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Abstract

International reserves are very important for emerging economies, as they allow to buffer possible liquidity vulnerabilities within a countries' balance of payments. Consequently, the issue of how many reserves should each country hold is a relevant issue for economic policy. The literature has identified two different methodological approaches to deal with this issue, namely reserve optimality and reserve adequacy indicators, which are carefully reviewed in this paper to determine which is the most appropriate to guide policy decisions in the Colombian case. The indicator proposed by the IMF (2011) was adopted to find the adequate level that this country should hold by calibrating it with historical data for Colombia. This new conservative index suggests that the accumulated levels of reserves have been adequate in recent years and that only in very extreme scenarios there is room to acquire additional reserves. Finally, it is worth highlighting that the methodology developed in this article provides a complementary indicator to the existing ones in order to evaluate the international reserves levels that Colombia should accumulate to reduce its vulnerability to external shocks.

JEL Codes: E58, F32

Key Words: International reserves, Reserve optimality, Reserve adequacy.

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Resumen

Las reservas internacionales son muy importantes para las economías emergentes, ya que permiten amortiguar las posibles vulnerabilidades de liquidez que se puedan presentar en la balanza de pagos. En consecuencia, la cuestión de cuántas reservas debe acumular cada país es un tema relevante para la política económica. La literatura ha identificado dos enfoques metodológicos diferentes para hacer frente a este problema, a saber, nivel óptimo de reservas e indicadores de nivel adecuado, que son revisados cuidadosamente en este trabajo para determinar cuál es el más conveniente para orientar las decisiones de política en el caso Colombiano. Se adoptó el indicador propuesto por el FMI en 2011 para encontrar el nivel adecuado que se debe tener calibrando datos históricos para Colombia. Este nuevo índice conservador sugiere que los niveles de acumulación de reservas han sido adecuados en los últimos años y que sólo en casos muy extremos hay espacio para adquirir reservas adicionales. Por último, cabe destacar que la metodología desarrollada en este trabajo es un complemento a las medidas ya existentes para evaluar los niveles de reservas internacionales que Colombia debe acumular con el fin de reducir su vulnerabilidad a los choques externos.

Códigos JEL: E58, F32

Palabras Clave: Reservas Internacionales, Nivel óptimo de reservas, Nivel adecuado de reservas.

1 Introduction

The accumulation of international reserves by central banks has become one of the main macro-prudential policies for emerging economies to buffer shocks to their balance of payments. Hoarding an appropriate amount of these assets allows countries to reduce the negative outcomes of balance of payments' crises through the provision of the necessary foreign liquidity to the economy in the eventuality of current account, balance sheet and currency bank run crises. Also, in the presence of these shocks, the accumulation of reserves signals that the economy is prepared to thoroughly cope with foreign vulnerabilities, which avoids a further deepening of these type of crises. Nonetheless, authors like Hviding, Nowak, and Ricci (2004) or Chivakul, Llaudes, and Salman (2010) have found that the benefits of holding reserves are decreasing with the level accumulated by a central bank. This, combined with the fact that hoarding these assets involves several costs, makes finding the appropriate level of reserves a very relevant issue for central banks in emerging economies.

Consequently, several authors have proposed two different types of methodologies to find the appropriate level of international reserves that a country should accumulate. On one hand, authors like Heller (1966), Ben-Bassat and Gottlieb (1992a), Jeanne and Rancire (2011), among others, have pursued a level of reserve optimality, which in general terms consists of maximizing a utility function of a central bank that depends on the opportunity cost of holding reserves and on the cost and probability of occurrence of an eventual crisis. However, there is still no consensus in the literature with respect to the accurate measurement of these variables, which makes the results of these models very dependent on the assumptions adopted.

On the other hand, authors like Triffin (1960), Guidotti-Greenspan (1999), Beaufort Wijnholds and Kapteyn (2001) and IMF (2011) have proposed measurements of reserve adequacy, which seek to hedge the possible outflows of the balance of payments by accumulating a specific proportion of a macroeconomic variable. In contrast to the methods which aim to find an optimal level of reserves, this one is limited by the fact that it disregards the costs of hoarding these assets. Nevertheless, it requires a weaker set of assumptions, which make it more reliable and robust, and consequently makes it more suitable for policy analysis.

Previous exercises for the Colombian case have followed models for reserve optimality and are consequently very dependent on the adopted assumptions. An example of this

can be found in the articles of López (2006) and Gerencia-Técnica (2003), which find that Colombia in 2003 should hold US$36,318 million and US$10,101 million respectively. This broad divergence is mainly explained by the difference in the assumptions of the cost of a crisis and of the variables that account for the probability of occurrence of such crisis.

Consequently, and considering that the main objective of this paper is to find the level of international reserves that Colombia should hold, we decided to adopt the methodology of reserve adequacy as it gives a more robust and reliable policy recommendation. In particular we adopted the methodology proposed by the IMF (2011), which is a combined metric that uses historical data of a wide sample of emerging economies to find the adequate level of international reserves that a country should hold as a percentage of exports, broad money, short term debt and other portfolio liabilities. This indicator provides a very complete benchmark to measure reserve adequacy as it considers the major potential risks for an economy in the eventuality of a shock to the balance of payments.

Nevertheless, its major shortcoming is the fact that it generalizes for all emerging economies that tend to have very heterogeneous outflows of capital. As a matter of fact, the IMF (2011) highlights that the measurement tends to underestimate the adequate level of reserves for countries that have a high amount of remittances, or whose exports are highly dependent of commodities with very volatile prices or for those which intervene frequently in the foreign exchange market to moderate its volatility. Since Colombia has all of these characteristics, these shortcomings imply that using the exact weights proposed by this article might result in important inaccuracies for the Colombian case.

Consequently, this paper calibrates the IMF indicator for the Colombian economy based on monthly data between January 2003 and December 2012. This new benchmark, specific for the Colombian economy, suggests a higher level of reserves than the other indexes measuring reserve adequacy, since it covers a wider set of potential outflows than any of the traditional indicators, as well as incorporating some of the characteristic traits of Colombia's balance of payments. It also shows that under scenarios of considerable stress (in the 5th and 10th percentiles of the distribution) the current levels of reserve accumulation are adequate, while on the most extreme scenario (the 1st percentile of the distribution) the actual level is slightly below the one suggested by this indicator.

The paper is structured as follows. Section 2 reviews the benefits and costs of the accumulation of international reserves. Section 3 presents a revision of the different approaches of reserve optimality and adequacy found in the literature. Section 4 reviews the previous exercises that have been conducted to find adequate and optimal levels of international re-

serves for Colombia. Section 5 introduces a measurement of reserve adequacy for Colombia based on the methodology proposed by IMF (2011) and compares it with other adequacy benchmarks. Section 6 concludes.

2 On the Benefits and Costs of International Reserves

The IMF (2009) defines international reserves as those external assets that are readily available to, and controlled by, monetary authorities for meeting balance of payments financing needs, for intervention in exchange markets to affect the currency exchange rate, and for other related purposes (such as maintaining confidence in the currency and the economy, and serving as a basis for foreign borrowing).

In Colombia, the article 371 of the Political Constitution of 1991 gave Banco de la República (central bank of Colombia), the authority and responsibility of managing the international reserves. Furthermore, law 31 of 1992 specifies that this duty must be done concerning public interest, the benefit of the national economy and having as main purpose the facilitation of national payments due abroad. Since these assets need to be readily available at all times, its management must regard safety, liquidity and return.

Besides the investment decisions, the central bank, in its role as international reserves manager, will also choose the level of these assets that the country should hold in order to facilitate the national payments due abroad. The determination of this amount should ensure that residents will have access to international liquidity, even in times of stress. The most common approach is to study the periods of crises in the balance of payments and, based on the historical outflows, choose a level which allows providing liquidity in the eventuality of such shocks.

However, before exploring the theoretical methods used to determine the appropriate level of international reserves, it is relevant to comment on the nature of the shocks to the balance of payments and the role of international reserves as buffers. In order to do so, the classification of the types of crisis proposed by Feldstein (1999) will be used to structure the following subsections[1]. Nonetheless, it is worth commenting that despite the individual treatment given to each type of crisis, this does not imply that they occur independently. As a matter of fact they tend to happen simultaneously, thus magnifying the effects of the

[1]This classification is chosen because it fully considers all of the eventual shocks to the balance of payments. The category titled Contagion Crises and Irrational Speculation is omitted because it is included under the other types of crises.

other variety of shocks.

2.1 Current Account Crises

Prior to the financial integration experienced worldwide in the last decades, current account crisis was the main reason for the precautionary hoarding of international reserves. Even though in past years the attention has shifted to shocks that affect the capital account, the current account still constitutes a considerable segment of the balance of payments so it is highly relevant to study its vulnerabilities.

This type of crisis usually starts with a shock that affects the demand for exports and which might have different origins. The most common one is mentioned by Edwards (2000) and by Caramazza, Ricci, and Salgado (2004) who mention that if there is an economic downturn in a given country the fall in income will generate a reduction in the demand for both local and imported goods, and would consequently affect the foreign sales of its trade partners.

Another source of an export-reducing shock is described by Glick and Rose (1999) who argue that in the eventuality of depreciation of a currency the exports of such country will receive a temporary boost in its competitiveness at the expense of its trade competitors who will experience a diminishment in the demand for their goods and services.

In case that any of the aforementioned circumstances occur, the immediate consequence of a contraction in exports is a fall in the demand for the local currency, thus forcing a reduction of its value. This depreciation will be enhanced by speculators, who trying to profit from this situation will drive down the value of the currency below its fundamental value. This situation will heavily affect importers who will have to pay more for their foreign goods and services, and in extreme cases might have trouble accessing the required international liquidity to comply with their obligations abroad.

Feldstein (1999) argues that if the central bank has enough foreign exchange reserves it can mitigate the impact of a shock to the demand for exports through two main channels. First of all, it can intervene in the foreign exchange market to contain the devaluation of the currency and provide importers with enough liquidity to ensure their payments in foreign currency. Secondly, it can signal in the exchange market that it has the sufficient amount of reserves to intervene if needed, consequently reducing the incentives for speculators to attack the exchange rate.

This means that, even though current account crisis are no longer the main source of

vulnerability for a country, the trade of goods and services is still a significant component of the balance of payments that is prone to external shocks, whose potential impacts on the economy can be buffered with an appropriate level of international reserves. Consequently, it is pertinent to consider the eventuality of this type of crisis when analyzing the amount of these assets that a country should hoard.

2.2 Balance Sheet Crises

As mentioned above, the increasing financial interdependence between countries has changed the focus about the risks faced by a country and have made the balance sheet crises the principal vulnerability to the balance of payments. Radelet and Sachs (1998) describe the different ways in which these types of crises start. First of all they consider a circumstance in which there is an abrupt change in international market conditions (such as shifts in interest rates, commodity prices, terms of trade or trade conditions) that affect the ability of debtors to repay their loans. Alternatively, these authors also consider the situation in which there is an unexpected change in political leadership, economic policies or in the burden of the debt, which leads creditors to reassess a country's ability or willingness to comply with their obligations.

However, this type of crisis may also arise in countries whose fundamentals have not suffered any shock and remained relatively solid. Calvo (1995) and Haile and Pozo (2008) describe a situation where the market is populated with informed and uniformed investors. Given this, a depreciation of the currency and decline in equity prices may lead to a large capital loss to some informed investors. These losses may induce investors to sell off good securities in other emerging markets to raise cash in anticipation of a higher frequency of redemption. The problem emerges when the uniformed agent misreads this action as a signal for low returns in this market and starts to reassess the ability of the country with healthy fundamentals to pay his obligations.

If any of the aforementioned situations occur, the affected country will have problems rolling over their debt, as the participants in the international markets will doubt on the ability of the nation to comply with its obligations. Even in the case that the country is solvent, the sudden inaccessibility to foreign funds will impose liquidity restrictions that will push down the currency's value. In this case, the cost of foreign debt servicing will rise, and thus will further increase the mistrust on the country's solvency, starting a vicious cycle.

This problem, which has a completely financial nature, will impact the real sector of the economy throughout a variety of mechanisms. First of all, Kaminsky and Reinhart (2000) argue that foreign banks will curtail credit in order to reduce their exposition in the affected country. On the other hand, Hale and Arteta (2007) suggest that firms will also lower their demand for credit in general, and for foreign credit in particular. The underlying reasoning is that there is a decline in aggregate demand which accompanies this type of crises. If the firm sells its product locally, they will experience an increase in inventories which will reduce the incentives to ask for credit. Meanwhile, if the firm sells its products abroad, the currency depreciation will increase the revenue, thus reducing its demand for credit. This fall in credit demand and supply will result in a fall in investment and in consumption.

Another possible transmission mechanism is proposed by Calvo (1999) who describes that once loans are not rolled over, countries are forced into costly, badly designed tax systems to carry out the necessary adjustments, and as a result, the economy suffers real damage via productivity losses, tax evasion, and corruption, amongst many others.

Finally, and similarly to the case of the current account crises, the subsequent depreciation caused by the balance sheet crises will hurt importers and consumers, since they will be forced to pay relatively higher prices for the goods produced abroad.

In this case, international reserves play several roles in the buffering of this type of crisis. Once it starts, either by a weakening of the external fundamentals or through contagion, an appropriate level of international reserves will allow the central bank to provide liquidity during the necessary time to meet the short-term debt obligations, and thus impeding a stronger depreciation of the exchange rate and all of its second-round effects. As a matter of fact, Mulder and Bussiere (1999), using a broad sample of emerging economies between the crisis period from 1994 to 1997, show that higher liquidity can offset weak fundamentals and limit the vulnerability in periods of contagion.

However, holding an appropriate level of international reserves helps to buffer this type of crisis even before they start. Guzmán and Padilla (2003) argue that low levels of reserves may be an indication that imprudent macroeconomic policies are being pursued. So, in the case that a country hoards the appropriate amount of these assets, it is signalling that it has solid fundamentals, and that in the eventuality that an adverse shock affects them, it is willing and able to intervene in the exchange market to buffer the impact of such shock. Empirically, Hviding et al. (2004) noticed that the latter argument holds by finding that a high level of reserves has been shown to reduce the likelihood of a currency crises

or a sudden stop, which is an abrupt unwillingness by international lenders to renew their credit lines at times of market uncertainty.

2.3 Bank-Run Currency Crises

A bank-run currency crisis rarely occurs by itself and tends to be a consequence of one of the aforementioned crises. Pineau and Dorrucci (2006) argue that once a currency has considerable pressures to depreciate, market participants will try to protect their savings in local currency so they will rush to convert them into US dollars, other reserve currencies or other safe havens. This will increase the demand for foreign liquidity pushing the value of the currency further down, redoubling the investor's incentives to buy foreign assets before the domestic currency weakens even more. This behaviour will result in a reduction of bank deposits that will put in risk their solvency. Radelet and Sachs (1998) describe that bank runs do not necessarily occur when the bank has made a bad investment decision, but when individual depositors fear that other depositors are withdrawing their money from the bank, thereby driving the bank into illiquidity and eventual liquidation. Once it starts the vicious cycle of people retiring bank deposits driven by the behavior of its peers, some of the additional cash in the economy will be placed in foreign assets which will generate a depreciation of the currency reinforcing the negative impact on the economy.

In case any of the shocks mentioned above occurred, the international reserves will allow the central bank to intervene at an early stage in the exchange market to stop the currency depreciation, and thus impeding a downward spiral of the currency's value. Once again, the deterrent effect is very important, as a higher level of international reserves signals that the central bank is able to mediate in case of exchange market pressures, consequently discouraging agents to retreat their deposits by reducing the perceived risk of a massive depreciation of the currency. Empirically, Obstfeld, Shambaugh, and Taylor (2010), using an unbalanced panel including 134 countries between 1980 and 2004, validate the role of reserves as buffers of potential drains from a bank run and emphasize on the importance of these assets to preserve the financial stability of a country.

The previous sub-sections reviewed in a very intuitive way the precautionary motive of reserve hoarding, which is the role of international reserves as buffers in the eventuality of balance of payments' crises. However, some authors, such as Sehgal and Sharma (2008) and Aizenman and Lee (2005) have argued that there is also a mercantilist motive in

the increasing accumulation of these assets. The basic reasoning behind this idea is that countries that base their growth model in the promotion of exports will try to give a boost of competitiveness to local goods sold abroad by artificially devaluing their currencies. This implies that the monetary authority will buy foreign currency, therefore increasing the level of international reserves.

Even though the mercantilist motive is relevant in the estimations of the demand for foreign exchange reserves, it must not be considered when trying to find the level of these assets that a central bank should hold. The main reason is that the mercantilist motive is a by-product of a macroeconomic policy, rather than fulfilling the main objective of international reserves, which is to meet the balance of payments financial needs, even in extreme cases. Hence, all of the measurements of an optimal or an adequate level of reserves (studied in section 3) will only cover the precautionary motives to accumulate these assets.

So far, the analysis has focused only on the benefits of reserve accumulation and has made a compelling case for central banks to store these assets. This poses the doubt on whether it is relevant to try to find an appropriate level of reserves or to just keep accumulating these assets boundlessly. Empirical evidence suggests it is pertinent to set a target for reserve hoarding as there is a decreasing marginal benefit in the role of these assets as buffers.

For instance, Hviding et al. (2004) show that holding sufficient reserves helps to reduce exchange rate volatility, but that this relationship seems to be non-linear to the extent that the benefits of holding reserves for lowering volatility reduce with higher reserve levels. Also Chivakul et al. (2010) find that pre-crisis reserve holdings are associated with a smaller output collapse during an adverse shock; however such benefit diminishes as the level of these assets increase.

In the case that reserves were free of costs, these diminishing returns of reserve hoarding would not imply a major problem as central banks would be able to store endless amounts of these assets. However, in the literature some costs to the accumulation of international reserves have been identified. This gives a significant relevancy to try to find a level of these assets that allows taking advantage of all the precautionary benefits of foreign exchange reserves without incurring in major outlays.

Jeanne (2007) thoroughly describes the most evident cost, and perhaps the most popular one in the literature of international reserves, as the difference between the returns on reserves and the return on more profitable investment alternatives. Conceptually, this opportunity cost is rather simple; however, in practice, selecting the appropriate invest-

ment alternative poses a major dilemma since one can choose between numerous higher yielding opportunities both domestically and abroad, either in financial assets or in real sector investments, such as building of public infrastructure. Traditionally, authors have chosen the local government bond as the suitable alternative; nonetheless a consensus has not been reached about this subject.

Additionally, Rodrik (2006) describes the social cost of these assets as an insurance premium measured as the spread between the private sector's costs of short-term borrowing and the yield that the central bank earns on its liquid foreign assets. The intuition behind is that once a private institution acquires debt abroad, the central bank should cover that foreign liability by increasing its reserves which will be invested in low yielding securities abroad, so society, as a general, will end up paying such difference.

Furthermore, Tosoni (2011) categorizes the sterilization costs incurred by the central bank when acquiring foreign exchange as one of the outlays generated by the accumulation of international reserves. This emerges from the fact that when the monetary authority intervenes in the foreign exchange market to buy international liquidity, it generates an increase in the circulating domestic currency that will cause inflationary pressures for the local economy. Consequently, the central bank will try to get rid of these pressures by sterilizing the accumulation of international currency by selling assets on their balance sheets, usually government bonds. The operating costs of this process and the spread between the return of the sold bonds and the yield of the international reserves are known as the sterilization costs. This cost is actually recorded in the balance sheet of the central bank, unlike the other costs mentioned, which are opportunity costs.

3 Theoretical Approaches in the Pursuit of an Optimal and an Adequate Level of International Reserves

Once the benefits and costs of reserve hoarding have been explored, it is relevant to try to find a level of international reserves which enhances the effectiveness of these assets in their role as buffers. The reviewed literature has identified two different methodological approaches to deal with this issue, which are known as reserve optimality and reserve adequacy indicators. We will review each of these methodologies in the following subsections.

3.1 Reserve Optimality

This approach aims to find an optimal level of international reserves by characterizing the issue as an optimization problem which studies the existing trade-off between the benefits and the costs of reserves accumulation. It requires a thorough specification of an economy and, in general, this type of model maximizes the expected utility function of a central bank which takes the form:

$$\Pi_{CB} = \rho C_0 + (1 - \rho) C_1 \tag{1}$$

Where: Π_{CB} is the expected utility of the central bank; ρ is the probability of occurrence of a shock; C_0 is the impact in the economy of the crisis induced by the shock; and C_1 is the opportunity cost of reserve hoarding. The interpretation and specification of each of these parameters varies amongst authors as it can be seen in the following review of literature.

The first documented attempt to find an optimal level of international reserves was made by Heller (1966) . He assumed a small open economy which cannot influence the world prices of traded goods. This economy starts in equilibrium, meaning that it is at full employment; the balance of payments is balanced; and given relative prices of goods, consumers, which can choose to participate or not in foreign trade, are on the highest possible utility level.

This economy is affected by a shock to the foreign demand for local goods, like those described in section 2, which generates an imbalance in the balance payments. The size of this deficit is taken by the author as the impact of the economy which is to be financed by the international reserves. The probability of depletion of these assets will then be equivalent to the probability of occurrence of an imbalance in the balance of payments, which Heller (1966) identifies to follow a random walk process with equal likelihood of happening or not. To complete the specification, the opportunity cost of reserve hoarding is assumed to be equal to the spread between the social rate of return on capital and the proceeds of the international reserves.

Based on this characterization of an economy it is found that optimal reserves will depend positively on the stability of a country's international accounts, as a lower volatility reduces the probability of using reserves, and negatively on the opportunity cost of holding reserves and on the marginal propensity to import. The explanation behind the result of this last variable, which is at plain view the most counterintuitive, relies on the fact

that under Heller's specification reserves are built by sacrificing imports. Nevertheless it could be argued that countries with a greater propensity to import will have larger outflows on their balance of payments which need to be hedged against eventual shocks, so the relationship between the marginal propensity to import and the amount of optimal reserves should be at least ambiguous.

Besides this controversial link, the model proposed by Heller (1966) has other important shortcomings which are noted by Hamada and Ueda (1977). These authors noticed that there are several ways to reach a deficit which were not taken into account by Heller (1966) in his specification.

In order to overcome this difficulty, Hamada and Ueda (1977) assume a small open economy with a process of change in the stocks of international reserves which follows a random walk with a step of arbitrary magnitude and a symmetric probability for an upward or a downward movement. Once the economy reaches a minimum of reserves it must adjust by reducing its expenditure, and thus sacrificing national income.

This economy is hit by a shock which affects the external demand for local goods and generates an imbalance in the balance of payments that causes the complete depletion of the international reserves. Once this occurs, further disequilibria need to be financed with national income at a cost which depends negatively on the propensity to import. The probability of occurrence of a shock falls as a response to an increase in the level of reserves. Finally, the cost of reserve hoarding is the theoretical spread between the rate of earnings in an alternative use and the return on liquid reserves.

Under these circumstances the optimal level of reserves will increase as the volatility of the balance of payments augments, and as the opportunity cost of reserve hoarding and the marginal propensity to import fall. Notice that the controversial relationship between the optimal level of reserves and the marginal propensity to import emerges once again, which is considered a significant shortcoming of this specification.

An alternative approach to find an optimal level of international reserves was proposed by Clark (1970). He assumed a small open economy below full employment, with constant import and export prices, and whose balance of payments is in equilibrium. The exchange rate of the currency of this economy is fixed at equilibrium. Exports are exogenous, while imports will depend solely on income and on the marginal propensity to import. Finally, the amount of reserves is taken as a random variable which fluctuates due to external disturbances.

In this economy, reserves help to reduce fluctuations in the level of income, so the

eventual cost of adjustment in the absence of international reserves will be expressed as a decline in national production and consumption. The probability that a country incurs in such loss, which is equivalent to the likelihood that reserves are completely depleted, is a function which depends positively on the variance of the external shocks affecting the country's balance of payments, and negatively on the optimal level of reserves and on the speed of adjustment of the economy to external disturbances. The cost of reserve hoarding will be the spread between the rate of return on domestic investment and the yield of the foreign assets where the reserves are placed.

Contrarily to the approaches previously reviewed, Clark (1970) does not provide a functional form of the optimal level of reserves, making the empirical adaptation of this model and the determination of the relationship between the desired level of reserves and the other variables endeavouring tasks. Nevertheless this shortcoming, the author finds that at a theoretical level the optimal amount of reserves responds positively to the volatility of the external shocks and to the income level at full employment, and negatively to the speed of adjustment of the economy to foreign disturbances, to the opportunity cost of reserve hoarding and to the marginal propensity to import.

Later on, Frenkel and Jovanovic (1981) propose a model which is based on inventory management principles with elements from a precautionary demand for model. They assume that both international receipts and payments are stochastic, so the accumulation of reserves will follow a standard Wiener process (the continuous time analogue of a random walk).

In the case a country faces a shock which generates a negative imbalance in the balance of payments; reserves must be depleted to finance such disequilibrium. If the economy does not have the sufficient amount to hedge the deficit, then national income must be sacrificed to do the required adjustment. This means that the probability of complete reserve exhaustion is equivalent to the likelihood of the occurrence of a crisis, and depends negatively on the level of reserves. The amount of product forgone during the eventual crisis is taken as the benefits of reserve hoarding, while the opportunity cost is approximated by the yield of the government bond (implicitly assuming that there is no return on reserves).

Based on this model, the optimal level of reserves is a function which depends negatively on the opportunity cost of reserve holding, and positively on the volatility of the stock of reserves and on the income sacrificed once all reserves have been depleted (the cost of adjustment). It is important to note that the empirical construction of this last variable is a striving task as it requires an indicator which thoroughly replicates the effect of a crisis

in the absence of reserves for a specific country.

Given the shortcomings of the aforementioned approaches, Ben-Bassat and Gottlieb (1992b) proposed a model which incorporated sovereign risk to the estimation of an optimal level of reserves. In order to do this they assume that reserves will be depleted in case of a government's credit default, so the prospects of a crisis and of a country neglecting its financial obligations are equivalent. Hence, this probability is a logistic function which depends on macroeconomic indicators which tend to predict liquidity and solvency problems.

Also, the authors assume that the cost of an eventual crisis (or government's default) is the present value of the difference between the actual and the potential national production. As an estimate, they run a regression which links this loss to the openness of the economy and (unlike Heller (1966)) they find a positive relationship between them. Finally, the cost of reserve hoarding is taken as the difference between the marginal productivity of capital and the return on reserves.

The authors do not provide a functional form for the optimal level of reserves; however they show that it will respond positively to the cost of a default and negatively to the opportunity cost of holding reserves. Also they find an ambivalent relationship between the level of reserves and the amount of external debt, but they argue that it is correct to assume a negative relationship, as empirically it has been found that reserves and debt act as complements. As we will review in detail in section 4, this type of specification has been widely used to conduct empirical estimations of the optimal level of reserves that a country should hold; however, as we will also show in section 4, the amounts of reserves suggested under these specifications tend to vary significantly depending on the assumptions on the cost of an eventual crisis, the variables included to calculate the probability of crisis and the opportunity cost of reserves. It is worth highlighting that there is no consensus on how to accurately estimate each of these three crucial variables, so this type of specification will not be very reliable in terms of policy analysis and recommendations.

The most recent attempt to set the theoretical background for an optimal level of reserves was made by Jeanne and Rancire (2011). They assume a small open economy which produces a single good which is consumed domestically and abroad. This country is composed by a continuum of identical infinitely lived consumers which maximize their welfare subject to a budget constraint that depends on current and past external debt, on domestic output, on consumption and on government transfers.

This economy follows a deterministic path which is only disturbed by sudden stops in

capital inflows, which happens with a probability that is exogenous[2]. In case the shock occurs, domestic output is sacrificed hurting inter-temporal consumption and household income. The amount of production forgone is assumed to be the impact in the economy of the crisis. In order to avoid this loss, the government will insure against shocks by hoarding reserves and financing it with a perpetuity that defaults only in the case that a sudden stop occurs. Under this contract the insurer agrees to provide valuable liquidity during the crisis and in exchange it receives a pure risk premium which is taken by the authors as the opportunity cost of reserves.

Under this specification, the optimal level of reserves has a functional form which depends, positively on: the level of short-term external debt, the domestic product lost due to the sudden stop, the risk aversion of the representative consumer and the probability of occurrence of the shock, increase; and negatively on the opportunity cost of reserves.

This article represents a major contribution to the theoretical explanation of the precautionary motives of the accumulation of international reserves by placing it within the framework of modern macroeconomic theory. However, as in the case of Ben-Bassat and Gottlieb (1992a), the level of reserves suggested by this model will vary significantly depending on the assumptions on the production foregone due to the crisis, the probability of crisis and the opportunity cost of reserves, so it will not be very robust if used to give policy recommendations to a central bank about the level of international reserves that they should hold.

As a conclusion for this sub-section, there have been some significant advances on the theoretical understanding of the precautionary motives of reserve accumulation. Nonetheless, when these models are calibrated to estimate the optimal level of reserves that a country should accumulate, the results obtained are very susceptible to the assumptions adopted, so these tend to be unreliable in the guidance of economic policy. Since the main objective of this article is to establish an appropriate level of reserves for Colombia, we will divert from the approach of reserve optimality to focus on reserve adequacy, which will be explained in detail in the next sub-section.

[2]In their work, Jeanne and Rancire (2011) calibrate a model which includes crisis prevention and where the probability of a sudden stop is a decreasing function of the level of reserves. Nevertheless, this model does not allow an analytical form for the optimal level of reserves. Since the survey of this article intends to portray the intuition behind the results of the models, it will focus on the basic model where the probability of a sudden stop is exogenous.

3.2 Reserve Adequacy

This approach intends to find an adequate level of reserves by linking it to a macroeconomic variable which thoroughly replicates the potential outflows of the balance of payments during a crisis. In contrast to the methods which aim to find an optimal level of reserves, this one is limited by the fact that it disregards the costs of hoarding these assets. Nevertheless, it requires a weaker set of assumptions, which make it more reliable and robust, and consequently makes it more suitable for policy analysis. As well, since it focuses on variables which are available for a wide array of countries, this kind of measurements are useful for international comparisons, and serve as an indicator of the liquidity of an economy.

The first proposal of a measurement of an adequate amount of international reserves was adopted and documented by Triffin (1960) during an evaluation of whether the level of these assets that countries held at the time was sufficient to meet the changes required by currency convertibility. To do so, he divided nations into categories based on the ratio of reserves to annual imports , where nations which reported a ratio lower than thirty-three per cent (roughly three months of average imports) were considered to have an insufficient amount of reserves to thoroughly hedge an eventual shock to the merchandise account.

As well, Triffin (1960) considered that this measurement was not appropriate to observe reserve adequacy in a country as it ignored other outflows of the current account which could be affected in the eventuality of a crisis. Also he mentions that the average level at the time was of thirty-five per cent of reserves to annual imports[3], which he argued were very low, and that falling below this level made that the requirements to meet the convertibility policies could not be achieved.

In spite of these facts, the rule which stated that countries should have a level of reserves that was sufficient to cover three months of average imports was vastly embraced as the main benchmark for reserve adequacy, and remained as such for several years. The explanation of this mainly relies on the practicality and on the sound theoretical basis of this indicator, as it allowed covering for three months the worst case scenario of a trade balance deficit[4].

It is important to highlight that at the time Triffin wrote his work, the main aim of international reserves was to finance imbalances in the trade section, which constituted the

[3] Triffin (1960) classified the countries in three groups according to the ratio of reserves to annual imports: low (below 33%); medium (33%-50%); and high (above 50%).

[4] The worst case scenario of a deficit is a situation in which there are no exports, due to an external shock to foreign demand of domestic goods, but the flow of imports coming into the country remain invariant.

main outflows of the balance of payments. This tendency started to change, and in the late 1980s a significant flow of capitals headed towards emerging markets. In fact, it has been widely argued that the main cause of the Asian and Latin American crises in the 1990s was a sudden reversal of these financial flows. As a consequence, the paradigm of hoarding international reserves changed and focused on the capital account of the balance of payments.

In this new context, Pablo Guidotti[5], the former Deputy Minister of Finance of Argentina, proposed in a G-33 seminar, that countries should hold enough international reserves to cover at least one year of external debt amortizations. Later on, Greenspan (1999) validated this measurement as a proper indicator of reserve adequacy.[6] This was adopted as a new benchmark for reserve adequacy and is known as the Guidotti-Greenspan rule.

The intuition behind this indicator is rather straight-forward, and is explained by the fact that during a sudden stop of capital inflows to a country, both solvency and liquidity become compromised, so it is desirable to hedge against this eventuality by having a buffer of international reserves which is enough to cover the amortizations of external debt for a certain amount of time. The period chosen seems arbitrary; however it is a very extreme scenario for a country to lose full access to the capital markets for a whole year.

A similar proposal to the Guidotti-Greenspan rule was made by Summers (2007) during an evaluation of the level of reserves in emerging markets. He intended to explain the surge in the hoarding of these assets in Asia and argued that, even with a higher bound of minimal coverage of 2 years of external debt amortizations, the recent accumulation in these economies seemed excessive. This new limit is now known as the Summers' rule, but has not been embraced as widely as the Guidotti-Greenspan rule since it is seen as a very sharp razor since the higher level proposed is regarded as unnecessary.

As an enhancement of the previous approaches, Beaufort Wijnholds and Kapteyn (2001) noticed that focusing only on the amortizations of external debt was insufficient to thoroughly cover the potential outflows of the balance of payments. They argued that emerging economies, in case of a crisis, were susceptible to a bank run as residents would try to secure their liquid assets by sending them abroad, thus increasing the requirements of international liquidity. In order to hedge against this eventuality, it is appropriate to add to the

[5] As reported in Greenspan (1999).

[6] Greenspan (1999) also proposed that nations' debt obligations should have a minimum average maturity of three years.

Guidotti-Greenspan rule a ratio of reserves to a monetary aggregate (usually M2) weighted by a country risk index to control for institutional factors. This new measurement varies according to the exchange rate regime since countries with a fixed rate are more vulnerable to capital flights than those which adopted floating one. Since the scope of the present article is the Colombian case, which uses a managed floating exchange rate, it is only worth mentioning that the suggested ratio in this particular situation is of 5.3%[7].

The proposal of Beaufort Wijnholds and Kapteyn (2001) was one of the first examples of a type of reserve adequacy indicators, known as combination metrics, which intends to capture a wider array of potential outflows in a single measurement without sacrificing the practicality of the previous methodologies.

Later on, IMF (2011) tried to incorporate the main reserve adequacy indicators (namely exports[8] , short term debt amortizations and a monetary aggregate) into a single measurement. Additionally, they included portfolio liabilities to capture the risk of a capital flight in case that a shock significantly affects the prices of domestic equity. These authors proposed weights for each variable based on the negative 10th percentile of historical flows, consequently providing some empirical support for this new indicator.

The new metric of IMF (2011) varies according to the exchange rate regime of the country as follows:

Fixed: 30% of STD + 15% of OPL + 10% of M2 + 10% of X

Floating: 30% of STD + 10% of OPL + 5% of M2 + 5% of X

Where STD stands for short-term debt, OPL for other portfolio liabilities, M2 is the monetary aggregate and X represents exports.

This indicator provides a very complete benchmark to measure reserve adequacy as it considers the major potential risks for an economy in the eventuality of a shock to the balance of payment. Nevertheless, its major shortcoming is the fact that it generalizes for all emerging economies that have very heterogeneous outflows of capital. As a matter of

[7]Beaufort Wijnholds and Kapteyn (2001) suggest a ratio of reserves to M2 of a specific country risk index multiplied by: 5% for purely floating exchange rates; 10% for the managed floating regime; and 20% for countries with their currencies pegged.

[8]The authors use exports, instead of the traditionally utilized imports, because they argue that the latter does not capture risks of external demand collapse () and tend to be endogenous to the amount of available financing, and so generally fall during crises, improving the balance of payments.

fact, IMF (2011) highlights that the measurement tends to underestimate the adequate level of reserves for countries that have a high amount of remittances, or whose exports are highly dependent of commodities with very volatile prices or for those which intervene frequently in the foreign exchange market to moderate its volatility. Since Colombia has all of these characteristics, these shortcomings imply that using the exact weights proposed by this article will result in inaccuracies for the Colombian case. However, its practicality and the fact that it captures most potential risks to be hedged by international reserves, it is relevant to recalculate the weights specifically for Colombia.

4 Previous Estimations for the Colombian Case

One of the first documented attempts to establish an optimal level of international reserves, for the specific case of Colombia, was made by Oliveros and Varela (1994) as a response to the significant increase of these assets since 1986. The authors adapt the model proposed by Ben-Bassat and Gottlieb (1992a) and use the ratio of reserves to imports, the outstanding of external debt divided in the value of exports, the average propensity to import and the gross domestic product, as the suitable variables to explain the perceived probability of a country to default on their international obligations. They also argue that the opportunity cost of hoarding international reserves is the spread between the domestic marginal productivity of capital and the returns of the investments in which the reserves are placed. Finally, they use the average propensity to import to approximate the loss generated by an eventual default.

Under these assumptions the model estimates that the optimal level of international reserves in Colombia for 1993 was of US$ 4,660 million, which was roughly half the observed level of US$ 8,129 million.

Shortly after, the level estimated by Oliveros and Varela (1994) became inadequate when Colombia's central bank (Banco de la República) implemented a crawling peg to manage the exchange rate of the peso against the dollar.

Under these new circumstances, Carrasquilla (1995) calibrated the model proposed by Krugman and Rotemberg (1990) to fit the Colombian case. In this approach the nominal exchange rate depends only of monetary variables and is guaranteed to oscillate between a fixed range by a finite amount of international reserves. The author finds that the necessary level of reserves to maintain the exchange rate in the established range was of US$ 4,800 million, which was widely met by the US$ 8,098 million that Banco de la República held

at the time. However, this value lacked robustness as it was very sensitive to changes in the semi-elasticity of the demand for money relative to the interest rate.

The end of the crawling peg in late 1999 and the aftermath of the financial crises in Asia and in Latin America shifted the motive of reserve hoarding in Colombia from defending the fixed exchange rate to buffering shocks to the balance of payment. However, there is a void in the literature about the subject until the technical research unit of the central bank (henceforth Gerencia-Técnica (2003)) wrote a report about the matter as a response to an inquiry by the Ministry of Finance and Public Credit on whether an eventual excess of reserves should be transferred to the government in order to use them in social and economic programs.

In the article by Gerencia-Técnica (2003) they follow a similar specification to the one proposed by Oliveros and Varela (1994) but they extend it by adding to the probability of crisis the risk coefficient of the emerging economies (EMBI) to include the possibility of crises by contagion. The authors find, using a cost of crisis of 5.5% of GDP and a opportunity cost of 4.37%, that the optimal level of reserves in 2003 was of US$ 10,101, million which implied an excess accumulation of roughly US$ 500 million. Nevertheless, the result was very sensitive to changes in the cost of a crisis and to the opportunity cost of hoarding reserves, so it was not recommended to reallocate a significant amount of these assets as this could result in vulnerabilities for the country. For instance, the authors show that if the cost of the crisis went from 5.5% to 10% the needs of reserves will rise by approximately US$ 2000 million, or that if they changed the opportunity cost from 4.37% to 6%, the optimal level would change by US$ 1000 million. Apart from the lack of robustness, this model also failed when it ignored the risk of a bank run by not including any variable that represented the domestic monetary mass.

The next estimation of an optimal level of international reserves for Colombia was conducted by López (2006) as he argues that it is very important to have an appropriate stock of these assets in order to cover the greater risks that the country faces as it becomes more financially integrated with the rest of the world. Once again the author follows the model proposed by Ben-Bassat and Gottlieb (1992a), but differs from previous exercises by the fact that he uses the Early Watch System to justify the choice of the indicators that approximate the probability of suffering a crisis. Using this method the selected variables are the real exchange rate, economic growth, the change in domestic credit and a monetary aggregate. However, it fails to include a variable that thoroughly portrays the possibility of a shock coming from the trade segment of the balance of payments which the literature

recognizes as a risk for emerging economies. Under these assumptions the optimal level of international reserves in 2003 was of US$ 36,318 million.

Note that the period of reference studied by López (2006) coincides with the one of Gerencia-Técnica (2003) and that the amounts calculated vary significantly amongst authors. This is explained by two factors. First of all, there are some variations in the variables adopted to estimate the probability of crisis. Secondly, there is a vast divergence in the assumed cost of an eventual crisis, which reflects the sensitiveness of the results of this methodology to the parameters adopted, and thus shows one of the major shortcomings of this type of models.

These conclusions were confirmed recently in two different articles that intend to find an optimal level of international reserves for Colombia in 2012, as both, using different methods and assumptions, arrived to very dissimilar results.

On one hand, Mejía (2012), following an earlier version of the model proposed by Jeanne and Rancire (2011), and considering short term debt (one year) as the only possible source of a sudden stop, found that for a twelve emerging countries sample, just Mexico and Colombia exhibit reserves levels below of the optimal level. According to the model, the optimal level for Colombian reserves should be US$54,000 million, under the following assumptions: a risk aversion coefficient of 2; a sudden stop of 10% of GDP; a drop of 12% of the GDP when the sudden stop occurs; and a probability of occurrence of a sudden stop of 10%.

On the other, Gerencia-Técnica (2012), prepared a document, in which following a similar model based on Ben-Bassat and Gottlieb (1992a), found that the optimal level is significantly lower, as it is between US$23,772 and US$37,476 million depending on the assumptions on the cost of the crisis. This is explained by the sensitivity of the optimal level methodologies to the different assumptions used to estimate the model, namely the probability of the sudden stop, the size of the sudden stop, and the cost in terms of output of the sudden stop.

Moreover, Gerencia-Técnica (2012) introduced the IMF (2011) methodology for various countries, finding that the international reserves level in Colombia was above the adequate level proposed by this indicator. Finally, this article describes that the levels of international reserves in Colombia were between the levels of the countries of the region, while the tendencies have not changed significantly from those observed in previous years.

As a conclusion for this sub-section, it is worth highlighting that previous estimations for Colombian reserve optimality are subject to all of the shortcomings of the methodologies

found in the literature, namely the difficulties to accurately estimate the cost of an eventual crisis, the probability of crisis and the opportunity cost of reserves. Consequently, this type of specification will not be very reliable in terms of policy analysis and recommendations.

5 A Measurement of Colombian Reserve Adequacy

After surveying the previous estimation exercises done to determine the level of reserves that Colombia should hold, it is worth highlighting that all of the earlier literature focuses mainly on the construction of a measurement of reserve optimality. This is not surprising since most of the criteria of reserve adequacy mentioned in section 3 are rather straightforward and only require the level of international reserves to be over a certain point of reference. Nonetheless, these measurements are central in the analysis on whether a country has sufficient reserve holdings to cope with an international liquidity crisis.

For instance, in the specific case of Colombia, in the report that the Board of Directors of Banco de la República gives to the Congress, all of the measurements of reserve adequacy are presented as indicators of foreign vulnerability. However, this is not limited to Colombia and most central banks in emerging economies use these rules of thumb to evaluate whether they are holding enough international assets to buffer an external crisis.

The fact that reserve adequacy measurements are more widely used in policy analysis than optimality analysis can be mainly explained because the estimations of reserve optimality tend to rely heavily on the assumptions made on three crucial aspects: the cost of an eventual crisis; the probability that such crisis occurs; and the opportunity cost of reserves. Given that there is no consensus on how to accurately estimate these variables, the results of these exercises will not be very robust, and as a result will not be very reliable to guide policy actions. This means that further work needs to be done in this field in order to fill this gap on the existing literature.

Aware of the caveats of the models used to measure reserve optimality, this article will diverge from the approaches used by other authors for the Colombian case and will focus on finding a measurement of reserve adequacy that captures the institutional framework of this country.

In order to achieve this objective, the indicator proposed by IMF (2011) will be adopted. As described in the prior section, this indicator provides a very complete benchmark to measure reserve adequacy as it considers the major potential risks for an economy in an eventual shock to the balance of payment. Nevertheless, its major shortcoming is that it

generalizes for all emerging economies, which have very heterogeneous outflows of capital. For that reason it is pertinent to analyze the particular Colombian case by finding the appropriate weights for the potential outflows of the country, which depend exclusively on the performance of the Colombian balance of payments. This procedure removes the inaccuracies of this indicator for the specific case of Colombia.

To estimate the weights of the methodology proposed by IMF (2011) for Colombia, we used data between January 2003 and December 2012. This period was chosen for several reasons. First of all, as mentioned in section 4, the exchange rate of the Colombian peso against the United States dollar was under the crawling peg regime until September 1999, so using balance of payments' data before 2000 would imply a significant divergence from the current institutional framework that could affect the results of this article. Also, after the 1999 financial crisis faced by Colombia, the economic authorities adopted a series of macro prudential policies that improved the macroeconomic environment of the country[9], so analyzing an older sample would not thoroughly capture the current economic institutions. Finally, the market for short-term sovereign bonds was not very deep before 2003, so their yields used to very volatile and the available data before that was not a good indicator of the market conditions. Since one of the variables considered to build an indicator of exchange market pressures (that will be discussed below) is the interest rate of short-term government bonds, using a sample before 2003 would affect the weight given to this variable, and consequently distort the results of the indicator.

After establishing the period of the data, we estimated an index of exchange market pressures (EMP), following Eichengreen, Rose, and Wyplosz (1996), in order to identify the periods in which the Colombian peso faced unusual depreciation pressures, as these are the moments in which the international reserves would be required to provide liquidity to the market as mentioned in section 2.

The EMP index compares some variables that reflect periods of pressure in the exchange rate against a benchmark. Eichengreen et al. (1996) uses Germany as the comparison reference as he argues that it is a country with a strong institutional framework. With the substitution of the Deutschmark for the Euro, this comparison seemed rather unnatural since the movement of the currency will not necessarily match those of the short-term rate of the German bond. Consequently, we chose the Special Drawing Rights (SDR) as the benchmark, since these capture the behavior of the most important reserve currencies (the

[9]For details see Grupo-Macroeconomía (2006).

US dollar, the euro, the British pound and the yen), but still gives a significant weight to the behavior of the indicators of United States , which is Colombia's main trading partner.

The variables used in the construction of the EMP index are:

The exchange (ER) rate between the Colombian peso and the Special Drawing Rights. The intuition behind the inclusion of this variable is rather straight-forward, as it reflects the actual performance of the domestic currency relative to those that compose the SDR.

The spread between the interest rate ($\triangle i$) of the 3-month Colombian Treasury and the SDR interest rate, which is composed of the short-term term rates of the sovereign bonds of the United States, the Euro Zone, the United Kingdom and Japan. This variable captures the fact that the monetary authority might raise its interest rate to reduce the unusual depreciation pressures on the exchange rate and its possible consequences.

The difference between the monthly percentage change of the international reserves in Colombia and the weighted average of the SDR countries ($\triangle IR$). Similar to the previous indicator, this variable captures the attempts made by the monetary authority to provide international liquidity in the exchange market to moderate any unusual depreciation pressures. This variable enters with a negative sign in the indicator as a greater relative reduction in reserves indicates an attempt to intervene in the exchange market.

So, the EMP index for a given month t will be as follows:

$$EMP_t = \alpha_1 EP_t + \alpha_2 \triangle i_t - \alpha_3 \triangle IR_t \tag{2}$$

Where $\alpha_1, \alpha_2, \alpha_3$ are positive weights that, just as in Eichengreen et al. (1996), are normalized so that each weighted variable has the same volatility in order to avoid that a particular indicator dominates the index.

An event of exchange market pressure occurs whenever the indicator at time t is one standard deviation over the mean of the EMP during the sample. This definition diverges slightly from the one established by Eichengreen et al. (1996) of one and a half standard deviations over the mean, since we studied a relatively short period, so we needed a weaker criteria in order to obtain a greater sample of periods of exchange market pressures to have a better defined distribution when analyzing the potential outflows of the balance of payments. Despite the practical and arbitrary nature of this decision, it does not affect considerably the obtained results since we are exploring events in the lower tail of the distribution, which tend to be associated with periods of high stress in the foreign exchange market. It also worth mentioning that this change implies that the sample used will be

more conservative than the one suggested by Eichengreen et al. (1996) as it will consider periods in which market pressures are not as extreme, but still could exhibit some important outflows of the balance of payments.

We found 16 periods within the sample that fulfilled the condition and can be thus considered periods of exchange market pressures[10]. These were concentrated in 2007 and 2008, which is consistent with the Global Financial Crisis that stemmed from the United States, and in 2011 and 2012, which is linked to the stress in the market related to the sovereign debt crisis in the Euro Zone.

Following the methodology proposed in IMF (2011), the next step is to quantify the potential outflows of the balance of payments according to the historical information of different components of this account during the periods of exchange market pressure. The chosen variables are: M2, which captures the possible outflows during a bank-run crisis, as described in section 2. Short-term debt (STD), which includes the possible outflows in the contingency of a balance sheet crisis, as described in section 2. Other portfolio liabilities (OPL), which captures the outflows that occur by the liquidation of foreign portfolio investments in periods of market stress. Exports (X), which show the possible outflows during a current account crisis. In line with the IMF (2011), imports were not included as they do not thoroughly capture the risks of a collapse in external demand and the levels of imports and exports are not very different from each other in most emerging economies. This is also true in Colombia were the difference between these levels is not substantial. The next step is to calculate the percentage change of each of these variables in periods of exchange market pressure with respect to their 12-month average. Then, for each variable we find the tenth percentile of these changes, which reflects the potential outflows under periods of high stress. This means that the adequate level of international reserves at any period t will be given by:

$$IR_t = 13.3\% \, of \, STD_t + 2.9\% \, of \, OPL_t + 8.7\% \, of \, M2_t + 19.2\% \, of \, X_{12m} \tag{3}$$

Where the sub-index t denotes the aggregate of the variable in month t, and 12m represents the aggregate of the 12 previous months, which is used in the case of exports, since it is the only flow variable in our sample. Using equation 3 and data to December 2012, the adequate level of reserves suggested by this indicator is US$29,824.13 million.

[10] Ussing one standard deviation, as suggested by Eichengreen et al. (1996), we found 7 periods that could be considered of exchange market pressures

We will now proceed to compare the level estimated by this indicator to the traditional adequacy indexes. This is shown in table 1, below:

Adequate level of internacional reserves for Colombia, according to several indicators

	Level of International Reserves (US$ Million)				
	2008	**2009**	**2010**	**2011**	**2012**
Actual Level /1	23,962.37	25,055.98	28,296.67	32,149.69	37,187.25
Adequate Levels					
Equation (3)	16,999.84	17,708.01	20,944.93	26,673.00	29,824.13
IMF (2011) / 2	14,707.85	16,051.65	19,509.05	24,445.35	26,362.36
Beauford-Wijnholds & Kapteyn (2001) /3	15,415.87	14,688.50	18,065.34	26,042.63	23,630.35
Guidotti-Greenspan (1999) /4	11,481.04	10,015.38	12,674.88	19,660.75	15,626.96
Triffin (1960) /5	11,312.22	10,533.07	13,139.88	16,478.13	16,828.99

1/ Values to December 31 of each year

2/ Using the weights that correspond to floating exchange rates (30% of STD + 15% of OPL + 5% of M2 + 5% of X)

3/ Using a conservative scenario, where the country-risk index is the one used by the authors (0.53) i.e. (1 year of debt amortizations + 5.3% of M2)

4/ 1 year of debt amortizations

5/ 3 months of imports (aggregate of October to Decemeber of each year).

Source: Banco de la República (Central Bank of Colombia); Authors' calculations.

Table 1 shows that the adequacy indicator estimated in this article suggests a higher level of reserves than any of the traditional indexes. This is not surprising if compared to those suggested in Beaufort Wijnholds and Kapteyn (2001), Greenspan (1999) and Triffin (1960), as the new indicator is a combined metric that captures more potential outflows of the balance of payments and has a conservative stance as it ignores the existing correlation between these variables. In comparison to the one of the IMF (2011), which consists of the same variables, the divergence is mainly explained by the fact that Colombian exports are closely linked to the international prices of oil and other commodities, whose prices are very volatile. This can be seen by the higher weight that exports have in the Colombian based index than in the one estimated by the IMF for a pool of countries.

It is also worth noticing that Colombia between 2008 and 2012 has had levels of international reserves that are above the adequate level estimated in this article and above any of the traditional indicators. This is a result of the pursuit by the economic authorities of a more favorable macroeconomic environment after the crisis 1999, which derived in the adoption of several macro prudential policies, including the accumulation of international

reserves, which is not surprising since the monetary authority of Colombia has adopted a policy of reserve accumulation, that intends to reduce the vulnerability of the country to external shocks, to moderate the volatility of the foreign exchange rate and to avoid possible mismatches between the fundamentals and the actual movements of the exchange rate that could harm the economy and its agents.

Finally, we intend to find out if the level of international liquidity that the country has accumulated is adequate in comparison to even more conservative indicators. To do so, we estimate percentiles one and five (rather than the tenth) of the percentage change in periods of exchange market pressure of each variable with respect to its 12-month average. It is worth mentioning that these values are in the farthest extreme of the tail of the distribution, so they will show the most acute potential losses in times of stress in the exchange market. This results in new weights for the more conservative indicators, which suggest the adequate levels of reserve shown in table 2, below:

Adequate level of international reserves for Colombia for the 1st, 5th and 10th percentile

	Level of International Reserves (US$ Million)				
	2008	**2009**	**2010**	**2011**	**2012**
Actual Level /1	23,962.37	25,055.98	28,296.67	32,149.69	37,187.25
Adequate Levels					
10th percentile	16,999.84	17,708.01	20,944.93	26,673.00	29,824.13
5th percentile /2	21,298.84	21,731.11	25,743.79	33,167.83	36,871.64
1rst percentile /3	23,063.20	23,541.91	27,871.87	35,901.00	39,979.69

1/ Values to December 31 of each year

2/ The resulting equation is: 18.0% of STD + 3.0% of OPL + 11.1% of M2 + 23.7% of X

3/ The resulting equation is: 18.3% of STD + 3.0% of OPL + 12.2% of M2 + 25.9% of X

Source: Banco de la República (Central Bank of Colombia); Authors' calculations.

Table 2 shows that under more conservative measurements, Colombia exhibited adequate levels of reserves between 2008 and 2010. However, in 2011 the accumulation of reserves can only be considered adequate under the estimation for the 10th percentile, while the measures for the 1rst and 5th percentiles suggest that the monetary authority should accumulate roughly US$3,750 million and US$1,020 million, respectively. During 2012, there was an active purchase of international reserves, which made the level of reserves adequate under the estimations for the 5th and the 10th percentiles. Meanwhile, the

estimation for the 1st percentile suggests that the central bank should increase its reserves by approximately US$2,792 million. Nonetheless, it is worth mentioning that this is a very extreme scenario in which all of the studied components of the balance of payments suffer considerable reversals at the same time, so only a very conservative central bank should guide itself by these exceptional adequacy levels.

Finally, it is worth mentioning that the adequate levels estimated in this article result in a proper guideline for the international levels that Colombia should accumulate in order to reduce its vulnerability to external shocks. First of all, the proposed indicator is more robust than any of the levels found using the methodology of reserve optimality, as it does not rely on parameters that are difficult to estimate, such as the probability of crisis, the cost of an eventual shock and the opportunity cost of reserves. Secondly, it considers a greater number of potential risks, than any of the traditional indicators, so it provides a more thorough estimation of the outflows of the balance of payments than any of the traditional adequacy indicators. Lastly, since it is built based only on the historical information of Colombia, it captures the idiosyncratic traits of the country, which corrects for the possible underestimation of the indicator proposed by IMF (2011).

6 Conclusions

International reserves are a very important for emerging economies, as they allow to buffer possible liquidity vulnerabilities within a countries' balance of payments. Consequently, the issue of how many reserves should each country hold is a very relevant issue for economic policy. However, there is still great discussion on how to establish the appropriate amount of reserves that a country should hold.

On one hand, studies of reserves optimality have been established as a good and rigorous theoretical approach to include the costs of reserves and the role of these assets on the behavior of the agents. Nonetheless, they tend to rely on a large number of assumptions, which affect the robustness of the levels suggested by these models, and hence make them limited for policy decisions. On the other, reserves adequacy metrics tend to disregard the incentives and costs generated by reserves in an economy, but rely on weaker assumptions, and hence provide more robust and reliable guidelines for economic policy. As a consequence, this last group was chosen in this paper to find the appropriate level of reserves that Colombia should hold to reduce its vulnerability to foreign shocks.

Within the reserve adequacy indicators, the one proposed by IMF (2011) is the most

complete, as it includes most potential outflows of the balance of payments, thus reducing the vulnerability of the country to balance-sheet, current account and bank run currency crises. However, one of disadvantages of the metric is that it generalizes all levels to emerging economies, which tend to have very heterogeneous outflows in their balance of payments. Hence, we calibrated the model using historical data for Colombia in order to capture some specific traits of the country and found a higher level than any of the traditional indicators of reserve adequacy. Under this new and more conservative metric the current levels of reserve accumulation in Colombia have proven to be adequate. Nonetheless, the sensitivity analysis suggests that under a very extreme scenario there is room to acquire additional reserves.

Finally, it is worth mentioning that the adequate levels estimated in this article result in a proper guideline for the international levels that Colombia should accumulate in order to reduce its vulnerability to external shocks. However, it is not a definite measure as it subject to several shortcomings, such as the fact that it considers a short sample for the different indicators. It also disregards the existing interaction between the different variables of the balance of payments that compose the indicator, as well as the costs of reserve accumulation. Consequently, we invite to use this indicator as a complemet to the existing ones in order to evaluate the international reserves levels that Colombia should accumulate to reduce its vulnerability to external shocks. Also, we strongly encourage further work in this relevant field in order to consolidate measures that can integrate the advantages of the methodologies of reserve optimality and adequacy.

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