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The Self-insurance Role of International Reserves and the 2008-2010 Crisis*

Antonio Francisco A. Silva Jr**

Abstract

There is no standard rule for the definition of an "optimal level" of international reserves and several assumptions underlie the rationale behind holding reserves. There are various theoretical approaches, but no standard for the evaluation of the performance of "optimal level" models, and their parameters are difficult to estimate. The literature suggests that the benefits of holding reserves are high, but the accumulation of reserves is a costly strategy. In fact, in a world of high liquidity and free capital flow, establishing an adequate level of international reserves is still a puzzle. The strategy of accumulating international reserves is evaluated here using data from the 2008-2010 crisis and it is shown that countries with higher international reserve levels had less adjustment costs between 2008 and 2010. The cost-benefit relationship of holding reserves in the 2008-2010 crisis is also discussed based on a sample with 71 countries.

Keywords: international reserves, crisis, central banks

JEL Classification: E44, E58, F21, F31, F41.

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1- Introduction

The literature concerning international reserve holdings has increased in recent years as many authors have tried to explain the growth of international reserve holdings in emerging market economies since the crises of the1990s. According to this literature there are several reasons for holding international reserves, including the provision of coverage for transaction operations and liquidity for debt payments, as a precaution against capital outflows, and to serve mercantilist and wealth management purposes. International reserves may also be a by-product of foreign exchange rate policy.

Despite all the effort that has gone into research there is no unified methodology to use as a reference for the process of reserves accumulation. This problem may be a consequence of the different rationale each country applies when defining its international reserves accumulation policy. The difficulties are also related to the measurement of the relevant variables that each model takes into account and also to the fact that it is difficult to establish a measurement of performance for the myriad of available models.

This paper contributes to the literature since it produces empirical evidence to show that countries with higher levels of international reserves had lower adjustment costs in the period of the financial crisis of 2008-2010[1]. The paper also discusses the cost and benefit relationship of international reserve holdings in a sample with 71 countries. The aim of the paper is not to provide an answer to the optimal reserves level conundrum but to contribute to this debate with empirical findings.

A literature review is discussed in the next section where it is also presented some findings in the empirical literature regarding the 2008-2010 crisis. In the recent empirical literature some authors find econometric evidence that international reserves helped countries to avoid the worst scenario while some others do not find this econometric evidence. In the third section it is presented an econometric analysis applied in the sample of 71 countries and it is shown that international reserves worked as an insurance against a crisis irrespective of the motivation for holding them. This

[1] The crisis is considered here to run from 2008 to 2010, since many countries had problems with GDP growth during this period. Some may argue that the crisis started earlier and that it was not over by the end of 2010.

section also discusses the cost-benefit relationship of holding reserves. Finally, the conclusions are presented.

2- Literature review

Traditionally the rationale behind holding reserves associates them with precaution and transaction considerations. Grimes (1993) argues that a country with a free floating foreign exchange rate policy will not intervene in the foreign currency market as long as the nature of the shocks to the exchange rate remain predominantly nominal, but may wish to intervene if it perceives that the stochastic environment has changed, and this intervention will affect the level of international reserves. According to Hawkins and Rangarajan (1970) international reserves may be viewed as national wealth in some cases, but also as a tool to finance balance-of-payments deficits. Other motives are mentioned in the literature, such as strengthening the bargaining position of a country in debt negotiations (Kohlscheen and O'Connell, 2004 and Detragiache, 1996) and the political considerations mentioned by Aizenman and Marion (2002a, 2002b and 2004).

Allen et al. (2002) propose an approach to analyzing crises in the government, financial and non-financial private sectors. According to the authors, an asset-liability currency match is crucial for crisis prevention. Turner and Moreno (2004) state that an integrated approach to managing risks in a broader national context is needed. The controversial question is how far the government should react to private sector decisions regarding their own balance sheet.

The crises in the 1990s showed how vulnerable countries were to capital flows. Since the Asian crisis countries in that region have substantially increased levels of international reserves to prevent similar episodes. Turner and Moreno (2004) argue that the increase in international reserve holdings in Asian countries is a consequence of a policy of currency devaluation, while Aizenman and Lee (2005) considered the importance of precautionary and mercantilist motives in accounting for the hoarding of international reserves by developing countries and concluded that the variables associated with mercantilism, although statistically significant, could only account for a small part of reserve accumulation. Accordingly, they state that the degree of capital account liberalization is a more conspicuous variable, and empirical evidence suggests that precautionary motives have played a more prominent role in the reserves

accumulation process in developing countries. Mateos y Lago et al. (2009) analyze the debate surrounding the International Monetary System and the weaknesses inherent to having a dominant country-issued reserve currency at a time of growing world demand for liquid reserve assets, particularly in emerging markets which attempt to self-insure against costly capital account crises.

The adequacy of international reserve holdings is also an open question linked to the motivation issue discussed above. There are several approaches but no standard for the calculation of an "optimal level". Four of them are discussed in this section: cover indicators, cost-benefit analysis, macroeconomic relationships and insurance approaches.

An adequate level of international reserves was previously considered to be the amount needed to cover at least three months of imports. Given increased capital flows this rule has generally come to be regarded as outdated (Mulder, 2000). A coverage indicator of international reserves adequacy which has become very popular is the amount needed to cover the short-term external debt (IMF, 2000 and IMF, 2004). The ratio of reserves to short-term external debt is a guide to reserve adequacy based on currency and financial crisis concerns[2]. Wijnholds and Kapteyn (2001) extended the Guidotti ratio by adding an M2 percentage to the Guidotti rule for reserves requirements. The authors state that, besides short-term debt, the calculation of an adequate level of reserves should also include a monetary supply ratio to take the possibility of capital outflows into account.

Heller (1966) was the first to analyse international reserves adequacy using a cost-benefit approach. According to Heller, a country can use some policies, such as expenditure-switching entailing welfare reduction, to mitigate external imbalances. Heller's model considers the avoidance of adjustment costs as a benefit of holding reserves. Clark (1970) developed a structural model based on this assumption considering the variability of reserve levels and the costs of adjustment[3]. In the buffer stock model (inventory model) proposed by Frenkel and Jovanovic (1981) an optimal reserves levels depends on the variability of international transactions, where reserves work as a buffer stock to accommodate fluctuations in external transactions, and it is expected that the optimal stock level is positively correlated to the extent of these

[2] This ratio is known as Guidotti ratio.

[3] Some papers which apply the cost-benefit approach are Flood and Marion (2002), Ramachandran (2004), Mora and Plazas (2004), Varella (2004), Soto et al. (2004) and Soto et al. (2005).

fluctuations and negatively correlated to carrying costs, since they are invested at lower rates than the opportunity costs[4]. Several empirical papers deal with variants of the cost-benefit approach[5].

The costs of financial crisis are measured as a function of the gap between the GDP after the crisis and the potential GDP if the crisis had not occured. According to Ben-Bassat and Gottlieb the more open a country is, the higher the GDP contraction due to a financial crisis will be. The cost-benefit approach is very sensitive to the factors which are assumed to underlie it, i.e. adjustment and opportunity costs and the crisis probability.

One alternative approach to evaluating international reserve holdings is to consider a macroeconomic model in which reserves are endogenous. Aizenman and Marion (2002) and Ades and Fuentes (2005) take this kind of approach, treating international reserves as a dependent variable in a panel regression with GDP per capita, population, volatility of exports, imports to GDP ratio and volatility of the nominal exchange rate. The rationale given in Aizenman and Marion (2002) is that reserves holdings should increase with the size of international transactions and with a country's population and standard of living. Reserves holdings should increase with the volatility of international receipts and payments and they should be positively correlated with the volatility of a country's exports. According to the authors, since reserves should increase with concerns about the vulnerability to external shocks, they should be positively correlated with the average propensity to import[6]. Obstfeld et al. (2008) investigate the empirical determinants of reserve growth and they consider the log of the ratio of M2 to GDP, a measure of financial openness, a pegged exchange rate dummy and a soft-peg exchange rate dummy. They conclude that reserve holdings are explicable, since they did not find major under prediction (at least not systematically), and they did not identify the suspected excessive accumulation in emerging-markets.

Some papers, like Caballero and Panageas (2003), Caballero and Panageas (2004a and 2004b), Cordella and Yeyati (2005) and Lee (2004), have driven discussions of

[4] Bar-Ilan and Marion (2004) propose a model of optimal reserve holdings where the reserve authority controls the upward and downward drift of international reserves and chooses the trigger points which induce changes in drift.

[5] Salman and Salih (1999), Ramachandran (2004) and Silva and Silva (2004) model the dynamics of international reserves using a GARCH specification. An interesting feature in these works is that they use time series for individual countries (Turkey, India and Brazil respectively) rather than working with cross-sectional data.

[6] Ainzeman and Lee (2005) and Calafell and Bosque (2002) also use this kind of approach with a different set of variables.

international reserve holdings in a different direction. Cordella and Yeyati (2005) discuss some forms of national insurance, such as capital controls, self-insurance (accumulation of international reserves), private insurance (hard to find) and IMF packages. Caballero and Panageas (2004a and 2004b) argue that central banks should adopt best-risk-management practices and they give the example of including the CBOE Volatility Index (VIX) in a reserves portfolio. Lee (2004) uses an approach based on option pricing which evaluates the insurance value of reserves. Jeanne and Rancière (2009) present a model for the optimal level of international reserves for a small open economy seeking insurance against sudden stops in capital flows. This is a modification to a previous paper which the same authors published in 2005. The optimal level of reserves is quite sensitive to the probability of a sudden stop, the risk premium and the risk aversion parameter.

It is important to highlight that the literature on adequacy of international reserve holdings rely on the benefits and costs. International reserves holdings may reduce the fall in the GDP growth rate, the borrowing costs and the fiscal costs in a crisis. However, reserves holdings imply carrying costs. Hutchison (2001) investigates the fall in real GDP in 1998 for five East Asian countries that experienced a severe currency and balance of payments crisis in 1997. He evaluates predicted versus unpredicted growth and states that the largest unexpected fall in real GDP was in Indonesia (17.6 percentage points) and the smallest was in the Philippines (3 percentage points).

Ben-Bassat and Gottlieb (1992) apply a log-linear equation which measures the current difference between actual GDP after a default and potential GDP (expected GDP) that would have occurred if the economy had continued to grow at the pre-default growth rate. The difference between the actual and predicted GDP is a function of the level of openness of the economy and according to the authors, output loss is higher than 50% of annual GDP.

Hoggarth et al. (2001) find that the cumulative output losses incurred during crisis periods were roughly 14%-24%, on average, of annual GDP. They cite other authors who put output losses in the range of 6%-8% of annual GDP for single banking crises but usually well over 10%, on average, when they are accompanied by currency crises ("twin" crises). Hoggarth, Reis and Saporta (2001) report output losses of 15%-20% of annual GDP for banking crises. Demirgüç-Kunt et al. (2000) find that a banking crisis is

accompanied by a decline in output growth in the order of 4%. Gupta (2002) reports costs of 5.1% of annual GDP for currency or banking crises and 13.3% of GDP for "twin" crisis. Jeanne and Rancière (2005) calibrate their model for an optimal level of reserves considering output losses of 10% of GDP.

Haldane, Hoggarth and Saporta (2004) emphasize that “twin crisis” episodes, when banking instability and sharp pressures on a country’s exchange rate occur at the same time, are associated with larger losses of GDP than single crises. Furthermore, estimates of fiscal costs are also larger.[7] Komarek and Melecky (2005) confirm the greater severity of crises with more than one cause (twin crisis). They report cumulative losses for current account reversals of 2% and for joint of current account and currency crises of 21% of GDP. Aziz, Caramazza and Salgado (2000) report losses in the range of 4%-9%.

Recently, Laeven and Valencia (2008) prepared a database with detailed data of currency crises and sovereign debt crises from 1970 to 2007. According to the authors, fiscal costs (net of recoveries) associated with crisis management average about 13.3% of GDP, and can be as high as 55.1%. Recoveries of fiscal outlays also vary widely, with the average recovery rate reaching 18.2% of gross fiscal costs. Finally, output losses (measured as deviations from the GDP trend) of systemic banking crises can be large, averaging about 20% of GDP during the first four years of a crisis, and ranging from a low of 0% to a high of 98%.

There are costs to holding international reserves. Aizenman (2007) points out that there are fiscal costs, including direct opportunity costs in the form of the marginal product of public capital and/or the cost of external borrowing, and the quasi costs of sterilization. When the central bank buys foreign currency in the domestic market, it sells domestic currency. In order to avoid impact on interest rates, which may undermine monetary policy, the central bank sterilizes the operations with repurchase agreement operations (repo). The cost of repo operations is close to the short term interest rate. Note that international reserves are normally invested abroad with lower yields, particularly for

[7] Silva Junior (2010) discusses the degree of freedom that a country has to manage a crisis if it has enough international reserves. According to the author, international reserves help an emerging market to operate with lower interest rates during a crisis than those which would be needed in an environment with low international reserves. For those countries with high domestic debt, lower interest rates are a fiscal benefit of international reserves. Note that international reserves themselves are not sufficient to operate with lower interest rates during a crisis, but they are a necessary requirement for this purpose. It is also worth mentioning that once a central bank raises interest rates it takes time to reduce them again.

emerging market economies. So, the difference between domestic and international interest rates (in general US yields for the relevant maturity) may be considered as the carrying costs of reserve holdings.

Despite the fact that the costs of carrying reserves can be seen as the costs of sterilization, it is important to remember that not all reserves are sterilized. For example, the returns on international reserves investments do not need to be sterilized in the market. Furthermore, foreign exchange reserves may also be funded from foreign currency borrowings rather than domestic monetary liabilities (The Central Bank Governance Group, 2009), so it is important to discuss the funding of reserves and their real opportunity costs.

It could also be argued that the opportunity costs of holding international reserves may be seen as the interest rate paid by the Treasury on the domestic debt, since foreign assets may be used to reduce debt.

International reserves are a source of financial risk on the central bank balance sheet. An appreciation of the domestic currency reduces the value of foreign assets since they are marked to market on the balance sheet. International Financial Reporting Standards (IFRS) require “fair value” accounting, which means that assets and liabilities must be marked to market. This approach may produce high variability in the income statements of central banks, which in turn raises issues with regard to the determination of the amount to be transferred to the government or received from the government. For some central banks that distribute income, the revaluation gains and losses which are not realised receive special treatment (The Central Bank Governance Group, 2009). Note that a “fair value” account does not mean that a gain or a loss has been realized.

The literature evaluating the impact of the recent global crisis on advanced economies and emerging markets is still evolving. This literature relies on econometric analysis to determine whether countries' economic fundamentals or others issues explain why the impact was different for each country. Berkmen et. al. (2009), Lane and Milesi-Ferretti (2010), Blanchard et. al. (2010) and Llaudes et. al. (2010) conduct econometric analysis with a measure of economic growth as the dependent variable. The authors use some explanatory variables which include trade, debt, financial market issues, population and capital flows among others. Despite the similarities in their aim, there are several

differences among these studies in the specification of the models, the size of the samples and the definition of dependent and independent variables. The focus in these papers is a set of variables which may explain the impact of the recent global crisis.

Berkmen et. al. (2009) find that financial factors such as leverage (measured as the credit to deposit ratio), appear to have been key in determining the size of the growth revision for emerging markets. According to them, the stock of international reserves (measured in numerous ways, such as a share of GDP, exports, or short-term debt) did not have a statistically significant effect on the growth revisions.

Lane and Milesi-Ferreti (2010) find a strong link between the fall in GDP growth rate (and also in domestic demand) and pre-crisis domestic financial factors such as rapid private credit growth and external imbalances measured as current account deficits. They find, albeit with less econometric robustness, a relationship between GDP growth (and also demand) and real-side variables such as trade openness and manufacturing share. They also find that countries with pegged exchange rate regimes experienced weaker output growth during the crisis and they find some evidence that countries with higher reserves experienced smaller declines in demand. They find that emerging and developing countries with higher short-term debt as a ratio of reserves experienced sharper declines in output and demand.

Some of the findings of Llaudes et. al. (2010) are aligned with those of Milesi-Ferreti (2010). Llaudes et. al. (2010) conclude that emerging markets with smaller initial vulnerabilities went into recession later and exited earlier, and suffered smaller declines in output during the first stage of the crisis. Emerging markets with greater external linkage (dependence on demand from advanced economies or exposure to foreign bank claims) experienced sharper falls in output. Countries with pre-crisis credit booms had sharper output falls since the credit booms were typically foreign-financed and the credit booms were more pronounced for countries with fixed exchange rate regimes. Llaudes et. al. (2010) also conclude that reserves, up to a certain point, helped dampen the impact of the crisis on emerging markets. Blanchard et. al. (2010) find that the most significantly robust variable explaining the fall in GDP growth rate is short-term external debt, suggesting a central role for the financial channel in the crisis. They did not find econometric evidence that international reserve holdings were important buffers to the crisis, which is in line with Berkmen et. al. (2009).

3- Data Analysis for the 2008-2010 Crisis

In the aftermath of the 2008-2010 crisis it is possible to determine whether the strategy of international reserves accumulation served its purpose as insurance or not. As many countries suffered from the impact of the crisis in different ways, the question of whether there was any relationship between levels of international reserves and the impact of the crisis is investigated in this section . The approach is similar to that used by the authors referred to in the previous section, but crisis period is different and the specification of the problem is also diffrent. The sample consists of 71 countries including 49 emerging markets.[8]

The impact of the crisis is measured here as average GDP growth for the years 2008-2010, i.e. an average of three years of GDP growth minus the expected growth (measured as the average annual growth from 2000 to 2007). This difference is considered here as unexpected growth. Data were collected from the "Country Economic Report & GDP Data" section of the Global Finance website and the IMF Special Data Dissemination Standard (SDDS).[9]

3.1- The self insurance effectiveness of international reserves

Five explanatory variables were chosen in order to evaluate the behaviour of the GDP in the sample countries during the crisis. The first variable is the value of shares in the capital market divided by GDP. This is considered to be a proxy of openness and development in a country's capital market. The second explanatory variable is a dummy of one (1) for developed economies and zero (0) for non-developed economies. The third variable is the total external debt of a country divided by GDP. The fourth variable is annual imports divided by GDP, which is used to capture openness in the trade

[8] Lane and Milesi-Ferreti (2010) consider a full sample of 176 countries and for robustness they split the sample into advanced economies and non-advanced economies. Berkmen et. al. (2009), Llaudes et. al. (2010) and Blanchard et. al. (2010) focus their analysis of the impact of the crisis on emerging markets. Berkmen et. al. (2009) use data from 43 countries, although some robustness tests were run with a larger sample. Llaudes et. al. (2010) consider a sample of 57 economies and Blanchard et. al. (2010) use a sample consisting of 29 countries.

[9] Blanchard et. al. (2010) consider unexpected growth as the forecast error for output growth during the semester composed of 2008:4 and 2009:1. Lane and Milesi-Ferretti (2010) apply econometric analysis with average GDP growth in 2008-2009 as the dependent variable and among the explanatory variables they include the average GDP growth over 2005-07. Llaudes et. al. (2010) use four alternative measures of output loss to assess the robustness of their findings. The preferred measure used by the authors is the country-specific peak to trough percentage change in quarterly seasonally adjusted real GDP. Berkmen et. al. (2009) focus on revisions of projections for GDP growth in 2009. They compare forecasts prior to and after the intensification of the crisis in September 2008.

account, and finally the amount of international reserves divided by GDP is investigated. Table 1 shows the correlation matrix for these explanatory variables.

Table 1 – Correlation of explanatory variables

	MKT_GDP	DUMMY	DEB_GDP	IMP_GDP	RES_GDP
MKT_GDP	1.00	-0.11	0.46	0.03	0.16
DUMMY	-0.11	1.00	0.38	-0.21	-0.35
DEB_GDP	0.46	0.38	1.00	0.06	-0.04
IMP_GDP	0.03	-0.21	0.06	1.00	0.63
RES_GDP	0.16	-0.35	-0.04	0.63	1.00

The highest correlation (0.63) is found between international reserves and imports. This means that it is difficult to include these two variables in the same regression as explanatory variables for crisis impact because of multi-colinearity problems. The high correlation between international reserves and imports suggests that the more a country imports the more international reserves are required for precautionary purposes. The second highest correlation (0.46) is between external debt and the market value of stocks. This is to be expected since the more open capital markets are, the more equity and fixed income assets are available. The high correlation between external debt and the dummy implies multi-colinearity problems if both variables are included in the same regression. The negative correlation between reserves and the dummy suggests developed economies hold fewer reserves than non-developed economies and this points in the same direction as much of the empirical evidence.

This brief analysis suggests that because of multi-colinearity, it is not feasible to include all the variables in the same regression equation in order to evaluate the impact of the crisis on the sample countries. However, including all the variables in the same regression is unnecessary since there are two different problems to be investigated. Firstly it is necessary to differentiate the reserves accumulation strategies of the countries in the sample, and then to control the results of those strategies in the crisis in order to evaluate their effectiveness as insurance.

The first equation to be estimated is international reserves as a function of imports and the dummy variable (see equation 1). This relationship captures one dimension of the strategy of holding international reserves, which is to have a minimum amount of resources for transaction purposes. The dummy variable is used in this equation because

the empirical evidence in the literature shows that developed economies hold lower reserves.

$$Reserves_t = \beta_1 Imports_t + \beta_2 Dummy_t + \epsilon_t \quad (1)$$

So, the relationship between international reserves holdings and imports allow us to control the transaction motivation for holding reserves, making it possible to evaluate the insurance effect during the crisis. This means that with the identification of the relationship between reserves and imports it is possible to differentiate countries with different degrees of commercial openness and the different impact of the crisis on the sample economies. Note that the aim is neither to state that international reserves are held only for trade purposes nor to suggest an adequate measure for reserves holdings. Table 2 shows that on average international reserves represent 63% of annual imports and developed economies have fewer reserves than non-developed economies.

Table 2 – International reserves as a function of imports

Variable	**Coefficient**	**Std. Error**	**p-Value**
Imports	0.634	0.055	0.000
Dummy	-0.073	0.032	0.027

R^2: 0.414.

White correction for heteroscedasticity.

It is now possible to investigate the economic impact of the crisis on the countries in the sample during the 2008-2010 financial crisis and evaluate the insurance effect of international reserves. Average annual GDP growth in the three years 2008-2010 minus the proxy for expected growth (average from 2000 to 2007) is taken as a function of the sum of stock market sizes and external debt. Since the crisis was financial, the hypothesis is that the more open its capital markets were the more a country would suffer the impact of the crisis. Furthermore, the difference between international reserves and the result of the estimation from equation (1) is also considered as explanatory variable. The rationale behind this specification is that higher levels of

international reserves may work as insurance against a crisis and that the size of international reserves is normalized by the result of equation (1) for each country.

$$grow_i - E(grow)_i = \theta_1 + \theta_2(market + debt)_i + \theta_3\left(Reserves - E(Reserves)\right)_i + \varepsilon_i \quad (2)$$

The impact of the crisis therefore is taken as a function of the size of the capital market and external debt as a fraction of GDP and the excess of international reserves over annual imports. The expected rationale behind this regression is that if the country had higher levels of international reserves measured against an average level it would suffer less in a crisis. The coefficient for this variable would therefore be positive. Furthermore, this rationale also implies that a more open capital market exposed the country to the impact of the crisis and the expected coefficient for openness is negative. Table 3 shows the result of this regression with the statistically significant coefficients.

These two regressions do not show that the main rationale for accumulating international reserves is the precautionary purpose. However they do show that international reserves work as insurance against a crisis irrespective of the motivation for holding them, since higher levels of reserves helped some countries to avoid the main negative impact of the crisis in terms of GDP fall. It is important to highlight that international reserves are not the only variable to take into account in explaining the behaviour of some economies during the 2008-2010 crisis. Furthermore, the main purpose of this study is not to argue that the level of international reserves is a purely exogenous decision. The above regressions simply aim to show that economies with higher levels of reserves reacted better to the crisis, as the literature review indicates. This data does not allow the reader to address the issue of defining an optimal level for international reserves or even to conclude that international reserves are the only means of avoiding a contagious crisis. The econometric findings here are similar to those of Llaudes et. al. (2010) and Milesi-Ferreti (2010).

Table 3 – Average GDP fall in three years as a function of reserves and capital market size

Variable	Coefficient	Std. Error	p-Value
Constant	-0.0290	0.0038	0.0000
Market+Debt	-0.0011	0.0004	0.0052
Reserves-E(Reserves)	0.0723	0.0207	0.0008

R^2: 0.296

White correction for heteroscedasticity.

3.2- Robustness tests

One of the aims of this paper is to verify whether international reserves contributed as a buffer to the impact of the recent global crisis. The robustness tests focus on this issue. Note that recently some authors have investigated the role of several variables in the crisis. With regard to international reserves, Llaudes et. al. (2010) and Milesi-Ferreti (2010) find econometric evidence that international reserves helped some countries to avoid a worse GDP fall, while Blanchard et. al. (2010) and Berkmen et. al. (2009) do not. As it is mentioned before, table 3 shows econometric evidence that international reserves helped to cushion the fall in GDP growth during the period of 2008-2010 in line with Llaudes et. al. (2010) and Milesi-Ferreti (2010). Robustness tests are shown in tables 4, 5 and 6. In table 4 the robustness tests are focused on specifications similar to those in equations 1 and 2. Table 5 shows robustness tests with unexpected GDP growth as the dependent variable and imports, market, debt and reserves as dependent variables, a specification similar to that in Llaudes et. al. (2010), Blanchard et. al. (2010) and Berkmen et. al. (2009). Table 6 shows robustness tests with realized GDP growth as the dependent variable, which is similar to the work of Milesi-Ferreti (2010).

Table 4 – Robustness tests for Equations 1 and 2

Variables	Base	Case 1	Case 2	Case 3	Case 4	Case 5
Eq1						
Imports	0.634	0.647	0.634	0.647	0.634	0.647
	0.000	0.000	0.000	0.000	0.000	0.000
Dummy	-0.073	---	-0.073	---	-0.073	---
	0.027	---	0.027	---	0.027	---
R2	0.414	0.395	0.414	0.395	0.414	0.395
Eq2						
Constant	-0.029	-0.029	0.018	0.027	-0.067	-0.070
	0.000	0	0.000	0.000	0.000	0.000
Market+Debt	-0.001	-0.001	-0.001	-0.001	-0.002	-0.002
	0.005	0.006	0.000	0.000	0.021	0.024
Reserves-E(Reserves)	0.072	0.079	0.077	0.080	0.110	0.124
	0.001	0.002	0.000	0.001	0.001	0.002
R2	0.296	0.308	0.313	0.378	0.261	0.278

Case 1: Developed countries (DC) removed from the sample.

Case 2: Only average growth from 2008-2010 as dependent variable.

Case 3: Only realized growth as dependent variable with DC removed.

Case 4: Unexpected growth: Growth from 2009 minus average growth from 2000-2007.

Case 5: Case 4 with DC removed.

White correction for heteroscedasticity.

The approach of equations 1 and 2 was used in order to minimize the problem of multi-colinearity and to capture information from a sample including both developed and emerging economies. Results are robust however and the conclusions do not change, even with specifications similar to Llaudes et. al. (2010), Milesi-Ferreti (2010), Blanchard et. al. (2010) and Berkmen et. al. (2009), as tables 5 and 6 show. These tests therefore show that the cushioning effect on the fall in GDP growth provided by international reserves during the 2008-2010 crisis has robust econometric support.

Table 5 – Robustness tests with specifications similar to Llaudes et. al. (2010), Blanchard et. al. (2010) and Berkmen et. al. (2009)

Variables	**Base**	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Constant	-0.027	-0.028	-0.024	-0.028	-0.031	-0.032
	0.000	0.001	0.000	0.001	0.000	0.000
Imports	-0.049	-0.056	-0.037	-0.044	-0.067	-0.074
	0.008	0.011	0.057	0.042	0.004	0.007
Market	-0.001	-0.001			-0.001	-0.001
	0.003	0.003			0.021	0.022
Debt			-0.005	-0.009		
			0.000	0.004		
Reserves	0.070	0.078	0.048	0.071	0.070	0.079
	0.001	0.002	0.035	0.009	0.010	0.021
R2	0.287	0.314	0.151	0.190	0.271	0.298

Case1: Developed countries (DC) removed from the sample.

Case 2: Change explanatory variable from Market to Debt.

Case 3: Developed countries (DC) removed from the sample.

Case 4: Unexpected growth: Average growth from 2008-2009 minus average growth from 2000-2007.

Case 5: Case 4 and DC removed.

White correction for heteroscedasticity.

Table 6 – Robustness tests with specifications similar to Milesi-Ferreti (2010)

Variables	**Base**	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Past growth	0.395	0.395	0.419	0.387	0.386	0.270
	0.000	0.000	0.000	0.000	0.003	0.015
Imports	-0.043	-0.045	-0.053	-0.039	-0.073	-0.062
	0.004	0.003	0.003	0.027	0.002	0.001
Market	-0.001	-0.001	-0.001		-0.001	-0.001
	0.027	0.000	0.004		0.007	0.000
Debt	-0.003		0.002	-0.010		
	0.096		0.701	0.001		
Dummy		-0.008				
		0.060				
Reserves	0.075	0.075	0.081	0.076	0.081	0.098
	0.000	0.000	0.001	0.002	0.011	0.000
R2	0.435	0.431	0.377	0.262	0.357	0.383

Case 1: Change explanatory variable from Debt to Dummy.

Case 2: Developed countries (DC) removed from the sample.

Case 3: Developed countries (DC) removed from the sample and explanatory variable Market removed from specification.

Case 4: Case 2 with dependent variable changed from average growth in 2008-2010 to average growth in 2008-2009.

Case 5: Case 2 with dependent variable changed from average growth in 2008-2010 to average growth in 2009-2010.

White correction for heteroscedasticity.

3.3- The cost-benefit relationship

The cost-benefit relationship of the strategy of accumulating international reserves is also investigated here on the basis of the 2008-2010 data. The costs and benefits are measured as fractions of GDP. In this study, costs are considered to be equated to the difference between domestic interest rates and the return on investment of international reserves. The benefits are associated with the avoidance of four problems: a GDP fall, loss of tax revenues, increase in domestic borrowing costs and external borrowing costs.

The cost-benefit analysis in Table 7 is only a base case. This base case was built on the possible scenario of a 10% fall in GDP during a crisis (if a country does not have enough reserves). This possible scenario finds support in the literature, and the empirical evidence in figure 1 from the period of 2008-2010 shows that some countries had an average fall in GDP above 4% in those three years (above 10% in the compounded period). The first benefit in the base case scenario is therefore considered to be the avoidance of a 10% fall in GDP over the three years.

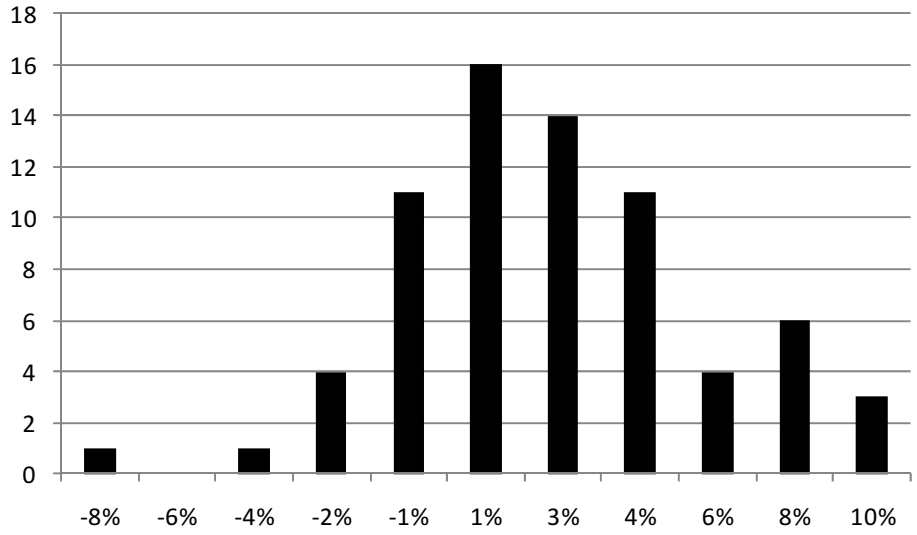

Figure 1 – Histogram of annual average GDP growth in the period 2008-2010

In fact the criteria underlying figure 1 could be considered to be very conservative, since potential GDP growth is not included. This means that the difference between GDP growth and expected GDP growth should be used as a measure of loss in a crisis. Figure 2 shows the histogram of this measure in the period of 2008-2010. Expected

GDP growth was measured as the average GDP growth in the period of 2000-2007 for each country.

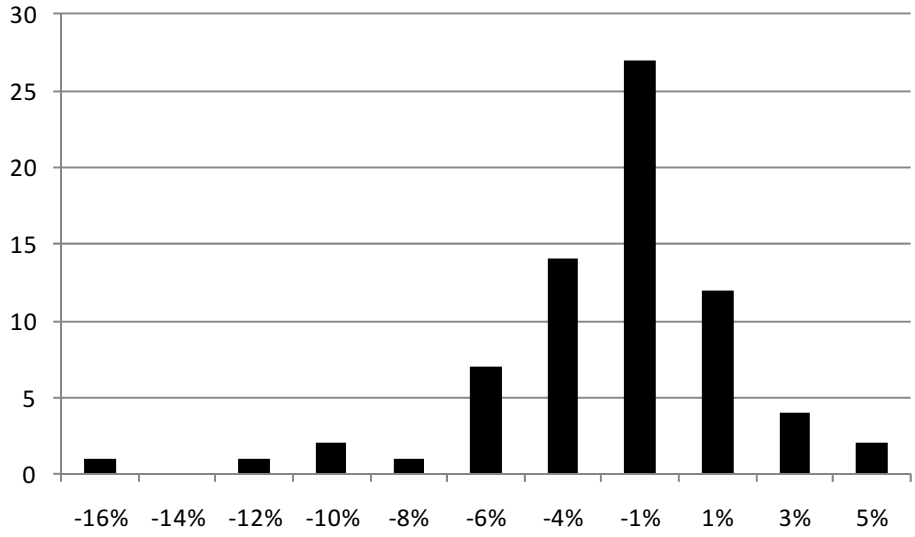

Figure 2 – Histogram of annual average GDP growth minus expected growth in the period 2008-2010

The second benefit is fiscal and it is related to the avoidance of tax losses. Loss of tax income in a scenario with a 10% fall in GDP is evaluated on the basis of fiscal charge data from the countries in the sample.

The benefits of avoiding higher burdens in the rollover of domestic debt in a crisis are difficult to measure since it would be necessary to evaluate the structure and the maturity of the domestic debt and the interest rates to be considered as the “level of avoidance of higher burdens” among others features. Some specific crisis events serve to illustrate the problem. In the Mexico crisis in 1995 there was an increase of 37% in annual average domestic interest rates. In the Asia crisis in 1997 there were increases in annual average domestic interest rates of 2.2% in Korea, 1.6% in Singapore, 1.3% in Taiwan and 6.8% in Thailand. In Russia annual average domestic interest rates increased 27.1% in 1998. During Argentina's debt crisis its annual average domestic interest rates increased 21.4%. In Brazil, domestic interest rates increased from 17.5% in 2001 to 22.9% in 2003 in a period including events such as contagion from the crisis in Argentina and the transition period between elections in 2002 and a new government taking office in 2003.

The maturity of debt and rollover strategy make it more difficult to evaluate the benefit of avoiding higher interest rates. The real impact of higher interest rates over the three years can only be estimated. The base case scenario supposes there to be a rollover of total domestic and external debt during the three-year period.

Evaluating the benefit of avoiding higher burdens on the external debt is not an easy task either. Figure 3 shows the EMBI global stripped spread. Note that the spreads did not reach the levels of the 1998-2002 period (808 bp on average). They remained at an average of 395 bp during the 2008-2010 period. 400 bp could therefore be taken as an indicator of lower spreads for those countries which have adequate insurance in a crisis.

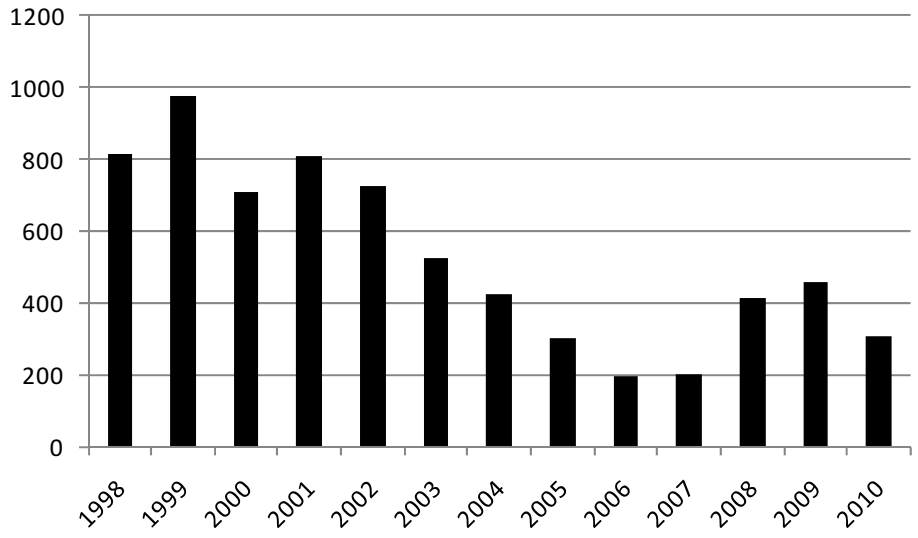

Figure 3 – Embi Global stripped spread (basis points)

In order to illustrate all the benefits the base case supposes a 1% increase in domestic interest rates (increase in the costs of a domestic debt rollover) and a 1% increase in the costs of borrowing externally if the country does not have the adequate level of self insurance. This means that the carrying costs of debt should be higher in a crisis if the country did not have enough international reserves.

It is also necessary to evaluate some assumptions regarding the costs of holding international reserves. As mentioned above, the costs of holding reserves are measured as the difference between domestic interest rates and the return on international reserves investments. The base scenario of Table 3 supposes a return on international reserves of 1%. For the period of 2002 to 2010 Israel reported an annual average return of 3.5% on

its international reserves investments and Switzerland reported 4.56%. This measure of costs is not a consensus since some authors argue that social opportunity costs would be a more adequate measure. Social opportunity costs are however difficult to find. In an alternative of costs measurement, the Central Bank of Brazil publishes a measure of international reserves carrying costs in its balance sheet based on a kind of weighted average cost of capital considering all the costs of its liabilities.

Note that the costs are measured on a one year basis but the benefits are measured as the adjustment cost reduction of a single crisis. In this scenario the average crisis adjustment cost reduction benefit is 14.45% of GDP and the average annual cost of holding reserves is 1.34%, excluding countries where domestic interest rates are equal to or lower than in the scenario of a 1% return on international reserves investments.

It is important to highlight that a cost-benefit analysis in which costs and benefits are measured on different bases would be more complete if it were to include the probability of a crisis occurring, by measuring the frequency of crisis events to see if the benefits cover the costs. It is not the aim of this work to evaluate crisis probability. However, the data in this paper makes it possible to evaluate the probability of a crisis in which costs equal benefits. For the scenario shown in Table 7 the costs would be covered by the benefits if a crisis occurred every 10.7 years, meaning that the probability of a crisis which would offset costs in this scenario is 9.3% in average for the whole sample.

Jeanne and Rancière (2009) discuss a model for international reserve holdings in which they calibrate the probability of a sudden stop to 10%, with output loss at 6.5% and the potential output growth at 3.3%.[10] The calibration of Jeanne and Rancière (2009) indicates that the scenario in Table 7 is a plausible one.

[10] The authors also mention a range of variation from 0 to 25% for the probability of a sudden stop and a range of 0 to 20% for output loss.

Table 7 – Cost-benefit relationship (base case)

Country	Benef/GDP	Costs/GDP	Country	Benef/GDP	Costs/GDP
Angola	10.98	2.91	Kazakhstan	13.57	2.18
Argentina	13.16	1.34	Latvia	15.10	1.63
Australia	14.23	0.13	Lebanon	13.83	11.68
Austria	17.09	---	Lithuania	13.23	0.74
Azerbaijan	11.89	0.85	Malaysia	12.36	0.49
Belgium	18.43	---	Mexico	11.60	0.67
Bolivia	13.42	2.51	Netherlands	17.64	---
Brazil	14.64	1.32	New Zealand	14.37	0.88
Bulgaria	14.41	1.84	Nigeria	10.80	1.78
Canada	14.33	---	Norway	20.23	0.06
Chile	12.38	0.65	Pakistan	11.87	1.37
China	11.95	0.94	Panama	11.98	0.56
Colombia	12.97	0.20	Paraguay	11.68	4.52
Costa Rica	12.10	0.88	Peru	11.96	1.58
Croatia	14.21	1.22	Philippines	12.33	1.65
Czech Republic	14.47	0.05	Poland	14.46	0.85
Denmark	17.30	0.06	Portugal	16.76	---
Ecuador	11.79	0.45	Romania	13.85	1.59
Estonia	14.49	---	Russia	14.11	2.52
Finland	16.41	0.03	Senegal	12.55	0.49
France	17.28	---	Serbia	14.62	3.13
Georgia	12.81	1.41	Singapore	12.42	---
Germany	16.23	---	Slovakia	14.05	0.08
Greece	16.54	---	Slovenia	15.40	---
Guatemala	11.91	0.56	South Africa	13.25	0.56
Honduras	12.05	1.06	South Korea	13.29	0.59
Hong Kong	14.79	---	Spain	15.94	---
Hungary	15.47	1.62	Sweden	17.30	---
Iceland	25.00	1.93	Switzerland	15.68	0.54
India	12.49	0.99	Taiwan	11.77	0.45
Indonesia	11.59	0.83	Thailand	12.39	0.55
Ireland	24.78	---	Turkey	14.10	0.68
Israel	14.90	---	Ukraine	14.91	1.77
Italy	16.53	---	United Kingdom	18.64	---
Jamaica	14.87	1.16	Uruguay	13.17	1.71
Japan	15.41	---			

Some alternative scenarios are shown in Table 8. In fact, there is no simple rule to select a single scenario, which means that the choice of the cost and benefit relationship is a risk management decision. It is important to remember that self-insurance is not necessarily the only motivation for holding reserves but is one of the objectives of a complex set of decisions in a world with high liquidity and free capital flow. This environment makes insurance against high movements of exchange rates an open

discussion. Table 8 may give indications of the cost-benefit relationship relative to the self insurance question in a crisis.

Table 8 – Scenarios for the cost-benefit relationship

GDP	Int Res Invest	Benefits	Costs	Years	Probability
5.00	1.00	8.08	1.34	6.01	16.63%
5.00	3.00	8.08	1.14	7.11	14.07%
10.00	1.00	14.45	1.34	10.75	9.30%
10.00	3.00	14.45	1.14	12.72	7.86%
15.00	1.00	20.82	1.34	15.50	6.45%
15.00	3.00	20.82	1.14	18.32	5.46%
20.00	1.00	27.19	1.34	20.24	4.94%
20.00	3.00	27.19	1.14	23.93	4.18%

4- Conclusions

There is no single motivation for countries to accumulate international reserves. Although some authors argue that there is a trend towards accumulating reserves for some hidden mercantilist agenda within foreign exchange rate policy, the evidence in the literature shows that this is not the main driving argument in many emerging markets. In fact, there is evidence in the literature that the precautionary motive is one of the reasons for emerging market economies to increase their international reserve holdings. These two motivations may take discussion of international reserves levels from a single endogenous consequence to a single exogenous decision, but it seems that the puzzle is more complex than any single view of the problem and that decision regarding the level of international reserves fall somewhere between these two extremes.

Aside from the motivation for holding international reserves, this paper provides empirical evidence for the fact that in the 2008-2010 crisis international reserves worked as self insurance for many economies, since countries with more international reserves had less adjustments costs in terms of GDP. This empirical evidence is in line with the discussion of the benefits of holding reserves as the data show that the strategy of accumulating reserves helped some markets to avoid the worst scenario in the 2008-2010 crisis.

Note that the precautionary motivation discussed by some authors in the literature as the main driver for the process of accumulating international reserves still leaves open the question of adequacy, since an optimal level of reserves is a function of risk aversion, the probability of crisis and the costs and benefit of this self insurance. The data discussed here is not intended to address the adequacy problem, but they give some dimension to the cost-benefit relationship and make it clear that with regard to cost-benefit, the choice is a risk management decision.

There is no accepted standard to establish a methodology for evaluating the optimal level for international reserves. In a world of high liquidity and free capital flow the level of international reserves will continue to be a puzzle for several economies. Suppose this puzzle of establishing a methodology for international reserves adequacy is solved by a given economy, then its next step may be the design of a wealth management policy which takes more risks with investments to offset the carrying costs.

As a suggestion for further studies, it may be worth evaluating the risk management strategy of holding international reserves for a specific country in more detail and the interaction between the many motivations for such decisions.

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