Foreign Reserve Management during the Global Financial Crisis

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Abstract

This paper examines how countries managed their foreign currency reserves during the global financial crisis. Evidence based on changes in reserve stocks suggests that many governments, even those with high levels of pre-crisis reserves, were reluctant to use them during the crisis. As a consequence, a number of recent studies of cross-country experiences during the crisis find little evidence of a positive role for reserves in macroeconomic crisis-management. This paper examines whether this assessment of the *non*-role of reserves during the crisis is justified. While the reserve stock data indicates stable reserve levels for many countries during the crisis, distinguishing between reserve changes that occurred due to interest income and valuation changes on existing assets and asset purchases and sales, indicates that many emerging economies actively depleted reserves. Further, the data indicate that countries whose pre-crisis reserve levels were in excess of what can be explained by standard models of reserve accumulation were the most likely to sell reserve assets during the crisis.

Key words: foreign exchange reserves, global financial crisis
JEL Classifications: F32, F41.

1. Introduction

The global financial crisis (GFC) led governments in hard hit countries to consider and often implement monetary and fiscal policy measures that would have been unthinkable prior to the crisis. Monetary authorities in many countries went from a singular focus on inflation targeting to embracing massive quantitative easing programs. Fiscal stimulus measures were passed in a wide array of countries, many of which had previously severely limited the role of government policies in the macro economy. In this context it is puzzling that the government policy tool that was particularly designed for crisis management, foreign reserves, seems not to have been widely used, even by those countries which had built up high levels of pre-crisis reserve stocks.

This paper examines the cross-country evidence on foreign currency reserve management during the global financial crisis. Evidence based on changes in reserve stocks suggests that many governments were reluctant to use them during the crisis. As a consequence, a number of recent studies of cross-country experiences during the crisis find little evidence of a positive role for reserves in macroeconomic crisis-management. This paper examines whether this assessment of the *non*-role of reserves during the crisis is justified.

The paper begins with an exploration of the measurement of reserve changes, which include both changes due to interest income and valuation changes on existing assets, as well as purchases and sales of reserves. The focus of the analysis in the paper is on changes in reserves that reflect policy decisions rather than market movements in asset prices. The data indicate that while reserve stocks remained stable for many countries during the crisis, interest income and valuation changes on these stocks of assets offset the effects of reserve sales, especially in emerging economies.

In order to better understand why certain countries chose to deplete reserves, while others relied on alternative policy tools to manage the crisis, the empirical analysis in the paper first seeks to establish the extent to which reserve accumulation prior to the crisis exceeded levels consistent with a benchmark empirical model that allows for both precautionary and exchange rate stability motives. I then test whether reserve accumulation behavior during and after the GFC differed for countries in which pre-crisis excess reserves were highest. The data indicate that depletion of reserves during the crisis was indeed higher in countries where pre-crisis excess reserve levels were more evident. I also find evidence that changes in reserves due to interest income and valuation changes, influences government decisions to purchase or sell reserve assets. Countries that experienced losses on their reserve stocks during the GFC tended to accumulate reserves after the crisis.

2. International Reserve Data

Reserve assets are denominated in foreign currency and are generally available to and controlled by monetary authorities for purposes of meeting balance of payments financing needs, for exchange rate intervention operations, and for other related activities that serve to maintain confidence in a country's currency and economy. Reserves are counted as part of national wealth, and are essential for countries with fixed exchange rates that want to avoid costly current account adjustments. When monetary authorities acquire international reserves they typically sterilize the effect of these purchases on the domestic monetary base by incurring domestic-currency liabilities, so that reserves in most countries are not net national assets. Because reserve assets are denominated in foreign currency and are most often held in the form of foreign government bonds, holding reserves exposes governments to foreign country, interest rate, and

currency risk[1].

Heller (1966) provides one of the first attempts at calculating an optimal country specific level of international reserves based on what he termed the precautionary motive. The three considerations he thought important to this calculation include: (1) the cost of adjusting to an external imbalance (measured as the propensity to import); (2) the cost of holding liquid international reserves (measured as the difference between the return on the reserves relative to a benchmark return on domestic bonds); and (3) the probability that there will actually be a need for reserves of a given magnitude (based on the history of past external imbalances). In practice there seem to have evolved a number of "rules of thumb" to determine optimal reserve levels loosely based on Heller's precautionary motive. These rules include maintaining reserves equivalent to: (1) three months of imports (to offset current account shocks); (2) 5-20 percent of M2 (to be able to shore up confidence in the value of the domestic currency in the event of a currency crisis); and (3) the value of all debt obligations falling due within the following 12 months (in the event of a sudden disappearance of short-term capital inflows)[2].

Reserve accumulation may also be the byproduct of a government strategy to keep the international value of the domestic currency low in order to boost export growth. Purchases of international reserves may not be motivated by a desire to smooth consumption in the face of external shocks, but rather may be the consequence of sterilized interventions in the foreign exchange market.[3] This rationale for reserve accumulation, often labeled the mercantilist motive, has been advanced by Dooley et al. (2003) as a description of the export-led development strategy followed by many East Asian countries, particularly China. Alternatively,

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[1] Dominguez et al. (2010) examine the implications of systematic reserve decumulation (intended to mitigate valuation losses) on domestic currency movements.
[2] This is often referred to as the "Greenspan-Guidotti rule".
[3] Dominguez and Frankel (1993), Dominguez (2006), Fatum and Hutchison (2006) and Ito (2003) examine the objectives and efficacy of foreign exchange intervention policies in the US and Japan.

it may be that reserve acquisition is motivated by a desire to dampen exchange rate movements, not for mercantilist reasons, but in order to provide a stable economic environment for foreign investment and domestic economic activity.

The broadest definition of international reserves (*IR*) includes two components: foreign currency reserves (*forexR*) and non-currency reserves (*nonCR*) (which include monetary gold *(Gold)*, Special Drawing Rights (*SDRs*), the reserve position at the International Monetary Fund (*IMF*) and other reserve assets (o*therR*)). Foreign currency reserves (*forexR*), in turn, consist of two broad classes of financial assets: securities (*SecR*) and currencies and deposits (*DepR*).

$$IR \ = \ forexR \ + \ nonCR \ = \ (SecR \ + \ DepR) \ + (Gold \ + \ SDR \ + \ IMF \ + \ otherR)$$

The *forexR* component of international reserves reflects foreign reserve policy actions, including foreign exchange market interventions and reserve portfolio management (involving shifts between currency denomination and asset maturities). The details of foreign reserve policy actions reflected in changes in *forexR* during the GFC are the focus of the analysis in this paper.

Researchers have typically used quarterly data measuring "international reserves minus gold" available from the International Financial Statistics to examine cross-country reserve behavior largely because this data is available for a wide sample of countries over a long time series. It is important to note that this broad measure of reserves includes non-currency components which may not be relevant to foreign reserve policy, particularly to the exchange rate stability motive for reserve accumulation. In this study I use a new source of data provided through the IMF's Special Data Dissemination Standard (SDDS) in the Reserve Template which provides end-of-month country-level data on foreign exchange reserves, *forexR*, and importantly, on the shares of assets (*SecR* and *DepR)* in *forexR*.

The SDDS is one of the IMF's recent data standardization initiatives and subscription is voluntary. There are currently 68 countries that subscribe to the SDDS and provide the requisite reserve data. Table 1 lists these countries and provides information on when each of these countries began to provide the detailed reserve data used in this study. SDDS data are available for most countries in 2000, though there are some exceptions, including India and Indonesia, who became subscribers early on but only began to provide the detailed reserve data in the last few years (Indonesia in 2006 and India in 2007). Although New Zealand is not an official SDDS subscriber, it also provides the detailed reserve data and is therefore included in the analyses presented in this paper. SDDS subscribers are required to provide detailed monthly reserve data by asset class (gold, SDRs, currency and deposits, securities, financial derivatives) and location (reserves held in other national banks, BIS, IMF, or domestic and foreign commercial banks) as well as detailed information on reserve-related liabilities.

Global international reserve stocks rose dramatically in the five years prior to the onset of the global financial crisis. Figure 1 shows that the rapid reserve accumulation was the most dramatic in developing countries, especially in developing Asia. The solid black line in the figure shows the percentage of total world reserves held by SDDS subscribers. In 2000 when most SDDS subscribers began to provide detailed reserve data, they represented a large fraction of total reserve holdings. By 2010 SDDS subscribers accounted for a much lower fraction (around 50%) of total reserve stocks in large measure because two of the top reserve holding countries, China and Saudi Arabia, are not SDDS subscribers.

Figure 1: Global International Reserves (USD million)
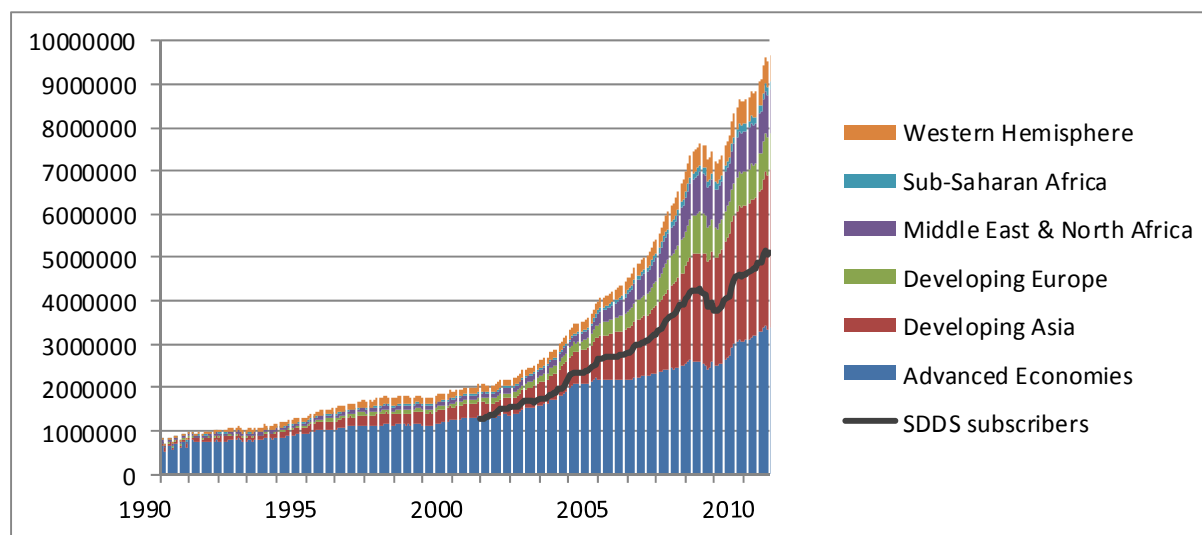
This paper is focused on understanding how countries managed their reserves during the global financial crisis, which in figure 1 appears as the dip in reserves prior to 2010. While it will be important to take into account the global upward trend in reserve accumulation before and after the GFC, the analysis in this paper will not attempt to explain what underlies the upward trend.

International reserve stocks change for four main reasons: (1) due to purchases or sales of foreign currency reserve assets, (2) due to the receipt of interest income on existing assets, (3) due to valuation changes in existing assets, and (4) due to changes in the non-currency components of reserves. Quarterly changes in international reserves therefore, are the sum of the changes in outstanding balances of each of its components:

$$\Delta IR = (\Delta^{ps} SecR + \Delta^{ps} DepR) + (r^s SecR + r^d DepR) + (\Delta^{val} SecR + \Delta^{val} DepR) + \Delta nonCR$$

where (Δ^{ps}) denotes purchases and sales, r^s is the interest rate on securities and r^d is the interest rate on deposits, and (Δ^{val}) denotes valuation changes. While the management of foreign

reserves presumably takes into account interest income and valuation changes, a key assumption in this paper is that purchases and sales of reserves are the main way that governments influence reserve accumulation and intervene in the foreign exchange market.

Few countries disclose their foreign exchange intervention operations, so researchers often use changes in international reserves as a proxy for interventions. This is problematic because changes in international reserves include components that are unlikely to have anything to do with intervention. Changes in international reserves will be a particularly poor proxy for intervention when interest income, valuation changes or changes in the non-currency components of reserves are large. Interest income and valuation changes, in turn, are impossible to measure without knowledge of what assets are held in the foreign currency component of reserves. [4] Another measure that has been used to approximate intervention policy is the "reserves and related items" variable reported in the balance of payments accounts (*bopR*). These data come directly from country-level balance sheets and include market valued purchases and sales of reserve assets as well as changes in the non-currency components of reserves. This series differs from changes in international reserves only in so far as it excludes valuation changes on existing assets.

$$bopR \ = \ (r^s SecR \ + \ r^d DepR) \ + (\Delta^{ps} SecR \ + \Delta^{ps} DepR) \ + \Delta NonCR$$

Countries that report both data on international reserves as well as "reserves and related items" in the balance of payments accounts, therefore, allow us to directly measure valuation changes in foreign currency reserves. (The sign convention in the balance of payments data is opposite that

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[4] Countries generally do not provide detailed accounts of their reserve management strategy, one exception is De Gregorio (2011), which provides a discussion of the motives for reserve accumulation in emerging economies with a special focus on the Chilean approach.

for changes in international reserves, so that to derive the difference, the two series need to be added.)

$$\Delta IR \; - \; bopR \; = \Delta^{val} SecR \; + \Delta^{val} DepR$$

Policy driven foreign exchange reserve changes in this paper are measured by subtracting: (1) derived valuation changes calculated using the *bopR* data, and (2) estimated interest income based on the SDDS *SecR* and *DepR* shares and COFER information on the currency denomination of assets in *forexR*. The SDDS Reserve Template, which requires reporting countries to break down foreign currency reserves into securities and currency and deposits, while not ideal, provides researchers with critical information needed to estimate interest income. It is also the case that countries are not required to provide information on the currency composition of foreign currency reserves. However, aggregated information on currency denomination (available for two groups: "advanced" and "emerging and developing" countries) is available from the Currency Composition of Official Foreign Exchange Reserves (COFER) database at the IMF.[5]

A precise measure of interest income on reserve stocks could be calculated if complete information on the types of assets held in reserve portfolios were available. In practice reserve portfolio information is limited to country-level shares of the two broad asset categories (*SecR* and *DepR*) as well as aggregated quarterly data on the currency denomination of assets. Therefore, in order to estimate interest income assumptions need to be made regarding the types of assets that are included in *SecR* and *DepR*. While some governments are likely to include a wide range of assets in the "securities" category of foreign currency reserves, most countries claim to mainly hold long-term government bonds. There is likely less heterogeneity in the types of assets held in the "currency and deposits" category. I follow Dominguez et al. (forthcoming)

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[5] These data are available at http://www.imf.org/external/np/sta/cofer/eng/index.htm.

and use 10-year government bond yields to proxy for returns on "securities" and 3-month inter-bank yields to proxy for returns on "currency and deposits"[6]. These assumptions regarding reserve composition are conservative, and are therefore likely to underestimate the interest income earned by countries that hold higher risk assets. Although some countries report information on the currency composition of their reserve portfolio, this information is not available for a broad sample, therefore, again following Dominguez et al. (forthcoming), I use quarterly COFER data to approximate the currency denomination of assets[7]. Figure 2 presents the underlying security and deposit data used in the interest income calculations. Although the long-term government bond yields are relatively stable (though diminishing) over this time period, the short-term bank yields are more volatile, and fall dramatically in the wake of the global crisis.

Figure 2: Interbank and Bond Yields used in Interest Income Estimation
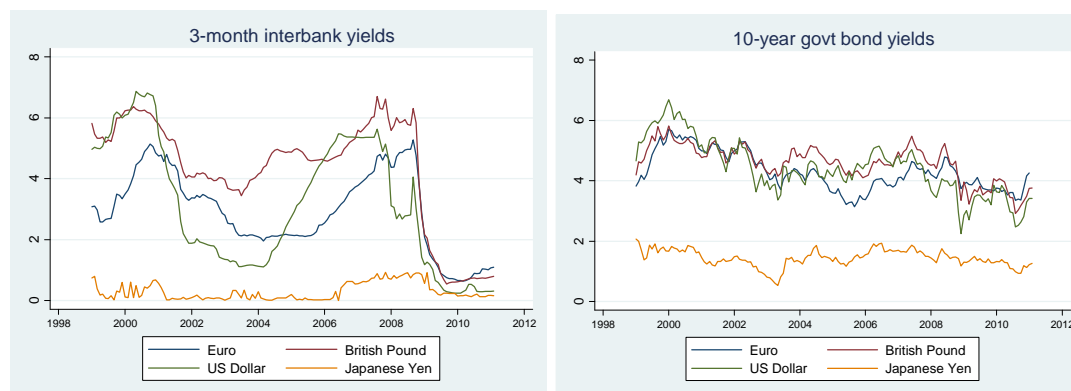
[6] These monthly data are from HAVER (http://www.haver.com/our_data.html). The long-term securities used include: Japanese 10-year benchmarked government bond yields EOP, UK Government Bonds 10-Year Nominal par yield EOP, US 10-Year Treasury Bond yields at constant maturity EOP, and Euro-area 10-year benchmark government bond yields EOP. The short-term deposits used include: Euro-area 11-17 3-month EURIBOR Rate EOP, UK 3-Month London Interbank offered Rate EOP, US 3-Month London Interbank offered Rate EOP, and the Japan Call Rate uncollateralized 3-Month EOP.
[7] COFER information is only available quarterly (so that in these calculations monthly shares are the same within the quarter) and at an aggregated level. The COFER information is used in such a way that issuing countries are not allocated shares of their own currency. For example, Euro assets are only included in the portfolios of countries not in the euro-zone.

Figure 3 shows average estimated interest income (as a percent of foreign currency reserves, *forexR*) for the SDDS countries from 2000 to 2011. Unsurprisingly, the estimates of interest income largely reflect the movements in the underlying bond yields used in their calculation.

Figure 3: Average estimated interest income for SDDS countries (as a percent of *forexR*)
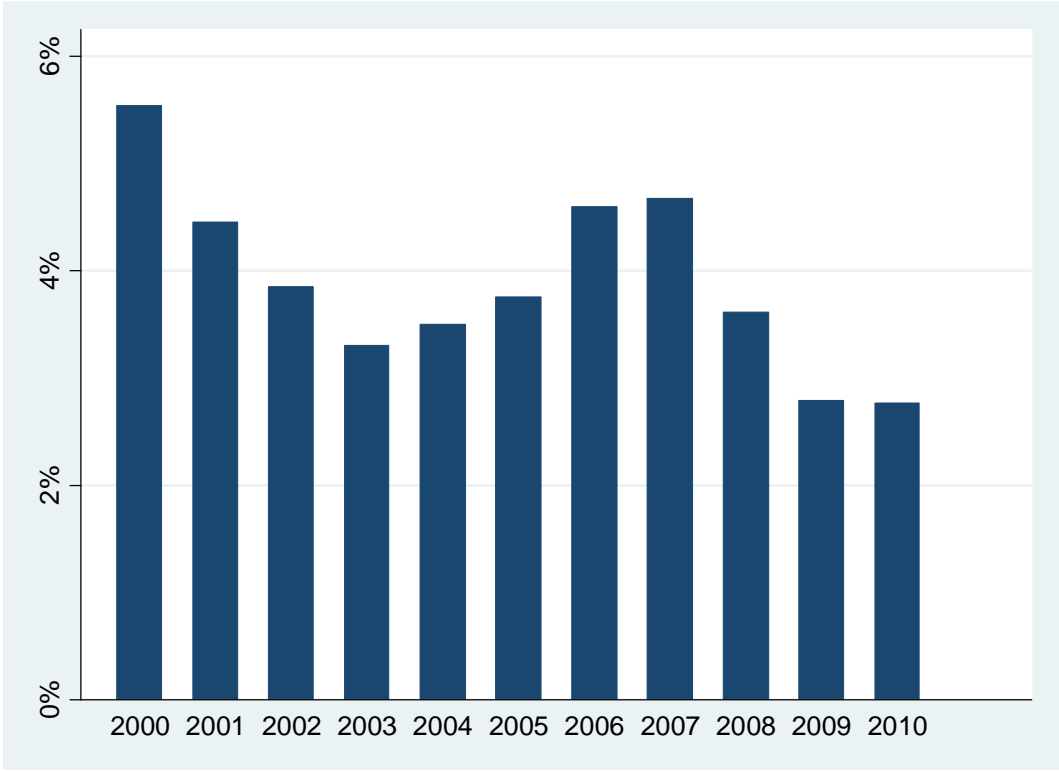
An important assumption underlying the estimated interest income calculation is that each country's share of foreign currency reserve assets in *SecR* and *DepR,* and the respective currency denominations of these assets, are not adjusted over the month; interest income in period $t+1$ is based on asset shares and currency denominations reported in period t. Foreign currency reserves at $t+1$ can be decomposed into the level that would have been achieved with no additions or subtractions of assets into the reserve portfolio from t to $t+1$, defined as

"simulated foreign currency reserves" (*forexR^sim*), plus the purchases and sales of reserve assets

from *t* to *t+1*:

$$forexR_{t+1} = forexR^{sim}_{t+1} + (\Delta^{ps} SecR + \Delta^{ps} DepR)$$

Simulated foreign currency reserves in *t+1* are calculated as foreign currency reserves in period *t*

plus estimated interest income and valuation changes on existing assets that occur between *t* and

t+1:

$$forexR^{sim}_{t+1} = forexR_t + (r^s SecR + r^d DepR) + (\Delta^{val} SecR + \Delta^{val} DepR)$$

Finally, "revalued reserves" (*forexR^rev*) are defined as foreign currency reserves stripped of

interest income and valuation changes:

$$forexR^{rev}_{t+1} = forexR_{t+1} - (r^s SecR + r^d DepR) - (\Delta^{val} SecR + \Delta^{val} DepR)$$
$$= forexR_{t+1} - (forexR^{sim}_{t+1} - forexR_t)$$

    Figure 4 shows the relative shares of each of the components of foreign currency reserves

for the sample of SDDS countries prior to the GFC in 2006Q4. The figure shows that for most

countries purchases and sales of reserves over the quarter are the largest component of foreign

currency reserve accumulation. The figure also shows that valuation changes sometimes go in

the opposite direction. For example, in 2006Q4 valuation loses in Uruguay more than offset the

increases in reserves due to purchases of foreign currency denominated assets.

Figure 4: Cross-Country Foreign Currency Reserve Accumulation/Decumulation Component Shares in 2006Q4
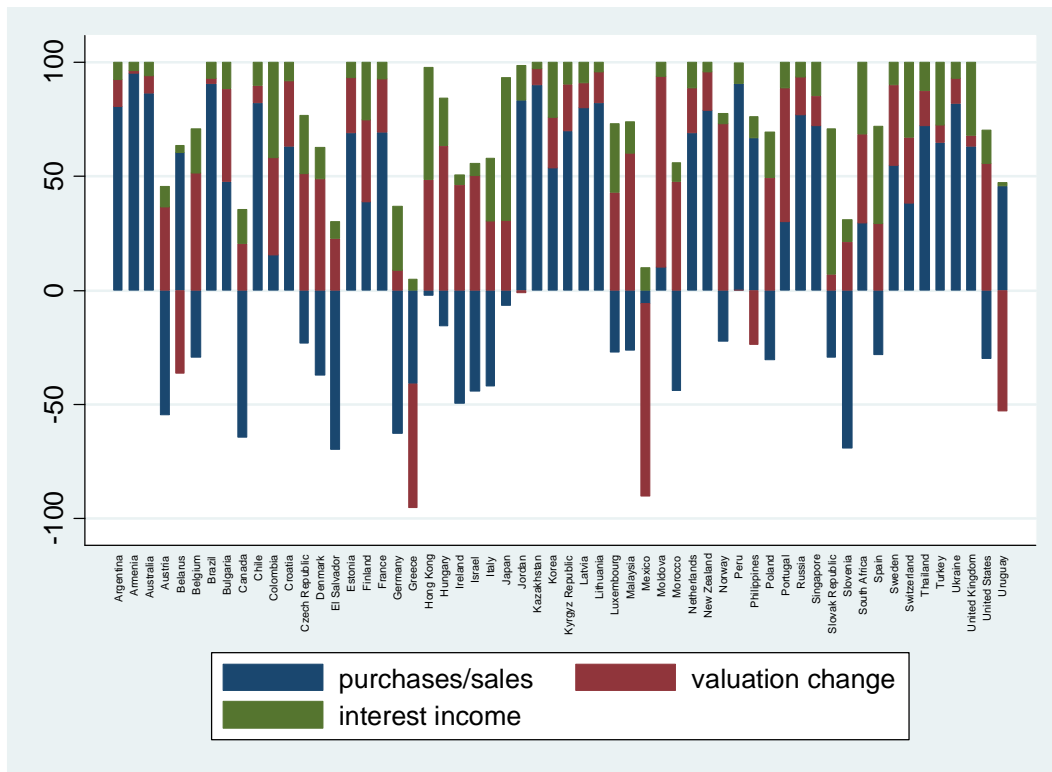
Figure 5 allows us to focus on dollar amounts of foreign currency reserve accumulation components, again in 2006Q4. The figure indicates that the relative importance of purchases and sales of reserve assets, valuation changes, and interest income differs widely across the countries in the sample. While Russia's purchases of reserve assets far outpaced accumulations by the other countries, most countries were increasing their reserve stocks by purchasing reserve assets at the end of 2006.

Figure 5: Cross-Country Purchase/Sales of Reserves, Valuation Changes, Interest Income, and changes in non-Currency Reserves, 2006Q4 (usd millions)
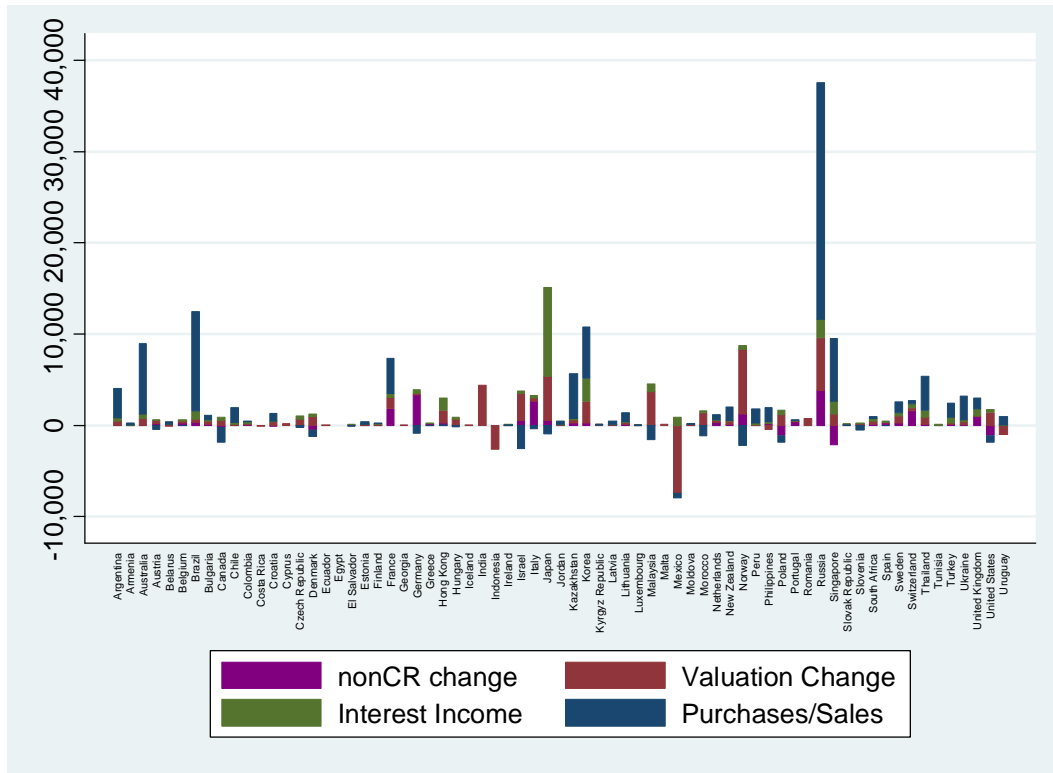
Figure 6 shows the standard deviation of the cross-country distribution of asset purchases and sales ($\Delta^{ps} SecR + \Delta^{ps} DepR$) and valuation changes ($\Delta^{val} SecR + \Delta^{val} DepR$), expressed as ratios to foreign currency reserve stocks. The figure captures the steady increase in dispersion of these components prior to the global financial crisis, with an especially sharp increase in the dispersion of asset purchases and sales in 2008, the peak year for the crisis.

Figure 6: Standard Deviation of Reserve Purchase/Sales and Valuation Changes
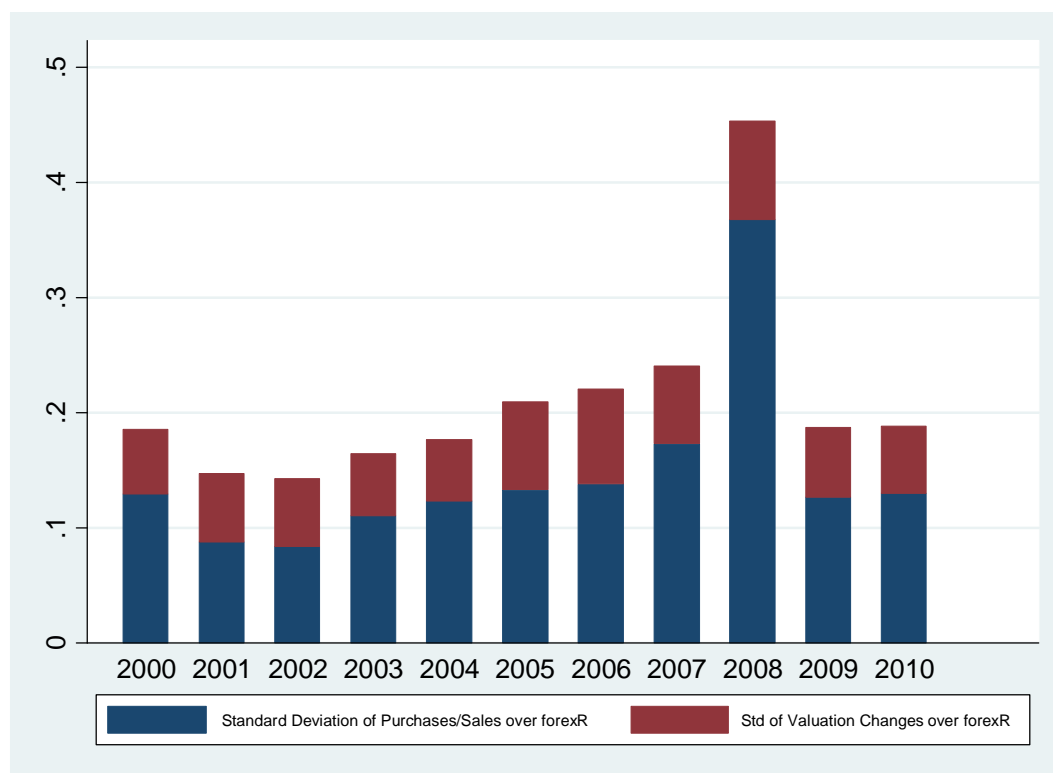
Figure 7 provides an additional time series view of average asset purchases and sales (relative to *forexR*) for the advanced and emerging economies in our sample. The graphs make clear that the behavior of the two groups of countries, in terms of additions and depletions of reserves, differs dramatically, especially during the global financial crisis when the advanced countries continued to accumulate reserves, while emerging economies depleted reserves.

Figure 7: Average Purchases/Sales of Reserve Assets (% *forexR***),**
Advanced and Emerging Countries
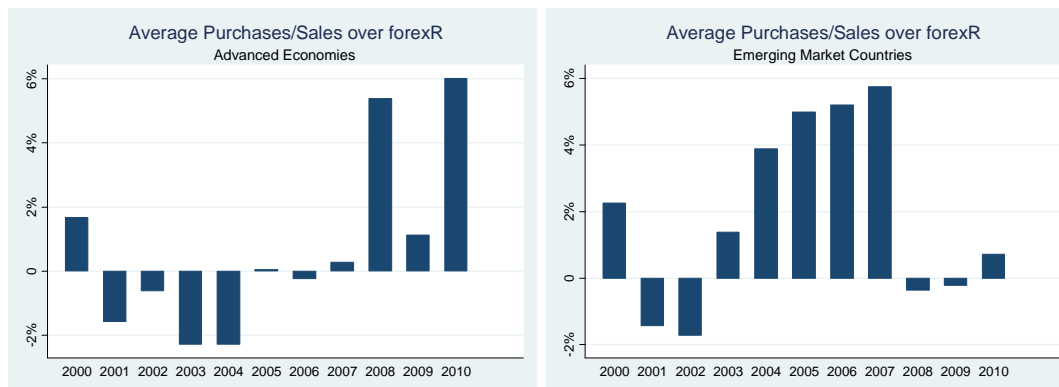
3. Determinants of Reserve Accumulation

Empirical studies of cross country international reserve accumulation behavior find
evidence in support of both precautionary and exchange rate stability motives (see, for example,
Aizenman and Lee (2007)), while at the same time finding that neither motivation fully explains
the upsurge in reserve accumulations by developing countries starting in 2000 (Jeanne (2007)
and Jeanne and Ranciere (2007)). Three recent studies that are better able to explain pre-crisis
reserve accumulations include: Obstfeld et al. (2010) who gauge reserve adequacy against the
size of the banking sector, Hashimoto and Ito (2007) who focus on the adequacy of reserves to
maintain exchange rate stability, and Dominguez (2010) who focuses on the role for reserves in
countries with underdeveloped financial markets.

There are also a few studies that examine reserve policy during the global financial crisis.
Aizenman and Sun (2010) find that trade-dependent countries relied most heavily on reserve
depletion during the crisis, while less open countries tended to allow their exchange rates to
absorb the brunt of adjustment. Obstfeld et al. (2009) and Aizenman et al. (2011) document the
heavy reliance on swap lines of inter-governmental credit during the crisis, especially by

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developed countries that did not have large reserve accumulations. They suggest that swap lines may substitute for reserves for some countries.[8]

Country level reserve data indicate that there is wide variation across countries in terms of both the size of their international reserve stocks as well as their quarterly accumulation trends. In order to better understand reserve management during times of crisis, it is important to first examine what standard models can tell us about why countries build up foreign currency reserves in non-crisis periods. Tables 3 and 4 present cross-country pooled and panel regressions of reserve accumulation, which allow for both self-insurance and exchange rate stability motives. The dependent variable in the regressions is either: (1) the log of international reserves (*IR*) measured using IFS data (this measure of reserves includes interest income, valuation changes in the underlying reserve assets, as well as gold, SDRs, IMF loans, SWFs, and swaps), or (2) revalued foreign currency reserves (*forexR^{rev}*) estimated using the SDDS and Balance of Payments data (this measure excludes changes in reserves due to interest income and valuation changes in the underlying reserve assets as well as gold, SDRs, IMF loans, SWFs, and swaps). The explanatory variables in the reserve accumulation regressions include: country size (GDP), exchange rate changes, export growth, short-term debt ratios (from JEDH), the current account to GDP ratio, the interest rate differential between domestic and US deposits, the share of M2 to GDP [9], a dummy variable indicating the country-specific peak to trough seasonally–adjusted real GDP during the global financial crisis, a dummy variable indicating that the country has a Sovereign Wealth Fund (starting the year the SWF was established), and a dummy variable

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[8] It is worth noting that swap lines that are drawn upon are part of a country's international reserves.
[9] Including M2/GDP as an explanatory variable in the regressions reduces the cross-country panel significantly. The (dropped) countries include: Australia, Austria, Belgium, Canada, Croatia, Finland, France, Germany, Greece, India, Ireland, Italy, Netherlands, Peru, Philippines, Portugal, Spain, Thailand, Tunisia, and UK.

indicating that the country drew on Fed Swap lines during the crisis. The data sources for the

variables included in the reserve accumulation regressions are provided in table 2.[10]

Tables 3 and 4 present the regression results using two measures of reserves (*IR* and

forexR^{rev}) and, in alternative columns, include only the emerging economies in our sample. Table

3 includes a wider range of explanatory variables (which limits the country sample) and table 4

maximizes country and time coverage at the expense of excluding some explanatory variables.

Analysis of the tables suggests that both precautionary and exchange rate stability factors were

important drivers of reserve accumulation for this sample of countries. The reported coefficient

estimates, across the various specifications, suggest that there are multiple reasons that countries

accumulate reserves; no one explanatory variable seems to be driving reserve behavior across

these countries. Interestingly, the influence of the explanatory variables is not qualitatively

different depending on whether the traditional international reserves measure or revalued foreign

currency reserves is used to measure the dependent variable. The coefficient signs on the

indicator variables in the table are generally intuitive, indicating that reserve accumulation was

higher for countries with SWFs, and lower for countries that drew on Fed swap lines. There is

evidence that countries with higher short-term debt ratios accumulate more reserves[11], as do

countries that have higher export growth (or current account surpluses). A higher interest

differential (indicating higher quasi-fiscal costs of reserve holdings) leads to lower

accumulations and higher M2 to GDP (which measures the degree of monetization in the

country's banking system) leads to higher accumulations.

The pooled and panel regressions generally explain around 50 percent of the variation in

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[10] I am grateful to Joshua Aizenman and Yi Sun for providing the data on a number of the included explanatory variables.
[11] The role of short-term debt both in motivating countries to build up reserves as well as its role during the global financial crisis has been the subject of a number of recent studies, including Blanchard et al. (2010), Frankel and Saravelos (2010) and Rose and Spiegel (2012). The estimated coefficients from the panel regressions reported in tables 3 and 4 indicate, as most studies do, that countries with higher short-term debt to GDP ratios accumulate larger stocks of reserves, reflecting the precautionary motive.

reserve accumulation for the SDDS countries over the period 2000 through 2010. This suggests

that while the standard motives for reserve accumulation are clearly important drivers, the

empirical model is not fully capturing reserve accumulation behavior for these countries. Put

another way, the inability of this type of benchmark model to fully explain recent reserve

accumulation behavior provides us with a measure of "unexplained" reserves, defined as reserve

levels that differ from the model predicted values.

4. Unexplained Reserves

There are a number of ways to measure expected reserve accumulation trends across

countries. The simplest approach is to predict reserve accumulation on a country-by-country

basis using a linear trend model. The underlying assumption in this case is that countries that

have been steadily increasing reserves in the past are likely to continue to do so into the future.

The first panel of Figure 8a shows actual foreign currency reserves (measured excluding interest

income and valuation changes) over the period 2000-2010 along with predicted values based on

a linear trend model. Unsurprisingly the linear trend tends to under-predict reserves in the years

when reserve accumulation was higher than in the past (2004-2008) and over-predict reserves in

the years when accumulation slowed down (2009-10).

Figures 8a: Actual and Predicted Foreign Currency Reserves (excluding interest income and valuation changes) based on a country-by-country linear trend and structural model
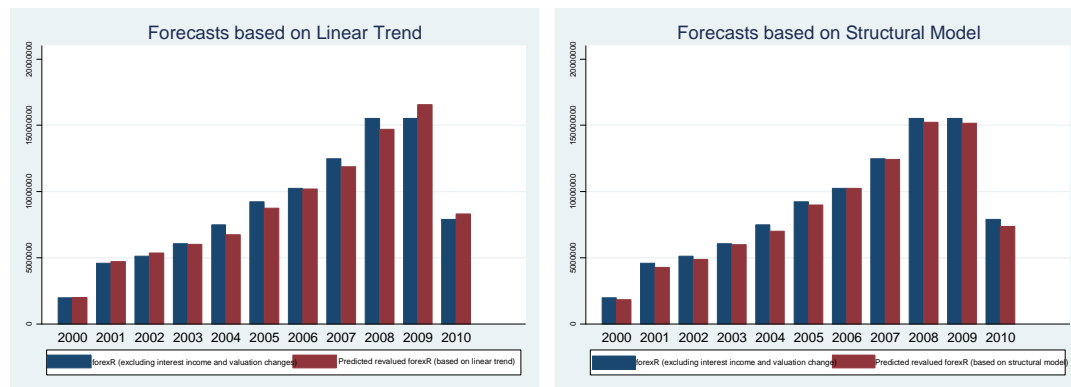
Another approach to predicting reserve accumulation is to use a regression model which includes explanatory variables that reflect the underlying motives for accumulation. The predicted values for revalued foreign currency reserves included in the second panel of Figure 8a are based on country-by-country regression specifications similar to those reported in tables 3 and 4. The regression specification used for each country was based on the availability of potential explanatory variables. The "unexplained" reserve growth based on country-by-country structural empirical models is generally smaller than is the case when predictions are based on a simple (own-country) linear trend. Actual reserves always exceed predicted values, but the model-based predictions also fall during the GFC reflecting declines in a number of the included explanatory variables (for example, GDP and export growth).

A third approach to predicting reserve accumulation is to use a panel specification, which allows us to incorporate cross-country as well as own-country information. If country's reserve accumulation trends are influenced by the behavior of other countries, then the panel predictions will outperform predictions based only on own-country information. The predicted values for revalued foreign currency reserves in Figure 8b are based on the panel regression specifications reported in tables 3 and 4. In this case fitted values tend to over-predict reserve accumulations

prior to 2004, under-predict accumulations through 2008, and then again over- predict

accumulations in 2010.

Figure 8b: Actual and Predicted Foreign Currency Reserves (excluding interest income and valuation changes) based on the panel structural model
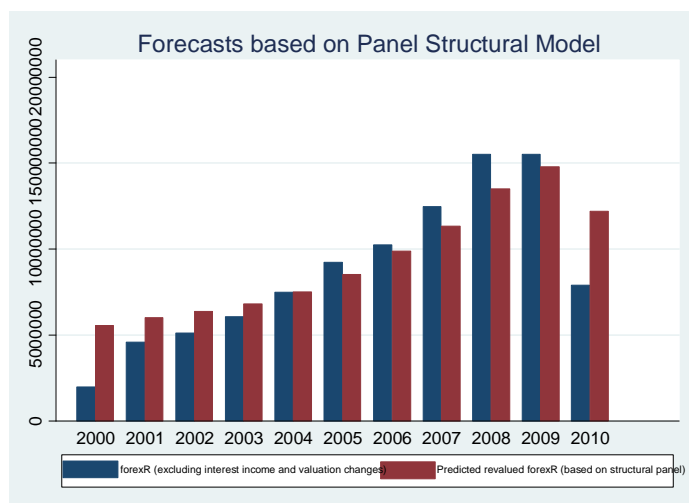

This paper measures "unexplained" reserves as the difference between actual reserves

and the estimated fitted values based on the country-by-country structural empirical model,

which on average, best predicted reserves over this period. Reserves are measured as total

international reserves as well as revalued foreign currency reserves (which exclude interest

income and valuation changes). In each case "unexplained" reserves are calculated as:

$R\_unexplained_{it} = R_{it} - \hat{R}_{it}$ where $\hat{R}_{it}$ is the fitted value from the estimated regression for country i

at time t. $R\_unexplained_{it}$ is a proxy for the extent of "unexplained" reserves, in the sense that it

reflects reserve accumulations that cannot be linked in a systematic fashion to the explanatory

variables included in the benchmark regression specification. To the extent that the benchmark

regression does a good job capturing "normal" reserve accumulations, one can distinguish

countries based on the relative size of their "unexplained" reserves.

The structural empirical model specification used in the calculations of unexplained reserves includes explanatory variables that reflect the precautionary and exchange rate stability motives that are typically thought to be the main drivers of reserve accumulation. Another set of variables that might influence a country's management of reserves include lagged values of interest income and valuation changes. If a country experiences valuation losses on their previously accumulated stock of reserves, or receives lower than expected interest income, this might lead to purchases or sales of assets depending on underlying motives for reserve accumulation. It may also be the case that countries holding an excess of "unexplained" reserves are more likely to further accumulate reserves. The specification reported in Table 5 allows us to examine the relationship between current reserve accumulation and past accumulation trends, valuation changes, interest income and unexplained reserve levels. The estimated regression coefficients suggest that accumulation trends and valuation gains in the past year (measured as accumulated lagged observations over the past four quarters) lead to lower current reserve accumulation, while gains in interest income and excess "unexplained" reserves in the past year lead to higher current accumulations.

5. Reserve Management during and after the Global Financial Crisis

The analyses of reserves in the previous section examined behavior over the full time-series available for SDDS subscribers, which for most countries is 2000Q1-2010Q4. In this section the focus will exclusively be on reserve accumulation during and after the global financial crisis (GFC). If one of the important motives for reserve accumulation is precautionary self-insurance against crises, countries that have accumulated large stocks of reserves prior to a crisis might be expected to behave differently than countries with lower levels of initial reserve

stocks. Further, those countries with the largest excess "unexplained" reserve positions prior to a crisis will presumably be in a better position to deplete reserves during a crisis.

Dominguez et al. (forthcoming) argue that getting the timing right in an analysis of country-level reserve behavior during the GFC is critical. While many of the advanced countries went into crisis in the fall of 2007, the crisis did not hit most emerging economies until mid-2008. Country level plots of reserve levels show that for many of the countries which depleted reserves during the crisis, this was done during their own country-specific crisis period (measured as peak-to-trough real seasonally-adjusted GDP after 2007). Further, those countries that lost the largest fractions of their reserves during the GFC were also often the countries whose reserves were rising fastest prior to the crisis, so that they both gained and lost reserves around the crisis period. An injudicious start and end date for measurement of reserve changes for these countries could easily indicate no change in reserve levels, while a view of the higher-frequency time series indicates dramatic variation. Figure 9 shows this pattern for Russia, one of the largest reserve accumulators in our sample. The shaded sections of the graph delineate Russia's country specific crisis period.

Figure 9: Estimates of Russia's Foreign Reserve Management during the GFC
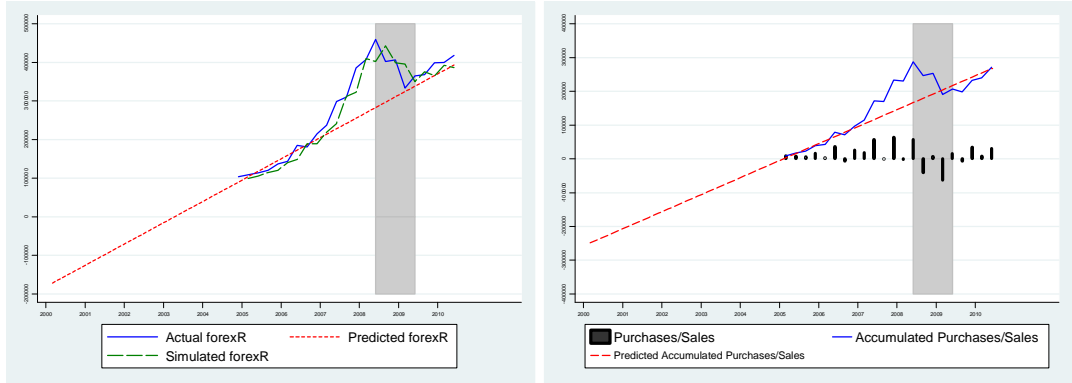
In order to examine reserve management during and after the GFC a cross-sectional database was created using country-specific crisis periods to measure changes in the relevant variables (these crisis dates are listed in table 1). Figure 10 shows total amounts of reserve purchases/sales, interest income and valuation changes for each of the countries in the sample during the global financial crisis, where the crisis is defined for each country based on its own peak-to-trough real seasonally adjusted GDP after 2007. Figure 11 shows the same variables measured after the country-specific crisis period. It is interesting to note that many of the countries that depleted reserves during the crisis show up as reserve accumulators after the crisis. It is also worth noting that the country with the largest increase in reserve accumulation after the crisis is Switzerland, which intervened heavily in March 2009 through May 2010 in an attempt to stop the appreciation of the Swiss franc.

Figure 10: Reserve Components during the GFC
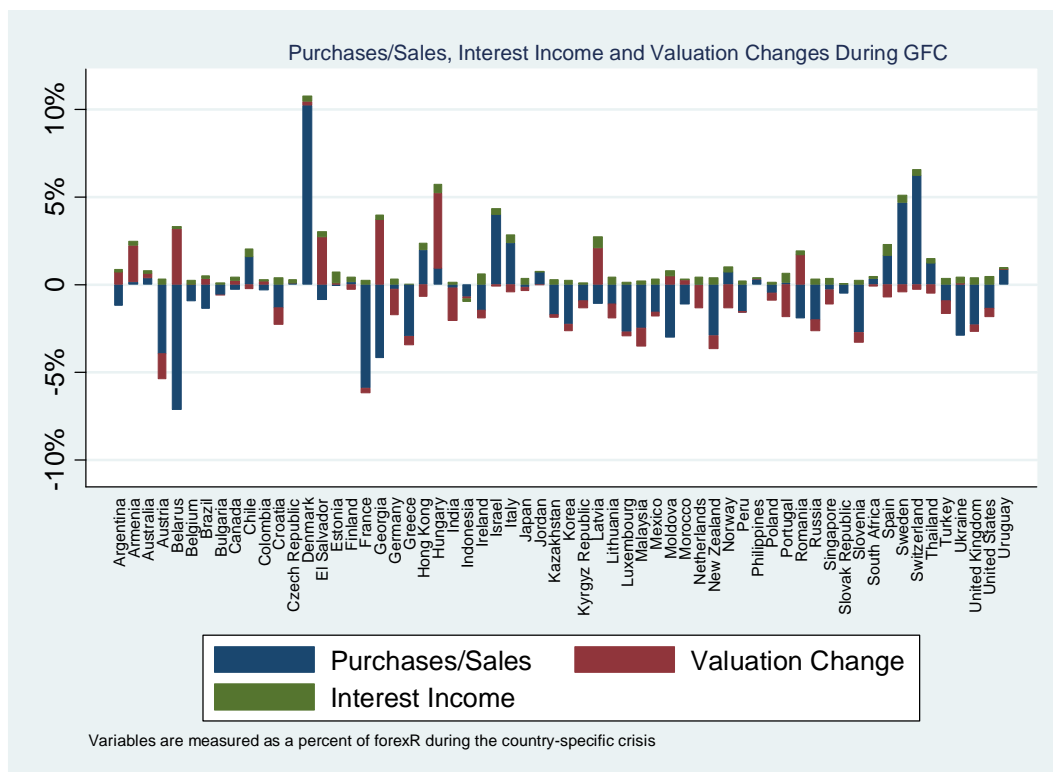
Figure 11: Reserve Components after the GFC

Purchases/Sales, Interest Income and Valuation Changes after the GFC

Legend: Purchases/Sales over forexR, Valuation Change over forexR, Interest Income over forexR
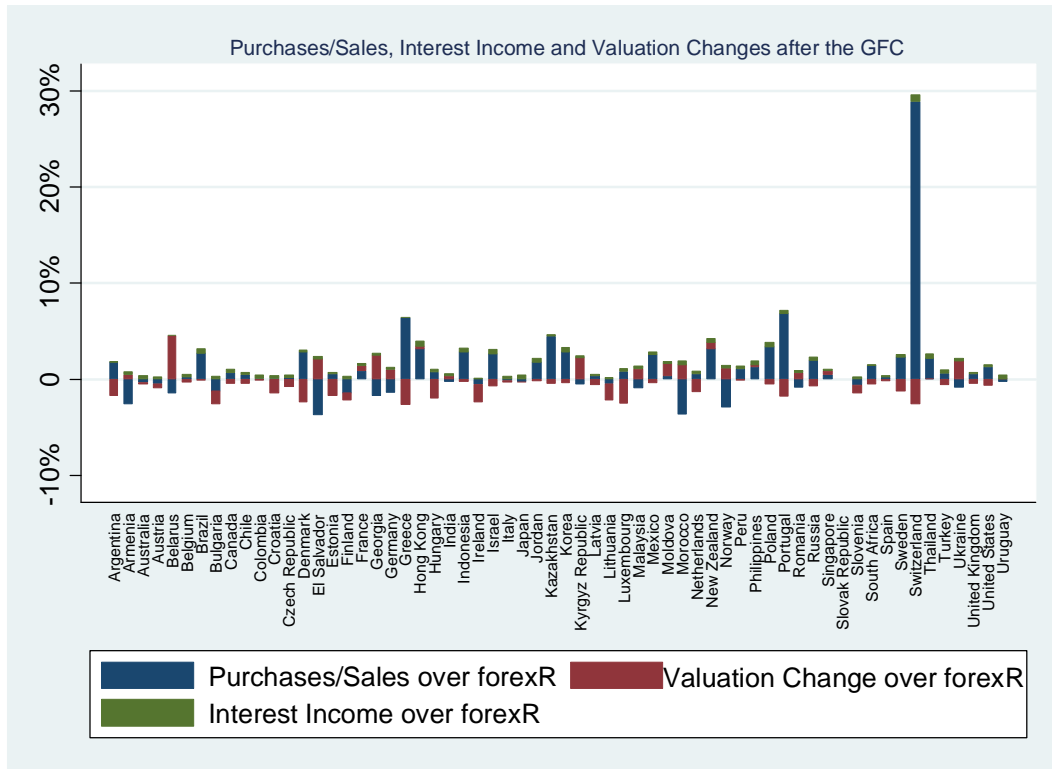
Table 6 presents results for cross-sectional regressions of the determinants of changes in international reserves (*IR*) and revalued foreign currency reserves (*forexR^{rev}*) which reflect reserve management during the GFC. Alternative columns in the table include only the emerging economies. The explanatory variables in these regressions are measured either in 2006Q4 (well before the onset of the crisis for any of the countries in the sample), or as changes over the period 2000-through the start of the country specific crisis. The dependent variables, *IR* and *forexR^{rev}*, are measured for each country over the country-specific crisis period. The independent variable in these specifications that is consistently statistically significant and negative is the measure of past unexplained reserves (based on estimates from the country-by-country empirical structural model). Greater excess unexplained reserves prior to the crisis allowed for depletions of reserves during the crisis. Interestingly the table also suggests that reserve purchases/sales, valuation gains and increases in interest income prior to the crisis led to

further accumulations of reserve assets during the crisis. Figure 12 shows the components of reserves (purchases/sales, valuation changes and interest income) for those countries that depleted reserves during their country-specific crisis period. Many of these countries experienced reductions in their foreign exchange reserve stocks during the crisis due to negative valuation changes on existing assets, as well as from outright sales of reserve assets.

Figure 12: Reserve Components as a share of *forexR* during the GFC for countries that depleted reserves
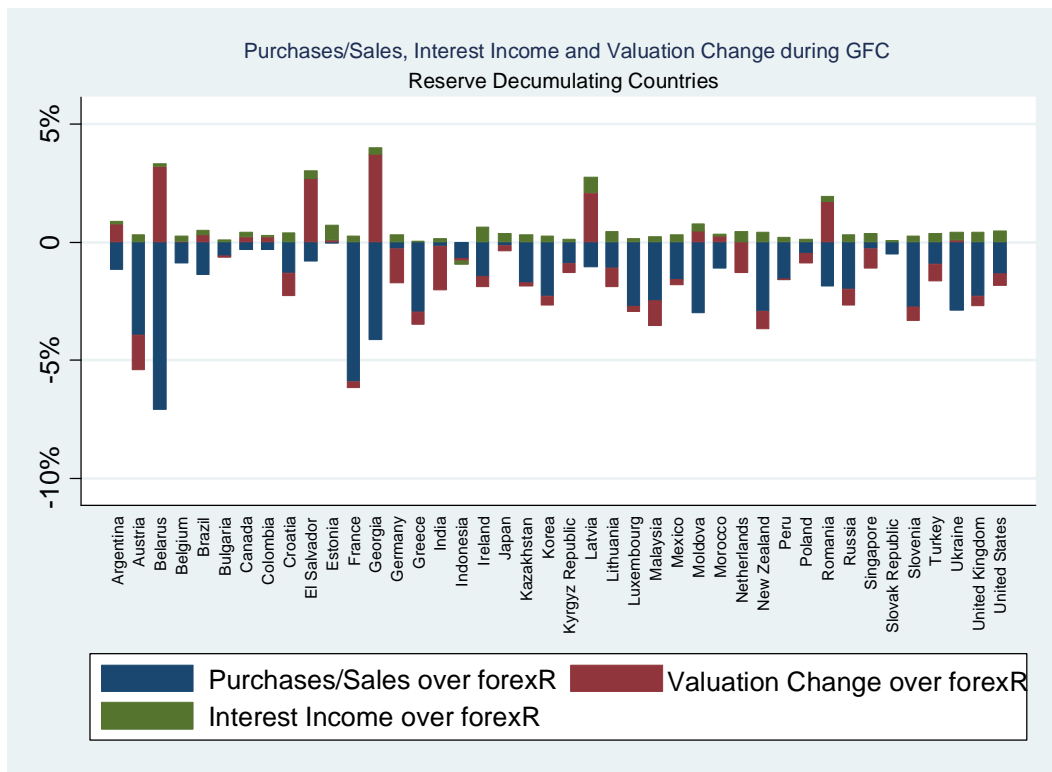
Table 7 presents results for a similar cross-section regression specification for the post GFC period. Again it is the case that higher excess unexplained reserves (this time measured during the GFC) led to lower reserve accumulation after the GFC. In the specifications using revalued foreign currency reserves (which exclude interest income and valuation changes) after

the global financial crisis, coefficient estimates suggest that countries that peg their exchange rates (and countries that experienced depreciations of their currencies during the crisis) increased reserve accumulation after the GFC. The only component of foreign currency reserves that seems to have influenced post GFC accumulations is interest income, where the effect is now negative. Since most countries experienced declines in interest income during the GFC (as shown in Figure 3) this suggests that countries reacted to these losses by increasing their rate of reserve accumulation in the post GFC period.

6. Conclusions

The analysis in this paper indicates that reserves played a role in macroeconomic crisis management during the global economic crisis. Although reserve stocks for many countries remained stable during the crisis, when reserve changes due to interest income and valuation changes are excluded, the data suggest that many emerging economies actively depleted reserves. Further, the data indicate that countries whose pre-crisis reserves were in excess of what can be explained by standard models of reserve accumulation were the most likely to use their reserves during the crisis.

The decomposition of foreign currency reserves into changes due to market movements in asset prices and changes due to purchases and sales of reserve assets was made possible by a new initiative at the IMF which requires subscribing countries to provide detailed monthly information on the asset composition of their foreign reserve portfolios. Unfortunately at this point only 68 countries have agreed to provide this data, limiting the sample of countries that can be included in the empirical analysis. It is for this reason that two major reserve accumulating countries, China and Saudi Arabia, are conspicuously missing. Neither of these countries are

SDDS subscribers. The results in this paper are therefore subject to the caveat that they do not

take into account the behavior of these two important reserve accumulating countries.

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Table 1: Reserve Data Coverage and Country-Specific GFC dates

Country	EM/AE	Date when subscriber met SDDS specifications — Date	SDDS reserve data (Monthly) Start date — Start date	IFS_IR (Monthly) Start date — year	IFS_IR (Monthly) Start date — m	*bopR* (Annual) Start date — year	*bopR* (Quarterly) Start date — year	*bopR* (Quarterly) Start date — Q	GFC start date — year	GFC start date — Q	GFC end date — year	GFC end date — Q
Argentina	EM	1-Nov-99	Sep-00	1957	1	1976	1976	1	2008	2	2009	1
Armenia	EM	7-Nov-03	Nov-03	1992	12	1993	1993	1	2008	3	2009	1
Australia	AE	23-Jul-01	Mar-00	1957	1	1960	1959	3	2008	3	2009	2
Austria	AE	5-Jul-01	Jun-00	1957	1	1967	1970	1	2008	4	2009	1
Belarus	EM	22-Dec-04	Nov-04	1994	12	1993	1996	1	2008	3	2009	1
Belgium	AE	26-Jan-01	Jul-00	1957	1	2002	2002	1	2008	3	2009	1
Brazil	EM	14-Mar-01	Feb-01	1957	1	1975	1975	1	2008	3	2009	1
Bulgaria	EM	1-Dec-03	Sep-03	1991	12	1980	1991	1	2008	3	2009	1
Canada	AE	19-Feb-99	Apr-00	1978	3	1977	1998	1	2008	3	2009	2
Chile	EM	30-Mar-00	Aug-00	1980	7	1982	2010	1	2008	2	2009	1
China: Hong Kong	EM	12-Jul-00		1984	6	1998	1999	1	2007	4	2009	1
Colombia	EM	9-May-00	Apr-00	1980	12	1968	1996	1	2008	4	2009	1
Costa Rica	EM	28-Nov-01	Apr-00	1992	12	1993	1993	1	2009	1	2009	2
Croatia	EM	30-Mar-01	Mar-00	1964	1	1976	1978	2	2008	3	2009	1
Cyprus	AE	1-Dec-09	Jan-10	1993	1	1993	1993	1	2008	2	2009	1
Czech Republic	EM	4-Jun-99	Mar-00	1993	1	1993	1993	1	2008	4	2009	1
Denmark	AE	1-Sep-00	Dec-99	1957	1	1975	1975	1	2007	4	2009	1
Ecuador	EM	14-Jul-00		1957	1	1976	1993	1	2007	4	2009	1
Egypt	EM	31-Jan-05	Aug-09	1962	1	1977			2009	1	2009	2
El Salvador	EM	12-Oct-99	Apr-00	1957	1	1976	1999	1	2007	4	2009	1
Estonia	EM	30-Mar-00	Jan-11	1992	6	1992	1992	1	2007	4	2009	1
Finland	AE	2-Jun-00	Apr-00	1957	1	1975	1975	1	2007	4	2009	1
France	AE	27-Apr-01	Aug-00	1957	1	1975	1975	1	2008	3	2009	3
Georgia	EM	17-May-10	Jan-07	1995	10	1997	1997	1	2008	4	2009	1
Germany	AE	23-Mar-00	Dec-99	1957	1	1971	1971	1	2008	1	2009	1
Greece	AE	8-Nov-02	Jan-03	1957	1	1976	1976	1	2008	3	2009	1
Hungary	EM	24-Jan-00	Apr-00	1983	12	1982	1989	4	2008	4	2009	1
Iceland	EM	30-Jun-04	Oct-00	1957	1	1976	1976	1	2008	4	2009	1
India	EM	14-Dec-01	Oct-07	1957	1	1975	1975	1	2008	4	2009	1
Indonesia	EM	2-Jun-00	Dec-06	1971	1	1945	1945	1	2008	3	2008	4
Ireland	AE	17-Jul-01	Apr-01	1958	1	1974	1981	1	2007	4	2009	4
Israel	AE	5-Jun-00	Dec-01	1957	1	1952	1972	1	2009	1	2009	4
Italy	AE	14-Apr-00	Aug-00	1957	1	1970	1970	1	2008	2	2009	2
Japan	AE	9-Jun-00	Apr-00	1957	1	1977	1977	1	2007	2	2009	1
Jordan	EM	28-Jan-10	Jan-06	1958	1	1972	1977	1	2008	3	2009	1
Kazakhstan	EM	24-Mar-03	Feb-03	1993	11	1995	1995	1	2008	3	2009	1

Country	EM/AE	Date when subscriber met SDDS specifications Date	SDDS reserve data (Monthly) Start date Start date	IFS_IR (Monthly) Start date year	m	bopR (Annual) Start date year	bopR (Quarterly) Start date year	Q	GFC start date year	Q	GFC end date year	Q
Korea, Republic of	EM	1-Nov-99	Jan-05	1957	1	1976	1976	1	2007	4	2009	1
Kyrgyz Republic	EM	26-Feb-04	Feb-04	1993	12	1993	1993	1	2008	3	2009	1
Latvia	EM	28-Sep-99	Apr-00	1993	7	1992	1993	1	2007	4	2009	4
Lithuania	EM	12-Jul-99	Apr-00	1992	12	1993	1993	1	2008	3	2009	1
Luxembourg	AE	12-May-06	Jan-06	1984	12	2002	2002	1	2008	4	2009	2
Malaysia	EM	1-Sep-00	Apr-00	1959	8	1974	1999	1	2008	3	2009	1
Malta	EM	1-Dec-09	Dec-09	1960	1	1971	1995	1	2008	3	2009	1
Mexico	EM	29-Jun-00	Jan-00	1957	1	1979	1979	1	2008	3	2009	1
Moldova	EM	2-May-06	May-06	1991	12	1994	1994	1	2008	4	2009	1
Morocco	EM	15-Dec-05	Nov-05	1961	1	1975	2003	1	2009	1	2009	3
Netherlands	AE	26-Apr-00	Apr-00	1957	1	1960	1960	1	2008	3	2009	2
New Zealand	AE		Mar-00	1967	9	1972	1980	1	2008	4	2009	2
Norway	EM	28-Apr-00	Apr-00	1957	1	1975	1975	1	2008	4	2009	2
Peru	EM	15-Jul-99	Jan-06	1957	1	1977	1977	1	2008	2	2009	1
Philippines	EM	17-Jan-01	Apr-00	1957	1	1977	1977	1	2008	4	2009	1
Poland	EM	2-Mar-00	Apr-00	1984	12	1976	1985	1	2008	4	2009	1
Portugal	AE	1-Dec-00	Apr-00	1957	1	1975	1975	1	2007	4	2009	1
Romania	EM	4-May-05	Jan-07	1979	1	1971	1991	1	2008	4	2009	1
Russian Federation	EM	31-Jan-05	Dec-04	1993	12	1994	1994	1	2008	3	2009	1
Singapore	AE	30-Jan-01	Aug-00	1969	1	1972	1995	1	2007	4	2009	1
Slovak Republic	AE	7-Oct-99	Dec-99	1993	1	1993	1993	1	2008	3	2009	1
Slovenia	AE	7-Jul-00	Mar-00	1991	12	1992	1992	1	2008	3	2009	1
South Africa	EM	18-Sep-00	Jul-00	1957	1	1946	1960	1	2009	1	2009	2
Spain	AE	21-Dec-00	Aug-00	1958	1	1975	1975	1	2008	2	2009	3
Sweden	AE	29-Jun-00	Aug-00	1957	1	1970	1975	1	2007	4	2009	1
Switzerland	AE	18-May-01	Sep-00	1957	1	1977	1999	1	2008	3	2009	2
Thailand	EM	16-May-00	Apr-00	1957	1	1975	1976	1	2008	3	2009	2
Tunisia	EM	20-Jun-01	May-01	1964	1	1976			2007	4	2008	1
Turkey	EM	20-Jul-01	Aug-00	1957	1	1974	1984	1	2008	3	2009	1
Ukraine	EM	10-Jan-03	Dec-02	1992	12	1980	1980	1	2008	3	2009	1
United Kingdom	AE	6-Jul-99	Apr-00	1957	1	1970	1970	1	2008	2	2009	2
United States	AE	19-Feb-99	Jan-08	1957	1	1970	1973	1	2008	3	2009	2
Uruguay	EM	12-Feb-04	Aug-03	1958	1	1978	2000	1	2007	4	2009	1

Total number of SDDS subscribers: 68 (as of May 2011)

Table 1 notes: IFS_IR data for Czech Republic are Total Reserves minus Gold. New Zealand is not a SDDS subscriber but provides the detailed data and is included in the analysis and graphs. Crisis dates are based on country-specific peak to trough percent change in SA real GDP after 2007.

Table 2: Data Used in the Regressions Analyses

Variable	Description	Frequency	Source
IR	IFS International Reserves	Monthly	IFS
forexR	SDDS Foreign Currency Reserves (Securities + Currency and Deposits)	Monthly	IMF SDDS database
Purchases/Sales	forexR(t) - forexR(t-1) - interest income - valuation changes	Quarterly	author calculations
bopR	Reserves and Related Items	Quarterly	IFS
GDP_WEO	Annual GDP (current usd prices)	Annual	World Economic Outlook (WEO)
GDP	Quarterly GDP (national currency)	Quarterly	IFS
GDP deflator	GDP deflator or CPI deflator if not available	Quarterly	IFS and country sources
Export Growth	Quarterly Export Growth	Quarterly	IFS
Exchange Rate Changes	Quarterly Exchange Rate Changes	Quarterly	IFS
Interest Differential	Domestic minus US interest rate	Monthly	IFS
M2	M2 (or M3 if M2 was not available)	Monthly	IFS
Current Account	Currency Account	Quarterly	IFS
ST Debt	short term debt (ST liabilities to BIS banks + ST international debt securities + cross-border loans from BIS reporting banks + international debt securities)	Quarterly	WB and WEO
SWF	Dummy for countries with SWF starting in year fund is established	Annual	country sources
Fed Swap Line	Dummy for countries which drew on Fed Swap Lines	Monthly	Fed
GFC Indicator	Dummy indicating country-specific peak to trough GDP during the GFC	Quarterly	author calculations

Table 3: Determinants of Reserve Accumulation for SDDS Countries (Quarterly Observations 2000-2010)

	Pooled Regression				Panel Regression			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	IR (all cos)	IR (EM)	$forexR^{rev}$ (all)	$forexR^{rev}$ (EM)	IR (all)	IR (EM)	$forexR^{rev}$ (all)	$forexR^{rev}$ (EM)
GDP	0.310***	0.249***	0.280***	0.167***	1.220***	1.116***	1.307***	1.203***
	(0.0120)	(0.0132)	(0.0158)	(0.0164)	(0.0293)	(0.0276)	(0.0365)	(0.0341)
Exchange Rate Change	0.120	0.0909	0.0224	-0.154	0.132	0.182**	0.311***	0.274***
	(0.320)	(0.281)	(0.261)	(0.241)	(0.0948)	(0.0894)	(0.0914)	(0.0827)
Export Growth	0.0369	0.0470	0.0703	0.0282	0.0875	0.0358	0.138**	0.0362
	(0.301)	(0.355)	(0.267)	(0.317)	(0.0591)	(0.0595)	(0.0677)	(0.0657)
Short-Term Debt (% GDP)	0.441***	0.402***	0.253***	0.00402	0.193***	0.417***	0.0749	0.270***
	(0.0389)	(0.126)	(0.0376)	(0.125)	(0.0495)	(0.0637)	(0.0488)	(0.0620)
Current Account (% GDP)	1.285***	1.248**	2.678***	1.500***	0.199	0.289*	0.237	0.438**
	(0.313)	(0.499)	(0.421)	(0.570)	(0.168)	(0.151)	(0.201)	(0.180)
Interest Differential	-0.00504	0.00370	0.00603**	0.0174***	-0.00249*	-0.00401***	-0.000614	-0.00159
	(0.00471)	(0.00451)	(0.00252)	(0.00359)	(0.00135)	(0.00120)	(0.00142)	(0.00124)
M2 (% GDP)	0.177***	0.236***	0.191***	0.250***	0.292***	0.513***	0.158***	0.356***
	(0.00810)	(0.0182)	(0.00808)	(0.0230)	(0.0195)	(0.0315)	(0.0198)	(0.0354)
GFC Indicator	0.182*	0.280**	0.150	0.128	0.0536*	0.0191	0.0747**	0.0255
	(0.103)	(0.122)	(0.0993)	(0.128)	(0.0310)	(0.0331)	(0.0302)	(0.0310)
SWF	0.559***	0.610***	0.165**	0.647***	0.0122	0.0560	0.313***	0.495***
	(0.0637)	(0.0907)	(0.0707)	(0.101)	(0.0491)	(0.0473)	(0.0797)	(0.0920)
Fed Swap Line	-0.410***	-0.159	-0.439***	-0.347**	-0.00176	-0.167**	0.0356	-0.195***
	(0.141)	(0.174)	(0.133)	(0.140)	(0.0429)	(0.0680)	(0.0407)	(0.0653)
Constant	0.899***	2.407***	1.934***	4.671***	-23.81***	-21.37***	-25.92***	-23.52***
	(0.330)	(0.373)	(0.427)	(0.475)	(0.780)	(0.729)	(0.981)	(0.906)
Observations	1,161	801	887	589	1,161	801	887	589
R-squared	0.569	0.512	0.546	0.449	0.764	0.841	0.739	0.836
Number of Countries	34	24	31	22	34	24	31	22

Notes: robust standard errors in parentheses; *, **, *** denote statistical significance at the 10, 5 and 1% levels, respectively; dependent variables are in natural logs; IR is "International Reserves" (includes interest income, valuation changes, purchases/sales of assets, gold, IMF loans, SDRs, SWFs, drawn swap lines), $forexR^{rev}$ is "Foreign Currency Reserves minus valuation changes and interest income" (includes only foreign currency denominated deposits and securities). "All" includes all countries that provide SDDS reserve data; "EM" includes only emerging market countries. Reserve data for countries prior to joining the Eurozone is excluded. Panel regressions include country fixed effects.

Table 4: Determinants of Reserve Accumulation for SDDS Countries (Quarterly Observations 2000-2010)

VARIABLES	Pooled Regression				Panel Regression			
	(1) *IR* (all cos)	(2) *IR* (EM)	(3) *forexR^{rev}* (all)	(4) *forexR^{rev}* (EM)	(5) *IR* (all)	(6) *IR* (EM)	(7) *forexR^{rev}* (all)	(8) *forexR^{rev}* (EM)
GDP	0.262***	0.242***	0.255***	0.183***	1.309***	1.286***	1.296***	1.300***
	(0.0119)	(0.0141)	(0.0147)	(0.0180)	(0.0255)	(0.0220)	(0.0411)	(0.0366)
Exchange Rate Change	-0.952*	-0.830	-0.245	-0.209	0.292***	0.346***	-0.355***	-0.465***
	(0.487)	(0.596)	(0.231)	(0.294)	(0.0936)	(0.0906)	(0.109)	(0.0993)
Export Growth	-0.0310	0.113	0.0850	0.0809	0.149***	0.0949*	0.166**	0.0947
	(0.218)	(0.305)	(0.197)	(0.306)	(0.0536)	(0.0565)	(0.0662)	(0.0740)
Short-Term Debt % GDP	-0.112***	0.677***	-0.105***	0.128	-0.0520***	0.382***	-0.0960***	0.241***
	(0.00655)	(0.146)	(0.00916)	(0.137)	(0.00821)	(0.0489)	(0.0114)	(0.0572)
Current Account % GDP	3.965***	2.339***	5.142***	2.328***	0.782***	0.0863	0.840***	0.233
	(0.447)	(0.627)	(0.560)	(0.687)	(0.169)	(0.167)	(0.219)	(0.224)
GFC Indicator	0.278***	0.428***	0.357***	0.313***	0.0737***	0.0758***	0.171***	0.145***
	(0.0861)	(0.122)	(0.0871)	(0.121)	(0.0261)	(0.0289)	(0.0290)	(0.0321)
SWF	0.677***	0.881***	0.357***	0.886***	0.0538	-0.0261	0.0968	-0.0155
	(0.0608)	(0.113)	(0.0634)	(0.112)	(0.0455)	(0.0435)	(0.0617)	(0.0681)
Fed Swap Line	0.121	-1.076***	-0.342***	-1.193***	-0.216***	-0.0370	-0.289***	-0.157*
	(0.0808)	(0.250)	(0.0999)	(0.322)	(0.0310)	(0.0815)	(0.0337)	(0.0928)
Constant	2.645***	2.779***	3.045***	4.659***	-25.09***	-25.20***	-24.70***	-25.43***
	(0.311)	(0.378)	(0.383)	(0.480)	(0.674)	(0.588)	(1.091)	(0.983)
Observations	2,342	1,243	1,812	882	2,342	1,243	1,812	882
R-squared	0.424	0.329	0.448	0.348	0.596	0.807	0.447	0.702
Number of Countries	62	34	57	31	62	34	57	31

Notes: robust standard errors in parentheses; *, **, *** denote statistical significance at the 10, 5 and 1% levels, respectively; dependent variables are in natural logs; *IR* is "International Reserves" (includes interest income, valuation changes, purchases/sales of assets, gold, IMF loans, SDRs, SWFs, drawn swap lines), *forexR^{rev}* is "Foreign Currency Reserves minus valuation changes and interest income" (includes only foreign currency denominated deposits and securities). "All" includes all countries that provide SDDS reserve data; "EM" includes only emerging market countries. Reserve data for countries prior to joining the Eurozone is excluded. Panel regressions include country fixed effects.

Table 5: Determinants of Reserve Purchases/Sales (Quarterly Observations through 2010)

Dependent Variable	Reserve Asset Purchases and Sales over *ForexR*			
	Pooled Regression		Panel Regression	
Independent Variables	All countries	EM countries	All countries	EM countries
Lagged purchases and sales	-0.0258	0.00793	-0.114***	-0.0682***
	(0.0276)	(0.0258)	(0.0147)	(0.0193)
Lagged valuation change	-0.152***	-0.130***	-0.185***	-0.189***
	(0.0393)	(0.0310)	(0.0289)	(0.0265)
Lagged interest Income	0.704	-0.826	1.542**	-0.811
	(0.694)	(0.502)	(0.628)	(0.553)
Lagged unexplained reserves	0.202***	0.195***	0.251***	0.248***
	(0.0501)	(0.0333)	(0.0212)	(0.0247)
Constant	-0.00356	0.0561***	-0.0302	0.0638***
	(0.0241)	(0.0196)	(0.0245)	(0.0215)
Observations	1,762	920	1,762	920
R-squared	0.069	0.158	0.091	0.147
Number of Countries	61	36	61	36

Robust standard errors in parentheses; *, **, *** denote statistical significance at the 10, 5 and 1% levels, respectively; "Lagged" denotes 4 accumulated lagged observations for the first three explanatory variables, "Lagged unexplained reserves" is the one-quarter lagged difference between actual reserves and fitted values from country-by-country regression specifications similar to those reported in tables 3 and 4.

Table 6: Determinants of Reserve Accumulation during the GFC

Independent variables dated prior to the GFC	*ΔIR* during GFC		*ΔforexR^rev* during GFC	
	All Countries	EM	All Countries	EM
asset purchases/sales	0.200**	0.130**	0.0205	0.214**
	(0.0969)	(0.0537)	(0.0636)	(0.0880)
valuation changes	0.220*	0.105*	0.284**	0.112
	(0.112)	(0.0603)	(0.107)	(0.0676)
interest income	-0.151	-0.0348	1.513**	-0.679
	(0.786)	(0.646)	(0.651)	(1.145)
unexplained reserves	-1.474***	-1.314***	-0.840***	-1.349***
	(0.415)	(0.337)	(0.278)	(0.256)
Peg indicator	-0.0376	0.0300	-0.0851	0.0570
	(0.0764)	(0.0848)	(0.0774)	(0.0848)
Constant	-0.0336	0.00322	-0.274***	0.0444
	(0.107)	(0.0916)	(0.0999)	(0.154)
Observations	51	28	51	28
R-squared	0.481	0.516	0.347	0.547

Robust standard errors in parentheses; *, **, *** denote statistical significance at the 10, 5 and 1% levels, respectively; "unexplained reserves" is the difference between actual reserves and fitted values from country-by-country regression specifications similar to those reported in tables 3 and 4. All explanatory variables are dated prior to the start of the country-specific crisis.

Table 7: Determinants of Reserve Accumulation after the GFC

Independent variables dated prior to or during the GFC	*ΔIR* after GFC		*ΔforexR^{rev}* after GFC	
	All Countries	EM	All Countries	EM
asset purchases/sales	0.865**	0.0328	0.0353	-0.237
	(0.370)	(0.486)	(0.217)	(0.230)
valuation changes	0.0421	0.596	0.185	0.292
	(0.383)	(0.618)	(0.517)	(0.300)
interest income	-4.368	-7.379**	-4.187	-5.567***
	(2.707)	(2.821)	(2.573)	(1.856)
unexplained reserves	-2.218***	-0.768	-0.555*	-0.502**
	(0.510)	(0.601)	(0.283)	(0.205)
exchange rate change	-0.0960	0.298	0.689***	0.620***
	(0.242)	(0.299)	(0.228)	(0.197)
peg indicator	0.0379	0.183	-0.0857	0.179*
	(0.125)	(0.193)	(0.110)	(0.103)
GDP growth	-0.0430	0.00368	-0.512	-0.543
	(0.559)	(0.512)	(0.413)	(0.327)
Constant	0.208***	0.222**	0.233**	0.214***
	(0.0768)	(0.0778)	(0.107)	(0.0584)
Observations	51	27	51	27
R-squared	0.597	0.532	0.197	0.622

Robust standard errors in parentheses; *, **, *** denote statistical significance at the 10, 5 and 1% levels, respectively ; "unexplained reserves" is the difference between actual reserves and fitted values from country-by-country regression specifications similar to those reported in tables 3 and 4. All explanatory variables are dated prior to the end of the country-specific crisis.