

UNITED NATIONS DEVELOPMENT PROGRAMME



Was the Asian Crisis a Wake-up Call? Foreign Reserves as Self-protection

By Ronald U. Mendoza

Abstract: This paper digs deeper into the self-protection rationale for holding reserves by examining the empirical link between reserve holding patterns and crisis vulnerability. Analyzing data for 51 developing countries during the period 1982-2004, it finds evidence that the elasticity of developing country reserves with respect to certain crisis vulnerability indicators like foreign debt service and total external liabilities seems to be higher in the post-Asian crisis period, suggesting that policymakers' precautionary responsiveness by holding more reserves has increased. Grouping countries according to their type of vulnerability (commodity, debt or sudden stop related), countries prone to sudden stops in capital inflows also seem to have adjusted their policies the most towards higher precautionary reserve holding. Furthermore, from the point of view of self-protection, China's reserve holding patterns seem to be in line with what developing countries more generally seem to be undertaking.

Office of Development Studies
United Nations Development Programme
New York, December 2007

Acknowledgements: I am grateful to Pedro Conceição, Paola Deles, Ralph Hepp, Baybars Karacaovali, Dominick Salvatore and Henry Schwalbenberg for very useful discussions on the topic and comments on an earlier draft, and to Hiro Ito and Carmen Reinhart for their generosity in sharing their respective datasets. The views expressed in this paper do not necessarily reflect those of UNDP. Please send comments and suggestions to Ronald.mendoza@undp.org

1. Introduction

The spate of financial crises in the developing world, including the *Mexican tequila* in 1995, the *Asian flu* in 1997, the Russian default in 1998, and the string of crises ushering in the new century in Brazil (1999), Turkey (2001) and Argentina (2002), has spurred an extensive literature on possible steps towards better crisis prevention and mitigation. These span across policies that countries, individually, could pursue in areas such as the choice of the exchange rate regime, establishing prudential regulatory frameworks, and undertaking banking sector and other institutional reforms—as well as collective action initiatives among countries in order to reform the international financial architecture, covering proposals for rules or frameworks to handle sovereign debt issues and the creation of contingent lending facilities among other instruments to further equip policymakers' arsenals.¹ Progress along these two main fronts—individual national efforts and international cooperation—has been uneven, and a casual survey suggests that more seems to have been done by countries, individually, to try and protect themselves against the vicissitudes of the international capital markets.² Perhaps the most notable lesson taken to heart by developing countries is the need to increase liquidity as a form of self-protection against abrupt reversals in capital flows and sudden massive adjustments in their balance of payments; and the strategy of choice it seems is that of increasing their international reserves.

The global stock of reserves held by both industrial and developing countries increased dramatically in the last two decades—between 1986 and 2005, global reserves including gold increased by over four-fold and global reserves excluding gold increased by more than seven-fold.³ As a result, during this same period, the share of gold in the global reserves stock declined from about 40 percent in 1986 to less than 10 percent by

¹ For a discussion of these policies, see among others Bryant (2004), Feldstein (2001), Sachs and Radelet (1998), Salvatore (2000), and Summers (2000).

² For example the sovereign debt restructuring mechanism (SDRM) which was proposed in 2001 to help bring about more orderly resolution to debt distress situations was scuttled in 2003. Furthermore, the IMF's contingent credit line (CCL) first introduced in 1999 to provide liquidity to countries that might be vulnerable to contagion was never used and it was allowed to expire on its scheduled sunset date in November 2003. For a review of these instruments and other, as yet unimplemented, proposals for collective action instruments, see Mendoza, R.U. (2007a).

³ Unless otherwise stated, the discussion will refer to data on total reserves minus gold, as is the practice in the literature on reserve holding, and the data will be drawn from the World Bank's *World Development Indicators Online*.

2005. However, scaled by the average global turnover in the foreign exchange market (which has also been expanding), resurgence in global reserve holding only really started to take place since 1998 (figure 1). A number of studies have since shown that developing countries are driving this reserve holding trend (see also figure 2).⁴ Based on the latest available data from the International Monetary Fund (IMF), developing countries hold in excess of \$4 trillion in foreign exchange reserves—a four-fold increase since 1998.⁵ While some note a possible mercantilist rationale for this,⁶ a number of studies find more evidence that developing countries are increasing their reserves as a means to self-protect against financial crises.⁷

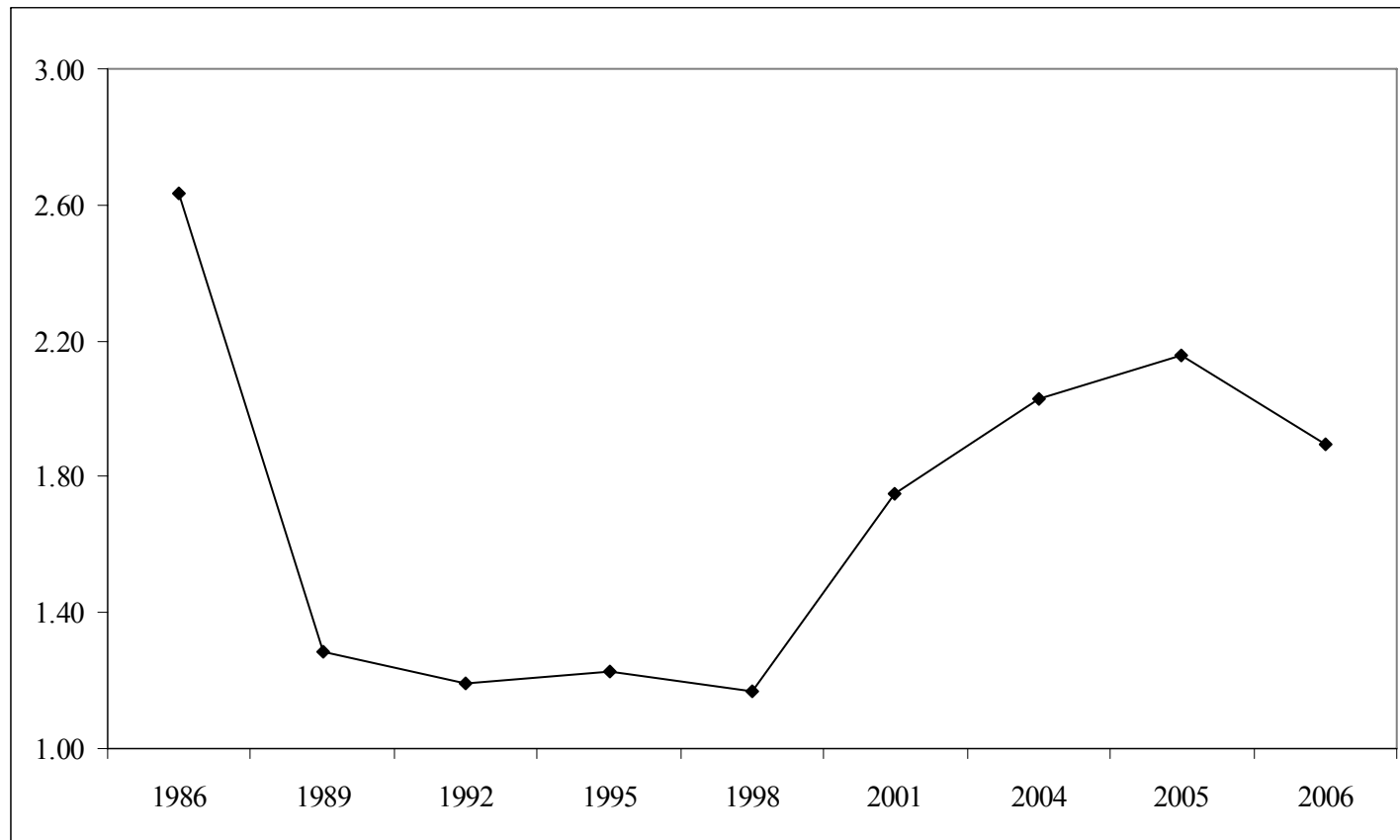
⁴ Reserves are comprised of special drawing rights (SDRs), reserves of International Monetary Fund (IMF) members held by the IMF, holdings of foreign exchange under the control of monetary authorities and gold. In analyzing reserve holding patterns, gold holdings are typically excluded because of the decline in their relative share in global reserves. For a discussion of recent reserve holding trends, see European Central Bank (2006) and Genberg and others (2005).

⁵ Figure refers to the aggregate reserve holdings of 95 (out of 160) developing countries reporting to the IMF's Composition of Foreign Currency Reserves (COFER) Database (last updated September 28, 2007) [<http://www.imf.org/external/np/sta/cofer/eng/index.htm>]. See also figure 3.

⁶ For instance, Dooley, Folkerts-Landau and Garber (2005) argue that the US trade deficit is tantamount to a supply of international collateral (US dollars) to the periphery; and two-way trade in financial assets is then facilitated through the use of this international collateral. Countries seeking to grow but hampered with still underdeveloped domestic financial markets would then export their gross savings (in the form of reserves) and have it redirected back through more efficient channels, such as through FDI inflows.

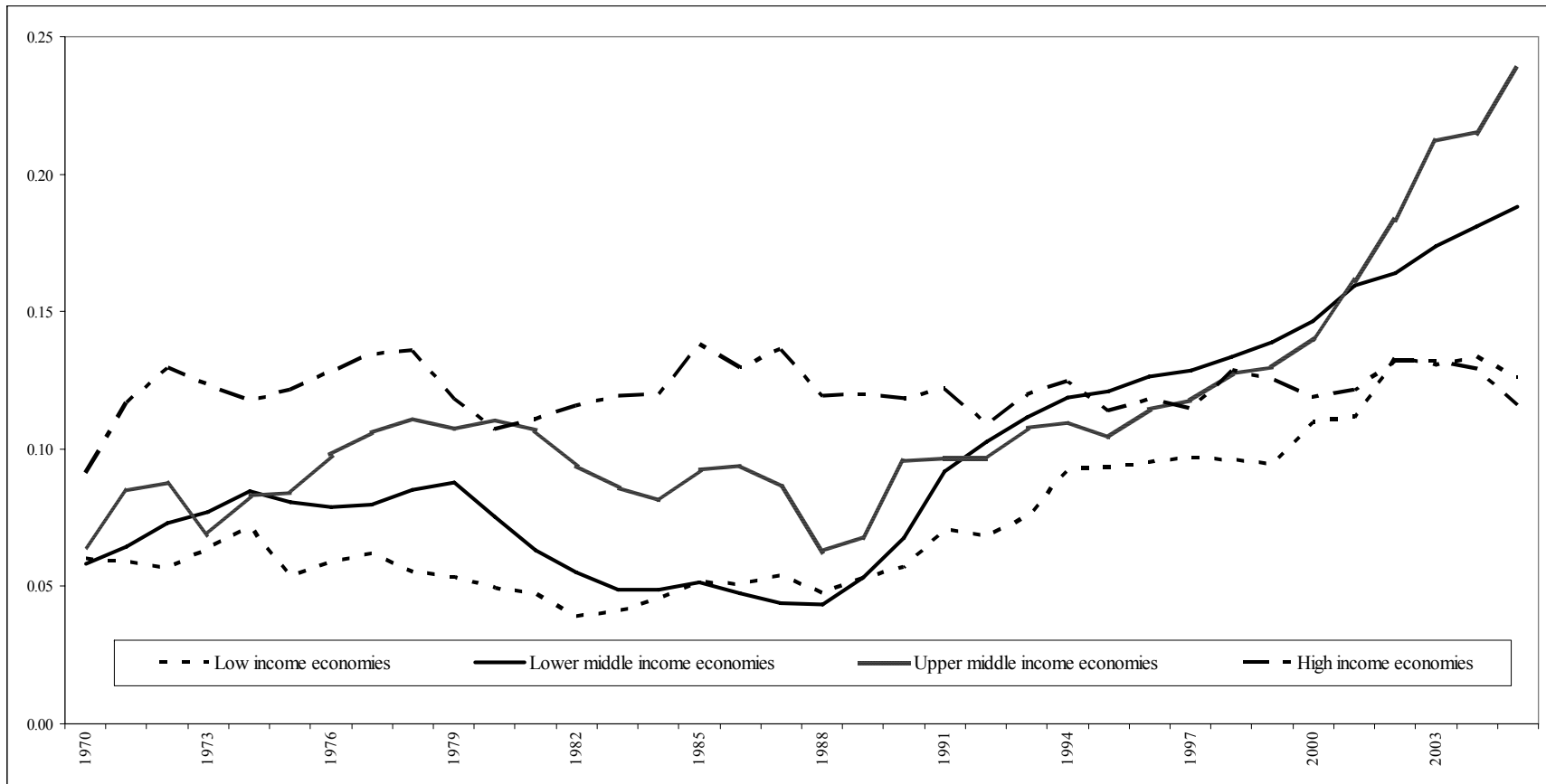
⁷ In addition to this paper, studies that provide further evidence of a self-protection rationale include Aizenman and Lee (2007), Aizenman, Lee and Rhee (2007), Aizenman and Marion (2003), Garcia and Soto (2006), Lane and Burke (2001), Prasad and Wei (2005), and Wyplosz (2007).

Figure 1. Ratio of Global Reserves to Daily Average Foreign Exchange Turnover, 1986-2006 (Selected years)



Sources: Data on foreign exchange reserves (minus gold) is drawn from the World Bank's *World Development Indicators Online* [<http://publications.worldbank.org/WDI/>]; unofficial estimates of the average daily foreign exchange turnover for each available year are drawn from International Financial Services, London [<http://www.ifsl.org.uk/research/index.html>].

Figure 2. Average Reserves by Income Group, 1970-2005 (In percent of GDP)



	1970	1980	1990	2000	2001	2002	2003	2004	2005
High income economies	0.09	0.11	0.12	0.12	0.12	0.13	0.13	0.13	0.12
• w/o Korea and Singapore	0.07	0.09	0.10	0.09	0.09	0.10	0.09	0.09	0.08
Upper-middle-income economies	0.06	0.11	0.10	0.14	0.16	0.18	0.21	0.21	0.24
• w/o Libya	0.04	0.09	0.09	0.12	0.14	0.14	0.16	0.17	0.18
Lower-middle-income economies	0.06	0.08	0.07	0.15	0.16	0.16	0.17	0.18	0.19
• w/o Jordan	0.05	0.07	0.06	0.14	0.15	0.15	0.16	0.17	0.18
Low-income economies	0.06	0.05	0.06	0.11	0.11	0.13	0.13	0.13	0.13

Source: World Bank's *World Development Indicators Online*.

However, much of the analyses of countries' reserve holding patterns do not yet disentangle the possible reasons behind this precautionary strategy, which could vary across countries.⁸ Different countries may have distinct underlying vulnerabilities, which in turn inform their reserve holding strategies to the extent that this could lower the probability of crises and/or mitigate their effects. For instance, countries dependent on a few commodity exports could be vulnerable to commodity-related shocks, and they could turn to reserve holding as a form of buffer stock in order to help smooth their macroeconomic impact. In addition, countries that have been prone to sharp reversals in their capital flows and/or have debt-related problems could also try to use reserves as a means to help smooth economic adjustments during bouts of financial instability. Indeed, in the absence of a true lender of last resort, hoarding reserves could be one of only a few alternatives for financially open countries to be able to minimize the output costs of a sudden stop in capital inflows. Under specific conditions, holding reserves might also help lower the probability of certain types of crisis, for instance, by deterring speculative attacks on currencies.

The contribution of this paper to the literature is that it digs deeper into the precautionary motivation for holding reserves, notably after the Asian financial crisis of 1997-1998. As would be suggested by the well-known Lucas critique, it is likely that some of the empirical relationships between reserves and various macroeconomic vulnerability indicators may have changed since the crisis. In order to address this as well as shed light on recent reserve holding behavior, the contribution of this paper will focus on three aspects, examining for potential structural breaks in reserve holding for developing countries in general, and also some groups of countries and China, in particular.

- ***Are developing countries self-protecting more after the Asian crisis, compared to before the crisis?*** This paper will explore whether the Asian crisis served as a

⁸ Aizenman and Lee (2007) and Hashimoto (2007) are notable exceptions. Aizenman and Lee attempt to analyze possible differences in the reserve holding patterns of Asian and Latin American countries as distinct groups, while Hashimoto examines specific crisis-hit countries in Asia as well as Mexico and the Russian Federation. The approach in this study builds further on these recent studies, as the country groupings used here are directly linked not to geography (or proximity to the crisis countries) but to the nature of the countries' vulnerabilities.

“wake up call” for developing country policymakers, as the crisis could have further clarified the dangers linked to financial openness and the vicissitudes of the international financial markets, which might be due to such factors as the absence of a true lender of last resort (Feldstein, 2001), herd behavior among investors (Kim and Wei, 2002; Sachs and Radelet, 1998), inadequate or inappropriate global financial standards and codes (Schneider, 2005) and the recurrent surge and “sudden stop” pattern in global capital flows to some emerging market countries (Calvo, 1998). The Asian crisis could also have revealed previously unknown weaknesses and financial fragilities within countries. Hence, there are two possible aspects to this “wake up call” effect: one applying to developing countries more generally, and another to some developing countries in particular. Focusing on the first aspect, this paper will examine whether developing countries as a group, when faced with heightened crisis vulnerability as shown by a number of empirically robust indicators, might be increasing their reserve holding more so in the aftermath of the Asian crisis as compared to before. Evidence of a general “wake-up call effect” could suggest that there is growing recognition that something is wrong with the international financial system itself, including as noted in the literature, a number of missing elements such as a true lender of last resort.

- ***Are especially vulnerable countries self-protecting more when compared to developing countries more generally?*** Even as many developing countries seem to be increasing their reserve holdings, some countries might nevertheless have distinct reserve holding strategies. One way to test for this would be to show whether certain developing country groups have different reserve holding elasticities with respect to a set of vulnerability indicators. This second, more country-related aspect of the “wake up call” effect will be examined by testing whether there are differences in the reserve holding patterns of commodity dependent exporting countries, as well as countries prone to debt defaults and sudden stops in capital flows, as compared to developing countries more generally.

- ***Is China's reserve holding strategy exceptional when compared to other developing countries?*** Further to the previous point on identifying country-specific patterns if any, China's reserve holding will also be examined separately. Its reserve stock breached \$1 trillion in 2007, and some see this reserve build-up as part of a strategy to keep its currency undervalued and thus promote its exports. Some of the possible drivers behind China's reserve build-up will be empirically examined vis-à-vis other countries' reserve holding patterns, in an effort to verify whether China's reserve holding is exceptional among developing countries.

This paper will draw on a number of widely used and robust empirical indicators of crisis vulnerability (e.g. Goldstein, Kaminsky and Reinhart, 2000; Reagle and Salvatore, 2000), as well as tap two recently released datasets: one on a *de jure* measure of capital account openness (Chinn and Ito, 2006); and another providing an estimate of the stock of total external liabilities (Lane and Milesi-Ferretti, 2007). Given the general finding in the literature that countries are undertaking precautionary reserve holding, the objective here is to go beyond this by examining the specific elasticities of reserve holding with respect to different possible vulnerability indicators, and verifying whether these have increased in the post-Asian crisis era.

The empirical results contained herein provide some evidence of a wake-up call in reserve holding for developing countries broadly in the post-Asian crisis era. For instance, the increase in reserves associated with crisis indicators like total external liabilities seems to be higher in the post-Asian crisis period. In the case of reserve holding responsiveness to the debt service indicator, what was once a negative link in the pre-crisis period turned into a positive relationship in the post-crisis period, suggesting a distinct change in policy stance towards more precautionary reserve holding.

Nevertheless, there also appears to be distinct reserve holding patterns across developing country groups. Countries prone to sudden stops in capital inflows seem to have adjusted their reserve holding strategy the most, among the developing countries in the sample. In addition, this paper finds that there is a lack of empirical evidence that China's reserve holding pattern is significantly different from that of other developing countries. Conditioned on a few indicators of crisis vulnerability—including debt service

and total external liabilities—China’s reserve holding patterns seem to be in line with what developing countries in the sample are undertaking.

In what follows, section 2 describes the data used in this study and outlines its empirical methodology for analyzing the factors behind the reserve build-up in the developing world. An analysis of the regression results is contained in section 3; and a brief conclusion reiterates the main findings of this paper.

2. Data and Empirical Methodology

Studies have analyzed reserve demand based on both its canonical components—its variance (Heller, 1968; Machlup, 1966), the level (Triffin, 1947) or the variance of trade (Heller and Machlup), money supply (Johnson, 1965), and a country’s propensity to import (Heller) or openness (Frenkel, 1974a;1974b)—as well as on possible heterodox features, such as the shadow exchange rate and its fundamental determinants (Flood and Marion, 2002). Some of the more recent literature on reserves has also explored possible trade-related and crisis vulnerability-related factors that might influence reserve holding patterns, finding evidence that points to a self-protection motivation for holding reserves. In particular, Aizenman and Lee (2007) empirically compare the importance of precautionary versus mercantilist motivations for reserve holding using data for a sample of 49 industrialized and developing countries during the period 1980-2000. In a horse race between two sets of variables—one indicating precautionary (e.g. capital account openness, crisis dummies, etc.) and the other mercantilist motivations (e.g. export growth, trade openness, etc.)—these authors find that variables associated with mercantilist motivations are statistically significant but they account for a very small part of total reserve accumulation. They find evidence that reserve holding is strengthened significantly by international capital flows, and that variables related to precautionary motivations are both statistically and economically significant in explaining reserve holding trends.⁹

However, there will always be at least one important challenge in trying to estimate reserve demand, and it centers on the issue of which crisis model to choose. The

⁹ For a comprehensive review of the theoretical and empirical literature on reserve holding, including the possible motivations behind it, see Bahmani-Oskooee and Brown (2002) and Mendoza, R.U. (2004; 2007b).

financial crisis literature has been as prolific as crises have been malignant. Multiple generations of financial crisis models have emerged, including fundamentals- and expectations-based models of speculative attacks, debt intolerance, and “sudden stop” phenomena—events wherein there is an abrupt fall (sometimes a complete reversal) in capital flows.¹⁰ Thus, the inevitable dilemma: Which type of crisis explanation would one follow—and hence, which type of crisis is a country self-protecting against? Agenor (2002) notes that this is the main drawback behind using crisis models to help empirically determine the demand for international reserves. Regression results would naturally be sensitive to the selection of the model. What is even more troubling is that the explanations for the most recent crises have come *after the fact*, demonstrating that previous models failed to predict the newer *strains* of financial crises. Hence, policymakers still find very little guidance on what the next crisis will look like, making the business of modeling reserve-demand and reserve adequacy extremely tricky.¹¹

Nevertheless, a useful starting point to gain insights on developing countries’ recent reserve holding behavior would be to draw on a small number of robust predictors of financial crises (spanning different crisis types) and at the same time leverage information from the literature on specific types of crisis vulnerabilities faced by certain groups of countries. Even as our understanding of different sets of country vulnerabilities are still unfolding, it might still be possible to examine how these same countries are responding to different prototypical sets of vulnerabilities—vis-à-vis commodity dependence and penchants for serial default and sudden stops—notably through their reserve holding patterns. This approach makes the empirical task more tractable, since one could derive insights from different countries’ reserve holding patterns without

¹⁰ It is beyond the scope of this paper to review this large body of literature. The interested reader may wish to refer to Frankel and Wei (2005) for a recent concise review of different crisis models.

¹¹ In connection, Cheung and Wong (2007) undertake a comprehensive empirical analysis of the patterns in seven reserve holding ratios of 174 countries, i.e. reserves scaled by: a) imports, b) total foreign liabilities, c) short term external debt; d) cumulative FDI inflows; e) money supply; f) population; and g) nominal GDP. They find that these different reserve holding ratios display significant variation across different countries, although a number of characteristics such as the country’s stage of development, debt and exchange rate regime seem to be linked to some of the ratios. Their main conclusion (which draws a strong analogy to Jeffrey Frankel’s observation on exchange rate regimes)—that “No single international reserve ratio is right for all economies at all times”—suggests how inconclusive the issue of modeling reserve demand and adequacy is.

having to specify each potential area of vulnerability that countries (or groups of countries) might have.

In the crisis forecasting and early warning system (EWS) literature, a variety of indicators have been put forward to help predict financial crises in the developing world. Drawing on some of these studies, notably Goldstein, Kaminsky and Reinhart (2000) and Reagle and Salvatore (2000), it is possible to identify a small number of robust crisis indicators centered around the current account balance, hot money flows, and foreign debt. The theoretical model used for this study is elaborated in the annex to this paper; and the reduced form equation is presented in equation 1, where Y_{it} is the ratio of international reserves to GDP and X_{it} is a vector of possible explanatory variables for reserves (i.e. money supply, economic openness, financial development, real exchange rate volatility (or foreign exchange intervention), and the crisis vulnerability indicators). Country- and (post-Asian crisis) period-specific interaction terms are then added in order to distill possible differences in reserve holding patterns across different (groups of) countries and between the pre- and post-Asian crisis periods (equation 2).¹² The regression model principally seeks to examine how reserve holding might be linked to factors that have to do with crisis vulnerability, and whether these links might be different across countries.

$$Y_{it} = a + \beta X_{it} + \varepsilon_{it} \quad (1)$$

$$Y_{it} = a + \beta_a X_{it} + \beta_b POST * X'_{it} + \beta_c POST * COUNTRY * X'_{it} + \varepsilon_{it} \quad (2)$$

To estimate the potential changes in the elasticities, the regression model incorporates interaction terms with a dummy variable for the post-Asian crisis period. This tests whether there is a structural break in the elasticities of reserve holding in the post-Asian crisis period for the entire group of developing countries being examined. In

¹² Note that for analytical tractability and given the present emphasis of this study, only the crisis variables were assigned *both* period- and country-specific interaction terms. Hence in equation 2, X' is a sub-set of X . Furthermore, the subscripts a, b and c represent sub-groups of the beta-coefficients that are elaborated more fully in tables 1-3 later.

addition, to examine more country- or group-specific trends, interaction terms with dummy variables for specific country groups and China are utilized. Drawing on the extensive financial crisis literature, the country groupings identified are commodity dependent exporters, and countries prone to debt defaults and sudden stops. Unless otherwise indicated, panel data for 51 developing countries during the period 1982-2004 is drawn from the *World Development Indicators* database of the World Bank.¹³ In addition, two recently constructed datasets are also used here. One refers to a *de jure* estimate of capital account openness developed by Chinn and Ito (2006). Another dataset used here pertains to recent estimates of the stock of total external liabilities by Lane and Milesi-Ferretti (2007). This dataset allows for a possible alternative, stock-based, measure of crisis vulnerability akin to the estimate of hot money flows.¹⁴ Table 1 provides a summarized description of the variables and their expected signs.

Three main regression models were estimated using the panel fixed effects method, all of which included indicators of economic openness and financial development as well as a money supply variable. The first model included variables to reflect foreign exchange intervention, debt service and hot money flows; the second included variables to reflect foreign exchange intervention, the current account and total external liabilities; and the third included variables to reflect real exchange rate volatility, debt service and hot money flows. In all three sets of regressions, interaction terms were introduced in order to help identify possible country- or group-specific elasticities. To help avoid possible endogeneity problems between reserve holding and the crisis variables, the latter are lagged, as is the practice in the empirical literature.

There are several caveats in the empirical analysis to be implemented. First, a proxy indicator for the cost of holding reserves was not included in the regression model,

¹³ Due to missing observations for different variables, the total number of datapoints for some regressions may be less. For the regressions involving the REERVOL (real exchange rate volatility) variable, data for only 26 countries were available. Of the 51 country sample, 8 of 12 commodity currency countries, 5 of 11 debt default countries and 7 of 19 sudden stop countries were left in the 26 country sample.

¹⁴ Traditionally, researchers turn to measures of short term external liability, akin to the development of reserve holding rules such as that attributed to Alan Greenspan and Pablo Guidotti. However, in an era of more open capital flows, the distinction between short- and long-term debts could be misleading. As argued by Wyplosz (2007), short term liabilities could be collateralized by long term liabilities, so that the distinction between the two could be deceptive. He further notes that holders of long term liabilities, in times of instability and uncertainty, tend to build short-term liabilities as a way to hedge their risks, which further suggests that total external liabilities could be a broader and better indicator of the potential vulnerability of a country.

given the conceptual and methodological challenges in identifying the appropriate costs—including quasi-fiscal and possible social opportunity costs—related to holding reserves (Baker and Walentin, 2001; Hauner, 2006; McCauley, 2007; Rodrik, 2006). Until better data is developed and collected, a careful treatment of this aspect must be left for future research.¹⁵ A second important caveat is that the analysis herein, like most studies in this area, is not general equilibrium in nature. Ideally, a fully-fleshed out general equilibrium framework of reserve holding, considering among other features monetary policy and exchange rates, would be used in order to properly reflect the different channels through which reserves are affected—and in some cases affect—various macroeconomic variables of interest. No such general equilibrium framework presently exists in the literature and this limitation in empirical studies of reserve holding is widely acknowledged (e.g. Hauner, 2006). In addition, there is as yet no unified theory of reserve holding behavior; and, as noted earlier, most models of financial crises have been developed after the fact.

Thus the analysis in this paper should be considered with these caveats in mind. The main objective of this paper is not to try and establish causality. Rather, it seeks to shed further light on recent reserve holding trends, by identifying any strong correlations as well as clarifying distinct patterns in reserve holding. The objective is to use this to further inform our thinking on how different countries might be utilizing this strategy.

¹⁵ As a very preliminary robustness check, I also implemented a few regressions which consider possible proxies for the cost of holding reserves, limited as they presently are.

- First, I follow Rodrik's (2006) suggestion to use the EMBI spread as a rough proxy for the cost of holding reserves. As data on the EMBI is limited, it resulted in a drastic reduction in the number of countries and years in the sample. Drawing on a sample of 10 developing countries during the period 1999-2004, the regression results suggest that the significance of the EMBI variable disappears with the addition of the crisis variables.
- Second, I also ran a few regressions using the real interest rate (i.e. the bank lending rate corrected for inflation which is reported in the World Bank's *World Development Indicators Online*), as a possible proxy for the opportunity cost of holding reserves. Due to data paucity, this resulted in a reduction in the sample from 51 to 30 countries. In this second robustness check, the real interest rate variable (both lagged and contemporaneous) was not statistically significant in any of the regressions.

These two sets of results do not materially change any of the findings discussed in this paper and are no longer reported here. The results are available from the author upon request.

Table 1. List of Explanatory Variables for Reserve Holding

Independent variables	Notes	Expected sign
<i>Crisis vulnerability variables</i>		
Current account	Excessively high current account deficits (typically in excess of 4-5% of GDP) are often precursors of turmoil in foreign exchange markets and sharp devaluations. This would suggest an expected negative coefficient. However, high current account surpluses could also prompt expectations of an appreciation in the currency, and could trigger speculative inflows. Since most developing countries do not have well-developed domestic financial markets that could re-cycle these flows outwards, the government may in many cases need to step-in in order to increase reserves. In this case, the expected sign would be positive.	- / +
Foreign debt	High levels of total foreign debt, short term foreign debt and foreign debt service (as a percentage of exports) could lead to a crisis if the debt becomes unsustainable and the country is unable to service it. Reserves could be used to help mitigate some of the costs of a debt crisis. Hence, greater vulnerability to debt problems is expected to be linked to higher reserve holdings.	+
Hot money	A potential indicator of hot money flows to a country is the sum of the current account (i.e. positive value indicates a surplus) and net FDI inflows (Hot = CA + FDI) scaled by GDP. A negative value, for example, provides a rough indication of the level of short-term flows that would be needed to finance a current account deficit. Hot money flows could easily reverse and lead to a liquidity crunch, and are therefore considered to be an indicator of crisis vulnerability. On the other hand, as noted earlier, if the current account is in surplus, and net FDI is also positive, then this indicator could also be construed as a possible inducement for appreciation pressure on the currency. In this case, there would be a positive link to reserve accumulation.	- / +
Total external liabilities	An indicator of the total stock of foreign liabilities for a country which includes portfolio investments (including equity and debt), FDI and derivatives. This data is drawn from Lane and Milesi-Ferretti (2007). Higher total foreign liabilities suggest higher financial openness, and perhaps vulnerability to external financial shocks. Hence, precautionary reserve holding is expected to increase with this variable.	+

<i>Other explanatory variables</i>		
Capital account openness	The Chinn-Ito index is a <i>de jure</i> measure for capital account openness—it measures the regulatory restrictions on capital account transactions. The index is based on the binary dummy variables that codify the tabulation of restrictions on cross-border financial transactions reported in the IMF’s <i>Annual Report on Exchange Arrangements and Exchange Restrictions</i> . (In order to focus on the effect of financial openness, rather than controls, they reverse the values of these binary variables.) The index takes on higher values as the country becomes more open to cross-border capital transactions. The expected sign with respect to this indicator is positive, as greater capital account openness could leave countries (notably those with weak financial institutions) vulnerable to the vicissitudes of the global capital market.	+
Financial development	Domestic credit to the private sector (as a share of GDP) is often used as an indicator of a country’s level of financial development. Greater financial development is expected to diminish the need for reserves given that the country would be less vulnerable to crises, and any “excess” reserves will be recycled outwards in the form of investments.	-
Foreign exchange intervention	The annual standard deviation of the monthly changes of the natural logarithm of total reserves minus gold could be used as a proxy indicator for foreign exchange market intervention (e.g. Hviding, Novak and Ricci, 2004). Monthly figures for total reserves minus gold is reported by the IMF in its <i>International Financial Statistics</i> online. Higher foreign exchange intervention implies a larger demand for reserves.	+
Money supply	Growth in money and quasi-money (M2) is expected to explain part of the growth in a country’s reserve holding. M2 is often used as a standard explanatory variable for reserve holding; and the expected sign is positive.	+
Real exchange rate volatility	This volatility indicator is calculated as the annual standard deviation of the monthly changes of the natural logarithm of the real effective exchange rate (REER). The REER is reported by the IMF in its <i>International Financial Statistics</i> online and is calculated based on relative consumer prices using 2000 as the base year. Because greater real exchange rate volatility is empirically linked to lower growth and financial instability notably in financially underdeveloped countries (Aghion, Bacchetta, Ranciere and Rogoff, 2006), and higher reserves is also empirically linked to reduced exchange rate volatility (Hviding, Nowak and Ricci 2004), this indicator is expected to be positively linked to reserve holding.	+
Trade openness	The sum of exports and imports scaled by GDP is a common indicator used to indicate a country’s trade openness. Greater trade openness is expected to increase the demand for reserves.	+

<i>Dummy variables</i>		
After Asia	This is a dummy variable for the post-Asian crisis period (i.e. 0 in years before the crisis, 1 in years after). The literature suggests that 1998 is a natural point of reference for the post-crisis period.	+
Commodity	This is a dummy variable for countries whose long-run real exchange rate has been found to be highly correlated with its real commodity export prices (Cashin, Cespedes and Sayat, 2002). Commodity dependent countries are expected to have a high demand for reserves in order to help smooth the impact of commodity-related shocks. ^a	+
Debt default	This is a dummy variable for countries experiencing at least one credit event during the period 1970-2001. Credit events are defined as default or debt restructuring of the country's external debt (Reinhart, Rogoff and Savastano, 2003). ^b Countries that are prone to experiencing credit events are expected to hold more reserves in order to help mitigate the impact of these events.	+
Sudden stop	This is a dummy variable for countries experiencing at least 1 sudden stop in capital inflows (an abrupt fall in the capital account—by greater than 5% relative to the previous year—which reduces domestic absorption) during the period 1975-2003 (Jeanne and Ranciere, 2006). Countries experiencing more frequent sudden stops are expected to have high demand for reserves in order to help manage the effects of these abrupt financial events. ^c	+
Interaction terms	Evidence of a “wake up call” in precautionary reserve holding would be suggested by significant coefficients for interaction terms for all countries in the sample (AA*crisis variable) and for specific country groups and China (AA*crisis variable*country group or China).	Depending on crisis variable

Notes: Reagle and Salvatore (2000) use a sixth variable, the months of import cover that a country's reserves could finance. Their model specification suggests that the lack of a precautionary strategy (indicated by reserve holding) could also help predict crises.

^a Commodity currency countries: Bolivia, Cote d' Ivoire, Ecuador, Ghana, Indonesia, Kenya, Mali, Morocco, Niger, Paraguay, Togo, Tunisia (i.e. 12 of 22 countries identified by Cashin, Cespedes and Sahay 2002 have complete data and are in the sample).

^b Debt default prone countries: Argentina, Brazil, Chile, Ecuador, Mexico, Panama, Peru, Philippines, Turkey, Uruguay, Venezuela (i.e. 11 of 14 countries identified by Reinhart, Rogoff and Savastano 2003 have complete data and are in the sample).

^c Sudden stop prone countries: Argentina, Bolivia, Brazil, Chile, Dominican Republic, Ecuador, Egypt, El Salvador, Honduras, Jamaica, Jordan, Malaysia, Mexico, Morocco, Paraguay, Peru, Philippines, Thailand, Turkey (i.e. 19 of 28 countries identified by Jeane and Ranciere 2006 have complete data and are in the sample).

3. Regression Results and Analysis

The following discussion elaborates on the regression results summarized in tables 1-3.¹⁶ The main empirical findings suggest that there is: a) evidence of a possible wake-up call in reserve holding in the post-Asian crisis era; b) evidence of distinct reserve holding elasticities across different country groups; and c) lack of evidence to suggest that China's reserve holding pattern is exceptional when compared to other developing countries.

The Asian crisis was a wake-up call

In general, the money supply variable and the indicator for capital account openness (Chinn-Ito index) in all the regression specifications were positive and significant, confirming evidence reviewed earlier that countries increase their reserves in response to growing domestic money supply and increasing financial openness. However, proxies for financial development and trade openness did not appear to be significant explanatory variables for reserve holding trends in the sample of countries examined. Interestingly, the coefficients of the indicator for foreign exchange intervention (used in regression models 1 and 2) and the indicator for real exchange rate volatility (used in regression model 3) were negative and significant, but its corresponding interaction terms with the post-Asian crisis dummy were positive and significant (see regression 1 in tables 1-3). Both sets of interaction terms, however, lost significance with the addition of the crisis variables in the regression, and this is a first indication of a more pronounced precautionary motivation for holding reserves.¹⁷ The over-all empirical results for the crisis variables suggest that there seems to be strong evidence of more reserve holding responsiveness to changes in a country's debt service or external liabilities. However, the results were less conclusive for hot money flows and the current account.

Debt and external liabilities

Table 1 summarizes the results of the regressions focusing on two crisis indicators that might also help explain reserve holding: the proxy for hot money flows and foreign debt

¹⁶ Regressions implemented using STATA (September 23, 2007).

¹⁷ Using lagged values of REERVOL and INTERVENE did not materially change these results so those regression results are no longer reported here.

service (scaled by exports). A striking feature of the results is the negative and statistically significant coefficient for the debt service variable, and the positive, statistically significant and numerically larger coefficient of its post-Asian crisis interaction term (see regression 3 in table 1).¹⁸ As noted earlier, greater financial openness was expected to diminish the need for reserves, as short term foreign debt, for example, could substitute for part of the demand for reserves. This might help explain a negative coefficient for the debt service variable (Eaton and Gersowitz, 1980). However the empirical evidence seems to point to a change in policy emphasis, as the coefficients suggest that reserves *rise* with debt service in the post-Asian crisis period.¹⁹ Nevertheless, a joint test of the sum of coefficients of the debt service and its post-Asian crisis interaction term does not suggest that this is jointly statistically different from zero.²⁰

¹⁸ Adding the country-specific interaction terms did not change this result (see regressions 4-7).

¹⁹ Analyzing the responsiveness of reserve holding to short term debt, Aizenman, Lee and Rhee (2007) make a similar observation for the Republic of Korea.

²⁰ If one replaces the foreign exchange intervention variable with the indicator for real exchange rate volatility, the results for the debt service variable are largely unchanged. The results for the third regression model are presented in table 3.

Table 1
Dependent: RES/GDP

	Hypothesis	1	2	3	4	5	6	7
M2	$\beta_1 > 0$	0.001923 [0.000172]**	0.001724 [0.000172]**	0.001507 [0.000181]**	0.001512 [0.000181]**	0.001385 [0.000183]**	0.001439 [0.000184]**	0.00149 [0.000201]**
kaopen	$\beta_2 > 0$	0.009 [0.002]**	0.008 [0.002]**	0.006 [0.002]**	0.006 [0.002]**	0.007 [0.002]**	0.007 [0.002]**	0.006 [0.002]**
findev	$\beta_3 < 0$	0.000033 [0.000069]	0.000033 [0.000068]	0.000035 [0.000067]	0.000035 [0.000067]	0.000042 [0.000067]	0.000029 [0.000067]	0.000034 [0.000067]
tradeopen	$\beta_4 > 0$	-0.000021 [0.000050]	-0.000025 [0.000049]	-0.00003 [0.000049]	-0.000028 [0.000049]	-0.00003 [0.000048]	-0.000027 [0.000048]	-0.000031 [0.000049]
INTERVENE	$\beta_5 > 0$	-0.434 [0.027]**	-0.366 [0.028]**	-0.357 [0.029]**	-0.358 [0.029]**	-0.342 [0.029]**	-0.355 [0.029]**	-0.357 [0.029]**
AAintervene	$\beta_6 > 0$	0.218 [0.060]**	0.145 [0.059]**	0.074 [0.065]	0.104 [0.075]	0.048 [0.068]	0.065 [0.070]	0.073 [0.065]
laghotgdp	$\beta_7 (?) = 0$		0.252 [0.032]**	0.215 [0.036]**	0.22 [0.036]**	0.203 [0.036]**	0.198 [0.036]**	0.215 [0.036]**
lagdse	$\beta_8 > 0$		-0.024 [0.013]	-0.037 [0.013]**	-0.041 [0.013]**	-0.028 [0.013]**	-0.031 [0.013]**	-0.037 [0.013]**
lagAAadse	$\beta_9 > 0$			0.053 [0.016]**	0.065 [0.017]**	0.128 [0.025]**	0.073 [0.027]**	0.053 [0.016]**
lagAAhotgdp	$\beta_{10} (?) = 0$			0.094 [0.059]	0.092 [0.062]	0.165 [0.062]**	0.009 [0.069]	0.094 [0.059]
lagAAadseCH	$\beta_{11} > 0$							-1.561 [1.123]
lagAAhotgdpCH	$\beta_{12} (?) = 0$							2.381 [1.841]
AAinterveneCH	$\beta_{13} > 0$							0.999 [5.163]
lagAAadseSS	$\beta_{14} > 0$						-0.032 [0.033]	
lagAAhotgdpSS	$\beta_{15} (?) = 0$						0.334 [0.114]**	
AAinterveneSS	$\beta_{16} > 0$						-0.182 [0.203]	
lagAAadseDD	$\beta_{17} > 0$					-0.099 [0.032]**		
lagAAhotgdpDD	$\beta_{18} (?) = 0$					-0.218 [0.155]		
AAinterveneDD	$\beta_{19} > 0$					-0.208 [0.239]		
lagAAadseCC	$\beta_{20} > 0$				-0.072 [0.040]			
lagAAhotgdpCC	$\beta_{21} (?) = 0$				0.007 [0.159]			
AAinterveneCC	$\beta_{22} > 0$				-0.065 [0.147]			
Constant	$\beta_{23} > 0$	0.054 [0.007]**	0.07 [0.008]**	0.077 [0.008]**	0.078 [0.008]**	0.076 [0.008]**	0.077 [0.008]**	0.077 [0.009]**
Observations		1105	1057	1057	1057	1057	1057	1057
Number of id		50	50	50	50	50	50	50
R-squared		0.36	0.4	0.4	0.41	0.42	0.41	0.41

Standard errors in brackets
* significant at 5%; ** significant at 1%

Wald Tests		Full Sample	Commodity Currency	Debt Default	Sudden Stop	China
Debt service	$\beta_8 + \beta_9 = 0$	$F(1, 997) = 0.83$ Prob > F = 0.3616	$\beta_8 + \beta_9 + \beta_{20} = 0$ $F(1, 994) = 1.48$ Prob > F = 0.2235	$\beta_8 + \beta_9 + \beta_{17} = 0$ $F(1, 994) = 0.00$ Prob > F = 0.9683	$\beta_8 + \beta_9 + \beta_{14} = 0$ $F(1, 994) = 0.23$ Prob > F = 0.6287	$\beta_8 + \beta_9 + \beta_{11} = 0$ $F(1, 994) = 1.89$ Prob > F = 0.1695
	Hot money	$\beta_7 + \beta_{10} = 0$ $F(1, 997) = 33.16$ Prob > F = 0.0000	$\beta_7 + \beta_{10} + \beta_{21} = 0$ $F(1, 994) = 4.56$ Prob > F = 0.0331	$\beta_7 + \beta_{10} + \beta_{18} = 0$ $F(1, 994) = 1.10$ Prob > F = 0.2938	$\beta_7 + \beta_{10} + \beta_{15} = 0$ $F(1, 994) = 34.27$ Prob > F = 0.0000	$\beta_7 + \beta_{10} + \beta_{12} = 0$ $F(1, 994) = 2.14$ Prob > F = 0.1442
FOREX intervention	$\beta_5 + \beta_6 = 0$	$F(1, 997) = 18.14$ Prob > F = 0.0000	$\beta_5 + \beta_6 + \beta_{22} = 0$ $F(1, 994) = 6.31$ Prob > F = 0.0122	$\beta_5 + \beta_6 + \beta_{19} = 0$ $F(1, 994) = 4.76$ Prob > F = 0.0293	$\beta_5 + \beta_6 + \beta_{16} = 0$ $F(1, 994) = 6.10$ Prob > F = 0.0137	$\beta_5 + \beta_6 + \beta_{13} = 0$ $F(1, 994) = 0.02$ Prob > F = 0.8898

Table 2
Dependent: RES/GDP

	Hypothesis	1	2	3	4	5	6	7
M2	$\beta_1 > 0$	0.001923 [0.000172]**	0.002543 [0.000157]**	0.002169 [0.000165]**	0.002089 [0.000165]**	0.002172 [0.000164]**	0.002133 [0.000169]**	0.002357 [0.000187]**
kaopen	$\beta_2 > 0$	0.009 [0.002]**	0.009 [0.001]**	0.007 [0.001]**	0.006 [0.002]**	0.007 [0.001]**	0.007 [0.002]**	0.007 [0.001]**
findev	$\beta_3 < 0$	0.000033 [0.000069]	-0.000045 [0.000060]	-0.000028 [0.000059]	-0.000028 [0.000059]	-0.00003 [0.000059]	-0.00003 [0.000059]	-0.000032 [0.000059]
tradeopen	$\beta_4 > 0$	-0.000021 [0.000050]	-0.000008 [0.000043]	-0.00002 [0.000043]	-0.000018 [0.000042]	-0.000013 [0.000042]	-0.000015 [0.000043]	-0.00002 [0.000043]
INTERVENE	$\beta_5 > 0$	-0.434 [0.027]**	-0.285 [0.026]**	-0.257 [0.026]**	-0.263 [0.026]**	-0.246 [0.026]**	-0.264 [0.027]**	-0.255 [0.026]**
AAintervene	$\beta_6 > 0$	0.218 [0.060]**	0.117 [0.053]*	-0.053 [0.061]	-0.07 [0.070]	-0.067 [0.063]	0.01 [0.065]	-0.052 [0.061]
lagcagdp	$\beta_7 (?) = 0$		0.215 [0.030]**	0.152 [0.034]**	0.152 [0.034]**	0.13 [0.034]**	0.141 [0.034]**	0.151 [0.034]**
lagtotalliab	$\beta_8 > 0$		0.018 [0.004]**	0.015 [0.004]**	0.018 [0.004]**	0.013 [0.004]**	0.015 [0.004]**	0.016 [0.004]**
lagAAcagdp	$\beta_9 (?) = 0$			0.135 [0.055]*	0.086 [0.059]	0.202 [0.059]**	0.065 [0.064]	0.133 [0.055]*
lagAAtotalliab	$\beta_{10} > 0$			0.026 [0.004]**	0.036 [0.005]**	0.037 [0.005]**	0.019 [0.005]**	0.025 [0.004]**
lagAAcagdpCH	$\beta_{11} (?) = 0$							1.407 [2.584]
lagAAtotalliabCH	$\beta_{12} > 0$							-0.151 [0.155]
AAinterveneCH	$\beta_{13} > 0$							-1.919 [4.695]
lagAAcagdpSS	$\beta_{14} (?) = 0$						0.166 [0.107]	
lagAAtotalliabSS	$\beta_{15} > 0$						0.019 [0.008]*	
AAinterveneSS	$\beta_{16} > 0$						-0.386 [0.182]*	
lagAAcagdpDD	$\beta_{17} (?) = 0$					-0.104 [0.134]		
lagAAtotalliabDD	$\beta_{18} > 0$					-0.033 [0.009]**		
AAinterveneDD	$\beta_{19} > 0$					-0.044 [0.213]		
lagAAcagdpCC	$\beta_{20} (?) = 0$				0.16 [0.131]			
lagAAtotalliabCC	$\beta_{21} > 0$				-0.025 [0.008]**			
AAinterveneCC	$\beta_{22} > 0$				0.109 [0.133]			
Constant	$\beta_{23} > 0$	0.054 [0.007]**	0.014 [0.007]	0.022 [0.007]**	0.022 [0.007]**	0.021 [0.007]**	0.024 [0.008]**	0.015 [0.008]
Observations		1105	1014	1014	1014	1014	1014	1014
Number of id		50	48	48	48	48	48	48
R-squared		0.36	0.44	0.46	0.47	0.48	0.47	0.47

Standard errors in brackets
* significant at 5%; ** significant at 1%

Wald Tests		Full Sample	Commodity Currency	Debt Default	Sudden Stop	China
Current account	$\beta_7 + \beta_9 = 0$		$\beta_7 + \beta_9 + \beta_{20} = 0$	$\beta_7 + \beta_9 + \beta_{17} = 0$	$\beta_7 + \beta_9 + \beta_{14} = 0$	$\beta_7 + \beta_9 + \beta_{11} = 0$
	F(1, 956) = 33.18	F(1, 953) = 10.89	F(1, 953) = 3.41	F(1, 953) = 17.48	F(1, 953) = 0.43	
	Prob > F = 0.0000	Prob > F = 0.0010	Prob > F = 0.0652	Prob > F = 0.0000	Prob > F = 0.5130	
Total liabilities	$\beta_8 + \beta_{10} = 0$		$\beta_8 + \beta_{10} + \beta_{21} = 0$	$\beta_8 + \beta_{10} + \beta_{18} = 0$	$\beta_8 + \beta_{10} + \beta_{15} = 0$	$\beta_8 + \beta_{10} + \beta_{12} = 0$
	F(1, 956) = 65.08	F(1, 953) = 13.66	F(1, 953) = 4.25	F(1, 953) = 55.38	F(1, 953) = 0.50	
	Prob > F = 0.0000	Prob > F = 0.0002	Prob > F = 0.0396	Prob > F = 0.0000	Prob > F = 0.4799	
FOREX intervention	$\beta_5 + \beta_6 = 0$		$\beta_5 + \beta_6 + \beta_{22} = 0$	$\beta_5 + \beta_6 + \beta_{19} = 0$	$\beta_5 + \beta_6 + \beta_{16} = 0$	$\beta_5 + \beta_6 + \beta_{13} = 0$
	F(1, 956) = 25.49	F(1, 953) = 3.89	F(1, 953) = 3.08	F(1, 953) = 14.20	F(1, 953) = 0.22	
	Prob > F = 0.0000	Prob > F = 0.0489	Prob > F = 0.0798	Prob > F = 0.0002	Prob > F = 0.6356	

Table 3
Dependent: RES/GDP

	Hypothesis	1	2	3	4	5	6	7
M2	$\beta_1 > 0$	0.001378 [0.000258]**	0.001187 [0.000245]**	0.00099 [0.000255]**	0.000997 [0.000255]**	0.000893 [0.000256]**	0.000976 [0.000259]**	0.000683 [0.000309]*
kaopen	$\beta_2 > 0$	0.011 [0.003]**	0.007 [0.003]**	0.006 [0.003]	0.005 [0.003]	0.007 [0.003]*	0.007 [0.003]*	0.006 [0.003]
findev	$\beta_3 < 0$	0.000021 [0.000121]	0.000037 [0.000117]	0.000049 [0.000117]	0.000042 [0.000117]	0.000039 [0.000116]	0.000031 [0.000117]	0.00005 [0.000117]
tradeopen	$\beta_4 > 0$	0.000076 [0.000092]	0.00005 [0.000088]	0.000035 [0.000088]	0.00004 [0.000088]	0.000054 [0.000088]	0.000043 [0.000088]	0.000034 [0.000088]
REERVOL	$\beta_5 > 0$	-0.067 [0.041]	-0.081 [0.039]*	-0.079 [0.039]*	-0.078 [0.039]*	-0.074 [0.038]	-0.071 [0.039]	-0.079 [0.039]*
AAreervol	$\beta_6 > 0$	0.385 [0.182]*	-0.042 [0.179]	-0.156 [0.183]	-0.153 [0.188]	-0.222 [0.187]	-0.127 [0.191]	-0.164 [0.183]
laghotgdp	$\beta_7 (?) = 0$		0.284 [0.042]**	0.253 [0.047]**	0.255 [0.047]**	0.246 [0.047]**	0.242 [0.047]**	0.253 [0.047]**
lagdse	$\beta_8 > 0$		-0.045 [0.019]*	-0.047 [0.019]*	-0.049 [0.019]**	-0.046 [0.019]*	-0.044 [0.019]*	-0.05 [0.019]**
lagAAadse	$\beta_9 > 0$			0.073 [0.028]*	0.105 [0.034]**	0.117 [0.033]**	0.098 [0.036]**	0.078 [0.029]**
lagAAhotgdp	$\beta_{10} (?) = 0$			0.084 [0.081]	0.077 [0.084]	0.177 [0.086]*	0.048 [0.091]	0.077 [0.081]
lagAAadseCH	$\beta_{11} > 0$							-1.571 [1.333]
lagAAhotgdpCH	$\beta_{12} (?) = 0$							2.83 [2.168]
AAreervolCH	$\beta_{13} > 0$							7.272 [8.549]
lagAAadseSS	$\beta_{14} > 0$						-0.096 [0.061]	
lagAAhotgdpSS	$\beta_{15} (?) = 0$						0.275 [0.176]	
AAreervolSS	$\beta_{16} > 0$						0.082 [0.767]	
lagAAadseDD	$\beta_{17} > 0$					-0.116 [0.076]		
lagAAhotgdpDD	$\beta_{18} (?) = 0$					-0.409 [0.246]		
AAreervolDD	$\beta_{19} > 0$					0.501 [0.916]		
lagAAadseCC	$\beta_{20} > 0$				-0.096 [0.068]			
lagAAhotgdpCC	$\beta_{21} (?) = 0$				0.117 [0.282]			
AAreervolCC	$\beta_{22} > 0$				-0.1 [0.991]			
Constant	$\beta_{23} > 0$	0.05 [0.011]**	0.076 [0.012]**	0.079 [0.012]**	0.079 [0.012]**	0.081 [0.012]**	0.079 [0.012]**	0.09 [0.013]**
Observations		565	541	541	541	541	541	541
Number of id		26	26	26	26	26	26	26
R-squared		0.11	0.2	0.21	0.22	0.23	0.22	0.22

Standard errors in brackets

* significant at 5%; ** significant at 1%

Wald Tests		Full Sample	Commodity Currency	Debt Default	Sudden Stop	China
Debt service	$\beta_8 + \beta_9 = 0$	$F(1, 505) = 0.59$	$\beta_8 + \beta_9 + \beta_{20} = 0$	$\beta_8 + \beta_9 + \beta_{17} = 0$	$\beta_8 + \beta_9 + \beta_{14} = 0$	$\beta_8 + \beta_9 + \beta_{11} = 0$
	Prob > F = 0.4436		Prob > F = 0.5282	Prob > F = 0.5203	Prob > F = 0.4373	Prob > F = 0.2474
Hot money	$\beta_7 + \beta_{10} = 0$	$F(1, 505) = 20.33$	$\beta_7 + \beta_{10} + \beta_{21} = 0$	$\beta_7 + \beta_{10} + \beta_{18} = 0$	$\beta_7 + \beta_{10} + \beta_{15} = 0$	$\beta_7 + \beta_{10} + \beta_{12} = 0$
	Prob > F = 0.0000		Prob > F = 0.0993	Prob > F = 0.9552	Prob > F = 0.0002	Prob > F = 0.1455
Exch. rate volatility	$\beta_5 + \beta_6 = 0$	$F(1, 505) = 1.68$	$\beta_5 + \beta_6 + \beta_{22} = 0$	$\beta_5 + \beta_6 + \beta_{19} = 0$	$\beta_5 + \beta_6 + \beta_{16} = 0$	$\beta_5 + \beta_6 + \beta_{13} = 0$
	Prob > F = 0.1957		Prob > F = 0.7333	Prob > F = 0.8191	Prob > F = 0.8758	Prob > F = 0.4112

Stronger evidence of a precautionary motivation is obtained from the second regression model (results reported in table 2) which includes a broader indicator of external liabilities that includes not just debt but also equity, FDI and derivatives. Focusing on regression 3 in table 2, the coefficient for total external liabilities is positive and statistically significant at the 1 percent level; so too is the coefficient of its interaction term with the post-Asian crisis dummy.²¹ Here, there does not seem to be any evidence of a change in policy stance with respect to accessing international capital and holding reserves: The link seems to be positive *before and after* the Asian crisis. However, the results do suggest that after the crisis, reserve accumulation was much more responsive, reflecting an intensified precautionary strategy. Joint tests of the sum of the coefficients of total external liabilities and its interaction term with the post-Asian crisis dummy are also statistically significantly different from zero at the 1 percent level.²²

Hot money and the current account

The coefficients for the indicator for hot money flows which was included in the first and third regression models were positive and significant; however, its post-Asian crisis interaction term was generally not significant (see regression 3 in tables 1 and 3). Its positive sign must be carefully interpreted, since it could draw on an explanation that might be less related to hot money dependence, and more possibly linked to a pre-emptive tempering of possible currency appreciation pressures and, linked to this, an influx of hot money flows. (We will turn to this point again when discussing the results for China later.)

Upon examination of the second regression model, which includes the current account variable, the results appear to be similar to those of the hot money flows variable in the first and third regression models. Focusing on the second regression model, and regression 3 in particular, the coefficient of the current account variable is positive and significant at the 1 percent level, but the coefficient for its post-Asian crisis interaction term is only significant at the 5 percent level. Significance of the latter becomes

²¹ Adding the country-specific interaction terms did not seem to change this result (see regressions 4-7).

²² The reserve elasticity after the crisis is $\beta_8 + \beta_{10}$. The Wald test reported at the bottom of table 2 rejects the null hypothesis that the sum of these coefficients is zero at the 1 percent significance level.

ambiguous with the addition of the country-specific interaction terms (regressions 4-7). Further examination of these country-specific terms may shed further light on this result.

Reserve holding elasticities are different across countries

The coefficients of the interaction terms with the different country groupings provide some insights into the reserve holding patterns of specific groups of countries—with the groupings determined by their historical vulnerabilities as identified in the financial crisis literature examining serial defaults and sudden stops (Eichengreen and Hausmann, 2005; Goldstein and Turner, 2004; Jeane and Ranciere, 2006; Reinhart, Rogoff and Savastano, 2003), as well as commodity dependent exporters and their vulnerability to external shocks (e.g. Cashin, Cespedes and Sayat, 2002; Dehn, Gilbert and Varangis, 2005; Devlin and Lewin, 2005). Based on the broad array of crisis vulnerabilities, three distinct groups of countries are identified, and their reserve holding patterns analyzed: a) commodity dependent exporters; b) countries with histories of debt defaults; and c) countries prone to sudden stops in their capital inflows. Except for regression 4 in table 2 which suggests a relatively lower reserve holding elasticity vis-à-vis increases in total external liabilities, the empirical results suggest that the reserve holding pattern of the countries that are vulnerable to commodity-related shocks are, in large measure, unremarkable. Thus, the rest of the analysis here focuses on the two other sets of countries and China. Over-all, the empirical results summarized in tables 1-3, and focusing on regressions 4-6 in each table, suggest that countries that tend to experience debt defaults and sudden stops in their capital flows tend to have distinct reserve holding elasticities, when compared to other developing countries in the sample.

Countries prone to debt events

For debt default countries the results suggest a lower reserve holding elasticity with respect to debt or external liabilities when compared to the rest of the sample in the post-Asian crisis period. In the first and second regression models, the coefficient of the interaction term for the debt default dummy and the post-Asian crisis interaction with debt service (first regression model) and total external liabilities (second regression model) were both negative and statistically significant at the 1 percent level (see

regression 5 in tables 1 and 2). However, a joint test that the sum of the coefficients of the debt service variable, its post-Asian crisis interaction, and its combined interaction with the sudden stop dummy were different from zero could not be rejected at robust significance levels.²³ A similar test for regression 2, focusing on the external liabilities variable, was significant, however, at the 5 percent level.²⁴

Over-all, it might be possible to interpret these results as indicative of a distinct reserve holding pattern for countries that are prone to debt events, but one that tends toward relatively less responsiveness to accumulate reserves when compared to the average developing country in the sample. This should not be immediately interpreted as evidence of relatively less precautionary policy. After all, on average the results still indicate that the elasticity is positive. More importantly, reserve holding is but one of the tools that policymakers have at their disposal to help manage this particular type of crisis vulnerability—reducing debt itself is an obvious alternative.²⁵ Recent comprehensive reviews of emerging market economies' debt levels and debt structure conclude that the over-all outlook seems to have markedly improved, as many countries that are historically prone to debt problems are bringing down their external indebtedness (though in some cases compensating by increasing their domestic debt), and improving the structure of their over-all public debt (e.g. through longer term maturity, and less foreign currency denominated debt) (see Jeanne and Guscina, 2006; IMF, 2006a; and Mendoza, R.U. 2007b). These alternative measures suggest that holding reserves is not the only instrument available to policymakers, at least in the area of managing risks related to debt.

Countries prone to sudden stops in capital inflows

As regards countries in the sample that are prone to sudden stops in their capital flows, the evidence points to a more pronounced precautionary policy vis-à-vis reserve holding in the post-Asian crisis period. In the first regression model, for example, the coefficient

²³ See Wald test of $\beta_8 + \beta_9 + \beta_{17} = 0$ reported at the bottom of table 1.

²⁴ See Wald test of $\beta_8 + \beta_{10} + \beta_{18} = 0$ reported at the bottom of table 1.

²⁵ In a theoretical model of the joint decision of holding sovereign debt and reserves, Alfaro and Kanczuk (2007) argue that the optimal policy is not to hold reserves. Similarly, Rodrik (2006) notes that it is vexing why countries do not minimize short term foreign debt more instead of choosing to accumulate large reserve levels.

of the interaction term of the sudden stop dummy with post-Asian crisis dummy and hot money indicator was positive and statistically significant at the 1 percent level (see regression 6 in table 1). While the analogous coefficient of this interaction variable was not significant in the third regression model which uses the real exchange rate volatility instead of the foreign exchange intervention variable in the first regression model (see regression 6 in table 3), in both cases, the joint tests that the sum of the coefficients of the hot money variable, its post-Asian crisis interaction, and its combined interaction with the sudden stop dummy were different from zero was statistically significant at the 1 percent level.²⁶

Focusing on external liabilities, countries prone to sudden stops in capital inflows seem to hold marginally higher reserves (scaled by GDP) in comparison to the typical developing country in the post-Asian crisis period (see regression 6 in table 2). The joint tests of the coefficients throughout the three regression models also seem to indicate that the sudden stop countries' coefficients are most consistently statistically significant, notably vis-à-vis hot money flows (first and third regression models) and the current account and total external liabilities (second regression model).

It is straightforward to interpret how sudden stop countries seem to hold marginally higher reserves compared to the rest of the countries in the sample in the post-Asian crisis period and compared to itself in the pre-Asian crisis period as a response to higher total external liabilities. However, marginally higher reserve holding propensity vis-à-vis the current account and hot money flows requires careful and cautious interpretation. Excessively high current account deficits often precede instability in foreign exchange markets and sharp devaluations, suggesting a negative relationship with reserve holding. Similarly, high current account deficits coupled with low net FDI inflows suggest high dependence on hot money flows, which also implies a negative relationship with reserves. Yet, the coefficients are all positive, so how could this be interpreted?

As noted earlier, high current account surpluses, possibly coupled with healthy net FDI inflows could be interpreted by markets as a precursor to currency appreciation. Expectations of an appreciation in the currency could trigger speculative inflows which

²⁶ See Wald test of $\beta_7 + \beta_{10} + \beta_{15} = 0$ reported at the bottom of tables 1 and 3.

could make a current account surplus environment just as potentially volatile as one with a current account deficit. Ideally, these speculative inflows would be recycled outwards by well developed domestic financial markets; however since most developing countries do not have these, government may need to step-in in order to recycle these flows outward as a precautionary measure (Genberg, McCauley, Park and Persaud, 2005; Prasad and Rajan, 2005). In this case, the expected sign would be positive; and the estimated coefficients for hot money flows and the current account balance seem to suggest that this explanation might fit the case of sudden stop prone countries.

A more detailed analysis, ideally using higher frequency data, is required to further disentangle the possible reasons behind this trend. For example, using quarterly data for the Republic of Korea from 1994 to 2003, Aizenman, Lee and Rhee (2007) analyze the country's reserve holding patterns and find evidence that the increase in reserves during the post Asian crisis period may have been contemporaneous with an increasing current account surplus (an artifact of its v-shaped recovery from the crisis); but the reserve increase was more closely associated with higher external liabilities that resulted from the country's decision to open up its economy to foreign investors. Foreigners' equity position (scaled by GDP) was 2 percent in 1997, rising to 23 percent by end-2003 (ibid, p.9). Suffice to say here that countries prone to sudden stops in capital inflows merit further empirical investigation at an individual country level.

China's reserve holding pattern is not exceptional

While China's reserve levels may be impressive at face value, the regression results in this paper suggest that its reserve holding elasticity is not different from other developing countries, when taking into consideration the factors that seem to explain general reserve holding patterns such as the current account balance, debt service, estimates of hot money flows and total external liabilities. None of the coefficients involving a dummy variable for China were statistically significant. Hence, the only thing impressive about China's reserves seems to be its size; but even this might be

easily explained by what the typical developing country would hold given the increased precautionary responsiveness to a given set of potential vulnerabilities.²⁷

These findings are in line with a number of recent empirical studies of China's reserve holding. Comparing the period from 1998-2000 and from 2001-2003, Prasad and Wei (2005, p.47) find that over 80 percent of the change in the pace of China's foreign reserve accumulation is associated with an increase in hot money flows and that only the residual seems to be associated with the current account surplus and an acceleration of inward foreign direct investment. This suggests that the increase in reserves is not trade-related; but due to speculative inflows on the renminbi. These authors also argue that China's recent policy measures do not seem to support the "mercantilist hypothesis." Citing anecdotal evidence, they point out that in 1997 and 1998, China opted not to devalue the renminbi despite the probably positive impact on its exports; and that in the 1980s and 1990s, there was evidence to suggest that China's currency was actually overvalued rather than undervalued.

One might be able to infer a mercantilist strategy by China, if there is a persistent undervaluation of the renminbi, yet studies on this topic lead to inconclusive results. For instance, Yang and Bajeux-Besainou (2006) undertake a very basic analysis of purchasing power parity (PPP), balance of payments flows and portfolio balance for China and find that there is no evidence that the renminbi is undervalued. Citing potential drawbacks in using PPP based analyses of exchange rate misalignment, as well as the long-standing debate on what actually constitutes the equilibrium exchange rate, Cheung, Chinn and Fujii (2007) instead use a panel regression method (on 160 countries during the period 1975-2004) in order to exploit the empirical relationship between deviations in absolute purchasing power parity and real per capita income. They also find no evidence that the renminbi is undervalued. However, Dunaway, Leigh and Li (2006) examine the robustness of estimates of China's equilibrium real exchange rates using different methodologies. They find that there is a large variance in estimates of the equilibrium real exchange rate—minor adjustments in the specifications of equations, definitions of variables, or time periods for estimation can lead to major differences in

²⁷ As a robustness check, I also ran the regressions with China excluded from the sample. This did not change the general findings so those regressions are no longer reported here.

the estimates of the equilibrium real exchange rate. Hence, this potential under-valuation of the renminbi is a question that remains unresolved.

The case of China could help illustrate how a careful and detailed analysis could help shed light on the link between the current account and reserves. For instance, Genberg, McCauley, Park and Persaud (from hereon GMPP 2005) argue that China's recent increase in reserves has less to do with its current account surplus, and more to do with increasing expectations of a renminbi appreciation—talked-up further by very public threats of trade retaliatory measures by the United States (see box 1). A sudden increase in speculative flows to China, notably commencing in late-2003 and continuing afterwards, seems to have prompted the Chinese authorities to tighten capital controls as well as step up reserve accumulation (Prasad and Wei 2005).²⁸

Table 4 provides updated calculations first presented by Prasad and Wei (2005), which show how net errors and omissions and the non-FDI capital account balance (comprised of net portfolio investments, net other investments and net errors and omissions)—both used as potential indicators of hot money or speculative flows—experienced a spike in 2003 and 2004. Comparing the 1998-2001 period to the 2002-2005 period, the change in the average capital account balance dwarfed that of the change in the average current account balance by almost threefold. The non-FDI capital account balance switched from an average of -\$42 billion in 1998-2001 to about \$19 billion in 2002-2005, translating to a turnaround of about \$60 billion in new inflows on average.

²⁸ Unofficial estimates by some analysts noted that hot money flows in 2007 were about \$5 to \$10 billion per month. This has prompted China's State Administration of Foreign Exchange to clamp down on banks (both foreign and domestic) for possibly facilitating the inflow of speculative capital into the country disguised as trade or investment. Some note that there is even a vibrant trade in physically bringing cash across the border from Hong Kong and Macao for investment in China's booming property and stock market ("China hits out over 'hot money'", *Financial Times*, June 27, 2007).

Box 1. “Talking up” the Renminbi

A series of actions by U.S. officials may have triggered a shift in expectations from one of a future depreciation to a future appreciation of the renminbi. U.S. Treasury Secretary John Snow traveled to China in September 2003 and was widely reported to have extracted a promise from Chinese officials to let the renminbi appreciate. Reportedly with US lobbying, increased exchange rate flexibility aimed at China emerged as one of the positions of the G-7 in a finance ministers’ meeting in Dubai in September 2004. John Taylor, Treasury Undersecretary, testified before the U.S. Congress in favor of a more flexible RMB on October 1, 2004; and later that same month, the semi-annual Treasury report was released, reflecting concerns over China’s currency manipulation. These same themes were also picked-up in the US presidential campaign in 2004, and received even greater public attention. In 2006, a bill was introduced in the U.S. Congress that proposed the application of a 27.5 percent tariff on Chinese imports unless their currency was not revalued against the dollar.

As for empirical evidence on whether political or technical (economic) considerations are behind this recent policy stance, Frankel and Wei (2007) empirically examine the findings of 31 bi-annual US Treasury reports spanning 1988 to 2005 which examine whether trading partners are manipulating their currencies vis-à-vis the US dollar. Using ordinal measures (i.e. 0=country not investigated; 1=examined as a potential manipulator; 2=policy changes recommended; 3=found to be manipulating its exchange rate) for a sample consisting of 63 US trading partners, they study the empirical relevance of two sets of possible motivations.

The first set alludes to technical factors (i.e. current account surplus of the trading partner; change in partner’s reserve holdings; and the value of the partner’s currency); and the second set alludes to political factors (e.g. bilateral balance of the US with the partner; US unemployment rate; and a dummy for an election year). Their empirical results suggest that both sets of factors are at play; but the authors nevertheless conclude that domestic political variables are more important determinants given: “the absence of a clear role for reserve accumulation by the partner country as mandated by the IMF criteria, the significance of US unemployment, and the very high significance of the bilateral balance notwithstanding that [the US] Treasury [...] deliberately excludes this indicator from its list of criteria (ibid p.13).”

Table 4. China's Balance of Payments, 1990-2007**(Current US\$ Billion)**

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	1998-2001	2002-2005	Change (%)
Current account balance	12.0	13.3	6.4	-11.9	7.7	1.6	7.2	29.7	29.3	21.1	20.5	17.4	35.4	46.0	69.0	161.0	179.0	200.0	22.1	77.9	252.7
Capital account balance	-2.8	4.6	-0.3	23.5	32.6	38.7	40.0	23.0	-6.3	5.2	2.0	34.8	32.3	98.0	111.0	63.0	41.0	30.0	13.6	76.1	459.4
Net FDI	2.7	3.5	7.2	23.1	31.8	33.8	38.1	41.7	41.1	37.0	37.5	37.4	46.8	47.0	53.0	68.0	54.0	52.0	38.3	53.7	40.4
Net Portfolio investment	-0.2	0.2	-0.1	3.1	3.5	0.8	1.7	6.8	-3.7	-11.2	-4.0	-19.4	-10.3	11.0	20.0	-5.0	5.0	3.0	-9.6	3.9	-141.0
Net other investment	-5.2	0.9	-7.4	-2.7	-2.7	4	0.2	-26	-43.7	-20.5	-32	16.9	-4.1	-6	38.0	-4.0	-18.0	-25.0	-19.7	6.0	-130.3
Net errors and omissions	-3.1	-6.7	-8.3	-9.8	-9.8	-17.8	-15.6	-17.0	-16.6	-17.8	-11.9	-4.9	7.8	18.0	27.0	-17.0	n.a.	n.a.	-12.8	9.0	-169.9
Non-FDI capital account balance	-8.6	-5.6	-16	-9.4	-8.9	-13	-14	-36	-64	-49.6	-47	-7.4	-6.7	23	85	-26.0	n.a.	n.a.	-42.1	18.8	-144.7
Increase in reserves	12.1	14.6	-2.1	1.8	30.5	22.5	31.6	35.7	6.4	8.5	10.5	47.3	75.5	117.0	206.0	207.0	220.0	230.0	18.2	151.4	732.9

Sources: Data for 1990-2002 from Prasad and Wei (2005, p.46); for 2003-2007 from IMF (2006b, p.38). Figures estimated for 2006 and 2007.

Note: Non-FDI capital account balance includes net portfolio investment, net other investment and net errors and omissions.

GMPP 2005 further argue that a massive revaluation in China could prove dangerous for the economy, triggering potential deflation, which therefore justifies sterilizing speculative capital inflows and even part of net FDI flows. One should also consider that China's domestic financial vulnerabilities—notably large contingent liabilities linked to its banking sector—could also further justify efforts by the Chinese government to try and secure more future policy maneuver should these contingent liabilities become realized. Various estimates of the non-performing loans of China's banks range from 20 to 30 percent of GDP, although analysts suggest that it could be much larger than this (Parasad 2004, table 7; Ma 2006, p.103). Recall that China's reserves are about over 40 percent of its GDP, so that the size of its reserve accumulation might actually be in the ballpark of matching the combined vulnerabilities in its financial sector. That China used about \$45 billion of its reserves to recapitalize two of its major state commercial banks in 2003 indeed suggests that this is one option that is in the minds of Chinese policymakers. Essentially, all this combined evidence points more towards precautionary rather than trade-related motivations for increases in China's foreign exchange reserves.

4. Conclusion

This paper examined the precautionary motivation behind the recent reserve build-up in the developing world. It sought to answer three main questions:

1. *Are developing countries self-protecting more after the Asian crisis, compared to before the crisis?*
2. *Are especially vulnerable countries self-protecting more when compared to developing countries more generally?*
3. *Is China's reserve holding strategy exceptional when compared to other developing countries?*

Given the general finding in the literature that countries are undertaking precautionary reserve holding, the main objective of this paper was to dig deeper into this by examining the specific elasticities of reserve holding with respect to different possible vulnerability indicators, and verifying whether these have increased in the post-Asian crisis era. This paper drew on a number of widely used and robust empirical indicators of

crisis vulnerability (e.g. Goldstein, Kaminsky and Reinhart, 2000; Reagle and Salvatore, 2000), as well as a few very recently released datasets: one on a *de jure* measure of capital account openness (Chinn and Ito, 2006); and another providing an estimate of the stock of total external liabilities (Lane and Milesi-Ferretti, 2007).

The empirical results in this paper provide some evidence of a wake-up call in reserve holding for developing countries broadly, in the post-Asian crisis era. For instance, the increase in reserves associated with certain crisis indicators like debt service and total external liabilities seems to be higher in the post-Asian crisis period, on average, for the developing countries in the sample analyzed. In the case of debt service, there is also cross-country evidence of a change in policy stance—whereas debt seemed to be a substitute for reserves in the pre-crisis period, in the post-crisis period rising debt was met with rising reserve holdings, indicating a switch towards greater precaution. This echoes the findings of other studies that have examined the link between debt and reserves before and after the Asian crisis (e.g. Aizenman, Lee and Rhee, 2007; Rodrik, 2006).

Notwithstanding this general finding, there also appears to be evidence of distinct reserve holding patterns across developing country groups. In particular, countries prone to sudden stops in capital inflows seem to have adjusted their reserve holding strategy the most among the developing countries in the sample. Their reserve holding elasticity with regard to increases in total external liabilities appeared distinctly higher than the rest of the sample. There are a number of possible explanations for this, including the array of other policy options for countries beset with commodity-related and debt-related challenges. This may not necessarily be the case for countries facing problems related to sudden stops in capital inflows, since there is presently no real lender of last resort and possible country-insurance-type instruments designed to respond to this type of challenge are still largely in the proposal stage.²⁹ Add to this the ineffectiveness or seeming political unpalatability of imposing capital controls. Hence, it might be possible to view the cost of holding reserves as the *de facto* price for not managing the capital account more actively (Rodrik, 2006).

²⁹ These instruments may include, for example, a country insurance facility (CIF) or a reserve augmentation line (RAL) at the International Monetary Fund (IMF). For a recent comprehensive review of these types of instruments, see Mendoza, R.U. (2007a).

Finally, this paper finds no evidence that China's reserve holding pattern is significantly different from that of other developing countries. Conditioned on a few indicators of crisis vulnerability—including debt service and total external liabilities—China's reserve holding patterns appear to be well in line with what developing countries on average seem to be undertaking.

All of these findings are merely suggestive of the possible factors at play in the build-up of developing countries' reserves. A more careful interpretation and country-specific analysis of trends, particularly those pertaining to the current account and hot money flows, is required in order to further clarify the role that reserves might be playing in these areas. Careful analysis of China's recent figures, for example, suggests that reserve holding could still be part of a precautionary strategy even in circumstances of current account surplus. The findings from the cross-country empirical analysis in this paper suggest that a more detailed assessment of each country's reserve holding is also fertile area for future research.

References

- Agenor, Pierre-Richard. 2002. "Comments and Discussion" to "Holding International Reserves in an Era of High Capital Mobility" by Robert Flood and Nancy Marion. In Susan M. Collins and Dani Rodrik, eds., *Brookings Trade Forum 2001*. Washington, D.C.: Brookings Institution Press.
- Aghion, Philippe, Philippe Bacchetta, Romain Ranciere and Kenneth Rogoff. 2006. "Exchange Rate Volatility and Productivity Growth: The Role of Financial Development." National Bureau of Economic Research Working Paper 12117. Cambridge, Mass. [<http://www.nber.org/papers/W12117>].
- Aizenman, Joshua and Jaewoo Lee. 2007. "International Reserves: Precautionary Versus Mercantilist Views, Theory and Evidence." *Open Economies Review* 18(2):191-214.
- Aizenman, Joshua and Nancy Marion. 2003. "The high demand for international reserves: What is going on?" *Journal of the Japanese and International Economies* 17(3):370-400.
- Aizenman, Joshua and Nancy Marion. 2004. "International Reserve Holdings with Sovereign Risk and Costly Tax Collection." *The Economic Journal* 114 (497): 569–591.
- Aizenman, Joshua, Yeonho Lee and Youngsop Rhee. 2007. "International reserves management and capital mobility in a volatile world: Policy considerations and a case study of Korea." *Journal of the Japanese and International Economies* 21(1):1-15.
- Alfaro, Laura and Fabio Kanczuk. 2007. "Optimal Reserve Management and Sovereign Debt." National Bureau of Economic Research Working Paper 13216. Cambridge, Mass. [<http://www.nber.org/papers/w13216>].
- Bahmani-Oskooee, Mohsen. and Ford Brown. 2002. "Demand for International Reserves: A Review Article." *Applied Economics* 34:1209-26.
- Baker, Dean and Karl Walentin. 2001. "Money for Nothing: The Increasing Cost of Foreign Reserve Holdings to Developing Nations." Center for Economic and Policy Research (CEPR) Briefing Paper. Washington, D.C. [<http://www.cepr.net/documents/publications/reserves.pdf>].

- Ben-Bassat, Avraham and Daniel Gottlieb. 1992a. "On the Effect of Opportunity Cost on International Reserve Holdings." *Review of Economics and Statistics* 74(2):329-332.
- Ben-Bassat, Avraham and Daniel Gottlieb. 1992b. "Optimal International Reserves and Sovereign Risk." *Journal of International Economics* 33(1992):345-362.
- Bryant, Ralph C. 2004. *Crisis Prevention and Prosperity Management for the World Economy*. Washington, D.C.: Brookings Institution Press.
- Calvo, Guillermo. 1998. "Capital Flows and Capital Market Crises: Simple Economics of Sudden Stops." *Journal of Applied Economics* 1(November):35-54.
- Cashin, Paul, Luis Cespedes, Ratna Sahay. 2002. "Keynes, Cocoa and Copper: In Search of Commodity Currencies." IMF Working Paper 02/223. Washington, D.C. [<http://www.imf.org/external/pubs/ft/wp/2002/wp02223.pdf>].
- Cheung, Yin-Wong, Menzie David Chinn and Eiji Fujii 2007. "The Overvaluation of Renminbi Undervaluation." *Journal of International Money and Finance* 26(5):762-785.
- Cheung, Yin-Wong and Clement Yuk-Pang Wong. 2007. "Are all measures of international reserves created equal? An empirical comparison of international reserve ratios." Economics Discussion Papers, No. 2007-24. [<http://www.economics-ejournal.org/economics/discussionpapers/2007-24>].
- Cheung, Yin-Wong and Qian, Xingwang. 2007. "Hoarding of International Reserves: Mrs. Machlup's Wardrobe and the Joneses." CESifo Working Paper No. 2065 [<http://ssrn.com/abstract=1002884>].
- Chinn, Menzie and Hiro Ito. 2006. "What Matters for Financial Development: Capital Controls, Institutions and Interactions." *Journal of Development Economics* 81(1):163-192.
- Dehn, Jan, Christopher Gilbert and Panos Varangis. 2005. "Agricultural Commodity Price Volatility." In Joshua Aizenman and Brian Pinto, Eds., *Managing Economic Volatility and Crises: A Practitioner's Guide*. Cambridge, UK: Cambridge University Press.
- Devlin, Julia and Michael Lewin. 2005. "Managing Oil Booms and Busts in Developing Countries." In Joshua Aizenman and Brian Pinto, Eds., *Managing Economic*

- Volatility and Crises: A Practitioner's Guide*. Cambridge, UK: Cambridge University Press.
- Dooley, Michael P., David Folkerts-Landau, Peter Garber. 2005. *International Financial Stability: Asia, Interest Rates and the Dollar*. Deutsche Bank Global Markets Research. [<http://econ.ucsc.edu/~mpd/Int%20Fin%20Stab.pdf>].
- Dunaway, Steven, Lamin Leigh and Xiangming Li. 2006. "How Robust are Estimates of Equilibrium Real Exchange Rates: The Case of China." International Monetary Fund Working Paper 06/220. Washington, D.C. [<http://www.imf.org/external/pubs/ft/wp/2006/wp06220.pdf>].
- Eichengreen, Barry and Ricardo Hausmann. 2005. "Original Sin: The Road to Redemption." In Barry Eichengreen and Ricardo Hausmann, Eds., *Other People's Money: Debt Denomination and Financial Instability in Emerging Market Economies*. Chicago: University of Chicago Press.
- European Central Bank. 2006. "The Accumulation of Foreign Reserves." ECB Occasional Paper Series 43. Frankfurt. [<http://www.ecb.int/pub/pdf/scpops/ecbocp43.pdf>].
- Feldstein, Martin. 2001. "Economic and Financial Crises in Emerging Market Economies: Overview of Prevention and Management." National Bureau of Economic Research Working paper 8837. Cambridge, MA. [<http://papers.nber.org/papers/w8837.pdf>].
- 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*. Washington, D.C.:Brookings Institution Press. Pages 1-68.
- Frankel, Jeffrey A. and Shang-Jin Wei. 2007. "Assessing China's Exchange Rate Regime." National Bureau of Economic Research Working Paper 13100. Cambridge, Mass. [<http://papers.nber.org/papers/w13100.pdf>].
- Frankel, Jeffrey A. and Shang-Jin Wei. 2005. "Managing Macroeconomic Crises: Policy Lessons." In Joshua Aizenman and Brian Pinto, Eds., *Managing Economic Volatility and Crises: A Practitioner's Guide*. Cambridge, UK: Cambridge University Press.

- Frenkel, Jacob A. 1974a. "Openness and the Demand for International Reserves." In R. Albier, Ed., *National Monetary Policies and the International Financial System*. Chicago: University of Chicago Press.
- Frenkel, Jacob A. 1974b. "The Demand for International Reserves by Developed and Developing Countries." *Economica* 41:14-24.
- Garcia, Pablo and Claudio Soto. 2006. "Large Hoardings of International Reserves: Are they worth it?" In Ricardo J. Caballero, César Calderón, Luis Felipe Céspedes, Eds. *External Vulnerability and Preventive Policies*. Central Banking Series Volume X. Banco Central de Chile. [http://www.bcentral.cl/eng/studies/central-banking/pdf/v10/171_206garcia_soto.pdf].
- Genberg, Hans, Robert McCauley, Yung Chul Park and Avinash Persaud. 2005. *Official Reserves and Currency Management in Asia: Myth, Reality and the Future*. Geneva Reports on the World Economy 7. London: Centre for Economic Policy Research.
- Goldstein, Morris and Philip Turner. 2004. *Controlling Currency Mismatches in Emerging Markets*. Washington, D.C.: Institute for International Economics.
- Goldstein, Morris, Graciela Kaminsky and Carmen Reinhart. 2000. *Assessing Financial Vulnerability: An Early Warning System for Emerging Markets*. Washington, D.C.: Institute for International Economics.
- Hashimoto, Yuko. 2007. "Too Much Self-Insurance? Asian Foreign Reserves." Mimeo. Toyo University.
- Hauer, David. 2006. "A Fiscal Price Tag for International Reserves." *International Finance* 9(2):169-195.
- Heller, Heinz Robert. 1968. "The Transactions Demand for International Means of Payment." *Journal of Political Economy* 76:141-5.
- Hviding, Ketil, Michael Nowak and Luca Antonio Ricci. 2004. "Can higher reserves help reduce exchange rate volatility?" IMF Working Paper 04/189. Washington, D.C. [<http://www.imf.org/external/pubs/ft/wp/2004/wp04189.pdf>].
- International Monetary Fund (IMF). 2006a. Structural Changes in Emerging Sovereign Debt and Implications for Financial Stability. In *Global Financial Stability*

- Report, April 2006*. IMF, Washington, D.C.
[\[http://www.imf.org/External/Pubs/FT/GFSR/2006/01/pdf/chp3.pdf\]](http://www.imf.org/External/Pubs/FT/GFSR/2006/01/pdf/chp3.pdf).
- International Monetary Fund (IMF). 2006b. "People's Republic of China: 2006 Article IV Consultation." Washington, D.C.
[\[http://www.imf.org/external/pubs/ft/scr/2006/cr06394.pdf\]](http://www.imf.org/external/pubs/ft/scr/2006/cr06394.pdf).
[\[http://www.imf.org/external/pubs/ft/weo/2007/02/index.htm\]](http://www.imf.org/external/pubs/ft/weo/2007/02/index.htm).
- Jeanne, Olivier and Olivier Ranciere. 2006. "The Optimal Level of International Reserves in Emerging Market Countries: Formulas and Applications." IMF Working Paper 06/229. Washington, D.C.
[\[http://www.imf.org/external/pubs/ft/wp/2006/wp06229.pdf\]](http://www.imf.org/external/pubs/ft/wp/2006/wp06229.pdf).
- Jeanne, Olivier. 2007. "International Reserves in Emerging Market Countries: Too Much of a Good Thing?" *Brookings Papers on Economic Activity* 2007(1):1-55.
- Jeanne, Olivier and Anastasia Guscina. 2006. Government Debt in Emerging Market Countries: A New Data Set. IMF Working Paper 06/98, Washington, D.C.
[\[http://www.imf.org/external/pubs/ft/wp/2006/wp0698.pdf\]](http://www.imf.org/external/pubs/ft/wp/2006/wp0698.pdf).
- Johnson, Harry G. 1965. *International Trade and Economic Growth: Studies in pure theory*. 2nd Edition. Great Britain: Allen and Unwin.
- Kim, Woochan and Shang-Jin Wei. 2002. "Foreign Portfolio Investors Before And During A Crisis." *Journal of International Economics* 56(1):77-96.
- Lane, Philip R. and Dominic Burke. 2001. "The Empirics of Foreign Reserves." *Open Economies Review* 12(4):423-434.
- Lane, Philip R. and Gian Maria Milesi-Ferretti. 2007. "The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970-2004." *Journal of International Economics* 73(2):223-250.
- Li, Jie and Ramkishan Rajan. 2005. "Can high reserves offset weak fundamentals? A simple model of precautionary demand for reserves." Center for International Economic Studies Discussion Paper 0509. University of Adelaide, Australia.
[\[http://www.adelaide.edu.au/cies/papers/0509.pdf\]](http://www.adelaide.edu.au/cies/papers/0509.pdf).
- Ma, Guonan. 2006. "Who foots China's restructuring bill." In *The Turning Point in China's Economic Development*. Ross Garnaut and Ligang Song, Eds. Canberra:

- Australian National University Press.
[\[http://epress.anu.edu.au/china/pdf/ch07.pdf\]](http://epress.anu.edu.au/china/pdf/ch07.pdf).
- Machlup, Fritz. 1966. "The Need for Monetary Reserves." Reprints in *International Finance* 5. Princeton University.
- McCauley, Robert N. 2007. "Assessing the Benefits and Costs of Official Foreign Exchange Reserves." In Age F.P. Bakker and Ingmar R.Y. van Herpt, Eds., *Central Bank Reserve Management: New Trends, from Liquidity to Return*. Cheltenham, UK and Northampton, MA:Edward Elgar.
- Mendoza, Ronald U. 2004. "International Reserve-holding in the Developing World: Self insurance in a crisis-prone era?" *Emerging Markets Review* 5(2004): 61-82.
- Mendoza, Ronald U. 2007a. "A Compendium of Policy Instruments to Enhance Financial Stability and Debt Management in Emerging Market Economies." United Nations Department for Economic and Social Affairs (UN-DESA) Working Paper 48. New York: UN. [http://www.un.org/esa/desa/papers/2007/wp48_2007.pdf].
- Mendoza, Ronald U. 2007b. "Was the Asian Financial Crisis a Wake-up Call? Foreign Reserves as Self-Protection." Mimeo. United Nations Development Programme, Office of Development Studies. New York.
- Prasad, Eswar and Raghuram Rajan. 2005. "Controlled Capital Account Liberalization: A Proposal." IMF Working Paper 05/7. Washington, D.C.
[\[http://www.imf.org/external/pubs/ft/pdp/2005/pdp07.pdf\]](http://www.imf.org/external/pubs/ft/pdp/2005/pdp07.pdf).
- Prasad, Eswar and Shang Jin Wei. 2005. "The Chinese Approach to Capital Inflows: Carrots and Sticks or Deeper Forces at Work?" IMF Working Paper 05/79. Washington, D.C. [<http://www.imf.org/external/pubs/ft/wp/2005/wp0579.pdf>].
- Prasad, Eswar. Ed. 2004. *China's Growth and Integration into the World Economy: Prospects and Challenges*. International Monetary Fund Occasional Paper 232. Washington, D.C.:IMF. [<http://www.imf.org/external/pubs/ft/op/232/op232.pdf>].
- Reagle, Derrick P. and Dominick Salvatore. 2000. "Forecasting Financial Crises in Emerging Market Economies." *Open Economies Review* 11:247-259.
- Reinhart, Carmen, Kenneth S. Rogoff and Miguel A. Savastano. 2003. "Debt Intolerance." *Brookings Papers on Economic Activity* 2003(1):1-74 and NBER

- Working Paper 9908. Cambridge, Mass.
[\[http://papers.nber.org/papers/w9908.pdf\]](http://papers.nber.org/papers/w9908.pdf).
- Rodrik, Dani. 2006. "The Social Cost of Foreign Exchange Reserves." *International Economic Journal* 20(3):253-266.
- Rodrik, Dani and Andres Velasco. 2000. "Short-Term Capital Flows." In Boris Pleskovic and Joseph E. Stiglitz, Eds., *Annual World Bank Conference on Development Economics 1999*. Washington, D.C.:World Bank.
- Sachs, Jeffrey and Steven Radelet. 1998. "The East Asian Financial Crisis: Diagnosis, Remedies and Prospects." *Brookings Papers on Economic Activity* 1:1-90. Washington, D.C.: Brookings Institution Press.
- Salvatore, Dominick. 2000. "The Present International Monetary System: Problems, Complications and Reforms." *Open Economies Review* 11(1):133-148.
- Schneider, Benu. 2005. "Do global standards and codes prevent financial crises? Some proposals on modifying the standards-based approach." United Nations Conference on Trade and Development (UNCTAD) Discussion Paper 177. Geneva: UNCTAD.
- Summers, Larry. 2000. "International Financial Crises: Causes, Prevention, and Cures." *American Economic Review* 90(2):1-16.
- Triffin, Robert. 1947. "National Central Banking and the International Economy." In William Allen and Clark Lee Allen, eds., *Essays in International Economic Equilibrium and Adjustment*. New York: MacMillan.
- Wyplosz, Charles. 2007. "The Foreign Exchange Reserves Buildup: Business as Usual?" Paper presented at the workshop on "Debt, Finance and Emerging Issues in Financial Integration". 6-7 March 2007. London.
[\[http://www.un.org/esa/ffd/Multi-StakeholderConsultations/FFDO/SovereignDebt/Wyploz.pdf\]](http://www.un.org/esa/ffd/Multi-StakeholderConsultations/FFDO/SovereignDebt/Wyploz.pdf).
- Yang, Jiawen and Isabelle Bajeux-Besnainou. 2006. "Is the Chinese Currency Undervalued?" *International Research Journal of Finance and Economics* 2(2006). [\[http://www.eurojournals.com/IRJFE%202%208%20Yang.pdf\]](http://www.eurojournals.com/IRJFE%202%208%20Yang.pdf).

Annex: An Illustrative Model of Precautionary Reserve Holding

To illustrate the relationship between reserves, costs of crisis, and crisis probability, we turn to a basic model of reserve holding drawing on work by Ben Bassat and Gotlieb (1992a;1992b) and Li and Rajan (2005). In the model, a developing country sovereign holds reserves in order to minimize the cost of a financial crisis (i.e. by minimizing its probability and mitigating its effect on output). The total cost function is reflected by equation A1.

$$TC = PC_C + RC_R \quad \text{Eq. A1}$$

- TC is the expected total cost of holding reserves and financial crisis;
- R is the stock of reserves;
- C_C , the cost of crisis, is the difference between non-crisis output, Y_N , and with output during crisis, Y_C ;
- C_R is the unit cost of reserve holding.

The probability of crisis, P is a function of the stock of reserves, R, and a vector of indicators indicating weak macroeconomic fundamentals, X. Hence, $P = f(R; X)$ and the probability of crisis increases with X ($P_X > 0$) and declines with increasing reserves ($P_R > 0$).

Output, Y, is a function of the capital stock, K, and exhibits the usual properties conducive to optimization: $\frac{\partial Y}{\partial K} > 0$ $\frac{\partial^2 Y}{\partial K^2} < 0$. The capital stock is \bar{K} during the non-crisis period and $A(R)\bar{K}$ during the period in crisis, with $0 < A(R) < 1$. The average productivity of capital increases with R as it helps cushion the impact of the crisis on output: $A_R > 0$. Hence, $C_C = Y_N - Y_C = f(\bar{K}) - f(A(R)\bar{K})$.

The first order condition for equation A2 indicates how the output loss during crisis decreases with an increasing stock of reserves.

$$\frac{\partial C_C}{\partial R} = -f'(A(R)\bar{K}) \frac{\partial A}{\partial R} \bar{K} < 0 \quad \text{Eq. A2}$$

Turning to equation 1 and minimizing the sovereign's total cost function subject to the policy variable—the choice in level of reserves to hold—produces equation A3.

$$\frac{\partial TC}{\partial R} = P \frac{\partial C_C}{\partial R} + C_C \frac{\partial P}{\partial R} + C_R = 0 \quad \text{Eq. A3}$$

Combining equations A2 and A3 in turn provides a representation of the optimum reserve holding (equation A4), suggesting that the unit cost of reserve holding must equal the marginal benefit of holding reserves: the sum of the marginal decline in the output cost of crisis (first left hand side term) and the marginal decline in the expected cost of crisis (second left hand side term).

$$P[f'(A(R)\bar{K})\frac{\partial A}{\partial R}\bar{K}] + -C_c\frac{\partial P}{\partial R} = C_R \quad \text{Eq. A4}$$