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

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ABSTRACT

There is no standard rule for the definition of an optimal amount 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 optimal level for international reserves is still a puzzle. The strategy of accumulating international reserves is evaluated here using data from the 2008-2010 crisis. It is shown that countries with higher international reserve holdings had less adjustment costs during the global financial crisis. The cost-benefit relationship of holding reserves is also discussed based on a sample of 71 countries.

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1. Introduction

The crises of the 1990s showed how countries were vulnerable to capital flows. Since the Asian crisis, many countries substantially increased levels of international reserves to prevent similar episodes. So, the literature concerning international reserve holdings has increased in recent years and many authors discuss the accumulation of international reserves in emerging market economies using a variety of explanatory issues. Based on the many issues found in the literature this paper emphasizes three main motivations for holding international reserves: precaution, mercantilism and economic policy. The precautionary motivation includes issues like the provision of coverage for transaction operations and liquidity for debt payments and for capital outflows. In the mercantilist motivation it is considered that countries devaluated foreign exchange rate to make exports more competitive or they accumulate more international reserves to seem more reliable to investors compared to neighbor countries. In the economic policy motivation it is considered that international reserves are a byproduct of monetary policy or they are the result of wealth accumulation for future generations.

Despite all the effort that has gone into research there is no unified methodology to reference for the process of reserves accumulation. This problem may be a consequence of the different rationales 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. In addition, it is difficult to establish a measurement of performance for the myriad of available models. This paper contributes to the literature by producing 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 using a sample of 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 presented in the next section to discuss three key issues: the motivation for holding international reserves, the optimal level of reserve holdings and the GDP performance in crises. In the third section it is presented the methodology applied in the paper to a sample of 71 countries. The fourth section presents an econometric evaluation of GDP losses and it is discussed the cost-benefit relationship of holding international reserves

[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.

for the countries in the sample. In the fifth section the empirical findings are discussed and it is shown that international reserves worked as an insurance against a crisis irrespective of the motivation for reserve holdings. Finally, the conclusions are presented.

2. Literature Review

In this section it is showed some literature issues used in explaining the rationale of holding international reserves. Then, it is showed that there are many models in the literature to calculate optimal level for international reserves and they are based on different assumptions. It is showed that the literature reports a broad range for GDP losses during crisis. Finally, the section presents some literature findings on the GDP and international reserves relationship during crises, since GDP performance during crisis is a key variable for the precautionary motivation of holding international reserves.

2.1. Motivation for Holding International Reserves

The literature emphasizes many issues to justify the accumulation of international reserves and this paper connects the issues with one of the three main motivations: precaution, mercantilism and economic policy. The precautionary motivation considers international reserves a tool to deal with uncertainty. The mercantilist motivation means an active strategy to take competitive advantage. The economic policy motivation is related to wealth management, monetary policy, foreign exchange rate policy etc.

Traditionally the rationale behind holding reserves associates them with precautionary motivation. 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. Indeed, international reserves and the balance of payments are interconnected and according to Allen, Rosenberg, Setser and Roubini (2002) the crises prevention depends on an asset-liability currency match. Alberola et al. (2016) argue that countries with lower international reserves are more likely to see their residents place their capital abroad during crisis. The evidence of precautionary motivation against crisis is discussed in Frankel and Saravelos (2012) and Steiner (2013).

Ghosh, Ostry and Tsangarides al. (2014) state that the motives for holding international reserves has shifted from insurance against current account shocks to insurance against

capital accounts shocks and then the international reserves became a by-product of a possible mercantilism approach. The work of Cheung and Sengupta (2011) evaluates a behavior that is connected to the mercantilist motivation. They evaluate if countries in Latin America continues to add international reserves to keep up with others countries in the region. The mercantilist behavior in particular in Asia countries is discussed in the works of Steiner (2013), Pontines and Rajan (2011), Srinivasan and Kumar (2012) and Bonatti and Fracasso (2013).

Obstfeld, Shambaugh and Taylor (2010) discuss one issue in open economies called as the "trilemma" where the policy-makers can only choose two of the three available policy choices: foreign exchange rate stability, free international capital mobility and monetary independence oriented toward domestic goals. This motivation is explored in Taguchi (2011), Taguchi, Nataraj and Sahoo (2011), Aizenman and Ito (2012) and Steiner (2015).

This paper focuses on the precautionary motivation of holding international reserves, and it does not intend to argue that other motivations are not relevant.

2.2. Optimal Level Approaches

There are several approaches but no standard for the calculation of an optimal level. This section presents four approaches: 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.

[2]This ratio is known as Guidotti ratio.

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 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 (1992) 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 reserve holdings should increase with the size of international transactions and with a country's population and standard of living. Reserve 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

[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).
[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.

shocks, they should be positively correlated with the average propensity to import[6]. Obstfeld et al. (2010) 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 authors develop models based on financial options or based on insurance approaches. Cordella and Yeyati (2005) discuss some forms of national insurance, such as capital controls, self-insurance (accumulation of 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 (2011) present a model for the optimal level of reserves for a small open economy seeking insurance against sudden stops in capital flows.

As it can be seen from the literature, there are many models that can be included in any one of the approaches: cover indicators, cost-benefit analysis, macroeconomic relationships and insurance. No matter the model is used, there are many questions that can be raised about assumptions and parameters choices. The next sub-section discusses a key issue for the precautionary motivation of holding international reserves which is the GDP losses during crises.

2.3. GDP losses in Crises

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 GDP losses, 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

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

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, Reis and Saporta (2001) find that the cumulative output losses incurred during crisis periods were roughly 14%-24%, on average, of annual GDP. 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 (2011) 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, i.e. banking instability and sharp pressures on a country’s exchange rate 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 et al. (2000) report losses in the range of 4%-9%. Laeven and Valencia (2012) reports the median output loss of 23%.

The assumption of GDP losses in a crisis is an important issue for the precautionary motivation of holding international reserves. The literature reports a broad range for GDP losses during crisis and a careful evaluation of this issue is needed in order to evaluate any measure of optimal level of international reserves.

[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. 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.

2.4 International reserves and GDP losses

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, Gelos, Rennhack, and Walsh (2009), Lane and Milesi-Ferretti (2010), Blanchard et al. (2010) and Llaudes, Salman and Chivakul (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. Dominguez, Hashimoto and Ito (2012) argue that more international reserves are related to higher GDP growth after the global financial crisis.

Some of the findings of Llaudes et al. (2010) are aligned with those of Lane and 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. Methodology

This paper evaluates if the strategy of international reserves accumulation served its purpose as insurance or not in the 2008-2010. The sample consists of 71 countries including 49 emerging markets.[8] The impact of the crisis is measured 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]

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

[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.

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 account, and finally the amount of international reserves divided by GDP is investigated.

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: GDP losses, tax revenues losses, increase in domestic borrowing costs and external borrowing costs.

4. Empirical Evaluation of 2008-2010 Crisis

This section presents an evaluation of the effectiveness of holding international reserves. This effectiveness is measured by GDP growth. If international reserves are effective, countries with higher international reserves should have lesser GDP losses in crisis. The section also evaluates the cost-benefit relationship of holding international reserves.

4.1. The Self-insurance Effectiveness of International Reserves

Because of multi-collinearities showed in Table 1, it is not feasible to include all the explanatory 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.

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 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.

$$Reserves_i = \beta_1 Imports_i + \beta_2 Dummy_i + \varepsilon_i \quad (1)$$

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 which is in the same direction as much of the empirical evidence.

The relationship in equation (1) between international reserves holdings and imports allows 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. The aim here 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 using equation (2). 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.

$$grow_i - E[grow_i] = \theta_1 + \theta_2(market_i + debt_i) + \theta_3(Reserves_i - E[Reserves_i] + \varepsilon_i \quad (2)$$

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 equation (2) 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 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), Dominguez et al. (2012) and Lane and Milesi-Ferreti (2010).

Table 3
Three years average GDP fall as a function of reserves and 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.

4.2. Robustness tests

This sub-section presents some robustness tests. It is important to highlight the results found by others works with similar purpose like Llaudes et al. (2010), Dominguez et al. (2012) and Lane and Milesi-Ferreti (2010) since they find econometric evidence that international reserves helped some countries to avoid worse GDP losses. However, Blanchard et al. (2010) and Berkmen et al. (2009) do not find econometric evidence that international reserves avoid GDP losses during the global financial crisis. Robustness tests are shown in tables 4, 5 and 6.

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.

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 Lane and Milesi-Ferreti (2010).

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 Lane and 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.

4.3. The cost-benefit relationship

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.

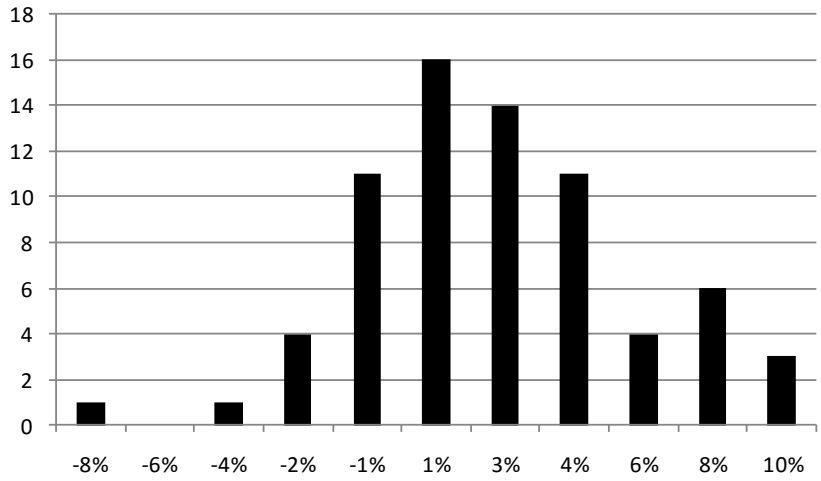

Figure 1
Histogram of annual average GDP growth in the period 2008-2010

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.

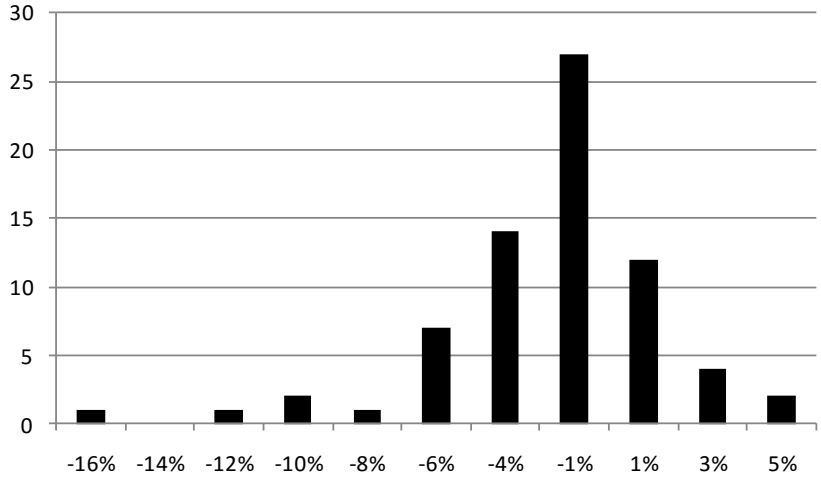

Figure 2
Histogram of average GDP growth minus expected growth in 2008-2010

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. 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.

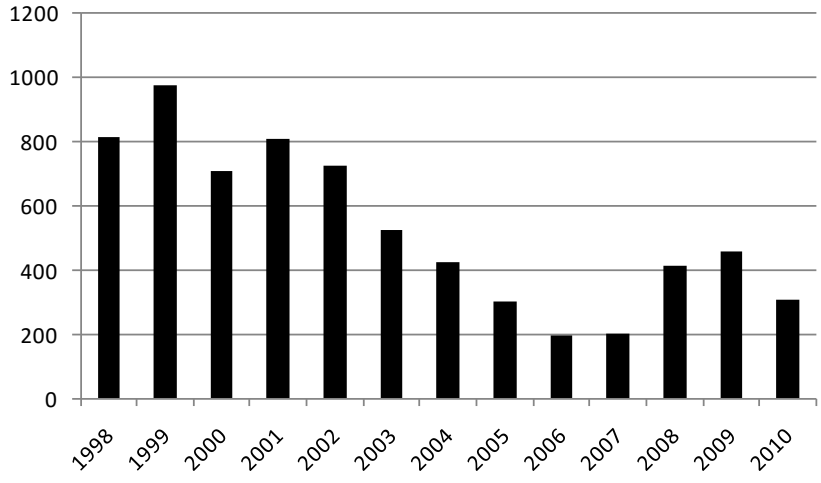

Figure 3
Embi Global stripped spread (basis points)

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. The costs are measured on a one year basis but the benefits are measured as the adjustment cost reduction of a single crisis.

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 (2011) 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 (2011) 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%

5. Discussion of Empirical Findings

The 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 Lane and Milesi-Ferreti (2010) and Dominguez et al. (2012).

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), Lane and 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.

With respect to the cost and benefit relationship, in a base case scenario the average benefit due to the reduction in crisis adjustment costs is 14.45% of GDP and the average annual cost of holding international 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 means that average benefits of holding international reserves are much higher than average annual costs. In fact, the optimal relationship between benefit and costs depends upon the probability of the crisis and the risk aversion.

6. Conclusion

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. Some authors argue that the decision of holding international reserves is a passive strategy due to others economic objectives of monetary policy or wealth accumulation. The precautionary motivation and the mercantilist motivation take discussion of international reserves levels from a single endogenous consequence to an exogenous decision. 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.

The precautionary motivation discussed 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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