	868	868
No. crisis	55	55	54	54	55	55	54	54

Source: Authors' calculations, based on data from the World Bank's *World Development Indicators*.
* Statistically significant at 10 percent.
** Statistically significant at 1 percent.
a. Absolute value of z statistics are in parentheses. See appendix for definition of explanatory variables.

Table 3. Benchmark Estimation of Crisis Probability, with Liquidity Measured as Reserves to Total Debt: World Bank Data[a]

Explanatory variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
REER MIS	–4.6	–5.147	–7.277	–5.674	–4.551	–5.174	–7.231	–5.668
	(3.61)**	(6.07)**	(4.26)**	(6.12)**	(3.44)**	(5.94)**	(4.17)**	(6.04)**
OPEN	0.985	0.565	1.178	–0.067	1.213	0.668	1.36	0.067
	(0.56)	(0.43)	(0.67)	(0.05)	(0.68)	(0.51)	(0.77)	(0.05)
R/TD	–2.58	–3.15	–1.952	–2.476	–2.716	–3.228	–2.072	–2.592
	(1.45)	(2.50)*	(1.04)	(1.97)*	(1.49)	(2.50)*	(1.10)	(2.01)*
STD/TD (BIS)	0.856		1.271		1.062		1.341	
	(1.03)		(1.46)		(1.23)		(1.50)	
CRED	0.329	0.125	0.49	0.307	0.428	0.214	0.53	0.349
	(1.13)	(0.48)	(1.33)	(1.12)	(1.39)	(0.82)	(1.41)	(1.27)
STD/TD (World Bank)		1.857		1.977		1.75		1.803
		(1.22)		(1.30)		(1.15)		(1.18)
Growth			–11.613	–5.291			–11.183	–4.765
			(3.65)**	(2.91)**			(3.48)**	(2.59)**
Exports					–2.471	–2.153	–1.427	–1.51
					(1.37)	(2.05)*	(0.76)	(1.40)
FIX	2.236	0.977	2.731	1.099	2.319	1.247	2.691	1.254
	(2.05)*	(1.47)	(2.39)*	(1.66)*	(2.08)*	(1.83)*	(2.35)*	(1.85)*
MANAGED	1.251	0.108	1.489	0.02	1.264	0.159	1.399	0.041
	(1.43)	(0.26)	(1.65)*	(0.05)	(1.42)	(0.39)	(1.56)	(0.10)
FLOAT	1.153	0.602	1.078	0.39	1.16	0.612	1.052	0.413
	(1.26)	(1.45)	(1.14)	(0.91)	(1.26)	(1.46)	(1.12)	(0.96)
Constant	–4.478	–3.443	–4.656	–3.156	–4.448	–3.416	–4.566	–3.138
	(4.52)**	(6.44)**	(4.63)**	(5.94)**	(4.40)**	(6.32)**	(4.53)**	(5.82)**
Summary statistic								
Pseudo R^2	0.12	0.17	0.2	0.2	0.13	0.18	0.2	0.2
No. observations	512	897	511	874	506	891	505	868
No. crisis	24	55	24	54	24	55	24	54

Source: Authors' calculations, based on data from the World Bank's *World Development Indicators*.
* Statistically significant at 10 percent.
** Statistically significant at 1 percent.
a. Absolute value of z statistics are in parentheses. See appendix for definition of explanatory variables.

In tables 1 and 2 the coefficient of reserves to short-term debt is statistically significant at 10 percent in all specification. In table 3 (using total external debt), half the specifications lead to a statistically significant estimate for the effect of the ratio of reserves to total debt. Moreover, the exchange rate deviation from trend is statistically related to the probability of a crisis in essentially all the specifications in all three tables.

We expanded these basic estimates with a number of other variables that are included in the literature. The effect of the inclusion of these variables, as well as their estimated impact, is discussed in what follows.

The effect of different measures of liabilities

Including as an additional explanatory variable the total stock of external debt, as a percentage of GDP, does not affect either the size or significance of the impact of the ratio of reserves to short-term debt and exchange rate deviations from trend in tables 1 through 3. It also does not appear to significantly affect the probability of a crisis.

In table 3, the inclusion of the structure of external debt similarly does not have a significant impact. However, if the ratio of reserves to total debt is used instead, then the estimated coefficient is an order of magnitude larger than the coefficient on the ratio of reserves to short-term debt in previous specifications.

This result must be interpreted with caution, as it is a product of the scaling of the variables and not a marginal contribution to the crisis probability. When we also incorporate the structure of external debt, the ratio of short-term to long-term debt appears to increase the crisis probability, but not with a statistically significant coefficient.

Economic growth and credit booms

Economic growth, measured as both aggregate GDP growth and export growth, appears to strongly influence the probability of a crisis in the expected way. This can stem from a number of causes. A fast pace of economic growth can reduce the demand for publicly provided assistance programs and allow for increased tax revenue over the cycle, while fast export growth, given domestic demand growth, reduces the current account deficit. Including both export growth and GDP growth indicates that the latter is the most significantly related to crisis probability.

Domestic credit expansion, on the other hand, has a positive impact on crisis probability. However, it is not statistically significant at conventional levels.

External conditions

In principle, one should expect that crises would be more likely whenever external conditions deteriorate. Declining terms of trade, an increase in international interest rates, and the interaction of the latter with the outstanding stock of external debt should make for difficult circumstances.

However, the results from our estimations are mixed. When we control for the ratio of reserves to short-term debt and for the deviation of the real exchange rate from trend, the effect of the terms of trade on crisis probability is far from clear-cut. Several exploratory specifications (not reported) suggest that a positive terms-of-trade shock—identified by either the change over previous periods or the deviation from a Hodrick-Prescott trend–increases the probability of a crisis. Another striking result is the lack of a statistically significant direct relation between changes in international interest rates (proxied here by the U.S. Treasury bill rate) and crisis probability.[9]

These odd results, if they stand closer scrutiny, could result from correlations with our main variables that relate to the crisis probability: the ratio of reserves to short-term debt and the deviations of the exchange rate from trend. A fall in the terms of trade or an increase in international interest rates could influence crisis probability through its impact on reserve policy. Evidence on this front is suggestive.[10]

The interaction term between international interest rates and the stock of total external debt (a common measure of the financial burden of external debt) is statistically related to crisis probability in only one specification.

Exchange rate regime

The stock of reserves is related to the exchange rate regime in a trivial way. A fixed exchange rate regime should lead to a close relation between the adjustment of the money market and movements in

9. Results are available in García and Soto (2004).

10. García (1999) finds that, in contrast to the predictions of standard models of reserve demand, the correlation between reserves and international interest rates is negative for emerging economies. Exploring regressions that include the ratio of reserves to short-term debt lead to a positive, but only slightly significant, effect of the international interest rate on crisis probability.

reserves, while a floating exchange rate regime should allow reserves to move more independently of monetary developments. A more difficult question is whether countries with a particular exchange rate regime would choose to hoard more or less reserves, on average. This is linked to is the sensitivity of a particular exchange rate regime to crises. To assess this latter issue, we include a measure of the exchange rate regime as an additional regressor in our crisis probability specifications. We use Reinhart and Rogoff's (2002) measure of exchange rate regimes, extrapolated for the period 2000 to 2002. To prevent the simultaneity problem that would arise from including the contemporaneous exchange rate regime and the occurrence of a crisis, we lag the regime variable by two years. The results obtained are included in tables 1 through 3. We find that the exchange rate regime is, in fact, related to crisis probability. The results are robust to a number of different specifications and measures of reserves, and they show that, compared to the baseline of a hard peg, fixed regimes are more prone to crisis. Flexible regimes, on the other hand, are not particularly less prone to crisis, as could be expected.

Hence, our results show that the worst choice, in terms of external vulnerability, is a weak commitment to a fixed exchange rate. This result is consistent with the commonly held view that economies have tended to abandon intermediate regimes for either a full float or a hard peg (Fischer, 2003).

2.3 Different Measures of Crises

In related literature, an alternative variable often chosen to indicate the occurrence of a crisis is a large current account reversal. We estimated similar specifications as those presented above, replacing the exchange rate market pressure variable with the occurrence of a large swing in the current account (more than 4 percent). Baseline results are presented in tables 4 through 6. The scaled reserve variable remains statistically significant in all cases, while the real exchange rate misalignment is still strongly related to this crisis measure. The specifications that include the exchange rate regime variable still have the same implications for the fixed regimes as the previous results, but they are statistically significant in only a few cases. However, flexible exchange rate regimes now seem to reduce the likelihood of crises, though the coefficients are not statistically significant. One variable that appears to be strongly related to the current account reversal is a measure of the openness of the economy.

Table 4. Benchmark Estimation of Crisis Probability (measured by Current Account reversals), with Liquidity Measured as Reserves to Short-Term Debt: BIS Data[a]

Explanatory variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
REER MIS	–3.013	–2.9	–2.841	–2.79	–2.625	–2.506	–2.41	–2.362
	(2.63)**	(2.52)*	(2.41)*	(2.36)*	(2.27)*	(2.15)*	(2.03)*	(1.98)*
OPEN	4.222	4.311	4.173	4.293	4.261	4.347	4.204	4.329
	(3.99)**	(4.08)**	(3.92)**	(4.06)**	(3.97)**	(4.06)**	(3.90)**	(4.04)**
R/STD	–0.458	–0.432	–0.456	–0.434	–0.463	–0.439	–0.459	–0.44
	(2.66)**	(2.58)**	(2.65)**	(2.59)**	(2.62)**	(2.55)*	(2.60)**	(2.56)*
TD/GDP	0.539		0.601		0.474		0.549	
	(1.24)		(1.34)		(1.08)		(1.21)	
CRED	–3.091	–2.999	–3.223	–3.093	–2.662	–2.589	–2.806	–2.696
	(3.85)**	(3.74)**	(3.82)**	(3.67)**	(3.19)**	(3.11)**	(3.24)**	(3.12)**
PUB. DEBT		0.664		0.704		0.572		0.618
		(1.32)		(1.37)		(1.12)		(1.19)
Growth			1.186	0.87			1.493	1.139
			(0.58)	(0.43)			(0.72)	(0.55)
Exports					–2.064	–1.937	–2.171	–2.018
					(1.58)	(1.50)	(1.64)	(1.55)
FIX	0.774	0.668	0.764	0.656	0.799	0.667	0.786	0.65
	(1.18)	(1.01)	(1.16)	(1.00)	(1.21)	(1.00)	(1.19)	(0.98)
MANAGED	0.237	0.105	0.237	0.096	0.183	0.049	0.181	0.037
	(0.52)	(0.23)	(0.52)	(0.21)	(0.40)	(0.11)	(0.39)	(0.08)
FLOAT	–0.512	–0.603	–0.502	–0.599	–0.623	–0.719	–0.616	–0.718
	(0.99)	(1.17)	(0.97)	(1.16)	(1.17)	(1.35)	(1.15)	(1.35)
Constant	–3.315	–3.184	–3.384	–3.22	–3.148	–3.01	–3.229	–3.052
	(5.65)**	(5.81)**	(5.57)**	(5.74)**	(5.30)**	(5.41)**	(5.26)**	(5.38)**
Summary statistic								
Pseudo R^2	0.13	0.13	0.13	0.13	0.14	0.13	0.14	0.13
No. observations	567	528	565	526	561	522	559	520
No. crisis	51	51	51	51	50	50	50	50

Source: Authors' calculations, based on data from the Bank for International Settlements (BIS).
* Statistically significant at 10 percent.
** Statistically significant at 1 percent.
a. Absolute value of z statistics are in parentheses. See appendix for definition of explanatory variables.

Table 5. Benchmark Estimation of Crisis Probability (measured by Current Account reversals), with Liquidity Measured as Reserves to Short-Term Debt: World Bank Data[a]

Explanatory variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
REER MIS	–0.214	–0.194	–0.254	–0.248	–0.107	–0.091	–0.117	–0.11
	(0.36)	(0.33)	(0.43)	(0.42)	(0.18)	(0.16)	(0.20)	(0.19)
OPEN	2.76	2.835	2.736	2.799	2.971	3.042	2.971	3.038
	(3.79)**	(3.92)**	(3.75)**	(3.86)**	(3.98)**	(4.10)**	(3.95)**	(4.07)**
R/STD	–0.153	–0.165	–0.152	–0.163	–0.141	–0.152	–0.142	–0.153
	(2.16)*	(2.35)*	(2.15)*	(2.32)*	(1.99)*	(2.16)*	(1.98)*	(2.14)*
TD/GDP	0.619		0.581		0.562		0.576	
	(2.03)*		(1.84)*		(1.82)*		(1.81)*	
CRED	–1.556	–1.569	–1.486	–1.478	–1.396	–1.41	–1.431	–1.425
	(3.10)**	(3.13)**	(2.81)**	(2.80)**	(2.72)**	(2.75)**	(2.65)**	(2.65)**
PUB. DEBT		0.691		0.656		0.631		0.644
		(1.93)*		(1.80)*		(1.74)*		(1.75)*
Growth			–0.491	–0.637			0.313	0.154
			(0.39)	(0.51)			(0.24)	(0.12)
Exports					–2.275	–2.267	–2.424	–2.398
					(3.14)**	(3.14)**	(3.23)**	(3.20)**
FIX	0.438	0.438	0.442	0.446	0.55	0.547	0.567	0.565
	(0.92)	(0.92)	(0.93)	(0.94)	(1.15)	(1.14)	(1.17)	(1.17)
MANAGED	0.201	0.168	0.211	0.18	0.21	0.179	0.237	0.203
	(0.75)	(0.64)	(0.78)	(0.67)	(0.78)	(0.67)	(0.86)	(0.75)
FLOAT	–0.239	–0.262	–0.244	–0.27	–0.276	–0.297	–0.258	–0.284
	(0.78)	(0.85)	(0.78)	(0.87)	(0.89)	(0.95)	(0.82)	(0.90)
Constant	–3.012	–2.918	–2.965	–2.875	–2.997	–2.913	–3.025	–2.932
	(8.48)**	(8.74)**	(7.99)**	(8.32)**	(8.32)**	(8.59)**	(8.01)**	(8.33)**
Summary statistic								
Pseudo R^2	0.07	0.07	0.07	0.07	0.09	0.09	0.09	0.09
No. observations	1000	1000	976	976	994	994	970	970
No. crisis	112	112	111	111	111	111	110	110

Source: Authors' calculations, based on data from the World Bank's *World Development Indicators*.
* Statistically significant at 10 percent.
** Statistically significant at 1 percent.
a. Absolute value of z statistics are in parentheses. See appendix for definition of explanatory variables.

Table 6. Benchmark Estimation of Crisis Probability (measured by Current Account reversals), with Liquidity Measured as Reserves to Total Debt: World Bank Data[a]

Explanatory variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
REER MIS	–3.226	–0.062	–3.124	–0.111	–2.813	0.025	–2.674	0.008
	(2.96)**	(0.10)	(2.80)**	(0.19)	(2.53)*	(0.04)	(2.35)*	(0.01)
OPEN	5.62	4.049	5.633	4.001	5.544	4.197	5.551	4.244
	(4.81)**	(5.22)**	(4.81)**	(5.09)**	(4.70)**	(5.27)**	(4.71)**	(5.23)**
R/TD	–4.734	–3.018	–4.758	–3.017	–4.604	–2.877	–4.618	–2.963
	(3.71)**	(3.79)**	(3.73)**	(3.70)**	(3.56)**	(3.55)**	(3.58)**	(3.57)**
STD/TD	0.905		0.888		1.095		1.079	
(BIS)	(1.88)*		(1.84)*		(2.13)*		(2.10)*	
CRED	–3.299	–1.475	–3.407	–1.392	–2.961	–1.339	–3.078	–1.365
	(4.03)**	(2.91)**	(3.94)**	(2.61)**	(3.45)**	(2.59)**	(3.46)**	(2.51)*
STD/TD		2678		2747		2585		2621
(WB)		(2.61)**		(2.67)**		(2.49)*		(2.52)*
Growth			0.925	–0.553			1.18	0.26
			(0.44)	(0.44)			(0.55)	(0.20)
Exports					–1.9	–2.223	–1.999	–2.368
					(1.47)	(3.08)**	(1.53)	(3.16)**
FIX	1.224	0.457	1.202	0.47	1.229	0.595	1.204	0.62
	(1.79)*	(0.95)	(1.76)*	(0.97)	(1.79)*	(1.21)	(1.75)*	(1.26)
MANAGED	0.583	0.232	0.567	0.249	0.528	0.239	0.511	0.268
	(1.24)	(0.87)	(1.20)	(0.92)	(1.11)	(0.89)	(1.07)	(0.98)
FLOAT	–0.252	–0.143	–0.256	–0.149	–0.372	–0.183	–0.378	–0.163
	(0.47)	(0.46)	(0.48)	(0.47)	(0.67)	(0.58)	(0.68)	(0.51)
Constant	–3.574	–3.184	–3.59	–3.168	–3.477	–3.179	–3.496	–3.205
	(6.55)**	(9.03)**	(6.50)**	(8.84)**	(6.34)**	(8.90)**	(6.30)**	(8.76)**
Summary statistic								
Pseudo R^2	0.14	0.08	0.14	0.08	0.15	0.1	0.15	0.1
No. observations	567	1000	565	976	561	994	559	970
No. crisis	51	112	51	111	50	111	50	110

Source: Authors' calculations, based on data from the World Bank's *World Development Indicators*.
* Statistically significant at 10 percent.
** Statistically significant at 1 percent.
a. Absolute value of z statistics are in parentheses. See appendix for definition of explanatory variables.

2.4 Financial Development, Political Variables, and Crisis Probability

One of the hypotheses we explore in this paper is that the probability of a crisis may be affected by institutional aspects. In particular we are interested in evaluating the impact of financial market development on crises and the role of political institutions in determining a country's vulnerability to external shocks. We expect that more developed financial systems should allow lessen the need for reserves to stave off crises. A deeper or better-functioning financial system should facilitate the funneling of domestic resources to prevent costly adjustments in the face of crises. At the same time, we expect that solid political institutions, in the sense that they are transparent and accountable, reduce the likelihood of crony capitalism, allow market participants to see economic policy measures as credible, and are themselves better suited to face financial turbulence promptly and efficiently.[11]

The empirical problem with this hypothesis is that it is inherently difficult to select a particular variable that summarizes the implication of political institutions for a country's vulnerability. We draw from other work and use an index of institutional development, constructed as the first principal component of four indicators: the prevalence of law and order, the quality of bureaucracy, the absence of corruption, and the accountability of public officials.[12] We call this the governance index, and we also use some of the indicators individually.

To analyze the implications of financial development on crisis probability, we use the database on financial system indicators presented by Demirgüç-Kunt and Levine (2001), from which we select four indicators. Two are intended to reflect the efficiency of the financial sector, and two capture the size of the financial market. With respect to efficiency, we expect that an efficient financial system reduces the probability of a crisis by increasing the informational content of price signals and thus allowing the private sector to adjust smoothly. The variables we selected to measure efficiency are the net interest margin and the stock market turnover. The net interest margin is measured as the accounting value of a bank's net interest

11. Aizenman and Marion (2004) show that the quality of political institutions may affect the optimal level of reserve holdings.

12. We thank César Calderón for providing us with this dataset. The original source is Political and Risk Services (PRS) Group, *International Country Risk Guide* (various issues).

revenues as a share of total assets. A lower reliance on this type of income reflects narrower spreads between lending and borrowing rates, and it is therefore indicative of a more competitive banking system. A low net interest margin also implies that the financial market is characterized by few informational asymmetries or by heterogeneous agents whose idiosyncratic risk is muted. Meanwhile, high stock market turnover is indicative of low transaction costs or a large degree of liquidity in stocks.

With regard to the size of the financial market, a large financial sector should allow the fiscal or monetary authorities to tap the required resources to stave off liquidity shocks, instead of having to draw on international reserves. We selected two variables to capture size: stock market capitalization and total private credit by banks and similar institutions.

Tables 7 and 8 summarize the effects of including the financial system variables and the governance index, both individually and with an interaction term, in the three benchmark estimates (one for each scaling variable for reserves). Both financial and political variables are lagged two years to mitigate simultaneity bias. Panel A in both tables reports the median of the coefficient of the benchmark variables and the number of times the respective variable is statistically significant out of the total number of specifications (in brackets). Panel B reports the coefficient of each of the institutional variables included in different specifications (these variables do not enter simultaneously, except for the interaction term).

The main results highlighted in the previous section still hold. Economic growth, real exchange rate misalignment, and the ratio of reserves to the different scaling variables are all statistically related to the crisis probability. The effect of the financial and political system variables is much less clear-cut. When included individually, governance variables (both the aggregate measure and the separate indicators of the prevalence of law and order and the absence of corruption) are far from statistically significant. The one exception is corruption, which seems to increase the crisis probability (see table 7).[13]

Financial system variables are also far from having a statistically significant effect on crisis probability when included alone. The exception here is the net interest margin, which has a negative effect on crisis probability. Interaction terms only slightly improve the results. The

13. A higher value for the index indicates a better quality of institution, so higher values for the corruption index indicate lower corruption.

Table 7. Crisis Probability and Institutional Development: Financial Variables

	Short-term debt (BIS)			*Short-term debt (World Bank)*			*Total debt (World Bank)*		
Explanatory variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
A. Benchmark variables (median coefficient)[a]									
REER MIS	−12.759	−13.421	−12.825	−5.539	−6.028	−5.5205	−6.1115	−6.5615	−6.251
	[4/4]	[4/4]	[4/4]	[4/4]	[4/4]	[4/4]	[4/4]	[4/4]	[4/4]
RES	−1.826	−1.887	−1.2955	−1.1785	−1.3635	−0.4215	−4.8805	−6.9565	−7.397
	[4/4]	[4/4]	[2/4]	[4/4]	[3/4]	[1/4]	[3/4]	[4/4]	[3/4]
Growth	−5.511	−9.073	−4.6	−1.6665	−1.94	−2.8	−2.136	−1.5755	−2.437
	[0/4]	[0/4]	[0/4]	[1/4]	[0/4]	[1/4]	[0/4]	[0/4]	[0/4]
Governance	.	0.1935	.	.	0.0985	.	.	0.0685	.
	.	[0/4]	.	.	[0/4]	.	.	[0/4]	.
B. Institutional variables[b]									
Capitalization	0.421	1.429	0.411	0.916	3.067	0.353	1.333	3.406	0.338
	(0.54)	(0.84)	(0.28)	(1.85)*	(2.58)**	(0.53)	(2.51)*	(2.88)**	(0.43)
Turnover	0.035	−1.212	4.397	−0.244	−1.116	2.635	0.1	−0.71	0.063
	(0.04)	(0.72)	(1.94)*	(0.31)	(0.96)	(1.49)	(0.13)	(0.63)	(0.05)
Credit	1.012	−0.823	0.685	1.472	1.751	1.541	2.114	2.276	0.423
	(0.99)	(0.44)	(0.50)	(2.23)*	(1.96)*	(1.76)*	(3.05)**	(2.46)*	(0.38)
Net. int. Margin	−25.345	−130.06	9.795	−13.039	−76.03	65.147	−10.935	−85.625	47.469
	(1.46)	(2.25)*	(0.26)	(0.68)	(1.76)*	(1.78)*	(0.62)	(2.07)*	(1.56)

Table 7. (continued)

Explanatory variable	Short-term debt (BIS)			Short-term debt (World Bank)			Total debt (World Bank)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
C. Interaction of Financial variables with Insitutional variables and reserves[b]									
Gov*Capitalization	.	–1.573	.	.	–2.035	.	.	–1.897	.
	.	(0.84)	.	.	(2.12)*	.	.	(2.16)*	.
Gov*Turnover	.	1.017	.	.	0.987	.	.	1.397	.
	.	(0.92)	.	.	(1.16)	.	.	(1.69)*	.
Gov*Credit	.	1.013	.	.	–0.264	.	.	–0.225	.
	.	(0.78)	.	.	(0.44)	.	.	(0.37)	.
Gov*Net. Int. Margin	.	109.85	.	.	86.292	.	.	88.872	.
	.	(2.10)*	.	.	(2.00)*	.	.	(2.07)*	.
RES*Capitalization	.	.	0.005	.	.	0.571	.	.	4.354
	.	.	(0.01)	.	.	(1.57)	.	.	(2.39)*
RES*Turnover	.	.	–6.254	.	.	–3.665	.	.	0.182
	.	.	(1.84)*	.	.	(1.61)	.	.	(0.04)
RES*Credit	.	.	0.541	.	.	–0.088	.	.	9.425
	.	.	(0.37)	.	.	(0.12)	.	.	(2.09)*
RES*Net. int. Margin	.	.	–40.536	.	.	–86.703	.	.	–369.69
	.	.	(1.01)	.	.	(2.32)*	.	.	(2.02)*

Sources: Authors' calculations, based on data from the Bank for International Settlements (BIS) and the World Bank's *World Development Indicators*.
* Statistically significant at 10 percent.
** Statistically significant at 1 percent.
a. The figures in brackets are the number of times the coefficient is statistically significant at 10 percent.
b. Absolute value of z statistics are in parenthesis.

Table 8. Crisis Probability and Institutional Development: Political Variables

	Short-term debt (BIS)		*Short-term debt (World Bank)*		*Total debt (World Bank)*	
Explanatory variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
A. Benchmark variables (median coefficient)[a]						
REER MIS	–8.175	–8.164	–6.172	–6.285	–6.635	–6.615
	[3/3]	[3/3]	[3/3]	[3/3]	[3/3]	[3/3]
RES	–0.437	–0.413	–0.21	0.115	–1.767	–2.334
	[3/3]	[1/3]	[0/3]	[1/3]	[1/3]	[1/3]
Growth	–10.903	–10.905	–8.44	–8.694	–9.268	–8.899
	[3/3]	[3/3]	[3/3]	[3/3]	[3/3]	[3/3]
B. Institutional variables[b]						
Governance	0.434	0.558	0.123	0.32	0.155	0.114
	(1.48)	(1.41)	(0.80)	(1.60)	(0.99)	(0.51)
L&O	0.225	0.233	0.058	0.195	0.08	–0.113
	(1.06)	(0.66)	(0.33)	(0.84)	(0.45)	(0.56)
Corruption	0.087	0.512	0.032	0.292	0.048	0.236
	(0.32)	(1.47)	(0.16)	(1.16)	(0.23)	(0.81)
RES*Governance	.	–0.109	.	–0.164	.	0.281
	.	(0.45)	.	(1.54)	.	(0.26)
RES*L&O	.	–0.006	.	–0.099	.	1.417
	.	(0.03)	.	(0.94)	.	(1.39)
RES*Corruption	.	–0.395	.	–0.186	.	–1.14
	.	(1.80)*	.	(1.90)*	.	(0.94)

Sources: Authors' calculations, based on data from the Bank for International Settlements (BIS) and the World Bank's *World Development Indicators*.
* Statistically significant at 10 percent.
** Statistically significant at 1 percent.
a. The figures in brackets are the number of times the coefficient is statistically significant at 10 percent.
b. Absolute value of z statistics are in parenthesis.

specifications in columns 2, 5, and 8 of table 7 better fit our hypothesis. These results indicate that good public institutions, measured by the governance variable, reduce the probability of a crisis, but this effect is biggest for economies with small financial systems, as measured by the amount of private credit or financial capitalization. These last two variables alone seem to increase the probability of crisis. Finally, our results show that a large net interest margin increases the probability of a crisis, but only for high values of the governance variable, which by itself is negatively, although not significantly, related to this probability.

The previous specifications attempt to detect whether institutional variables per se affect crisis probability. An alternative is that institutional variables are substitutes for reserves in determining the likelihood of a crisis. If this was the case, the marginal contribution of the stock of reserves to the crisis probability should depend on the degree of institutional development. The bottom rows of tables 7 and 8 present specifications in which the reserves variable is interacted with the institutional measures. The results are again inconclusive, and only in a few cases are they statistically significant. These results, and those reported above, are not clear enough to make a strong case that institutional variables reduce the likelihood of a crisis once one controls for reserve accumulation and real exchange rate misalignment. Of course, good institutions could limit the probability of a crisis indirectly through the choice of exchange rate regime, as well as reserves and exchange rate policies.

Political and financial variables thus do not appear to be strongly related to crisis probabilities in our specifications. The effects are not always statistically significant, and the signs are often opposite to what we expected. In contrast, the results of the benchmark estimates hold. The ratio of short-term debt to several measures of liabilities, the growth rate, and exchange rate misalignment are all still strong determinants of crisis probability.

3. An Assessment of Recent Trends in Reserve Accumulation

In the debate on reserve accumulation by East Asian economies, some analysts argue that while reserves may be a useful tool for avoiding a crisis, the level of reserves needed to actually prevent a financial crisis is limited. Specifically, a ratio of reserves to short-term external debt above one would considerably reduce the crisis vulnerability of a

country, but a ratio much above one would do nothing to reduce the risk of a crisis (see, for example, IMF, 2003). While theoretical arguments can be made to justify such an assertion, no one has undertaken a systematic quantitative evaluation of the contribution of reserves to reduce the crisis vulnerability.

In this section, we take our earlier estimates of crisis probability at face value to evaluate recent trends in reserve accumulation by some emerging East Asian economies and Chile. Importantly, our model for crisis probability encompasses nonlinear effects of liquidity measures. While these nonlinear effects may not be enough to capture a possible threshold level for the ratio of reserves to short-term debt above which its marginal contribution to reducing the risk of a crisis is nil, at least the quantitative magnitude arises from empirical estimates.

We perform two types of exercises. First, we determine the optimal level of reserves for each country under different assumptions about the cost of a crisis. Second, we establish the implicit cost of a crisis that underlies actual holdings of reserves, under the assumption that the reserve level is optimally determined in each country through a cost-benefit analysis.[14]

To determine the optimal level of reserves, we closely follow the cost-benefit analysis of Ben Bassat and Gottlieb (1992). Consider the problem of a central bank that decides the amount of reserves it will carry over period t by minimizing an expected loss function that considers both the effects of reserve accumulation in terms of reducing the expected cost of a crisis and the opportunity cost of reserves.[15] We assume the loss function for the authority takes the following form:

$$\Lambda_t = p_t C_t + (1 - p_t)\rho_t R_t , \tag{6}$$

where p_t is the probability of a crisis, which depends on the ratio of reserves to short-term debt and which is given by expression 5 above; C_t is the cost of a crisis; R_t is the level of reserves; and ρ_t is the unit cost

14. The optimal or adequate level of reserves for a country is usually determined either by estimating a reserve demand model (Aizenman and Marion, 2003; Flood and Marion, 2001) or by using simple adequacy indicators (Wijnholds and Kaptyen, 2001). Lee (2004) develops an alternative options-based approach to establish the optimal amount of reserves.

15. De Gregorio and Lee (2003) and Park and Lee (2002), among others, show that real output growth typically follows a *V* pattern over the period before and after a crisis. However, the post-crisis growth rate for those countries does not exceed the precrisis period average, which means that a crisis entails a permanent output loss.

of reserves. The authority decides the optimal amount of reserves each period by minimizing equation 6 subject to

$$K_t - W_t + R_t = D_t\,, \tag{7}$$

where K_t is the capital stock of the economy, W_t is total wealth, and $D_t = S_t + \text{LTD}_t$ is the total debt of the country (composed of short-term debt, S_t, and medium- and long-term debt, LTD_t). We assume that short-term debt is predetermined, and any change in reserves is financed with medium- and long-term borrowing. This assumption allows us to reach an interior solution for the optimal amount of reserves. If reserves are completely financed with short-term debt, then any change in reserves conveys a one-to-one change in short-term debt, and the ratio between these two variables is never modified. This implies that the authority cannot affect the probability of a crisis by adjusting reserves. Since carrying reserves is costly and provides no benefit, then the optimal amount would tend to be zero.

We assume that reserves affect not only the probability of a crisis, but also the cost of a crisis. Depending on how reserves are used and whether the crisis originates in a liquidity shock, large amounts of international reserves could imply that countries avoid costly liquidation of assets. This, in turn, would reduce the impact of the shock on domestic output. De Gregorio and Lee (2003), for example, find a statistically significant effect of liquidity—measured as reserves relative to either domestic liabilities (M2) or short-term debt—on reducing the cost of a balance-of-payments crisis.[16]

In our case, we assume that the cost of a crisis (as a share of GDP) is a function, among other variables, of the ratio of reserves to short-term debt:

$$\frac{C_t}{Y_t} = C\left(\frac{R_t}{Y_t},\ldots\right).$$

The first-order condition for the authority's problem is given by the following expression:

$$p_{R,t}C_t + p_t\frac{\partial C_t}{\partial R_t} + (1 - p_t)\rho_t - p_{R,t}\rho_t R_t = 0\,, \tag{8}$$

16. De Gregorio and Lee (2003) also find that financial soundness, real exchange rate depreciation, and monetary policy play a critical role in reducing output losses associated with balance-of-payments crises.

where the partial derivative of the crisis probability with respect to R_t is given by

$$p_{R,t} = p_t(1-p_t)\left(\beta_0 \frac{1}{S_t} + \beta_0 \frac{1}{Y_t}\right).$$

We have assumed that the opportunity cost of reserves is independent from the ratio of reserves to short-term debt. In theory, this opportunity cost corresponds to the difference between the marginal productivity of capital in the economy and the yield on reserves, which is typically lower than then productivity of capital. In our empirical application below, we use the sovereign spread of each country in our sample as a proxy for this opportunity cost. These sovereign spreads depend on the perceived risk of each country, and they could therefore be affected by the country's international liquidity. However, empirical estimations of the determinants of sovereign spreads for emerging economies show that the effect of reserves is negligible and in many cases statistically insignificant. Some recent empirical studies for emerging markets further show that short-run movements in spreads are explained by changes in market conditions rather than fundamentals (Naudon, 2004). Since we do not consider possible effects of reserves on spreads, our results should tend to underestimate the optimal level of reserves.

On combining the previous two expressions, we obtain the following nonlinear equation in R_t:

$$0 = (1-p_t)p_t\left[\beta_0\left(\frac{S_t}{Y_t}\right)^{-1} + \beta_1\right]\left(\frac{C_t}{Y_t} - \rho_t \frac{R_t}{Y_t}\right) + p_t \eta \left(\frac{S_t}{Y_t}\right)^{-1}(1-p_t)\rho_t, \qquad (9)$$

where

$$\eta = \frac{\partial C_t}{\partial (R_t / S_t)}$$

corresponds to the change in the cost of a crisis associated with a change in the ratio of reserves to short-term debt.

3.1 Optimal Level of Reserves for Selected Economies

We compute the optimal level of reserves derived from equation 9 for four Asian economies (China, Korea, Malaysia, and Thailand) and Chile. As a proxy for the opportunity cost, we use data on sovereign

spreads from the J.P. Morgan Emerging Markets Bond Index Global (EMBI Global). We use two of our benchmark estimates of crisis probability from the previous section: one based on BIS data to construct the ratio of reserves to short-term debt (specification 7 in table 1) and one that draws on World Bank data (specification 7 in table 2). Finally, we assume that $\eta = -0.0025$, which is the value estimated by De Gregorio and Lee (2003) for the marginal effect of the ratio of reserves to short-term debt on the cost of a crisis.

Table 9 presents the estimates of the optimal level of reserves for three possible crisis costs: 5 percent GDP, 10 percent GDP, and 15 percent GDP. These figures correspond roughly to the costs of a currency crisis, a currency crash, and a banking crisis, respectively, according to estimates by the International Monetary Fund (IMF, 1998).[17]

The results based on the BIS data indicate that the amount of reserves held by Korea, Malaysia, and Thailand in 2003 is not above what would be optimal for those countries.[18] The amount of reserves that these countries are countries would be justified even if the cost of a crisis is low. In fact, for a mild crisis cost, the optimal amount of reserves could be up to 100 percent higher than what is actually being held. If we consider the results based on the World Bank data, however, the amount of reserves held by Korea and Thailand is roughly consistent with the optimal amount for a mild crisis, whereas Malaysia is holding a clear excess of reserves.

In the case of China, actual reserves are at least twice the optimal level according to the BIS estimates, no matter how strong the crisis. Based on these estimates, the optimal level of reserves in 2003 was approximately 12.3 percent of GDP if we consider a crisis cost of 15 percent of GDP. This number is 85 percent less than the amount of reserves that China is currently holding. When we consider the World Bank estimates, China's reserves are consistent with a cost of a crisis that ranges from mild to strong.

In the case of Chile, actual reserves are systematically above the optimal level. The only exceptions are when the comparison is the optimal

17. According to figures reported by the IMF (1998), the average cost of a currency crisis, a currency crash, and a banking crisis in emerging markets—in terms of loss of output relative to trend—is approximately 7.6 percent of GDP, 10.7 percent of GDP, and 14.0 percent of GDP, respectively.

18. The optimal level of reserves for these three countries is not well defined for the years 2000 and 2001 because the crisis probability in those years is polluted by the recovery period after the Asian crisis.

Table 9. Actual and Optimal Reserves

Country and year	Actual reserves (% GDP)	Optimal reserves					
		Crisis cost = 5% GDP		Crisis cost = 10% GDP		Crisis cost = 15% GDP	
		BIS	World Bank	BIS	World Bank	BIS	World Bank
Chile							
2000	20.0	7.77	9.10	10.16	13.39	11.58	16.05
2001	19.9	0.00	1.81	13.84	11.72	27.57	17.93
2002	21.6	0.12	0.66	19.20	10.66	30.94	16.93
2003	23.9	0.00	0.00	16.18	11.34	31.62	19.66
China							
2000	15.9	4.45	6.63	6.58	10.48	7.87	12.86
2001	15.6	5.89	6.31	8.98	9.21	10.83	11.01
2002	18.3	6.88	8.74	9.67	17.52	11.35	22.96
2003	23.0	7.51	12.15	10.48	21.54	12.28	27.36
Korea							
2000	18.2	...	...	...	...	...	...
2001	20.8	...	...	...	...	...	...
2002	24.1	21.80	0.33	34.85	18.87	42.65	30.52
2003	25.5	37.06	17.14	52.08	38.53	60.98	51.86
Malaysia							
2000	38.6	...	...	...	...	...	...
2001	32.7	...	...	...	...	...	...
2002	34.6	41.49	0.00	57.43	11.64	66.75	20.12
2003	36.1	51.12	2.01	69.17	17.38	79.70	27.04
Thailand							
2000	27.8	...	...	...	...	...	...
2001	26.1	...	...	...	...	...	...
2002	28.0	38.37	0.00	53.27	19.31	62.10	35.77
2003	30.0	30.31	1.40	43.34	24.82	51.11	39.50

Sources: Authors' calculations, based on data from the Bank for International Settlements (BIS) and the World Bank's *World Development Indicators*.
... Does not apply (see footnote 18).

level for the past three years based on BIS data and when the cost of a crisis is 15 percent of GDP. For a moderate cost (10 percent of GDP), reserves are between 40 and 100 percent above the optimal level.

3.2 Implicit Cost of a Crisis

An alternative method for evaluating reserves consists in determining the implicit cost of a crisis that is behind the actual reserve level being held. Table 10 presents these estimates, under the assumption that the reserve level is determined optimally according to equation 9.

The implicit cost of a crisis ranges from 2.9 to 6.6 percent GDP in the case of Korea to 4.9 to 11.6 percent of GDP for Thailand. In other words, the reserve levels of these two countries is consistent with a soft to mild crisis. In the case of Malaysia, the implicit cost of a crisis could be very low if we use the estimates based on BIS data (2.8 percent) or relatively high if we consider the World Bank data (21.7 percent). Our conclusion with respect to the adequacy of reserves for this country is thus mixed.

The cost of a crisis that is implicit in the level of reserves held by China is extremely high when we consider the estimate based on BIS data. According to our calculations, the cost of a crisis that would justify the amount of reserves held would be approximately 150 percent of GDP, which is clearly larger than any actual crisis. Under the estimates based on World Bank data, the implicit cost of a crisis is consistent with a mild crisis (approximately 11 percent of GDP).

To understand why the reserve level held by countries such as Korea and Thailand do not seem to be above the optimum for those countries, it is necessary to consider both the cost of holding reserves and the probability of a crisis. For these two countries, the estimated probability of a crisis in the last two years was not extremely high (2.6–5.9 percent in the case of Korea and 2.5–5.0 percent in the case of Thailand), but it was much larger than the crisis probability of countries like China (roughly 0–1 percent percent). At the same time, the cost of carrying reserves for these two economies has been very low, at around 100 basis points over the last two years. Therefore, the cost-benefit analysis implicit in equation 9 suggests that the optimal level of reserves should be relatively high.

The clear excess of reserves in the case of China with the BIS data stems from the fact that the crisis probability is very low. In fact, the cost of reserves for China is the lowest of all the countries in our sample (less than 100 basis points in the last two years). In other

Table 10. Implicit Cost of a Crisis and Crisis Probability

	Actual reserves	*Spread*	*Crisis probability (%)*		*Implicit cost (% GDP)*	
Country and year	*(% GDP)*	*(basis points)*	*BIS*	*World Bank*	*BIS*	*World Bank*
Chile						
2000	20.0	197	4.31	0.49	7.6	27.0
2001	19.9	192	3.53	1.66	12.0	17.0
2002	21.6	177	3.30	1.35	10.9	20.1
2003	23.9	126	2.53	1.39	12.3	18.4
China						
2000	15.9	136	0.13	0.34	48.8	24.9
2001	15.6	127	0.14	0.15	41.8	40.7
2002	18.3	89	0.05	1.07	77.7	10.6
2003	23.0	57	0.02	0.73	159.6	11.1
Korea						
2000	18.2	216	...	...	...	...
2001	20.8	211	...	...	...	...
2002	24.1	121	3.04	2.61	5.7	12.0
2003	25.5	106	5.87	4.61	2.9	6.6
Malaysia						
2000	38.6	217	...	...	...	...
2001	32.7	237	...	...	...	...
2002	34.6	187	8.84	1.33	3.7	29.3
2003	36.1	151	10.01	1.57	2.8	21.7
Thailand						
2000	27.8	163	...	...	...	...
2001	26.1	160	...	...	...	...
2002	28.0	103	5.05	2.87	3.0	12.4
2003	30.0	91	2.60	2.49	4.9	11.6

Sources: Authors' calculations, based on data from the Bank for International Settlements (BIS) and the World Bank's *World Development Indicators*.
... Does not apply (see footnote 18).

words, the excess reserves for this country does not result from the high cost of carrying reserves, but from the low benefits of holding them. The low spread in the case of China reflects, in part, the low risk of a crisis for this country.

Finally, the implicit cost of a crisis in the case of Chile corresponds to the cost of a mild to severe crisis. However, this implicit cost is much lower that the cost of the Chilean crisis in the early 1980s which was in the range of approximately 20 to 40 percent of GDP.

4. Conclusions

A number of studies argue that reserve accumulation allows countries to reduce the likelihood of self-fulfilling speculative attacks. Analysts also stress that reserve accumulation is a relatively costly self-insurance strategy that can actually be counterproductive. Large stocks of reserves may create moral hazard problems that could weaken a country's financial system. This, in turn, could make crises deeper in those economies.

In this paper, we estimated the impact of reserves on the probability of a crisis. Our goal was to evaluate how robust reserves (or the lack of thereof) are in explaining a crisis after we control for set of indicators, including the quality of political institutions and the soundness of the financial system. The empirical evidence we presented indicates that the probability of crisis is still strongly related to the ratio of reserves to short-term debt even when we control for institutional variables.

We then used our estimates of crisis probabilities to evaluate the optimal level of reserves from a cost-benefit analysis for a selected group of East Asian economies and for Chile. This exercise demonstrated that the actual size of the reserve stock observed today in some of these countries is not out of line with the usual cost of a crisis. Our results lead us to the conclusion that recent trends in reserve accumulation by Asian economies could be a sensible approach to dealing with the current macroeconomic conditions in the world economy.

APPENDIX
Variable Definitions

Variable	*Definition*[a]
REER MIS	Lag of real effective exchange rate deviation from Hodrick-Prescott tendency (IFS)
R/STD	Lag of real reserves to real short-term debt (IFS/BIS, IFS/World Bank)
R/TD	Lag of real reserves to real total debt (IFS/WB)
STD/TD	Lag of short-term debt to total debt
Pub debt	Public debt (WB)
Growth	Real GDP growth average of lags 1 and 2 (World Bank)
Exports	Lag of real exports growth (IFS)
Corrupt	Second lag of corruption annual average ICRG(106)
L&O	Second of law and order annual average ICRG(113)
Governance	Second lag of governance (ICRG)
Capitalization	Second lag of stock market capitalization to GDP (DL2001)
Turnover	Second lag of stock market turnover to GDP (DL2001)
Credit	Second lag of private credit by deposit money banks and other financial institutions to GDP (DL2001)
Net int. margin	Second lag of net interest margin (DL2001)
Gov*Credit	Second lag of interaction between governance and private credit (ICRG, DL2001)
Gov*Capitalization	Second lag of interaction between governance and stock market cap (ICRG, DL2001)
Gov*Turnover	Second lag of interaction between governance and stock market turn (ICRG, DL2001)
Gov*Net. int. margin	Second lag of interaction between governance and net interest margin (ICRG, DL2001)
RES*Capitalization	Second lag of interaction between reserves and private credit (IFS, DL2001)
RES*Turnover	Second lag of interaction between reserves and stock market cap (IFS, DL2001)
RES*Credit	Second lag of interaction between reserves and stock market turn (IFS, DL2001)
RES*Net. int. margin	Second lag of interaction between reserves and net interest margin (IFS, DL2001)
RES*Governance	Second lag of interaction between reserves and governance (IFS, ICRG)
RES*L&O	Second lag of interaction between reserves and law and order (IFS, ICRG)
RES*Corruption	Second lag of interaction between reserves and corruption (IFS, ICRG)

a. Sources in parentheses.
DL2001: Demirgüç-Kunt and Levine (2001).
ICRG: *International Country Risk Guide.*
IFS: *International Financial Statistics.*

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