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STAFF STUDIES

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The views presented in these papers are those of the authors and do not necessarily indicate the views of the Central Bank of Sri Lanka.

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Demand for and Adequacy of International Reserves in Sri Lanka

Dimuthu Samaratunga and Anil Perera[1]

Abstract

During the last few decades, especially emerging economies have opted to accumulate large stocks of international reserves to withstand unexpected external turbulences and also to reinforce external sector performances through maintaining exchange rate stability. Substantial reserve accumulation entails several benefits as well as direct and indirect costs. Particularly, holding excess reserves for a long time could generate welfare losses which is an important policy consideration. In this context, the key objectives of our study are twofold: first to develop a reserve demand model based on historical data; and second, to assess the reserve adequacy for Sri Lanka based on conventional and recent methodological innovations in the reserve adequacy literature. Based on data for the period 1996 – 2012, we observe that international reserves in Sri Lanka are broadly determined by import propensity, trade openness, short-term debt and liabilities and money supply. In terms of key conventional measures of reserve adequacy, we find that Sri Lanka has held adequate reserves, despite some variations in some years. At the same time, based on the new risk-weighted reserve adequacy metrics proposed by the International Monetary Fund, we observe that Sri Lanka has had adequate levels of reserves except in the years 2000, 2008 and 2011.

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This new metrics appears to be a better standard to measure reserve adequacy than the conventional bench-marks from a precautionary perspective. Our results have important policy implications for exchange rate, reserve accumulation and the monetary policy of the Central Bank of Sri Lanka.

JEL Classification: F31, F32, F41

Key Words: International Reserves, Reserve Adequacy, Reserves Demand Function, Risk-Weighted Reserve Adequacy Metrics

PART 1: INTRODUCTION

An individual country's international reserves consist of the stock of assets held by its central bank (or monetary authority) that can be converted, with certainty, into another financial medium and used to influence the value of the country's exchange rate. International reserves (also called foreign exchange reserves) are generally defined in gross terms in the literature, to include central bank holdings of convertible foreign exchange, gold, special drawing rights (SDRs) and the reserve position at the International Monetary Fund (IMF) (Bahmani-Oskooee and Brown, 2002). In a technical sense, the IMF defines an economy's international reserves as "those external assets that are readily available to and are controlled by monetary authorities, for direct financing of payment imbalances through intervention in exchange markets, to affect currency exchange, and/or for other purposes (IMF Balance of Payments Manual, 1993).

Foreign reserves are demanded by countries with a view to build a buffer against sudden withdrawal of foreign exchange or to manage exchange rates to support the export sector. Hence, international reserves provide two main benefits: self-insurance against financial turbulence and mercantilist export promotion. However, during recent decades, reserve accumulation has become subservient in industrial countries. Particularly, over the past three decades, shifts to flexible exchange rate regimes and the ability to borrow in domestic currency have eased pressure on industrial countries to accumulate reserves (Green and Torgerson, 2007). In contrast, emerging countries have been pursuing sustainable efforts to build-up large stocks of international reserves.[2]

2 International reserves in emerging economies are four times as large as in the early 1990s in terms of their GDP (Jeanne, 2007).

Amongst emerging economies, several Asian economies have accumulated large stocks of international reserves (García and Soto, 2004). The 1997 crisis in East Asia led to profound changes in the demand for international reserves and hence motivated Asian countries to aggressively hoard reserves over time (Aizenman and Lee, 2007; Ruiz-Arranz Zavadjil 2008; Cheung and Ito, 2009). In particular, some Asian countries like China, Japan, Korea, Malaysia, and Taiwan have attempted to accumulate large amounts of reserves, fuelling the recent discussion/debate of the extraordinary and puzzling accumulation of international reserves in the new millennium (Cheung and Qian, 2009). Table 1 shows reserve levels of selected countries including the top ten reserve holders by 2011. It appears that Asian countries dominate reserve accumulation and it is also observed that substantial reserve accumulation was driven by both precautionary and mercantilist motives (Park and Estrada, 2009).

Table 1

Ranking of Countries by Foreign Exchange Reserves *(at end 2011)*

Rank	Country	Foreign Exchange Reserves (USD Mn)	Share (%)
1	People's Republic of China	3,204,610	29.9
2	Japan	1,259,494	11.8
	Eurosystem[1/]	932,675	8.7
3	Saudi Arabia	541,234	5.1
4	Russia	455,474	4.3
	Republic of China (Taiwan)	386,277	3.6
5	Brazil	350,414	3.3
6	Republic of Korea	304,349	2.8
	Hong Kong	285,300	2.7
7	Switzerland	281,187	2.6
8	India	272,249	2.5
9	Germany	256,455	2.4
10	Singapore	255,769	2.4
17	United States	150,964	1.41
19	United Kingdom	79,808	0.75
37	Australia	42,921	0.40
57	Pakistan	14,639	0.14
65	Bangladesh	8,533	0.08
69	Sri Lanka	6,000	0.06
	World	**10,706,657**	

Source: IMF, International Financial Statistics (IFS)

[1/] *EU member states, which have adopted the euro, including ECB.*

With the build-up of substantial reserves positions, particularly in Asian countries, there had been a growing consensus that the reserve levels of many Asian countries now far exceed all plausible estimates of what they need for liquidity purposes, or in other words, the reserve levels are substantially above optimal levels (Park and Estrada, 2009). Hence, particularly during the last decade, there is a growing interest of empirical research on the different aspects of international reserves such as the optimal level, adequacy, demand and determinants, cost and benefits, and management of international reserves.

In Sri Lanka, both key motives of reserves accumulation have been important. During the recent episodes of financial crisis, Sri Lanka's international reserves declined substantially to low levels mainly due to the impact of significant outflows of short term foreign investments and the drain of foreign exchange inflows on account of the dampened external environment. Several measures taken by authorities helped to boost foreign exchange inflows received by Sri Lanka, advancing the reserve position to historically high levels. Foreign exchange reserves reaching higher levels induce interest for investors, policy makers and particularly researchers. This is due to benefits such as protection against unexpected shortages of foreign exchange and currency crisis and also the costs such as opportunity and welfare losses associated with the accumulation of large and excessive amounts of foreign reserves. These concerns are particularly important in the Sri Lankan context, given the record high levels of international reserves in recent years and hence Sri Lanka is a particularly interesting country to examine the demand and adequacy of international reserves, contributing to the ongoing discussion in this area. To that end, the objectives of our study are to develop a reserve demand model for Sri Lanka and to assess the level of reserve adequacy of the country in terms of conventional as well as the risk-weighted metrics proposed by the IMF. As far as we are aware, this is the first attempt to conduct an empirical study on the country's international reserves.[3] The findings of our study would be useful for policy makers in general, in better calibrating macroeconomic policies in Sri Lanka and also to the Central Bank of Sri Lanka (CBSL) in particular, in pursuing its exchange rate and reserve management policies.

The remainder of this paper is structured as follows: Part 2 of the paper contains a discussion of the conceptual outline of international reserves including different measures of reserve adequacy and a review of prior academic literature. Part 3 provides the analysis and the related discussion pertaining to demand and adequacy of international reserves in Sri Lanka, followed by the conclusion.

3 Sri Lankan context is considered in prior literature, for example, Hauner, 2006; Cheung and Qian, 2009 and Dominguez, Hashimoto and Ito, 2012, only as part of a large panel of countries and do not focus on individual country-specific discussion.

PART 2: CONCEPTUAL OUTLINE

In this section, we attempt to provide a comprehensive discussion of the motivations, determinants and costs and benefits associated with international reserves and review prior theoretical and empirical literature.

2.1 Motivations for Reserve Accumulation

The traditional purposes for holding international reserves have been to: directly finance international payments imbalances; intervene in financial markets to provide liquidity in times of crisis; and influence the exchange rate (Neely, 2000). It clearly indicates that traditionally, the reserves accumulation motive was centered around exchange rate considerations. As such, during the 1960s, the debate focused on defining the optimal level of international reserves necessary to maintain the value of a currency, within the fixed exchange rate systems (García and Soto, 2004). Particularly, when countries opt to maintain a certain level of stability in the exchange rates, they would need to hold adequate levels of international reserves. Therefore, foreign reserve accumulation becomes a prime motive of the monetary authority in countries focusing predominantly on exchange rate stability.

Based on the contemporary practices of reserve accumulation across countries, Cruz and Walters (2008) define three main motives behind reserve accumulation: (i) precaution, (ii) mercantilist approach and (iii) policy autonomy.

First, theoretically, large precautionary demand for international reserves arises as a self-insurance to avoid costly liquidation of long-term projects when the economy is susceptible to sudden stops of capital flows (Aizenman and Lee, 2007). During the 1970s, when most countries adopted free floating foreign exchange rate regimes, international reserves were seen as a buffer to absorb a transitory current account shock (García and Soto, 2004). Particularly, the issue of the accumulation of international reserves has regained relevance since the mid-1990s because of the occurrence of financial crises in the developing world, which were associated with the adoption of the neo-liberal liberalization strategy of free mobility of capital, notably in Mexico, Thailand, Korea, Malaysia, Philippines, Indonesia, Brazil, Turkey, Russia and Argentina (Aizenman and Lee, 2007). Hence, stockpiling international reserves has been seen as the central policy option that a country can pursue to avoid a financial crisis and its high economic costs (Bird and Rajan, 2003).

Second, the mercantilist view focuses on hoarding international reserves in order to maintain a competitive real exchange rate with the ultimate goal of increasing export growth (Wijnhold and Kapteyn, 2001, Aizenman and Lee, 2007). Frenkel and Ros (2006) argue that if the rate of accumulation in the tradable goods sector is a positive function of profitability, and profitability in that sector is a positive function of the RER, then a competitive RER will lead to faster growth of the traded goods sector. In this sense, a more depreciated currency is equivalent to a uniform tariff on imports. Thus, by maintaining a competitive RER with the concomitant reserve accumulation, the profitability of the tradable sector can be promoted and, in turn, firms will invest and expand production.[4] Reserve accumulation is also used as a policy tool for growth (Noyer, 2007). Dooley, Garber, and Folkerts-Landau (2003) argue that Asian emerging economies are pursuing export-led growth strategies by deliberately maintaining undervalued exchange rates, while providing the funding for the US current account deficit, as the US is a key consumer of these exports. Further, central banks in dollarized financial systems may need foreign exchange reserves to serve as a lender of last resort to banks with high levels of foreign currency liabilities (Green and Torgerson, 2007).

Third, the policy autonomy argument contends with multilateral institutional attachments of countries. Avoiding financial crises avoids the interference of and dependence on international agencies. The eruption of financial crises has led to the involvement of international multilateral institutions, and their conditional assistance packages, with an inevitable loss of policy autonomy. If countries attempt to prevent a crisis through the accumulation of liquidity, they could also minimise conditional assistance from multilateral agencies and gain policy autonomy, even in the event of a crisis actually occurring. Therefore, developing countries see reserve accumulation as a strategy of policy independence or sovereignty (Cruz and Walters, 2008).[5]

4 Aizenman and Lee (2007) find that variables associated with trade openness and exposure to financial crises are both statistically and economically important in explaining reserves. In contrast, variables associated with mercantilist concerns are statistically significant, but economically insignificant in accounting for the patterns of hoarding reserves. They also provide a model that shows that precautionary demand is consistent with high levels of reserves.

5 As external vulnerability is high in those countries, the pattern in reserve demand also significantly differs from developed countries (Wijnhold and Kapteyn, 2001). Hence, in summary, the precautionary, mercantilist and policy sovereignty motives are the driving forces behind developing countries' hoarding of international reserves (Cruz and Walters, 2008).

2.2 Determinants of International Reserves

In many past empirical studies, some key variables have been found to be robust predictors of a country's holdings of international reserves. Such variables include: the current account balance, exchange rate regime, and marginal propensity to import (Romero, 2005). The most recent extended literature identifies a range of variables that may influence reserve holdings. Since there is no consensus on a theoretical model of reserves behaviour, these take a broad approach and attempt to include a large number of potential determinants such as output per capita, trade openness, country size, export volatility, financial development, capital controls, the exchange rate regime, an oil dummy, and external debt variables (Lane and Burke, 2001).

According to the literature, determinants of international reserves can be divided into three categories: traditional macro variables, financial variables, and institutional variables. The group of traditional macro variables consists of the propensity to import, volatility of real export receipts, international reserve volatility, the opportunity cost of holding international reserves, real per capita Gross Domestic Product (GDP), and population. These variables have been commonly considered as macro determinants since the 1960s. The second group of explanatory variables includes money supply, external debt, and capital flows. The use of money in explaining the hoarding of international reserves can be dated back to the 1950s. The third group of explanatory variables is institutional variables. It has been argued that institutional characteristics like corruption, political stability, and capital controls affect the hoarding of international reserves (Cheung and Ito, 2009).

The IMF (2003) categorises the determinants of reserve holdings into five categories, namely economic size, current account vulnerability, capital account vulnerability, exchange rate flexibility and opportunity cost. This approach of categorisation is used throughout the current study.

2.3 Benefits and Costs of Reserve Accumulation

Maintaining a high level of international reserves can help an economy, particularly a small open economy, to smooth-out the domestic impact against external shocks and hence reduce the welfare cost of a crisis. As argued by Jeanne (2007), there are two ways in which reserves can help to mitigate the impact of a balance of payments crisis on domestic welfare. First, the reserves can be used to mitigate the fall in domestic output. Second, the reserves can be used to buffer the impact of the balance of payments shock on domestic absorption.

Furthermore, it is argued that reserves help to maintain stability in exchange rates and hence, to promote export growth through a competitive RER. In some cases, although exchange rate stability is not explicitly focused, large stocks of reserves may reduce the volatility in the exchange rate by way of reducing speculative attacks (Aizenman, 2006; Aizenman and Riera-Critchton, 2006; Cady and Gonzalez-Garcia, 2006). In addition, as a result of large reserves, the cost of foreign borrowing may also be reduced (Cruz and Walters, 2008).

However, many agree that holding reserves, particularly holding excess reserves, incurs costs than benefits (Park and Estrada, 2009). The prime cost of international reserves is usually defined as the opportunity cost of not consuming them, or not investing them in a more profitable manner. Reserves could be spent on the consumption of imported goods rather than being accumulated in the central bank. Hence, reserve accumulation leads to a welfare cost of postponing the consumption of tradable goods.[6]

Reserve accumulation could lead to some monetary costs to the monetary authority and fiscal costs to the government. When monetary authorities acquire international reserves, they typically require sterilising the effect of the foreign currency purchases on the domestic monetary base, which would lead to incurring domestic-currency liabilities. At the same time, reserves held by the fiscal authority are typically financed with domestic government bills. If the interest rate on reserve assets is lower than the domestic interest rate, holding reserves entails quasi-fiscal costs (Dominguez *et al*., 2012). Moreover, reserves have a fiscal (opportunity) cost as they could alternatively be used to finance public investment or to pay down external debt and reduce interest expenditure. Hence, it is considered that reserves can have a substantial fiscal impact through interest expenditure, central bank profits and – indirectly – a lack of funds for public investment (Hauner, 2006). Furthermore, holding reserves also exposes the country to currency risk. If the domestic currency appreciates against the currencies denominating the reserve assets, the domestic currency value of reserves drops (Dominguez *et al*., 2012).

Mohanty and Turner (2006) show that large and prolonged reserve accumulation aimed at resisting or delaying currency appreciation can create a range of domestic macroeconomic risks through its effects on the balance sheets of the central bank and the

6 This cost can be proxied by the difference between the interest rate at which domestic consumers would be ready to borrow in order to increase their consumption of tradables and the rate of return on reserves (Jeans, 2007).

private sector including near-term inflation, ineffective sterilisation, high intervention costs and monetary imbalances. Park and Estrada (2009) observe three major costs of reserve accumulation: inflation, fiscal costs, and higher interest rates. In addition to the aforementioned direct costs, reserve accumulation can be counterproductive, potentially generating further long term imbalances (Cruz and Walters, 2008). For example, large reserve stocks may create moral hazard problems that could weaken the financial system of a country, causing crises to be deeper, as currency intervention injects liquidity into domestic money markets, producing liquid market systems that can spill over into overheated asset markets and perhaps distort the banking system (Schiller, 2007).

In addition, the empirical significance of using international reserves to promote growth (the mercantilist view) is contested (Cruz and Walters, 2008).[7] Reserve hoarding may exacerbate trade competition and emphasize regional tensions rather than promoting export growth.

2.4 Assessing Reserve Adequacy

Wijnhold and Kapteyn (2001) observe three major developments during the last fifty years with regard to reserve adequacy. First, the focus on money based measures, which was prevalent prior to the Bretton Wood System, has been largely diverted. Second, during the post-World War II period, reserve adequacy in individual countries has been entirely defined in terms of trade and trade variability. Third, the focus on different levels of development and market access between countries and different types of exchange rate regimes have been increased in explaining different levels of demand for reserves. Although trade based measures of reserve adequacy have gained much importance for a long period of time, contemporary analysis of reserve adequacy focuses on broader measures. Accordingly, four major reserve adequacy ratios can be found in contemporary literature: reserves to short-term external debt, reserves to broad money, months of imports and reserves to GDP. Ratios of reserves to short-term external debt and broad money are measures of reserve adequacy pertaining to reducing an economy's vulnerability to capital account shocks (Park and Estrada, 2009). At the same time, it is also observed that reserve adequacy measures essentially are influenced by the internal and external drain of financial assets during crises. Hence, broad money and short-term debt based indicators and/or the combination of these two ratios become the significant determinants of international reserve adequacy, particularly for emerging economies

7 During the last decade, developing (and some developed) economies have accumulated large amounts of international reserves, mainly for precautionary reasons. However, according to Cruz and Kriesler (2008), this phenomenon has been coupled with moderate economic growth.

(Ozyildirim and Yaman, 2005). These four conventional measures are briefly explained below:

(i) Import Coverage

Until recently, the most widely spread indicator of reserve adequacy was reserves expressed in months of imports of goods and services. To that end, contemporary literature considers the reserve-to-import ratio, a proper measure of reserve adequacy and a three month prospective level of imports cover became the rule of thumb to determine the adequacy (Fischer, 2001). This criterion which implies forward import covered by reserves, is a guarantee of no hindrance in external trade transactions even in a case of complete cut off from foreign flows (Sehgal and Sharma, 2008). Although, such three month benchmark was earlier considered sufficient for adjusting imports without shocks to the economy, financial crises proved this indicator itself is insufficient to avoid problems and it should be augmented with additional criteria (Shcherbakov, 2002).

(ii) Reserves to Short-term External Debt and Liabilities

The ratio of reserves to short-term external debt and liabilities indicates that reserves should allow a country to sustain without foreign borrowing for up to one year (Jeanne, 2007). More precisely, according to the Greenspan-Guidotti rule,[8] the critical value of this ratio is one (or 100%), with a value above one signalling safety and a value below one signalling adverse implications. Hence, a country with reserves equal to or more than all external debt falling within one year, should be able to service its immediate external obligations even during a financial crisis. This ratio appears to be the most relevant single indicator of reserves for countries that borrow in international financial markets (Wijnhold and Kapteyn, 2001) and serves as a significant determinant of an economy's vulnerability to financial crisis (Park and Estrada, 2009).

(iii) Reserves to Broad Money

The ratio of reserves to broad money (more specifically M_2) is especially relevant for countries at a significant risk of capital flight. Hence, this ratio indicates the degree of risk of capital flight from the country (Chan, 2007). Also, this is considered a decent indicator of reserve adequacy where demand of money supply is not stable and financial markets are not strong (Sehgal and Sharma, 2008). The basic premise is that the higher the ratio, the greater the confidence of the general public in the value of the local

8 The "Greenspan-Guidotti" rule recommends that reserves should enable full coverage of total short-term external debt in order to be able to pay back that debt in the event of a sudden termination of the rolling-over of foreign debt (Noyer, 2007).

currency and hence lower the likelihood of massive crisis-provoking flights into other currencies. There is no general consensus on the critical value of the reserves to M_2 ratio, given the inherent difficulty of measuring capital flight. However, Wijnholds and Kapteyn (2001), suggest reserves equivalent to 5–20% of M_2 (depending on the exchange rate regime) is an acceptable level for this ratio.

(iv) Reserves to GDP

In the reserve adequacy literature, for example, Aizenman and Lee (2007), Lloyd-Ellis and Nechi (2008) and Park and Estrada (2009), among others, the ratio between international reserves and GDP is taken as an indicator for reserve adequacy. Reserves equal to 10% of GDP is considered the benchmark. It is argued that self-insurance against external liquidity problems cannot be simply explained by the reserves to GDP ratio (Lloyd-Ellis and Nechi, 2008). Although comparing a large amount of GDP with a small amount of reserve does not provide a reasonable basis, it still provides some implication about such large economy's need of reserves for dealing with larger amounts of international capital flows and trade.

Although these measures are informal rules of thumb, based on general economic intuition rather than rigorously derived theoretical concepts and models, they provide useful guidance for policymakers. In particular, many such studies find the ratio of reserves to short-term external debt to be a significant determinant of an economy's vulnerability to financial crisis (Park and Estrada, 2009). However, considering the advantages and disadvantages of these indicators, it is suggested they should be used simultaneously (Calvo and Mendoza, 1996, Berg and Pattillo, 1999).

Recently, the IMF has developed a new methodology to assess the reserve adequacy across countries based on a risk-weighted approach. It is being argued that conventional approaches of assessing reserve adequacy do not appear to be fairly representative and therefore not closely followed by countries in their reserve-holding decisions (IMF, 2011). As such, the IMF suggests a new metrics to encompass various possible drains on reserves. This appears to perform well as a more broad-based measure against which to assess reserves levels. We discuss this measure in detail in Part 3.

2.5 Theoretical and Empirical Literature

As Park and Estrada (2009) observe, theoretical and empirical literature exploring reserve adequacy more rigorously was very limited until very recently. However, there has been increased motivation for theoretical and empirical research on optimal reserves with the surge in reserves in emerging countries, particularly in Asia.

Many researchers have focused on constructing theoretical models, which can be used to analyse the reserve demand and adequacy under different circumstances. For example, Özdemir (2004), Jeanne and Rancière (2006), Barnichon (2008), Drummond and Dhasmana (2008), Li, Sula and Willett (2008), Dehesa, Pineda and Samuel (2009), Tereanu (2010), among others have developed theoretical models to assess the optimal level of reserves under different conditions and parameters affecting the reserve endowment. To that end, these theoretical underpinnings incorporate macroeconomic factors, such as monetarism, as well as microeconomic central bank optimizing behaviour (Bahmani-Oskooee and Brown, 2002).

At the same time, a number of empirical studies discuss demand and adequacy of international reserves. The empirical literature can be divided into two distinct periods, *i.e.,* pre-1973 literature when most countries participated in the Bretton-Woods Agreement of fixed exchange rates and post-1973 which coincided with the newly instituted floating-rate system (Bahmani-Oskooee and Brown, 2002). The empirical interest is significant and useful during this floating-rate system and we discuss some empirical attempts in the context of our study.

For example, Aizenman and Marion (2003) measure reserve demand in a broad cross-section of countries, compare predicted to observed reserves outside the sample period and then find evidence for excess reserve accumulation. Also, Edison (2003) estimates a demand model using panel data for 122 emerging countries for the period 1980–1996 and finds that while actual reserves were broadly in line with forecasts during 1997–2001, actual reserves exceeded forecasts after 2001. Meanwhile, Aizenman, Lee and Rhee (2004) characterise the precautionary demand and show that the crisis led to structural change in the hoarding of international reserves in Korea. Mendoza (2004) investigates a possible self-insurance motivation behind increased reserve-holding in the developing world after the Asian financial crisis and proves that several countries accumulate reserves with the self-insuring motive. Gosselin and Parent (2005) estimate a long-run reserve-demand function for a panel of eight Asian emerging-market economies, find evidence for a positive structural break in the demand for reserves in the aftermath of the financial crisis of 1997-98, and indicate that the actual level of reserves was in excess relative to that predicted by the model. Using panel data from 21 African countries, Elhiraika and Ndikumana (2007) show that reserve accumulation cannot be justified by portfolio choice motives or stabilization objectives. Moreover, Marta and Zavadjil (2008) empirically suggest that reserves are not too high in the majority of Asian countries, though China may be a special case and conclude that much of the reserve increase in Asia can be explained by an optimal insurance model under which reserves provide a steady source of liquidity to cushion the impact of a sudden stop in capital inflows on output and consumption. Sehgal and Sharma (2008) analyse the demand function of India's reserve holdings and find evidence for both precautionary as well as mercantile motive behind holding excess reserves. Park and Estrada (2009) re-estimate the same model of Edison (2003) using panel data for 130 emerging economies from 1980 to 2004. The coefficients of their model have the expected signs and hence, estimation results are broadly similar with those of Edison.

PART 3: DEMAND FOR AND ADEQUACY OF INTERNATIONAL RESERVES IN SRI LANKA

In this section, we briefly discuss developments in international reserves in Sri Lanka and then develop a reserve demand model followed by an estimation of reserve adequacy based on the new risk-weighted metrics.

3.1 Trends in International Reserves in Sri Lanka

The Sri Lankan economy has experienced several external shocks since independence. Although the Sri Lankan economy benefitted from a few export booms (eg. during the Korean War in the 1950s), it was frequently affected by sharp downturns in exports, particularly during 1957–60 and 2008-2009 and the sharp increase in imports due to escalation of oil prices in 1973–74, 1981 and 2007–2008 (CBSL Annual Reports, 1998–2009). Such declines in terms of trade led to sharp contractions in gross official reserves (GOR)[9] to critical levels during several periods. The performance in the external sector during the last sixty years is illustrated in Table 2.

9 Gross official reserves (GOR), excluding the Asian Clearing Union (ACU) balances, have been considered throughout this paper.

Table 2

Selected External Sector Indicators by Decades (1951 - 2010)

Period Averages

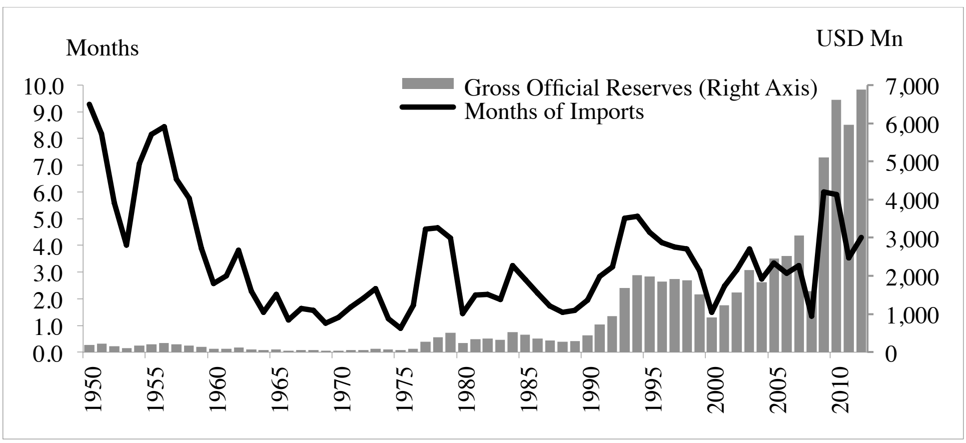
Indicator	1951 - 1960	1961 - 1970	1971 - 1980	1981 - 1990	1991 - 2000	2001 - 2010
Export Growth (%)	3.3	-0.9	13.0	7.4	11.1	3.3
Import Growth (%)	6.1	-0.5	20.6	3.0	10.8	5.2
Current Account Balance (% of GDP)	-1.0	-2.7	-3.4	-6.6	-0.5	-3.2
Debt Service Ratio (% of earnings from exports of goods and services)	1.7	4.7	19.2	21.4	15.5	13.2
Exchange Rate (US dollar/LKR)	4.8	5.0	8.6	25.8	52.3	99.7
Gross Official Reserves (USD Mn)	170	65	186	366	1,544	2,812
Months of Imports (Same Year's Imports)	6.0	1.9	2.5	2.1	3.7	3.5

Sources: CBSL, IFS

Figure 1 illustrates the historical movements of Sri Lanka's international reserves along with the primary benchmark of reserve adequacy, 'months of imports'.

Figure 1

Gross Official Reserves and Months of Imports (1950–2012)



In 1950, Sri Lanka's GOR stood at USD 191 million and reserve adequacy in terms of months of imports[10] stood at a relatively high level of 9.3 months. Reserves which remained around this level started to deteriorate in the late 1950s due to increased import expenditure. By the mid-1970s, reserves declined gradually to below the USD 50 million level mainly due to the high import growth. As a result, reserve adequacy declined to the lowest level of 0.9 months in 1975. However, with the introduction of economic reforms in 1977 and the relaxation of exchange control regulations pertaining to current account transactions, the reserve position of the country improved considerably over time.

Supported by workers' remittances and private capital inflows, the GOR has increased gradually over the decades, despite the sharp declines in the years 2000 and 2008. In 2000, the higher crude oil prices and increased generation of thermal power caused the import bill to rise significantly, driving the reserves below USD 1 billion. Foreign exchange reserves of Sri Lanka were severely affected during the global financial crisis in 2007-08. CBSL intervened in the foreign exchange market in the presence of mounting pressures on the exchange rate due to withdrawal of short-term investments by foreign investors, the setback in exports, decline in foreign remittances and drying up of capital inflows and the settlement of large oil import bills (CBSL Annual Reports, 2007–2008). As a result, reserves of the country declined from USD 3.1 billion recorded at end 2007 to USD 1.6 billion by end 2008, with corresponding months of imports declining from 3.3 months to 1.4 months by end 2008.

Figures A1.1 – A1.4 in Appendix 1 show the historical movements (1970 – 2012) of conventional reserve adequacy measures along with the respective adequacy benchmarks explained under section 2.4. Based on these graphs, it is broadly observed that, except for 'reserves to short term external debt and liabilities', Sri Lanka's international reserve position has remained at adequate levels other than in a few instances when the country was affected by external shocks. In order to arrive at firm conclusions we require a comprehensive analysis and we provide a detailed discussion in Section 3.3 based on the most recent developments.

3.2 Developing a Foreign Reserves Demand Model for Sri Lanka

The most common method for estimating the reserve demand in a country is to estimate the best fitting econometric model incorporating the most relevant variables influencing reserves, based on historical data. Such a long-run reserve demand equation could be

10 Based on GOR and imports of merchandise goods (same year).

used to highlight the country's major motives for holding reserves as well as for estimating the required level of reserves in the future, for a given set of explanatory variables. However, a model developed accordingly is unlikely to give accurate analysis in comparing reserve adequacy of peer countries, as the model will only capture the inherent issues relative to reserves of that particular country, over time.

3.2.1 The Model

In order to develop the model for reserve demand, we need to identify the most appropriate determinants of international reserves. To identify the most representative set of explanatory variables capturing the key categories of determinants in establishing a long-run demand function for reserves, we reviewed prior empirical studies and broadly followed the approach of Aizenman and Lee (2007), Park and Estrada (2009), Edison (2003) and Prabheesh, Malathy and Madhumati (2007). Such determinants are summarised in Table 3.

Table 3

Empirical Determinants of Reserve Holdings

Determinant	**Explanatory Variable**
Economic Size	– Population – Per Capita GDP
Current Account Vulnerability	– Imports – Trade Openness – Ratio of Current Account to GDP
Capital Account Vulnerability	– Ratio of Capital & Financial Account to GDP – Short-term External Debt and Liabilities – Broad Money
Exchange Rate Flexibility	– Standard Deviation (Volatility) of Exchange Rate
Opportunity Cost	– Interest Rate Differential

It is expected that reserve holdings will rise with respect to economic size. Hence, population and GDP per capita will have a positive impact on reserves. Similarly, a high ratio of import to GDP and trade openness lead to high current account vulnerability and this may in turn induce high reserve demand. In other words, larger external shocks and thus high current account vulnerability raises the demand for reserves. Also, a high ratio of short-term debt to GDP and high broad money to GDP could be associated with higher capital account vulnerability and this may lead to a rise in reserve holdings. Greater exchange rate flexibility would reduce the demand for reserves as central banks would no longer need to hold a large stock of reserves to manage the exchange rate. Similarly, a higher opportunity cost is expected to lead to a reduction in reserve holdings because alternative investments become comparatively attractive.

Although the best representative model would contain the 10 variables shown in Table 3, due to data limitations and the possibility of loss of degrees of freedom due to a higher number of variables with relatively fewer number of observations, we are constrained in using all 10 variables in the model. Based on preliminary investigations with regard to data properties and their significance to the model, we selected only 6 explanatory variables to be included in our model to reflect vulnerabilities in the current and capital accounts, exchange rate volatility and the opportunity cost.

Therefore, the reserve demand function for Sri Lanka proposed in our study is specified as:

$$GOR = \beta_0 + \beta_1 IMP + \beta_2 OPEN + \beta_3 STD + \beta_4 MS + \beta_5 XVOL + \beta_6 OPCOST + \varepsilon \qquad (1)$$

Table 4 provides details of the variables and descriptive statistics. Figure A2.1 in Appendix 2 depicts the movements of the variables concerned.

The data used for this study is the quarterly data ranging over Q1-1996 to Q2-2012, extracted from various publications and databases of CBSL and the databases of IMF. The variables GOR, IMP, STD and MS are expressed in millions of US dollars, while OPEN and OPCOST are percentages. XVOL is the standard deviation of the exchange rate series, derived using GARCH (1,1). In the analysis, natural logarithms of the variables GOR, IMP, STD, and MS are used while XVOL and OPCOST are expressed in percentage.

3.2.2 Methodology

The majority of prior studies estimate reserve demand functions using the ordinary least squares (OLS) method. However, since many of the relevant variables (for example, reserves, imports, *etc*.) are likely to be non-stationary, the results of OLS estimates would be inappropriate and at worst spurious. The contributions of Engle and Granger (1987) and Johansen (1988) have provided an opportunity to derive statistically appropriate estimates based on the analyses of cointegrating relationships between non-stationary variables, (*i.e.,* if the variables are found to be non-stationary, then the long-run relationship can be appropriately examined through cointegration tests). To that end,

Table 4

Description of Variables and Descriptive Statistics

Indicator	Variable Name	Description	Descriptive Statistics								
			Mean	Median	Max.	Min.	Std. Dev.	Skew-ness	Kur-tosis	Jarque-Bera	Proba-bility
Reserves	GOR	Gross official reserves : Reserve holdings of the CBSL and the Government (excluding ACU balances)	2,681	1,919	7,451	906	1,746	1.5	4.0	26.3	0.0
Imports	IMP	Current year imports of merchandise goods	2,372	1,930	5,619	1,262	1,102	1.3	4.1	22.1	0.0
Openness	OPEN	Trade Openness (imports + exports) as a percentage of GDP	60.1	60.8	78.3	39.1	9.5	-0.3	2.7	1.1	0.6
Short-term External Debt & Liabilities	STD	Short-term external debt and liabilities (including medium to long-term debt maturing within a year and trade credits)	3,469	2,134	10,429	1,721	2,208	1.5	4.3	27.8	0.0
Broad Money	MS	Broad money as measured by M_2	8,377	6,225	19,250	4,287	4,495	1.1	2.9	12.1	0.0
Exchange Rate Volatility	XVOL	Standard deviation of the LKR/US Dollar monthly average exchange rate	5.0	3.7	26.0	0.2	5.1	2.3	8.5	138.4	0.0
Opportunity Cost	OP COST	Interest differential of 91-day treasury bill rate minus the US Fed. Rate	8.6	7.3	16.7	4.4	3.3	0.9	2.6	8.8	0.0

studies of reserve demand rely on Error Correction Models (ECM) and cointegration analysis to provide best estimates. As such, following the prior empirical work in this area, for example, Badinger (2004), Gosselin and Parent (2005) and Prabheesh *et al.* (2007), among others, we adopt the error correction model and cointegration analysis in this study. We start with the unit root tests and then proceed to estimate Eq. (1) using the cointegration techniques.

3.2.3 Empirical Results

As explained above, prior to performing cointegration analysis, it must be first controlled for statistical requirements for the existence of a cointegration relationship. To achieve this, Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests are performed on all variables to find the existence of a unit root. If the variables are found to be non-stationary, then the long-run relationship can be appropriately examined through cointegration tests. Table 5 gives the results of the ADF and PP tests.

Table 5

Unit Root Test Results

Variable	Indicator	ADF		PP	
		Level	1st Diff	Level	1st Diff
LNGOR	Statistic	-0.4339	-6.7498	-1.5492	-6.0462
	P-Value	0.8963	0.0000	0.8739	0.0000
LNIMP	Statistic	0.1908	-4.7378	-0.5743	-8.2202
	P-Value	0.9698	0.0003	0.8685	0.0000
LNOPEN	Statistic	-1.2748	-3.9588	-2.8777	-19.9770
	P-Value	0.6358	0.0030	0.3430	0.0000
LNSTD	Statistic	1.8497	-9.3826	2.1628	-9.3975
	P-Value	0.9997	0.0000	0.9999	0.0000
LNMS	Statistic	1.6004	-5.7417	1.6396	-5.6738
	P-Value	0.9994	0.0000	0.9995	0.0000
XVOL	Statistic	-2.7466	-4.5300	-2.7466	-3.9820
	P-Value	0.2222	0.0030	0.2222	0.0027
OPCOST	Statistic	-3.1167	-4.9319	-2.5192	-4.8260
	P-Value	0.1113	0.0008	0.3182	0.0012

Note: Critical values are taken from MacKinnon, 1991

The ADF and PP test the null hypothesis of “non-stationarity” (i.e. the series has a unit root) against the alternative of “stationarity”. At levels, the test statistics of both ADF and PP for all seven variables (GOR, IMP, MS, OPEN and STD are in logs) are not significant at the 5% level, and hence the null hypothesis of existence of a unit root cannot be rejected. This indicates that all the data series are non-stationary. However, at differences, both tests indicate that all variables are significant at the 5% significance level. From the results of the ADF and PP above, it can be seen that all variables are non-stationary and therefore, Johansen’s Maximum Likelihood (ML) test can be performed to examine the existence of any cointegrating relationship between the variables. In performing the Johansen’s ML cointegration test on the seven variables, first, the unrestricted VAR is estimated to find the lag length, for which the Akaike Information Criteria (AIC) and the Schwaz Information Criteria (SIC) are used. Both AIC and SIC are minimised at level 2 and therefore lag 2 is selected as the optimal lag length. The summary of cointegration tests is reported in Table 6.

Table 6

Cointegration Test Results

Null Hypothesis	λ-Trace	λ-Trace 5% CV	λ-Max	λ-Max 5% CV
$r = 0$	88.66	69.81	42.23	33.87
$r \leq 1$	46.42	47.85	28.31	29.58

The test results show that both test statistics, Trace test (λ-Trace) and Maximum Eigen Value (λ-Max), reject the null hypothesis at r=0, but not at r=1 at the 5% level of significance. This indicates that there exists one cointegrating vector between the variables. Therefore, an error correction model was specified and resultant normalized cointegrating coefficients (with respect to GOR) are presented in Table 7.[11]

11 Following Aizenman and Lee (2007), a crisis dummy was introduced for the quarters Q4-2000 to Q3-2001 and Q3-2008 to Q2-2009 when the country’s external sector was affected and reserves slumped due to the global economic downturn in 2001 and the global financial crisis in 2008, respectively. However, it was found that the crisis dummy was not significant at the 5% level, and therefore the crisis dummy was excluded in deriving the model.

Table 7

Normalised Cointegrating Coefficients

	LNGOR	LNIMP	LNOPEN	LNSTD	LNMS	XVOL	OPCOST
β Coefficient	1.0000	25.7922	-12.2335	-4.4365	-18.8787	-0.0546	-0.0763
Standard Errors		4.8196	5.4845	2.2236	5.4783	0.0705	-0.0705
T-Statistic		5.3515*	-2.2306*	-1.9952*	-3.4461*	-0.7748	-1.0831

** Significant at 5% level*

The t-statistics of each variable in the normalised equation (Table 7) show that, imports (LNIMP), trade openness (LNOPEN), short term debt and liabilities (LNSTD) and money supply (LNMS) are significant at the 5% level, whereas exchange rate volatility (XVOL) and opportunity cost of holding reserves (OPCOST) are not. Meanwhile, the normalised equation shows that the expected signs of the variables in influencing demand for reserves hold true for all variables except for imports (LNIMP), exchange rate volatility (XVOL) and opportunity cost of holding reserves (OPCOST). Since the two variables, XVOL and OPCOST are anyway not significant at the 5% level, these two variables should be dropped from the reserve demand equation.

Table 8

Error Correction Model

	D(LNGOR)	D(LNIMP)	D(LNOPEN)	D(LNSTD)	D(LNMS)	D(XVOL)	D(OPCOST)
α Coefficient	-0.1217	-0.0341	-0.0160	0.0005	-0.0008	-0.3692	0.2885
Standard Errors	0.0219	0.0120	0.0123	0.0081	0.0036	0.2742	0.1553
T-Statistic	-5.5442*	-2.8318*	-1.2983	0.0634	-0.2263	-1.3469	1.8567

** Significant at 5% level*

In the ECM (Table 8), we see the coefficient of the Error Correction Term (ECT) of D(LNGOR) (-0.1217), which indicates the speed of adjustment to the long-run equilibrium is significant. However, this implies a rather slow adjustment to equilibrium

(Badinger, 2004) and only 12% of the deviation from equilibrium is eliminated within one quarter, taking around 2 years to reach long-term equilibrium. Hence, the model indicates a slower response from the authorities when the reserves deviate from the desired level. We further observe that trade openness (LNOPEN), short-term debt and liabilities (LNSTD) and broad money (LNMS) are weakly exogenous to the model.

Since the model indicated that exchange rate volatility is not significant to the reserve demand function, it is important to verify whether it holds true in practice as well. Sri Lanka's exchange rate policy till 2011 was mainly focused on maintaining stability in the domestic foreign exchange market and avoiding undue volatility in the exchange rate. In the presence of excessive foreign inflows to the country, the CBSL has been active in absorbing foreign exchange from the market to prevent undue appreciation in the exchange rate while supporting to maintain export competitiveness. Similarly, during the recent global financial crisis, in the presence of sudden outflows of short-term investments, the CBSL opted to utilise its reserves to avoid undue depreciation in the exchange rate. Therefore, these could be the reasons for the non-significance of 'exchange rate volatility (XVOL)' to the model. Further, this observation does not contradict prior literature on other countries. For example, Aizenman and Lee (2007) show exchange rate volatility could be insignificant across models. In particular, they observe some significance only when the Asia-specific crisis dummy is used in their models for 53 countries. Cheung and Qian (2009) also highlight that although international reserve holding is found to be negatively affected by exchange rate volatility, the impact of exchange rate volatility could be zero.

The variable 'opportunity cost (OPCOST)' being not significant to the model implies that Sri Lanka's accumulation of foreign reserves is less sensitive to the opportunity cost of holding reserves.

The change in expected sign in imports (LNIMP) in the model could be due to the fact that although theoretically we should hold a higher level of reserves when imports tend to be high, actual circumstances have led reserves to decline due to the utilisation of reserves to finance the increasing import bill, contradicting the precautionary motive for holding reserves. In fact the negative coefficient for imports is not surprising when we consider prior empirical literature. For example, in a survey article, Bahmani-Oskooee and Brown (2002) argue that imports report mixed signs across empirical literature of reserve demand. In particular, although a positive coefficient is generally expected, negative coefficients have been observed for the variables that capture the impact of imports, for example in Huang (1995), Badinger (2004), Sehgal and Shrama (2008) among others. Specifically, based on the evidence for China, Huang

(1995) shows that although most of the country's foreign exchange is counted as reserves, it will flow in the opposite direction to imports. Hence Huang argues that imports no longer reflect indirect transactional requirements for reserves, and instead, they reflect the opposite flows of goods and money in and out of the country. He further argues there is a concern that while imports affect reserves, reserves could also affect imports.

Therefore, the resultant long-run model for reserves demand for Sri Lanka can be specified as follows:

$$Ln(GOR) = -48.8 - 25.8Ln(IMP) + 12.2Ln(OPEN) + 4.4Ln(STD) + 18.9Ln(MS) \quad (2)$$

According to this equation it can be seen that a 1% increase in imports will lead the reserves to decline by 25.8%, while a 1% increase in each of the variables, trade openness (OPEN), short-term debt and liabilities (STD) and broad money (MS) will increase reserves by 12.2%, 4.4% and 18.9%, respectively.

Using the estimated reserves demand model, the required level of reserves in the future for an appropriate set of explanatory variables can be forecasted. The reserves estimated accordingly for the third and fourth quarters of 2012 are given in Table 9.

Table 9

Actual Reserves Vs. Estimated Reserves Demand as per the Model

Period	Actual GOR (USD Mn)	GOR Estimated as per Model (USD Mn)	Excess Reserves (USD Mn)
Q3 - 2012	7,054	7,827	-733
Q4 - 2012	6,877	5,933	944

It can be seen that actual reserves held by Sri Lanka in the third quarter is short by USD 733 million while in the fourth quarter it is in excess by USD 944 million from the reserves estimated by the model.

3.3 Assessing International Reserve Adequacy in Sri Lanka: *The IMF's New Risk-Weighted Metrics*

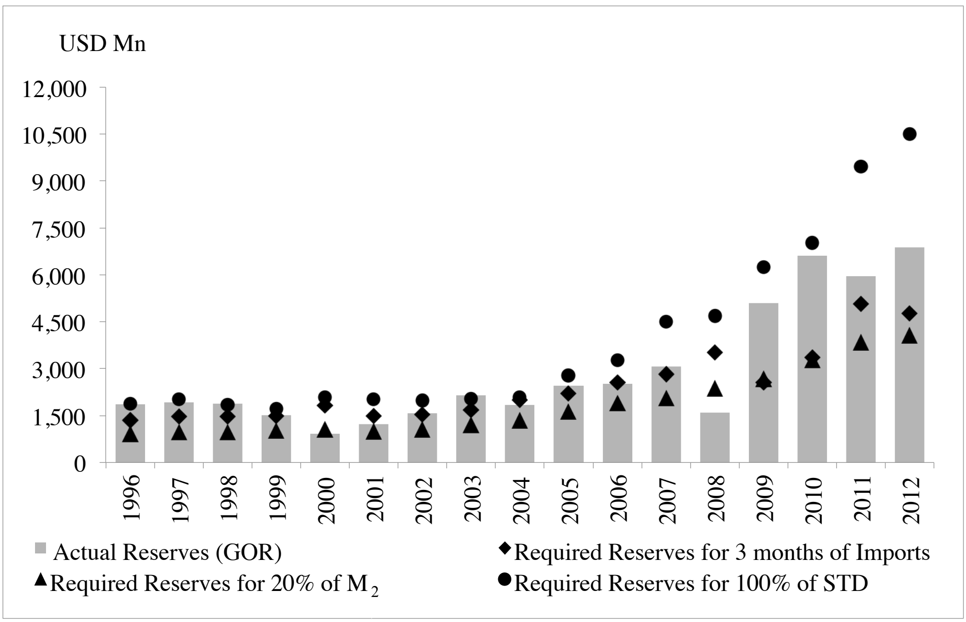
3.3.1 Features and Drawbacks in Conventional Metrics

To assess reserves adequacy for comparison purposes, we first use the conventional metrics based on simple rules of thumb such as 3-months of imports, 100% coverage of short-term debt and liabilities (STD) and 20% of broad money (M_2). Although these benchmarks are internationally accepted standards, they focus only on specific aspects of external vulnerability. Therefore these conventional metrics are often used individually or in combination, such as the highest of: 3-months of imports; 100% of STD; 20% of M_2.

Figure 2 depicts the actual GOR of Sri Lanka against the required (or adequate) level of reserves as per conventional international standards, *i.e.,* 3-months of imports and 100% coverage of STD and 20% of M_2, over the past 15 years.

Figure 2

Actual Reserves (GOR) Vs. Required Level of Reserves as per the Conventional Metrics



It is observed that reserves have increased gradually over the years, except in the years 2000, 2008 and 2011. In 2000 and 2008, reserves slumped when Sri Lanka's external sector was adversely affected by the two episodes of the global economic downturn in the respective years, and actual reserves in those two years were inadequate in terms of all three conventional metrics. In 2011, although the reserves were utilized to ease market pressure for foreign exchange in the presence of a widening trade deficit on account of an increased oil import bill, (CBSL Annual Report, 2011), we observe that the reserves were within the levels required, at least by two of the three benchmarks.

In general, Sri Lanka has maintained reserves in excess of 3-months of imports over the past years, except in the years 2000, 2001, 2004 and 2008. With respect to the broad money benchmark of 20% of M_2, reserves have broadly remained above the required level except in the two exceptional years, 2000 and 2008. However, with respect to adequacy in terms of STD, reserves have always remained lower than the standard benchmark of 100% of STD. This gap has widened in recent years. This could mainly be due to the opening up of the Treasury bond and bill market to foreign investors in 2006 and 2008, respectively. The reserve adequacy in terms of 100% STD has reached the highest level of USD 10.5 billion in 2012 from the previous record level of USD 9.5 billion in 2011. By end 2011, Treasury bonds with tenors of 1–20 years accounted for around 70% (USD 1.7 billion) of the total foreign holdings of treasury securities. This could be one of the reasons for the higher outstanding value of STD, apart from the USD 500 million sovereign bond which was due for settlement in October 2012. Considering the long term maturity aspect of Treasury bonds, if we exclude it from the outstanding STD at end 2011, the reserves requirement of 100% of STD would only be equivalent to around USD 7.8 billion (as opposed to the USD 9.5 billion in Figure 2). Similarly, by end 2012, outstanding Treasury bonds with 1-20 year tenors amounted to USD 2.5 billion (80% of the Treasury securities portfolio), and STD excluding such bonds amounted to USD 8.0 billion (contrary to USD 10.5 billion in Figure 2).

In this context, it is worth considering whether conventional metrics should be used in entirety, or any judgmental factors could as well be incorporated in deciding the adequate level of reserves to be held by a country. This could be one of the reasons for countries to move away from following the conventional metrics in their reserve holding decisions, and instead, use more broad-based risk weighted metrics.

3.3.2 New Risk-Weighted Reserve Adequacy Metrics Proposed by the IMF

The above mentioned drawbacks of conventional metrics were addressed by the IMF in developing a more broad-based risk-weighted metrics for assessing reserve adequacy

(IMF, 2011). Although this metrics is still being reviewed and is subject to academic discussion, it has been recommended as a more representative and broad-based measure of assessing reserve adequacy.

The scope of the new metrics developed by IMF has entirely been focused on the precautionary aspect of holding reserves. This reflects the key distinguishing characteristic of reserves, namely, their availability and liquidity, for potential balance of payments needs. Metric-based approaches focus on adequacy in the face of potential balance of payments pressures, but they specify that judgment is required on the intensity of potential shocks the country would face and the resulting level of reserves that should be maintained. IMF (2011) specifies that although the judgment necessarily involves an arbitrary element based on past experience, this approach also has the advantage of simplicity, tractability and transparency. In the IMF (2011), two approaches have been produced to assess reserve adequacy for emerging countries (EMs) and low-income countries (LICs) separately. To assess the reserve adequacy of Sri Lanka, we use the metrics developed for EMs.

The IMF's new proposal for developing a reserve adequacy metrics for EMs is based on a two-stage 'risk-weighted' approach as discussed below.

Stage 1: Identifying Risk Factors and Assigning Weights

In the first stage, the metrics is developed based on observed foreign exchange outflows during periods of exchange market pressures (EMP)[12]. The IMF (2011) cites that studies of individual crisis episodes show balance of payments pressure from a range of potential sources of risks, emanating from both financial and current account variables. They have identified four specific sources of such drains, namely, export earnings (X), short-term debt (STD), other portfolio liabilities (OPL) and broad money (M_2).

In the event of a drop in external demand, there will be a loss of earnings expected from exports (X). Although imports expenditure is the most commonly used current account variable, it is not directly affected by a downfall of external demand, and, as imports usually depend on available financing, during crisis periods, imports tend to fall, supporting the balance of payments to some extent. Therefore, exports as an indicator is more responsive to external shocks than imports. Short-term debt (STD) and

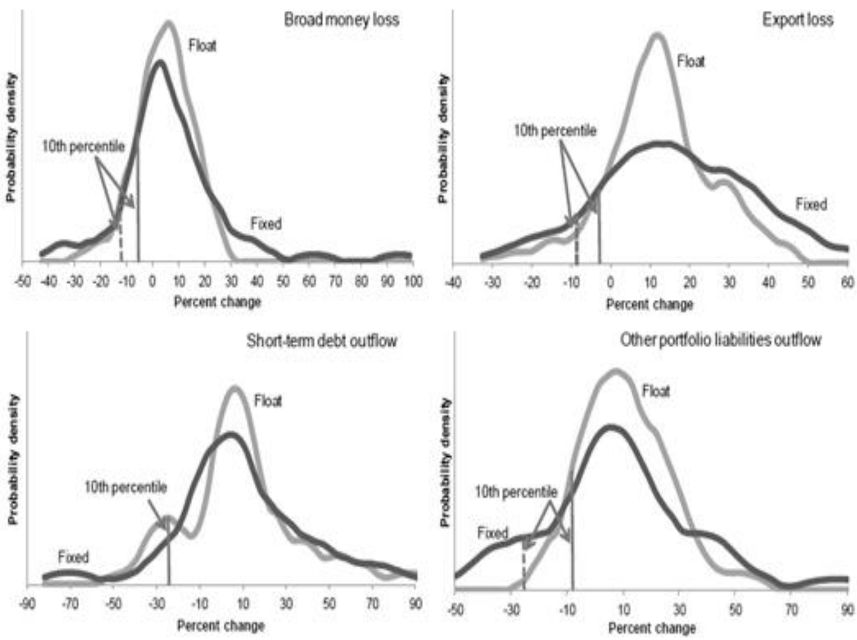
12 EMP measures the total excess demand for a currency in international markets as the exchange rate change that would have been required to remove this excess demand in the absence of exchange market intervention, given the expectations generated by the exchange rate policy actually implemented (Weymark, 1995).

other portfolio liabilities (OPL) are both indicators of external liabilities and account for additional observed drains. In a crisis situation, short-term debt as well as equity is more prone to be withdrawn fast. This may ultimately lead not only to a depreciation of the exchange rate, but equity prices too may fall. To capture capital flight risk, broad money as measured by M_2 has been used to represent the stock of liquid domestic assets that could be sold and transferred into foreign assets during a crisis, (IMF, 2011).

In deriving the risk weights, the IMF has selected a sample of 48 countries covered in the IMF's 'Vulnerability Exercise' for EMs over the period of 1990–2009, (Assessing Reserve Adequacy - Supplementary Information, IMF, 2011). The risk weights have been based primarily on tail event outflows associated with periods of EMP. The potential loss of foreign exchange during such periods has been computed as annual percentage losses of the above identified sources of drains, namely, X, STD, OPL and M_2. Such probability distributions are presented in Figure 3.

Figure 3

Risk-Weights against Different Potential Foreign Exchange Drains



Source: Extracted from IMF (2011)

The proposed approach has focused on drains observed at the 10th percentile of each of the distributions (Figure 3). The 10th percentile has been chosen as a reasonable balance between data limitations and the need to test reasonably severe shocks (IMF, 2011). Such probability distributions have been estimated separately for fixed and floating exchange rate regimes and two sets of weights have been derived for the two exchange rate regimes. For example, in "other portfolio liabilities outflows" (panel 4 of Figure 3), the probability at 10th percentile for the fixed exchange rate regime gives a percentage change of a drain of around 28%. This broadly means that 28% of "other portfolio liabilities outflows" are needed to insure against 90% of the risk during an EMP episode. Estimated risk weights derived accordingly for each exchange rate regime by IMF are given in Table 10.

Table 10

10th Percentile Outflows during Exchange Market Pressure Events

	Exports (X)	Broad Money (M_2)	Short-term Debt (STD)	Other Portfolio Liabilities (OPL)
Fixed	8.9	12.4	24.4	27.6
Floating	2.3	7.1	24.4	9.2

Source: IMF Staff calculations

With further adjustments based on scenario analysis and judgmental factors, the following weights have been proposed by the IMF for the fixed and floating exchange rate regimes. Accordingly, the required levels of reserves under the risk-weighted metrics (R-Requirement) for respective exchange rate regimes are defined as:

$$\text{R-Requirement}_{\text{(Fixed)}} = 10\% \text{ of } X + 10\% \text{ of } M_2 + 30\% \text{ of STD} + 15\% \text{ of OPL} \qquad (3)$$

$$\text{R-Requirement}_{\text{(Floating)}} = 5\% \text{ of } X + 5\% \text{ of } M_2 + 30\% \text{ of STD} + 10\% \text{ of OPL} \qquad (4)$$

It could be seen that R-Requirement for fixed exchange rate regime (Eq. 3) carries higher weights relative to that of the floating exchange rate regime (Eq. 4). This is mainly due to the need of maintaining additional reserves to defend the fixed exchange rate during a crisis.

Stage 2: Determining the Level of Adequacy

The second stage of the IMF's approach is to determine the reserve coverage or reserve adequacy ratio which is the actual level of GOR a particular country should hold relative to the risk-weighted metrics. Therefore, the reserve adequacy ratios (R-Adequacy Ratios) for respective exchange rate regimes are given by:

$$\text{R-Adequacy Ratio}_{(\text{Fixed})} = \{ \text{GOR} / \text{R-Requirement}_{(\text{Fixed})} \} *100 \quad (5)$$

$$\text{R-Adequacy Ratio}_{(\text{Floating})} = \{ \text{GOR} / \text{R-Requirement}_{(\text{Floating})} \} *100 \quad (6)$$

In deciding a benchmark for reserve adequacy ratio, the IMF has studied past crisis episodes and used three approaches to help inform this judgment, focusing on crisis prevention, crisis mitigation, and observed reserve losses, and derived an adequate level of reserves to be held by a country. The IMF (2011) states that their results highlight the necessity of a high degree of judgment but taken together suggest a coverage in the region of 100%−150% of the metrics that might be regarded as adequate for a typical country. This means that if the reserve adequacy ratio is in the range of 100%–150%, we could be satisfied that country's reserves are adequate to avoid or mitigate the adverse implications of an external shock. However, IMF (2011) also states that even if 100%−150% of reserves is accepted as an adequate range, it would not preclude countries from wanting to hold more or less than this, depending on their particular circumstances and degree of risk aversion.

The proposed reserves adequacy metrics is still in the developing stage, providing guidance only at the most general level and the IMF recommends that it best be regarded as a potential advance on existing metrics. Therefore, the IMF suggests that additional experience and analysis can yet be brought to bear both on what weights should be put on different sources of risk and also on how much of the resulting metrics is reasonable to hold and particularly considerable judgment would be required in application of this metrics to individual countries. The IMF has highlighted a few examples:

i. If foreign STD is primarily held by foreign parents, then the weight on STD may be reduced, while a higher weight should be assigned if STD is mainly raised from international capital markets. Similarly a large share of trade credits within STD might imply less need for reserve cover mainly owing to their ability for being rolled over during the absence of a crisis. However, IMF, 2000, carries a contradictory view. Although in the early periods, trade credits have not been included in the STD, this paper has cited that the experience in the recent crisis episodes has underscored that during severe crises all short-term lending has been drastically curtailed, as banks and other investors have sought to limit their overall country exposure. A comprehensive concept of debt that includes trade credits is therefore most useful as a general measure.

ii. The weight on exports might need to be much higher for countries that export commodities, which are subject to wide price fluctuations.

iii. The weight on M_2 could be reduced (or even eliminated) where effective capital controls that would prevent capital flight are in place.

iv. Within the floating rate classification, a country that is willing or able to tolerate large fluctuations in the exchange rate might be comfortable holding a lower reserve coverage of the metrics, whereas a country that desires to avoid a significant depreciation might want to hold more.

3.3.3 Application of the IMF's Risk-Weighted Metrics to Assess Reserve Adequacy for Sri Lanka

For assessing reserve adequacy under the new metrics for Sri Lanka, risk weights computed by the IMF for EMs are directly applied in this study. It would be ideal to have derived a new set of country-specific risk weights, but, since that should be done by conducting out a comprehensive survey, and to our knowledge, this being the first attempt of research in this area for Sri Lanka, we have applied the same weights that IMF has researched and derived for emerging economies, to estimate reserve adequacy for Sri Lanka.

In assessing reserve adequacy for Sri Lanka based on new metrics, annual data for the period from 1996 to 2012 for export earnings (X), short-term debt and liabilities (STD), other portfolio liabilities (OPL) and broad money (M_2) were selected. The variable X captures earnings from exports of merchandise goods, while broad money as measured by M_2 is considered. In estimating the STD, in addition to Treasury bills and bonds and trade credits, all medium and long-term debt of the government and the private sector, that are maturing within a year, have also been added to the STD. OPL mainly includes the foreign equity holdings at the Colombo Stock Exchange.

In deriving the reserve adequacy ratio, first, the reserve requirement under the risk-weighted metrics for both exchange rate regimes are estimated using equations (3) and (4), and reserve adequacy ratio for both exchange rate regimes are then computed using equations (5) and (6). Table 11 presents the GOR, reserve requirement and reserve adequacy computed for Sri Lanka for each exchange rate regime for the period 1996–2012.

Table 11

Reserve Adequacy under each Exchange Rate System

Year	Gross Official Reserves (USD Mn)	Reserve Requirement (USD Mn)		Reserve Adequacy Ratio (%)	
		Fixed	Floating	Fixed	Floating
1996	1,855	1,476	1,028	125.7	180.5
1997	1,922	1,620	1,123	118.6	171.1
1998	1,892	1,564	1,065	121.0	177.6
1999	1,519	1,522	1,025	99.8	148.1
2000	912	1,729	1,180	52.7	77.2
2001	1,231	1,613	1,113	76.3	110.6
2002	1,565	1,629	1,117	96.1	140.1
2003	2,147	1,789	1,212	120.0	177.1
2004	1,834	1,962	1,308	93.5	140.2
2005	2,458	2,407	1,641	102.1	149.7
2006	2,526	2,795	1,917	90.4	131.7
2007	3,063	3,371	2,398	90.8	127.7
2008	1,594	3,542	2,497	45.0	63.9
2009	5,097	4,221	3,097	120.7	164.5
2010	6,610	5,186	3,744	127.5	176.6
2011	5,958	6,397	4,714	93.1	126.4
2012	6,877	6,867	5,125	100.2	134.2

Sources: CBSL and Estimates by Authors

In analysing the reserve adequacy as per the risk weighted metrics, the exchange rate regime of Sri Lanka should first be identified. Sri Lanka moved to an independent floating exchange rate regime in 2001 from the managed floating system that it had followed since economic liberalization in 1977. Although the country follows a de jure floating exchange rate regime since 2001, the IMF's-Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER) (1996–2012), which carries out in-depth analyses of the exchange rate systems of member countries, has classified

Sri Lanka as having followed a pegged or stabilised exchange rate system in certain years. Therefore, further analysis was carried out to ascertain how daily spot exchange rates have varied over the period under review of this study. A country in general is said to be following a pegged (or stabilised) exchange rate system, if the exchange rate fluctuates within a narrow margin of ± 1% around a central rate for at least six months. Table 12 presents the de facto exchange rate regime as classified by the IMF, and the classification as per our analysis based on the above definition.

Table 12

Classification of Exchange Rate Regime of Sri Lanka

Year	IMF - AREAER Classification	Classification based on Authors' Analysis *
1996	Managed floating	Floating
1997	Managed floating	Floating
1998	Managed floating	Floating
1999	Crawling band	Floating
2000	Crawling band	Floating
2001	Managed floating	Floating
2002	Managed floating	Floating
2003	Independent floating	Floating
2004	Independent floating	Floating
2005	Independent floating	Floating
2006	Managed floating	Floating
2007	Managed floating	Floating
2008	Conventional peg	Stabilised arrangement
2009	Floating	Floating
2010	Stabilised arrangement	Stabilised arrangement
2011	Crawl-like arrangement	Stabilised arrangement
2012	Floating	Floating

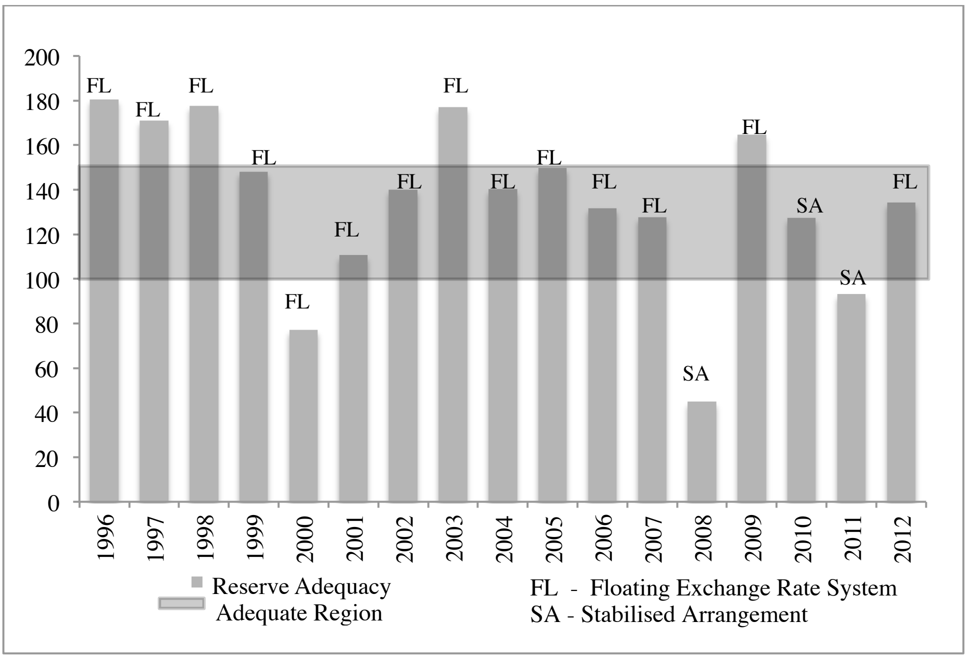
Sources: IMF - AREAER (1996–2012) and Authors' Analysis

* *If the exchange rate fluctuates within a margin of less than ±1% around a central rate for at least six months, then the regime is classified as "Pegged" (or Stabilised) and, if otherwise as "Floating".*

Based on the criteria specified, we notice that in the years, 2008, 2010 and 2011, the exchange rate of LKR/USD has moved within a narrow margin of ±1% around a central rate at least for six months, and therefore it is reasonable to conclude that during these three years Sri Lanka has not followed a floating exchange rate system. This is consistent with IMF's AREAER classification that Sri Lanka has followed a more stabilised exchange rate system during the said years. Therefore, from the reserve adequacy ratios that were estimated for both exchange rate systems (Table 11), we decided to select the respective ratios capturing the regimes that are based on the above findings (Table 12). Accordingly, reserve adequacy ratios applicable for fixed exchange rate regime (which is more rationally termed as stabilised arrangement) were selected for the years 2008, 2010 and 2011, while ratios for the floating exchange rate system were selected for the remaining years. Figure 4 depicts the reserve adequacy ratios selected accordingly, with labels "FL" for the Floating Exchange Rate Regime and "SA" for the Stabilised Arrangement to highlight the exchange rate system followed in that particular year.

Figure 4

Reserve Adequacy Ratios as per the New Risk-Weighted Metrics (with Respective Exchange Rate Systems)



As per the IMF (2011), reserves are said to be adequate if the reserve adequacy ratio is in the range of 100%-150%. From Figure 4, it can be seen that Sri Lanka has had adequate ratios above 100% throughout, except in the years 2000, 2008 and 2011. Lower ratios in years 2000 and 2008 were due to the decline in the country's reserves amidst the two respective episodes of global economic downturns. However, the lower ratio in 2011 was mainly due to the utilisation of reserves to ease the heavy foreign exchange demand in the domestic market emanated from the high volume of petroleum import bills due for settlement (CBSL Annual Report, 2011).

3.3.4 Comparison of Reserve Adequacy in terms of Conventional and New Risk-Weighted Metrics

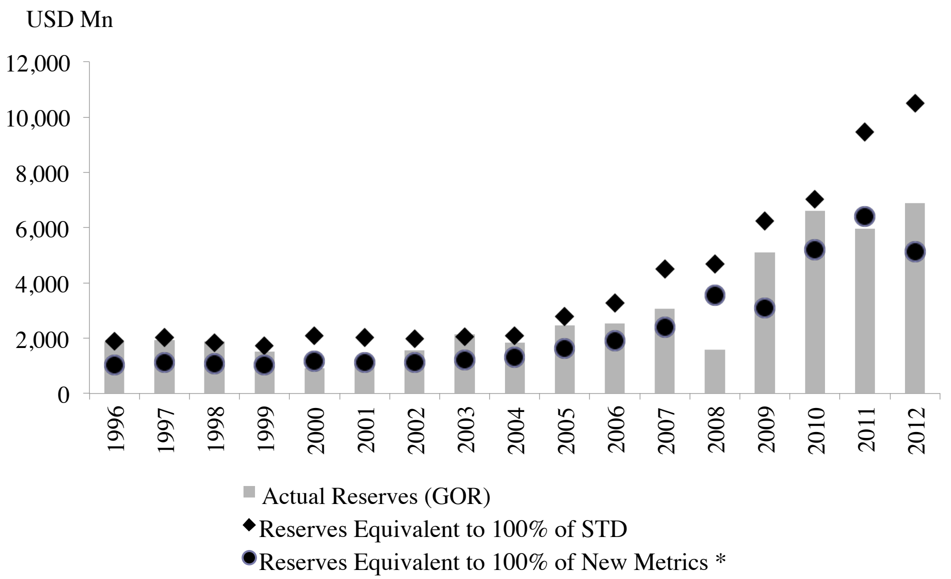
Finally, in order to assess Sri Lanka's reserve adequacy relative to conventional metrics and the new risk-weighted metrics, Figure 5 is constructed. Figure 5 shows actual GOR against: (i) Maximum reserves required as per the conventional metrics, *i.e.,* 100% of STD, and (ii) Reserves requirement equivalent to 100% of the new risk-weighted metrics[13].

From this figure, it can be well observed that even though actual reserves were low throughout, in comparison to the conventional measure of 100% of STD, in terms of the new metrics, actual reserves in Sri Lanka have been in excess of 100% of the new metrics except for the years 2000, 2008, and 2011. IMF (2011) also reveals that the new metrics is a better yardstick against which to measure reserves from a precautionary perspective than the conventional metrics – whether the latter are examined in isolation or together. Hence according to the new risk-weighted metrics, Sri Lanka has broadly held adequate levels of foreign exchange reserves throughout the reference period.

13 Following the findings of Section 3.3.3, new metrics values for the years 2008, 2010 and 2011, are for "Stabilised Arrangement" while values applicable for "Floating Rate Regime" are considered for the remaining years.

Figure 5

New Metrics Vs. Maximum of Conventional Metrics



* *Based on the analysis above, new metrics values are for floating exchange rate system for all years except for 2008, 2010 and 2011*

4. Conclusions and Policy Implications

International reserves are important financial resources for an economy as they have notable implications for the external and internal balance of an economy. At the same time, the quantity of reserve-holding can be simply interpreted as an indicator of economic strength. In this context, monetary authorities attempt to accumulate reserves mainly with a view of using them as a buffer in a crisis situation and strengthening the external sector through maintaining exchange rate stability. Similarly, the CBSL also pays increased attention on hoarding stocks of international reserves based on these key motives.

In this study, we have attempted to examine the reserve demand and adequacy in the Sri Lankan context. We find that in the period of investigation, Sri Lanka's long-run reserve policy appears to have been guided by import propensity, economic openness, short-term debt and liabilities and money supply. However, the reserve accumulation by the CBSL seems less sensitive to exchange rate volatility and the opportunity cost of holding reserves. In assessing reserve adequacy using the risk-weighted metrics developed by the IMF, we find that despite some variations during some turbulent periods, Sri Lanka has held adequate reserves and hence evidence for holding persistently excessive or inadequate levels of reserves is not found. Hence, the CBSL's focus on the reserve accumulation policy is justified.

However, caution should be exercised with regard to the reserve accumulation policy. While it is a sensible policy to accumulate reserves in order to withstand external stocks, it may be unwise to hoard reserves beyond a certain threshold. As excessive reserve accumulation leads to future consumption sacrifices, undue opportunity costs as well as monetary and quasi-fiscal costs, authorities may need to abstain from adopting a long-run *'excessive reserve accumulation'* policy. At the same time, as the growth promoting mercantilist's view to accumulate large amounts of foreign reserves has been largely contests, prolonged reserve accumulation, which is aimed at exchange rate stabilisation and export promotion, may not be prudent as such policies entail several domestic macroeconomic risks.

From our analysis we observed that the opportunity cost of holding reserves was not significant to the model, implying Sri Lanka's reserve accumulation is less sensitive to the interest rate differential. Further, based on the reserve demand model, we noticed that it takes around 2 years to reach long-term equilibrium, indicating a slower response from the authorities when there were deviations from the desired level of reserves. Therefore, it may be argued that further emphasis should be placed on following more prudent and active reserve management practices by maintaining reserves to minimise opportunity cost and maximise returns, while adopting measures to build-up reserves to the desired levels, in the aftermath of a shock.

On the other hand, considering reserve adequacy in terms of the conventional metrics of "reserves to short term debt and liabilities", the international norm is to include both Treasury bills and bonds. However, 80% of the portfolio of foreign holdings of Treasury securities accounting for Treasury bonds with tenors of 1-20 years drives up the required level of reserves unnecessarily. This issue is addressed in the new risk-weighted metrics, where short term debt and liabilities is assigned a reasonable weight of 30% only. Therefore, it is advisable that we move away from using conventional metrics and adopt newly developed broader-based risk-weighted metrics.

Finally, we understand that our study is subject to several caveats and hence further research in this area is warranted. In particular, our observations are confined and limited to a static sample. As a further step to this research, it would warrant considering changes in the determinants over time, given the dynamic changes in the economic and financial structure of the economy. At the same time, it would be useful to have a more rigorous framework in which to characterise additional factors affecting the reserve demand in Sri Lanka and also to incorporate the interactions between the financial system and the process of reserve accumulation. We leave such untouched areas for the future research discourse.

It should be noted that risk weights computed by the IMF have been used without any modification in our study and we are aware about the limitation of using such common weights for the Sri Lankan context. However, as the first research in this area for the Sri Lankan context, we attempted to directly apply the weights provided by the IMF for emerging countries to Sri Lanka and as an initial step, it helps us to benchmark the Sri Lankan context against the IMF standards. Given the importance of considering country specific factors, we intend to extend our research after conducting necessary surveys to obtain the required weights applicable to Sri Lanka.

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Appendix 1

Reserve Adequacy (Conventional Benchmarks)

Figure A1.1

Gross Official Reserves to Months of Imports

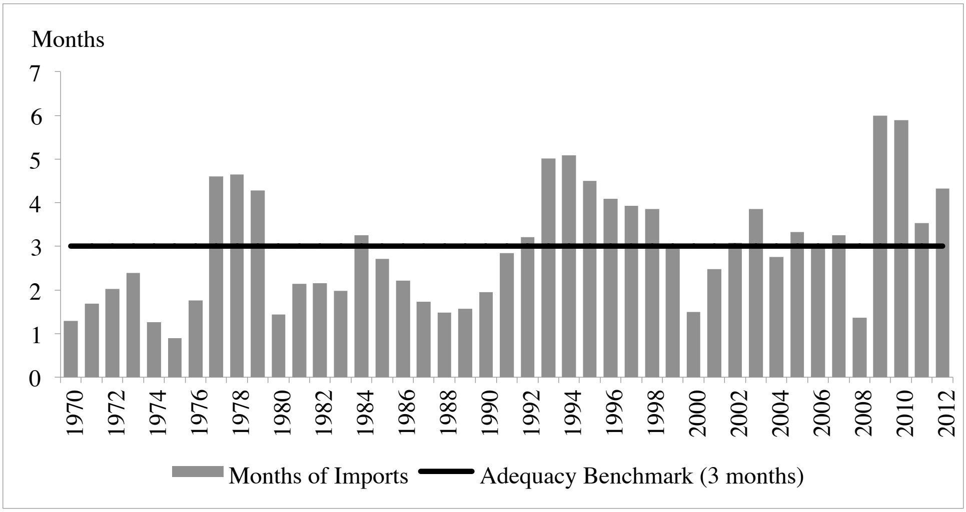


Figure A1.2

Gross Official Reserves to Short-term Debt and Liability

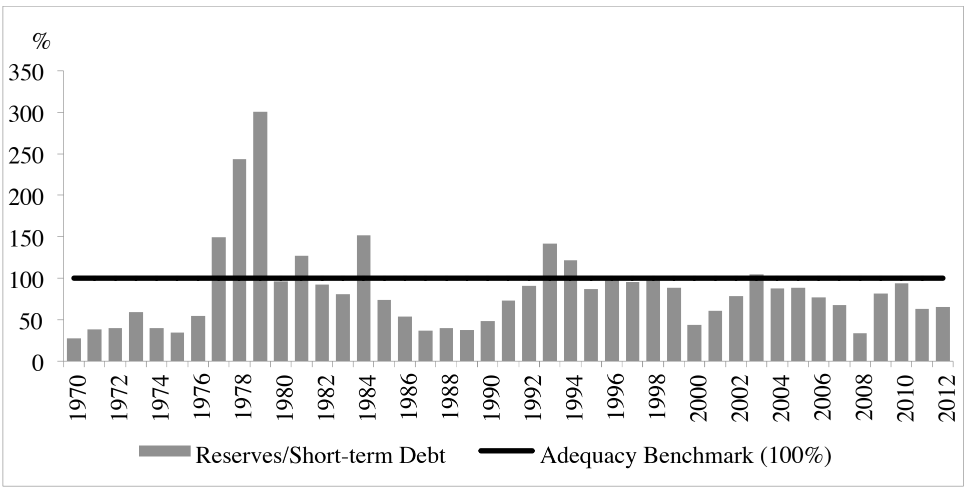


Figure A1.3

Gross Official Reserves to Broad Money

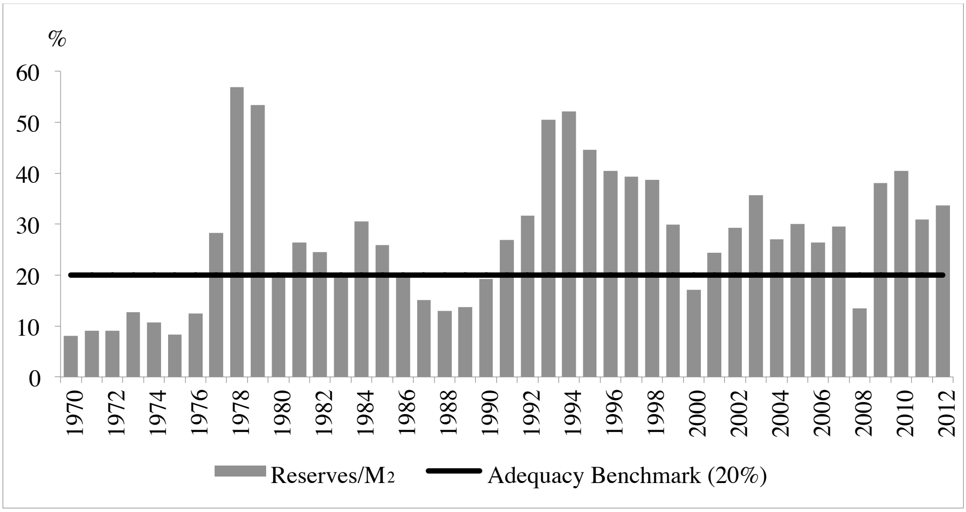
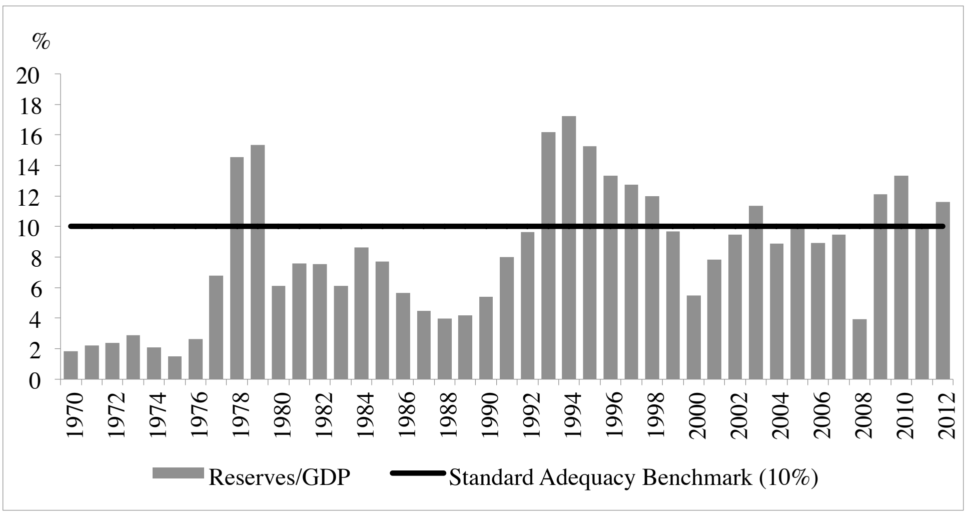


Figure A1.4

Gross Official Reserves to GDP

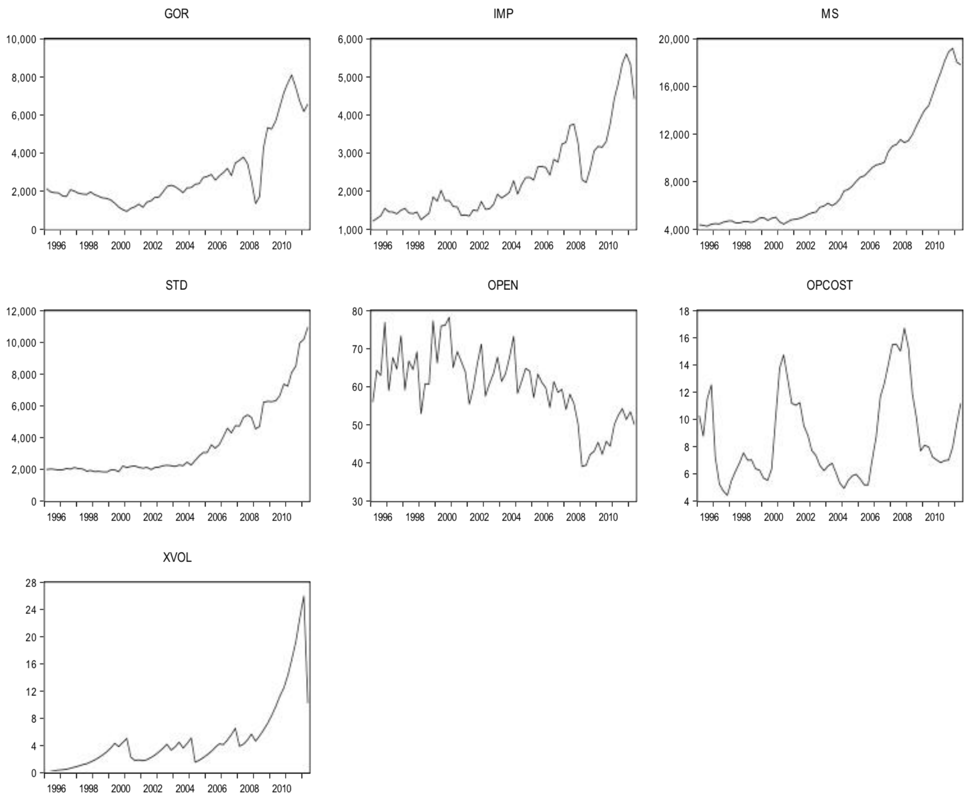


Appendix 2

Reserve Demand Model – Movements in Model Variables

Figure A2.1

Movements in Empirical Model Variables



Note: Variable names are as given in Table 4.

Validity of the Monetary Model of the Exchange Rate: Empirical Evidence from Sri Lanka[1]

Sujeetha Jegajeevan

Abstract

This paper studied the behaviour of the US dollar vis-à-vis the Sri Lankan rupee exchange rate in order to check the empirical validity of the flexible price monetary model of exchange rate. Data from January 2001 to March 2011 has been studied by employing the Johansen multivariate cointegration test and the Vector Error Correction Model (VEC) as the key techniques. A long-term cointegrating relationship between the nominal exchange rate and variables of monetary model has been found. The error correction term is quite large and significant indicating that short-term deviation from long-term equilibrium is restored within a year. However, regardless of the existence of a long-term relationship found between variables of the monetary model and exchange rate, the evidence is not strong enough to support the validity of the monetary model. This is mainly because of statistically insignificant domestic money supply and incorrect sign reported for foreign money supply. Improper evidences found on key variables of the model led to serious doubt about the ability of the flexible price monetary model in explaining exchange rate movements of US dollar – Sri Lankan rupee in the free floating exchange rate regime.

1 The author is thankful to her supervisor Dr. Gianluigi Vernasca for his guidance and support throughout this study and the anonymous referee for his valuable comments and corrections that helped to improve the quality of this paper.

1. Introduction

Understanding and predicting movements of exchange rates have been essential tasks for traders as well as policymakers from the time the rates were allowed to float. Policy makers want to ensure that the exchange rate is moving according to economic fundamentals and does not fluctuate exceptionally, which is harmful not only to the foreign exchange market but also to the economy as a whole. The main objective of this study is to empirically assess the long-term relationship between the US dollar-Sri Lankan rupee exchange rate and economic variables of the flexible price monetary model of exchange rate and their short-term dynamics to determine whether exchange rate movements are in line with economic fundamentals. Though there is ample research on modelling exchange rate for advanced countries, studies based on emerging countries are limited to a few recent studies. This study is the first attempt, to the knowledge of the author, to test the validity of the monetary model of exchange rate for Sri Lanka. This paper contributes to the literature by adding empirical evidence on the validity of the monetary model from a small open economy that did not receive much attention in the literature in the past. Price stability being one of the key objectives of the Central Bank of Sri Lanka, exchange rate management and the monetary policy are closely related, even though exchange rate is not explicitly targeted. Since Sri Lanka is a small open economy adopting the monetary targeting framework, evidence about the long-term relationship between the exchange rate and monetary fundamentals is very helpful for the policy makers. This paper focuses on studying the validity of the flexible price monetary model during the free floating exchange rate regime to answer the following three main research questions.

1. Is there a long-term relationship between exchange rate and variables of the monetary model?

2. If there is any disturbance to the long-term relationship, how long will it take to revert to the long-term equilibrium level?

3. Can variables of the monetary models be used to predict movements of exchange rate in the long-run?

The study is based on monthly data from January 2001 to March 2011. Nominal exchange rate, money supply, income and interest rates of Sri Lanka and the USA are selected as the key variables of the model. The long-term relationship among these variables is studied by employing Johansen multi-variate cointegration analysis, while short term dynamics are studied based on the Vector Error Correction Model (VEC). Further, monetary restrictions imposed on the restricted flexible price model in theory are also tested to determine the empirical validity of such restrictions.

The rest of the paper is organized into four more sections. Section 2 provides a brief overview of exchange rate regimes in Sri Lanka, a review of theoretical underpinning and empirical evidence. Section 3 briefly describes the data and methodology, while the main data analysis and presentation of results are presented in section 4. Finally, the summary of conclusions of the analysis and limitations of this study and further extensions are discussed in the final section.

2. Related Theory and Empirical Evidences

2.1 Overview of Exchange rate Regimes in Sri Lanka

Sri Lanka‘s foreign exchange rate policy has evolved according to different regimes starting from fixed exchange rate at the time of independence in 1948. In 1950 with the establishment of the Central Bank of Sri Lanka, the value of the rupee was fixed against gold. In 1971, with the suspension of convertibility of US dollar for gold, the Sri Lankan rupee was linked to US dollars and it was later linked to a basket of currencies of countries with which Sri Lanka had important trading linkages. In 1977, the managed floating regime was introduced and the US dollar became the intervention currency. The Central Bank announced it’s buying and selling rates of US dollar for its transactions with commercial banks, while commercial banks were allowed to quote their buying and selling rates for currencies within the specified margins. The margin between the Central Bank’s buying and selling rates were adjusted from time-to-time. In January 2001, foreign exchange transactions were liberalized by allowing commercial banks to determine the exchange rate freely with the objective of stabilizing the value of the rupee. The Central Bank no longer buys or sells foreign exchange at pre-announced rates, but monitors the movements of the exchange rate in the market, reserving the right to intervene in the market when there is high volatility in the short-term. It intervenes in the market by filling in temporary shortfalls in supply and demand that could otherwise result in unwarranted excessive fluctuations in exchange rates. Thus, Sri Lanka experienced a gradual transformation from a fixed exchange rate to a freely floating exchange rate over a half century. Overall, the US dollar-Sri Lankan rupee exchange rate has depreciated continuously, ignoring small appreciations experienced from time-to-time. For instance, by 1977 the exchange rate was around Rs.16 per US dollar. It depreciated to around Rs. 90 per US dollar in 2001 at the time of moving to free floating and hovered at around Rs. 110 per US dollar by 2011. The US dollar has been a major currency for international transactions throughout the past and countries to do so in the present.

2.2 Monetary Models of Exchange Rate and Empirical Evidences

A number of structural models are developed in the literature of international finance to model exchange rate behavior. Before the 1970s, many countries adopted a fixed exchange rate regime and fixed price assumption based model, *i.e.,* the purchasing power parity model (PPP), was considered as the most suitable model to study exchange rate behaviour. However with the transformation to floating exchange rate regimes in major advanced countries, since the 1970s monetary based models became popular in modelling long-term exchange rate behaviour. Following the liberalization of current and capital accounts of balance of payment and developments of exchange rate markets, several other variables such as volatility of capital flows, forward premium, government interventions and micro level dynamics in the exchange rate market became increasingly important in the determination of exchange rate behaviour in the short-term (Dua and Ranjan, 2011).

The PPP model states that prices are equalized by arbitrage forces at home and overseas when measured by a single currency. There could be a short-term deviation from PPP model, but in the long-term the exchange rate converges to the equilibrium level of the PPP. The PPP model was proved to be successful in modelling long-term exchange rate behaviour in the early literature.

In the monetary model, money supply in both domestic and foreign countries as opposed to money demand function determines the exchange rate. Monetary models are built on the basis of the PPP model. This model was built based on four main building blocks; continuous PPP, uncovered interest parity, stability of money demand function and exogeneity of money and real income. Thus the assumptions of these building blocks are applicable to the monetary model as well. This model has two main classifications known as flexible price and sticky-price models. The flexible price model (originally developed by Frenkel, 1976) is based on the assumption that prices are perfectly flexible and therefore any increase (decrease) in domestic money supply should increase (decrease) the domestic price level and as a result domestic currency will depreciate (appreciate) discretely to equalize prices in two countries. An important implication of this model is that PPP holds both in short-term and long-term. This is highly criticized by the pioneers of sticky price model.

The sticky price model was developed by Dornbusch (1976) by relaxing the assumption of short-term PPP while holding the long-term PPP assumption. It considers price rigidities in an economy in modelling exchange rate. Therefore, as noted by Moosa (2000) it is considered a 'hybrid model' in the sense that it incorporates the Keynesian property of fixed prices in the short-term and the classical property of flexible prices in the long-term. In this model domestic interest rate changes relative to foreign interest rate to equate the money market for a change in money supply relative to demand for money in the absence of a corresponding fall in price level. In the sticky price model PPP holds only in the long-run and an increase in domestic money supply does not depreciate the exchange rate proportionally in the short-run. Because of this, an increase in money supply leads to a fall in domestic interest rate and resulting capital outflow, instead of proportional depreciation in the exchange rate. Such an outflow of capital will result in the exchange rate overshooting above its equilibrium level in the short-term. The long run solution for the exchange rate in the sticky-price model is equal to the flexible-price model, but the sluggish adjustment of prices causes temporary overshooting of the exchange rate compared to the long run equilibrium (Schroder & Dornau, 1999). Empirically, the sign and the significance of the coefficients of the interest rates and the long term inflation expectations are used to differentiate the flexible-price and the sticky price models. The basic structural models and models with different modifications are employed empirically by many researchers to model exchange rate behaviour for different countries and to forecast at different time spans. The empirical performance of the monetary models is discussed in the following section.

Empirical evidence over the last four decades on the applicability of monetary models to model exchange rate behaviour is mixed. Schroder and Dornau (1999) noted that monetary models were the centre of interest in exchange rate theory in the seventies and early eighties. Earlier research covering the 1970s for industrial countries is supportive of the monetary approach to exchange rate [see Frenkel (1976), Bilson (1978) and Dornbusch (1976)]. It has been observed that the in-sample performance of the monetary models were favourable in the years immediately following the breakdown of the Bretton Woods system and it collapsed in the 1980s (Dua and Ranjan, 2011).

Following the influential work of Meese and Rogoff (1983), who concluded that naïve random-walk model outperform out-sample forecast performance of any monetary model, the empirical interest in the monetary models started to fade. While some researchers were concentrating on different models, some researchers attempted to validate the monetary model by extending it with some variations and by applying new statistical and econometric techniques. Buiter and Miller (1981, cited in Dua and Ranjan 2011) extended the sticky price model by including trend inflation, which was proved to be successful in a few other later studies. Hooper and Morton (1982) extended the sticky price model by including changes in the long-run real exchange rate that is expected to be correlated with unanticipated shocks to the trade balance. The recent studies attempted to include market based variables such as transaction volumes or order flows, forward premia, capital flows, volatility in capital flows and central bank intervention that influence short term volatility of exchange rate.

Several reasons have been highlighted for the failure of the monetary approach in modelling exchange rate behaviour. Meese (1990, cited in Dua and Ranjan, 2011) attributed the failure of the monetary models to their underlying relationship with PPP, instability in the money demand function and irrational expectations of agents. Abas and Yusof (2009) further added quoting Boughton (1988), Mac Donald (1988) and MacDonald and Taylor (1992) that the constraints imposed on relative money, income and interest rates, exogeneity of money supply, uncovered interest parity and inappropriate application of econometric tools are the causes of the failure of these models. Meredith (2003) stated that the exogeneity of money supply is no longer valid in the current financial system and monetary policy approaches of the central banks, since money supply is endogenously determined with other macro variables. Flood and Rose (1995, cited in Dua and Ranjan, 2011) stresses a valid point that while exchange rate exhibit substantial volatility, the economic fundamentals do not show such volatility in the short-term. So, exchange rates based only on economic fundamentals will not be adequate in explaining the exchange rate behaviour in the short-term. Sarno and Valente (2008) attributed weak out-sample performance of exchange rate models to poor performance of model selection criteria, rather than lack of information contents in fundamental. They further added that model selection becomes more difficult due to frequent shifts in the set of fundamentals driving exchange rate, which is a result of shift in market expectations over time. Further, exchange rate movements are dependent on speculative forces, rational and or irrational expectations of market players in the short-term, which make exchange rate relatively more volatile than the other macro variables in the short time span. Another explanation for this failure is that fundamental models are based on the current values of macro variables, but in practice the market responds to various information and expectations about fundamentals. It may not be a surprise if the models with current values fail to track actual movements of the exchange rate.

Regardless of all these criticisms, one cannot completely neglect evidence in favour of fundamental models, especially in the medium term and long-term. Fundamental economic models with few variations have shown evidence of good fit to the data and produce reasonably good forecast for certain currencies in the mid to long-term. Though in a short horizon of one to three years monetary fundamentals do not help much to predict the exchange rate, the predictive power is stronger for some currencies when the time span is widened to four to five years as summarized by Dua and Ranjan (2011), based on empirical literature. Meredith (2003) quoted that limited research in the 1990s such as MacDonald and Taylor (1994), Mark (1995), Chen and Mark (1995) and Mark and Choi (1997) have found the predictive power of monetary models in the medium term. Mark (1995) has found that both in-sample and out-sample forecast performance of monetary models increased when the forecast horizon was strengthened and forecast error was half of the error generated by the random walk forecast. Several other studies are quoted in Liew *et al*. (2009) that have found evidences on long-term relationships between exchange rate and the variables of monetary models in the advanced countries, using the cointegration techniques of Johansen (1988, 1989), Johansen and Juselius (1990) and the Engel Granger approaches (see MacDonald and Taylor (1991) and Choudhry and Lawler (1997).

Moreover, many recent studies based on emerging countries are supportive of the long-term validity of monetary models. While Abas and Yusof (2009), Liew *et al*. (2009) and Chin *et al*. (2007) have proved the long-term validity of the monetary models in Malaysia, Thailand and the Philippines, respectively, Dua and Ranjan (2011) have shown that different variations of the monetary model forecasts over-perform the random walk model in India.

Engel *et al*. (2007) stress a peculiar and interesting argument about the approaches to evaluate exchange rate models. Contrary to the consensus of empirical literature they highly criticized the central criterion of judging the models by comparing them with the random walk model. Good models do not necessarily out-perform the random walk models, since many such models indeed imply that exchange rates are nearly a random walk and beating the random-walk model forecast is too strong criterion in accepting the model.

To sum up, the empirical evidence of monetary models based on individual time series are mixed. The extensions to validity of these models in the recent past consider three different approaches such as use of panel data, increase the time span to more than a decade and application of non-linear models. There are ample research attempts and evidence on the validity of the monetary models in advanced countries. But, evidences from emerging countries is limited to a little recent research and most of them have proved the long-term validity of monetary models in these countries. The long-term relationship between monetary model based variables and exchange rate has been well accepted both in theoretical and empirical literature, though short-term validity was challenged. Finally, evidence that the models do not out-perform the random walk model alone cannot be used to reject the validity of monetary models. Table 2.1 summarizes the main features of some empirical works, which are more relevant to this study.

Table 2.1 : Summary of Empirical Evidences

Authors	Scope	Methodology	Key Findings
Meese and Rogoff (1983)	1973- 1981 – monthly data for US dollar and UK pound	Univariate time series model, flexible price and sticky price monetary models using unconstraint VAR	Random walk model outperforms the time series and structural models in short-term
Mark (1995)	1973-1991 – quarterly data for Canadian dollar, deutsche mark, Swiss franc and yen against US dollar	Monetary models	Out-sample point predictions of the models outperform drift-less random walk forecast when forecast horizon is longer.
MacDonald and Taylor (1991)	1976-1990 – monthly data for currencies of German, Japan and UK against US dollar	Monetary model using multivariate cointergration technique	Unrestricted monetary model is a valid framework for analyzing the long run exchange rate. Further, the proportionality of the exchange rate to relative money supplies is valid for the German mark
Groen (2002)	1975-2000 – quarterly data for euro against the currencies of Canada, Japan and US	Monetary models using panel VEC techniques	Forecasting performance of monetary model based common long-run model is superior to random walk and standard VAR model based forecasts.
Meredith (2003)	Mainly 1981-2002 – monthly and annual data for G-7 currencies and currencies of selected small industrial and emerging countries	PPP, uncovered interest rate parity (UIP), monetary model	Though PPP and monetary model are favourable in in-sample forecast, when adjusted for finite-sample estimation bias they lose their predictability in medium term.
Civcir (2003)	1986-2000 – monthly data for Turkish lira – US dollar	Different versions of monetary models	Exchange rate is cointegrated with long-run fundamentals and equilibrium correcting monetary models significantly outperform random walk.

(Contd.)

Authors	Scope	Methodology	Key Findings
Islam & Hasan (2006)	1974-2003 – quarterly data for yen against US dollar	Monetary model using cointegration and VEC technique	There is long-term causation flowing from monetary variables to exchange rate and forecast performance of monetary model outperforms random walk model
Lam et al. (2008)	1973-2007 – quarterly data for euro, UK pounds and yen against US dollar	PPP, UIP, sticky price monetary model, a model based on Bayesian model average and a combined model of all above models	The combined model outperforms the random walk model and yields better result than any of the single model.
Abas & Yusof (2009)	1980-2007 – quarterly data for ringgit and yen against US dollar	Flexible price monetary model using cointegration and error correction	Strong evidences of long-term relationship between exchange rate and monetary fundamentals in the selected countries.
Liew et al. (2009)	1977-2006 – monthly data for Thailand baht against yen	Flexible price monetary model using cointegration and VECM	There is long-term relationship between exchange rate and monetary fundamentals and monetary models works well in small and open emerging economy (Thailand)
Dua and Ranjan (2011)	1996-2006 – monthly data for India rupee against dollar	Monetary model and various extensions of it using VAR and BVAR	Monetary model with extensions (including central bank interventions, capital flows and forward premia) outperforms random walk model and BVAR model outperforms corresponding VAR model.

3. Data and the Model

3.1 Data

Data used in this paper consists of secondary data with respect to Sri Lanka and USA. Since the free floating exchange rate regime was introduced in Sri Lanka only recently in 2001, quarterly series could not be selected for this research as opposed to many other similar studies. Instead, data on monthly frequency for the period from January 2001 to March 2011 is considered. Data related to Sri Lanka is collected from a database available at the Central Bank of Sri Lanka, while that of United States is gathered mainly from International Finance Statistics (IFS) of the IMF and statistical publications of the Federal Reserve Bank. Key macroeconomic variables involved in the money demand function, such as money supply, interest rate and income have been chosen to develop the flexible price monetary model of exchange rate. Since GDP estimates are available only quarterly, the industrial production index has been chosen as a proxy for income. In addition to these fundamental variables, it was attempted to extend the model by including some additional variables such as trade balance, current account balance, trade volumes, central bank interventions and forward premia. However, due to the lack of availability of data for the selected period and frequency only central bank intervention has been chosen as the additional variable to extend the basic version of the monetary model. Further, due to the nature of the economy and the status of the foreign exchange market, central bank intervention plays an important role in determining the exchange rate behaviour for Sri Lanka rather than any other variables mentioned above. A detailed description of data is included in Appendix Table 1A. E-views 7.0 has been used for econometric analysis of the model.

3.2 Theoretical Model

The empirical evidences shows that monetary models work well in the long-run, but lose their predictability in the short-run to naïve random walk forecasts, as the volatility of exchange rates substantially exceeds that of the volatility of macroeconomic fundamentals. This paper is based on the flexible price monetary model in the long-term. Monetary models are based on a few assumptions such as PPP, uncovered interest parity, a stable money demand function and exogeneity of money and real income with respect to exchange rate (Meredith, 2003). The Vvalidity of the flexible price monetary model in the Sri Lankan perspective is tested using the cointegration and Vector Error Correction (VEC) framework.

A brief note on the derivation of the model is discussed in this part. The derivation of the model basically follows the ideas of Moosa (2000) and Neely and Sarno (2002).

Flexible The flexible price model assumes that PPP holds continuously in short-term and long-term and any change in the money supply will lead to a proportional change in exchange rate through changing the domestic price level. The simplest version of the monetary model is derived by assuming the following stable money demand function.

$$m_h = p_h + k_h y_h - \lambda_h i_h \qquad (3.1)$$

$$m_f = p_f + k_f y_f - \lambda_f i_f \qquad (3.2)$$

Variables *m, p, y* and *i* denote the log-level money supply, the price level, income and the level of interest rates, respectively, and subscripts h and f refers to home and foreign. The labels k and λ are constants. According to the flexible price model PPP holds, so that the log nominal exchange rate between home and foreign will be given by the following equation.

$$e = p_h - p_f \qquad (3.3)$$

where, e is the log nominal bilateral exchange rate.

Solving equations 3.1 and 3.2 for p_h and p_f, respectively, and replacing in 3.3 yields the following equation.

$$e = (m_h - m_f) - k\,(y_h - y_f) + \lambda\,(i_h - i_f) \qquad (3.4)$$

For simplicity, the assumption of symmetry and proportionality has been imposed in deriving equation 3.4, which represents the restricted form of the flexible price model. The symmetricy assumption implies the equality of income elasticity and interest semi elasticity of the demand for money in home and foreign. According to the assumption of proportionality, a rise in the domestic money supply leads to a proportional rise in the price level via the quantity theory of money and to a proportional depreciation of domestic currency via the purchasing power parity and vice versa (Liew *et. al.*, 2009) .

The testable form of equation 3.4 is as follows.

$$e = \beta_1 m_h - \beta_2 m_f - \beta_3 y_h - \beta_4 y_f + \beta_5 i_h - \beta_6 i_f \qquad (3.5)$$

Equation 3.5 is the unrestricted flexible price monetary model. In the literature, tests on monetary restrictions are usually performed (MacDonald and Taylor, 1991). The proportionality between money supply and nominal exchange rate can be tested by the null hypothesis $H_1{:}\beta_1 = 1$ and $H_2{:}\beta_2 = 1$. The symmetry can be tested by the null hypotheses $H_3{:}\beta_1 = -\beta_2$, $H_4{:}\beta_3 = -\beta_4$ and $H_5{:}\beta_5 = -\beta_6$.

Since the nominal exchange rate is expressed in terms of domestic currency per unit of foreign currency, a positive relationship between domestic money supply and nominal exchange rate and a negative relationship between foreign money supply and exchange rate are expected. Similarly, an increase in domestic income through an increase in demand for money tends to appreciate the exchange rate and therefore a negative relationship is expected and vice versa. According to the assumption of flexible price model the changes in interest rate reflects the changes in expected inflation. Thus, when the domestic nominal interest rate increases domestic currency is expected to lose its value through inflation (Abas and Yusof (2009). The domestic interest rate is expected to have the same effect as the domestic money supply, and therefore a positive relationship is expected with the exchange rate. An increase in foreign interest rate, in contrast, tends to appreciate the local currency.

The beta coefficients are expected to have the following signs in the estimates.

$\beta_1 > 0 , \beta_2 < 0$

$\beta_3 < 0 , \beta_4 < 0$ and

$\beta_5 > 0 , \beta_6 < 0$

Empirical evidences shows only a weaker correlation between exchange rate and fundamental macroeconomic variables in the short-term. The movement of exchange rate in the short-term, like any other asset price, is largely dependent on the expectation of market players, which is not captured by the standard exchange rate models. Dua and Ranjan (2011) have highlighted transaction volumes or order flows, forward premia, capital flows, volatility in capital flows and central bank intervention as a few useful variables in the short to medium-term forecasts. Due to the lack of availability of data and relevance to the Sri Lankan context, only central bank intervention is used to extend the basic version of the monetary model. Accordingly, the extended model can be expressed as follows.

$$e = \beta_1 m_h - \beta_2 m_f - \beta_3 y_h + \beta_4 y_f + \beta_5 i_h - \beta_6 i_f + \beta_7 cbint \quad (3.6)$$

Central bank intervention is the net purchases of foreign exchange by the central bank in the foreign exchange market. Central bank intervenes in the market to control excess fluctuations in the market. It buys foreign exchange when there is an abnormally high inflow of foreign exchange, to avoid high appreciation of exchange rate and *vice versa*,. So that, net purchases will reduce the level of appreciation and therefore, a positive relationship between central bank intervention and exchange rate is expected ($\beta_7 > 0$).

3.3 Methodology

The main analysis of this paper is based on multivariate cointegration analysis and vector error correction modeling. The monetary model is tested using a VAR based cointegration technique developed by Johansen (1995). The cointegration analysis requires all the variables to be integrated of the same order, generally I(1). Therefore, before running a cointegration test all the variables are tested for the presence of unit root using the Augmented Dickey Fuller (ADF) test. Neely and Sarno (2002) explains the need to test for stationary as follows. A stationary series tend to return to its expected level (mean reverting) when it departs from it. But, if the series is not mean reverting and infinitely persistent that series is nonstationary. A regression is meaningful only if the equation can be written so that the error is I(0). If error is I(1) the estimates of coefficients will be inconsistent. This requires either all variables in the equation to be I(0) or some combination of them is to be I(0). The cointegration test is a test to check whether there is a linear combination of I(1) variables that is I(0).

Generally, most of the macroeconomic variables are not stationary. Thus, a regression involving these variables will be spurious, though the goodness-of-fit of the model is high and the variables are statistically significant. Thus, cointegration analysis is carried out to check for the presence of a long-term relationship among the selected macroeconomic variables. The presence of cointegration relation implies that the linear combination of nonstationary variables is stationary and there is a corresponding error correction representation which shows the short-term deviation from the long run relationship.

Another way to confirm the existence of a cointegrating relation is the test for causality. If two variables are cointegrated causality in the Granger sense must exist in at least one direction (Granger, 1988, cited in Dua and Ranjan 2011). VEC Granger Causality/ Block Exogeneity Wald test is employed to check whether there is causation running from the variables of the monetary model to the exchange rate or from the exchange rate to such variables.

VEC estimates help to study short-term dynamics more than the long-term relations established by the cointegration test. The VEC has cointegration relations built into the specification that limits long-run movements of the variables in the model to converge to their cointegrating relationships while allowing for short-run adjustment dynamics. The cointegration term, which is also known as the error correction term, shows how deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. Generally a larger error correction term (α) means convergence to equilibrium level at a faster rate.

More than finding long-term validity of the monetary model and its short-term dynamics, validity of the assumptions of monetary restrictions of the restricted version of the monetary model are also tested to check the validity of the chosen unrestricted model. Checking forecast performance of the model is out of the scope of this study, mainly because of the restricted sample period.

4. Empirical Results

4.1 Unit Root Test

In simple terms, a time series is stationary if it's mean and variance do not vary systematically over time. In a stationary time series the mean and variance (at various lags) remain the same no matter what point we measure them. Therefore, time series will tend to return to its mean and fluctuations around this mean will have broadly constant amplitude. The Unit root test is carried out to test whether a series is level stationary [I (0)] or first difference stationary [I (1)]. The Augmented Dickey-Fuller test (ADF) has been employed in this research. If the test statistic value (*i.e.,* estimated value) is smaller than the critical values at 1 per cent, 5 per cent or 10 per cent significance level, then the null hypothesis is accepted. The null hypothesis is that the series has a unit root, or the series is not stationary at its level.

Table 4.1 : **Outcome of Unit Root Test**

Variables	**ADF Test**		
	At levels	**Ist Difference**	**Result**
Inexr	-2.62	-3.88	I(1) at 5%
slmoney	-2.26	-4.09	I(1) at 1%
slind_pro	-2.15	-4.19	I(1) at 1%
slint	-1.55	-2.83	I(1) at 10%
usmoney	-2.00	-3.53	I(1) at 5%
usind_pro	-2.10	-3.46	I(1) at 5%
usint	-2.35	-2.71	I(1) at 10%
cbint	-5.45		I(0) variable

		Intercept	Intercept & Trend
Test critical values:	1% level	-3.49	-4.03
	5% level	-2.89	-3.45
	10% level	-2.58	-3.15

Note: *Variables other than slint, usint, usind-pro and cbint have shown a clear trend. So that intercept and trend are included in the test equation for these variables.*

Source: Author's Estimates

Table 4.1 reports the outcome of the ADF test. Different lag levels are used for different series that maximizes maximize the Akaike Information Criteria (AIC). Accordingly all the variables, except central bank intervention, are nonstationary at their levels or in other words all these variables are I (1) variables.

4.2 Cointegration Analysis and Vector Error Correction Estimates

Having established that the key variables of the model are I (1), Johansen (1995) multivariable cointegration analysis is carried out to check whether these I (1) variables are linearly cointegrated in the long-run. Central bank intervention, which is found to be I(0), is used as an exogenous variable in the cointegration test. Also a dummy variable is included as an exogenous variable mainly to capture the impact of the financial crisis on the US industrial production index, immediately following the crisis.

A lag length of 2 has been chosen in first difference terms (*i.e.,* lag of 3 in levels) initially for correlation and vector error correction analysis that maximizes the AIC criterion. At this lag length the autocorrelation LM test rejects the null hypothesis of the presence of serial correlation in the model. It confirms that the chosen lag level is optimum and the model is not mis-specified. Deterministic trend specification of the cointegration test assumes that level data have linear trends but cointegrating equations have only intercepts. Critical values for the test are based on MacKinnon-Haug- Michelis (1999) p-values.

The test results of Johansen trace and max-eigen value tests are reported in Table 4.2. According to the table, both tests only reject the null hypothesis of no cointegrating vectors. In other words, the test results accept that there is at least one cointegrating relationship between nominal exchange rate and the monetary variables, such as money supply, income and interest rate. The identified cointegrating relationship can be interpreted as a long-term relationship among these variables. It supports the fact that the monetary approach is a reasonable explanation of exchange rate behavior during the sample period.

Table 4.2 : **Johansen Test for Cointegration Relations**

		Test Statistics		**5% critical Values**	
H_0	**H_1**	***Trace***	**Max-Eigenvalue**	***Trace***	**Max-Eigenvalue**
$r = 0$	$r > 1$	157.17	70.47	125.62	46.23
$r \leq 1$	$r > 2$	86.71	31.87	95.75	40.08
$r \leq 2$	$r > 3$	54.83	21.64	69.82	33.88
$r \leq 3$	$r > 4$	33.19	16.80	47.86	27.58
$r \leq 4$	$r > 5$	16.40	9.84	29.80	21.13
$r \leq 5$	$r > 6$	6.56	6.55	15.49	14.26
$r \leq 6$	$r = 7$	0.01	0.01	3.84	3.84

Source : Author's Estimates

Since all variables, except interest rates, are specified in logs the normalized equation denotes implied long-term elasticities. According to the equation, coefficients of US industrial production and US interest rates are not only very small but are also statistically insignificant. Coefficients of Sri Lankan interest and US money supply are significant at the 95% confidence level, while Sri Lankan money supply and industrial production are significant at the 90% confidence level. Sri Lankan industrial production, Sri Lankan interest rate and US interest rate have reported correct signs as expected theoretically. However, the result shows incorrect signs for money supply both in Sri Lanka and the US and US industrial production. Since central bank intervention is included as an exogenous variable, its sign and significance was checked with VEC output. Central bank intervention indicates net purchases of foreign exchange by the central bank. Therefore, the higher the purchases from the central bank the higher the demand for foreign currency, which is expected to depreciate the domestic currency. However, the empirical finding was contrary to the this expectation. The coefficient was not only small with wrong sign, but also was not statistically significant. Similarly, the dummy variable was also not significant.

Since both the exogenous variables are found to be statistically insignificant, they are dropped from the original model and cointegration equation and VEC were recalculated. New The new specification indicates that a lag level of 3, maximises the AIC criterion and eliminates serial correlation from the model. The new estimation confirms the presence of 2 cointegrating vectors among the variables, according to both max-eigen value and trace statistics. The re-estimated long-term cointegrating equation is as follows.

$$Inexr_t = -1.96 + \underset{(-0.68)}{0.13slmoneyy_t} - \underset{(5.19)}{0.83slind\text{-}pro_t} + \underset{(-8.03)}{0.017slint_t}$$

$$+ \underset{(-2.92)}{0.94usmoneyy_t} + \underset{(-2.68)}{0.344usind\text{-}pro_t} - \underset{(3.23)}{0.017usint_t}$$

The new specification is superior to the old specification in many ways. The re-estimated cointegration equation reports relatively more statistically significant variables with correct signs and the values of coefficients are also improved. All Sri Lankan variables now report correct signs, though money supply was statistically insignificant. Among the US related variables, money supply has reported the incorrect sign. Several other studies have reported similar mixed findings regarding the signs of the monetary fundamentals [see Liew *et al*. (2009), Islam and Hasan (2006) and Abas and Yusof (2009)].

In addition to the long-term relationship, short-term dynamics of the models could be analysed based of on the VEC output shown in Table 2A of the Appendix. Accordingly, the error correction term is negative, as expected, and statistically significant. The significance of the lagged error-correction term implies a long-term causality from all variables in the monetary model towards the nominal exchange rate. A coefficient of -0.115 indicates that around 11.5% of disequilibrium in the nominal exchange rate in the short-term is corrected monthly. To be more specific, it takes less than a year to correct short-term disequilibrium and to restore long-term equilibrium of nominal exchange rate.

Existence of a short-term relationship between exchange rate and a few variables of the monetary model is evident from the outcome of the error correction model. SL industrial production with 1 and 2 lags, US money supply with 3 lags and US interest rate with 2 lags are significant at the 95% confidence level, whereas SL money supply with 2 lags is significant at the 90% confidence level. This indicates that there is short-term causality from these variables to the nominal exchange rate.

Table A3 in the Appendix summarizes Granger causal relationship among the variables in the VEC model with 3 lags. VEC Granger Causality/ Block Exogeneity Wald test result shows some evidence of single directional causality running from macro variables to the exchange rate. Sri Lanka industrial production and US interest rate reject the null hypothesis of no causality running from these variables to exchange rate at the 10% and 5% significance levels, respectively. Similarly, exchange rate Granger causes US industrial production index. Thus, the Granger causality test provides some further evidence on the causation between the exchange rate and monetary variables, though it is not very strong.

4.3 Testing for Monetary Restrictions

Test result of monetary restrictions based on theLikelihood Ratio test (LR test) has been reported in Table 4.3. Findings of this test are mixed. Hypotheses H_1, H_2 and H_3 are rejected at the 1% significance level, while H_4 is rejected at the 5% significance level. Rejection of H_1 and H_2 implies that neither domestic money nor foreign money proportionally influence nominal exchange rate. In economic terms, there is non-neutrality of money. Similarly, rejection of H_3 proves that domestic and foreign money supply do not have the same impact on the exchange rate that is operating in the opposite direction. Rejection of H_4 indicates inequality of income elasticities in home country and foreign. However, non rejection of H_5 gives evidence to the fact that interest semi-elasticities are similar in home and foreign. In other words, changes in interest rates in home and foreign influences exchange rate by the same proportion but in opposite directions. These findings are not much different from the findings of a few other studies on emerging countries [see Islam and Hasan (2006) and Abas and Yusof (2009)]. These mixed findings indicate that the proposed relationship between exchange rate and variables of monetary model are not simple and direct empirically as assumed in the restricted flexible price monetary model. These findings also suggest that the restricted version of the monetary model that assume equality of coefficients of home and foreign may fail due to the rejection of these monetary restrictions.

Table 4.3 : **Johansen Test for Cointegration Relations**

Null Hypothesis	Chi-Square	Probability
$H_1 : \beta_1 = 1$	7.14	0.008
$H_2 : \beta_2 = -1$	9.02	0.003
$H_3 : \beta_1 = -\beta_2$	10.56	0.001
$H_4 : \beta_3 = -\beta_4$	4.59	0.03
$H_5 : \beta_5 = -\beta_6$	0.01	0.933

Source: Author's Estimates

4.4 Testing for Exclusion Restrictions

The test result of the exclusion restriction is presented in Table 4.4. This test is carried out to check whether any of the variables of the monetary model can be excluded from the cointegrating vector. This is done using the LR test on the null hypothesis of the coefficient of the selected variable being zero. The null hypothesis of Sri Lankan money has been accepted, while the null hypotheses of other variables have been rejected. It indicates that Sri Lankan money could be excluded from forming cointegrating relations. Though this finding is contrary to the findings of several other studies, it confirms the long-term cointegration equation that reported the insignificance of Sri Lankan money supply.

Table 4.4 : **Testing for Exclusion Restrictions**

Null Hypothesis	Chi-Square	Probability
$H_6 : \beta_1 = 0$	0.24	0.63
$H_7 : \beta_2 = 0$	7.58	0.00
$H_8 : \beta_3 = 0$	16.17	0.00
$H_9 : \beta_4 = 0$	3.85	0.05
$H_{10} : \beta_5 = 0$	3.47	0.00
$H_{11} : \beta_6 = 0$	5.31	0.02

Source: Author's Estimates

5. Summary

5.1 Conclusion

In this paper, the empirical validity of the flexible price model has been studied for Sri Lanka, in order to determine whether US dollar – Sri Lankan exchange rate movements are in line with the changes in monetary fundamentals. Nominal exchange rate, money supply, income and interest rate in both countries and central bank intervention in the Sri Lankan foreign exchange market have been chosen as key variables of the model. A sample period of ten years from 2001:1 – 2011:3 was considered for the study. The long-term cointegrating relationship and short-term dynamics have been studied by employing Johansen multivariate cointegration analysis and VEC. Also, the empirical validity of assumptions imposed on the restricted flexible price monetary model has been tested using LR test. This part summarizes major findings of this research.

Given that all variables are integrated of the same order, the Johansen cointegration test was carried out including central bank intervention and a dummy to capture the impact of the recent financial crisis on US industrial production as exogenous variables. The unique cointegrating vector was identified at the chosen lag of 2, both by trace statistics and max-eigen value. The application of this model revealed that even though in general central bank intervention is deemed to be important in exchange rate determination, in Sri Lanka, it is not statistically significant. The same finding was reported for the dummy variable. Therefore in order to improve the model, these two insignificant variables were dropped from the model and the cointegrating equation was re-calculated.

For the revised model, 2 cointegrating equations were identified, both by trace statistics and max-eigen value at the appropriate lag of 3. This finding provides evidence of a long run relationship between exchange rate and monetary fundamentals. The long-term cointegrating equation of the revised model was far better than the initial model in terms of significance of the variables and the signs of the coefficients. All the variables, other than Sri Lankan money supply, are statistically significant at the 95% confidence level. Insignificance of the Sri Lankan money supply is contrary to theory as well as empirical findings.

All Sri Lankan variables have reported correct signs for the coefficients, as expected by theory. Accordingly, a rise in Sri Lankan money, depreciates US dollar – Sri Lankan rupee exchange rate, while an increase in Sri Lankan income appreciates the exchange rate. Similar to the impact of money supply, a rise in Sri Lankan interest rate has a positive relationship with exchange rate, expressed in terms of Sri Lankan rupee per US dollar. Among the US related variables, variables other than money supply have reported correct signs. This kind of mixed findings in the directions has been reported in many other similar studies.

Outcome of VEC reports a negative and significant error correction term. Accordingly, around 11.5% of the disequilibrium is corrected monthly and long-term equilibrium is restored within a year. In other words, disequilibrium in exchange rate is adjusted to revert back to monetary fundamentals within a reasonable time. The high speed of adjustment implies the existence of fewer barriers to the adjustment process. This could also be interpreted as less intervention and turbulence in the exchange rate market that deviate the exchange rate behavior from economic fundamentals.

Though the causality test using VEC Granger Causality/ Block Exogeneity Wald test confirmed the presence of some causality, the overall finding of this test is not satisfactory. Single directional causality was found from Sri Lankan industrial production to exchange rate and US interest rate to exchange rate. Similarly, exchange rate Granger cause US industrial production index.

The test on commonly imposed assumptions of reduced form flexible price monetary model rejects the proportionality assumption of exchange rate and money supply. It denotes that changes in money supply in home and foreign do not affect the nominal exchange rate proportionally, so that money is non-neutral. The test of monetary restriction also rejects equal and opposite effects of money differential and income differential on exchange rate. The empirical findings being contrary to theoretical specifications could be due to the problems associated with the PPP relationship on which the model was built and/ or the existences of price stickiness and wage rigidities. However, the assumption of equal interest semi elasticity has been accepted. This signifies the influence of interest rate changes that result from monetary policy changes in both countries, on exchange rate. The rejection of most of these monetary restrictions of restricted form confirms the validity of the chosen unrestricted monetary model in explaining the long-term nominal exchange rate for Sri Lanka.

The result of the test of exclusion restrictions, that checks whether any of these fundamental variables can be excluded from the cointegrating vector, confirms the findings of the VEC. That is, only Sri Lankan money can be excluded from the model and all the other variables are statistically significant. This finding is, however, puzzling. The statistically insignificant nature of the relationship between exchange rate and money is somewhat a strange finding. The robustness of the finding to the choice of monetary aggregate has also been tested using M_2 money supply that excludes deposits held by off-shore banking units. This estimate also produced a similar finding. So the findings are robust to the choice of monetary aggregates.

It is worth discussing further about the possible reason for the puzzling, statistically insignificant nature of the relationship between domestic money supply and exchange rate. This could be attributed to the validity of assumptions underlined in the monetary model of exchange rate, such as PPP, uncovered interest parity, stable money demand, exogeneity of money and income to exchange rate. Empirical evidence suggest the existence of a stable money demand function in Sri Lanka [see Dharmaratne (2004) and Jegajeevan (2009)]. However, the validity of exogeneity of money supply in the current context of monetary policy in a small country like Sri Lanka is questionable. Many authors in the past challenged this assumption and suggested that money supply is, rather, determined endogenously with other macroeconomic fundamentals. Testing the validity of such assumption is beyond the scope of this study. The validity of PPP in the Sri Lankan context was studied by Wickremasinghe (2004) and adequate supportive evidences was not found to prove its validity. It is also important to keep in mind that many authors, who found evidence against the monetary model attributed the short time span of floating exchange rate data as the possible reason for the failure of this model. Groen (2000) highlighted the fact that a relatively short time span reduces the power of tests on unit root and cointegration. He further suggests the use of a panel data set to circumvent this problem. Another possible reason is the use of current period data of economic fundamentals in predicting current period exchange rate. The current period money supply, for instance, may not hold any leading information in predicting current period exchange rate movements. Rather, expectations about future money supplies, income levels and interest rate could possibly hold valuable information about exchange rate movements. Last, but not least, the explanation is associated with the sample period selected for this study. A considerable part of the sample includes financial crisis period and recovery periods. Money supplies in both countries have been increased as a part of expansionary monetary policy adopted by the respective central banks, as a response to the great financial crisis of 2008–2009. The improper findings related to money supplies and exchange rate could reflect the breakdown of the relationship found among the macroeconomic fundamentals and exchange rate in normal economic conditions.

Overall, the findings of this study did not provide adequate evidence to support the empirical validity of the flexible price monetary model as a long-term explanation of the US dollar – Sri Lankan rupee exchange rate. Although a cointegrating relationship between variables of the monetary model and exchange rate was found, the key variables of the model such as domestic money supply and foreign money supply have shown inaccurate findings. Domestic money supply was statistically insignificant and foreign money supply has reported with a wrong sign of causation. Therefore, based on the empirical evidence found in this research it is hard to accept the empirical validity of the flexible price monetary model of exchange rate in the selected sample period for Sri Lanka. However, the monetary model cannot be rejected entirely and future research with a few modifications and extensions to the model is warranted, before drawing any firm conclusion.

5.2 Limitations and Extensions

The key limitation of this study is the short sample period and frequency of data. Sri Lanka entered into the floating exchange rate regime only in 2001. This limits the appropriate sample only to ten year. Generally, studies on exchange rate were based on quarterly data. Data on quarterly frequency was not considered in this research due to inadequate observations. Further, due to unavailability of real income data (GDP) on monthly frequency the industrial production index has been considered a proxy for real income. However, both in Sri Lanka and the US the industrial production index is not a key economic indicator, though it has been widely used by researchers as a proxy for real income. The findings would have been more precise if GDP data had been included. Also, the short sample period limits the feasibility of extending the analysis to include forecasting exchange rate behavior based on the chosen model and evaluating its performance with that of random walk. Exchange rate movements in considerable periods covered in the sample were much influenced by the recent financial crisis and resulting changes in economic fundamentals. It is reasonable to expect a more accurate and influential outcomes from counterfactual analysis in the absence of such an event.

There is future potential for research in this area by studying this model based on a sticky price version, because the findings of this study could be due to the presence of price stickiness in the economy. Also, extending this study to a forward-looking monetary model might give supporting evidence that expectations of macroeconomic fundamentals have leading information on the movements of exchange rate in the long-run. Several other studies with this forward-looking version of this model have found evidence in favour of this model (*e.g.,* Groen, 2000). It is recommended for future research to improve the model to capture market expectations on future fundamentals, such as inflation expectations, growth expectations. In addition, the model could be extended to widen the sample period and frequency to verify whether more accurate findings are feasible. The forecasting performance of the models could be evaluated when the sample is extended to a reasonable length, since these fundamental based models work well in the medium and long-term.

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Appendix

Table A1 : Data Definition and Source

Variable	Definition	Source
lnexr	Month-end nominal US dollar – Sri Lankan rupee exchange rate, expressed in rupee per one dollar. (in log)	Database of Central Bank of Sri Lanka
slmoney	Seasonally adjusted M_{2b} money supply in log. M_{2b} is the sum of currency held by the public and all deposits held by the public with commercial banks (both in domestic banking units and off-shore banking units)	Database of Central Bank of Sri Lanka
slind-pro	Seasonally adjusted industrial production index in log. (1997=100)	Database of Central Bank of Sri Lanka
slint	Month-end call money market rate	Database of Central Bank of Sri Lanka
cbint	Central bank interventions in foreign exchange market. It is the net purchase in foreign exchange market shown in US dollar million.	Database of Central Bank of Sri Lanka
usmoney	Seasonally adjusted M_2 money supply in log. M_2 includes M_1, money market mutual funds, savings and small time deposits.	Statistical release of Federal Reserve Bank
usind-pro	Seasonally adjusted industrial production index in log. (2000=100)	International Financial Statistics, IMF
usint	Month-end money market rate	International Financial Statistics, IMF

Table A2 : Parameter Estimates of Error Correction Models

	D[LNEXR)	D[SLMONEY)	D[SLIND_PRO)	D[SLINT)	D[USMONEY)	D[USIND_PRO)	D[USINT)
CointEq1	-0.115177	0.051505	-0.049481	15.45017	0.001554	0.238927	1.820541
	[-2.31019]	[1.99022]	[-0.42993]	[2.15504]	[0.06030]	[3.82699]	[3.33278]
D[LNEXR(-1)]	0.09333	0.056112	0.009626	5.252079	-0.002317	-0.347576	0.414012
	[0.91201]	[1.05633]	[0.04075]	[0.35690]	[-0.04380]	[-2.71233]	[0.36925]
D[LNEXR(-2)]	0.060349	-0.060625	-0.120998	-3.529382	-0.012034	-0.168015	1.060987
	[0.58797]	[-1.13788]	[-0.51066]	[-0.23912]	[-0.22681]	[-1.30720]	[0.94344]
D[LNEXR(-3)]	0.080287	0.000425	-0.230576	3.808847	0.009394	-0.127976	1.776839
	[0.83604]	[0.00852]	[-1.04009]	[0.27581]	[0.18924]	[-1.06420]	[1.68871]
D[SLMONEY(-1)]	0.226113	-0.094946	0.408277	20.14082	-0.047233	-0.075978	-0.323415
	[1.13435]	[-0.91762]	[0.88726]	[0.70265]	[-0.45839]	[-0.30438]	[-0.14808]
D[SLMONEY(-2)]	-0.34948	0.081581	0.398734	-60.97869	-0.003712	0.064415	-0.140112
	[-1.76497]	[0.79372]	[0.87231]	[-2.14157]	[-0.03626]	[0.25979]	[-0.06458]
D[SLMONEY(-3)]	0.024634	0.256952	0.050703	-17.63426	-0.027411	-0.18032	-1.021588
	[0.12248]	[2.46130]	[0.10921]	[-0.60974]	[-0.26366]	[-0.71598]	[-0.46360]
D[SLIND_PRO(-1)]	0.111625	-0.036208	-0.480566	-3.239379	-0.05269	-0.038651	0.093515
	[1.98535]	[-1.24064]	[-3.70258]	[-0.40066]	[-1.81293]	[-0.54897]	[0.15180]
D[SLIND_PRO(-2)]	0.133875	-0.008864	-0.211673	3.292004	-0.048254	-0.097623	0.318547
	[2.52637]	[-0.32224]	[-1.73036]	[0.43201]	[-1.76159]	[-1.47115]	[0.54865]
D[SLIND_PRO(-3)]	0.061561	-0.022218	-0.05176	1.560109	-0.001949	-0.040073	-0.20423
	[1.44472]	[-1.00452]	[-0.52620]	[0.25461]	[-0.08848]	[-0.75101]	[-0.43744]
D[SLINT(-1)]	-0.00138	9.79E-05	0.002156	-0.401166	0.000129	0.002115	0.01327
	[-1.49863]	[0.20490]	[1.01423]	[-3.02970]	[0.27149]	[1.83389]	[1.31531]
D[SLINT(-2)]	-0.000916	-0.000363	0.002881	-0.292317	0.000419	-0.000295	-0.027293
	[-1.14320]	[-0.87411]	[1.55826]	[-2.53791]	[1.01216]	[-0.29421]	[-3.10994]
D[SLINT(-3)]	-0.000882	-0.000311	0.003381	0.11203	0.000879	0.000316	-0.008935
	[-1.21070]	[-0.82203]	[2.00945]	[1.06888]	[2.33391]	[0.34574]	[-1.11883]
D[USMONEY(-1)]	0.258726	0.028746	-0.452301	-14.7035	0.001078	-1.273129	-0.777241
	[1.34857]	[0.28866]	[-1.02126]	[-0.53296]	[0.01087]	[-5.29929]	[-0.36976]
D[USMONEY(-2)]	0.069765	-0.00295	-0.156304	-24.8127	-0.365351	0.357499	0.504817
	[0.35300]	[-0.02876]	[-0.34260]	[-0.87308]	[-3.57621]	[1.44453]	[0.23313]
D[USMONEY(-3)]	0.433204	0.155128	-0.405625	-15.59948	0.103275	-0.438615	-0.442705
	[2.03376]	[1.40301]	[-0.82491]	[-0.50928]	[0.93794]	[-1.64438]	[-0.18969]
D[USIND_PRO(-1)]	-0.020062	-0.037308	-0.067151	0.008083	-0.067828	-0.542106	0.621862
	[-0.26106]	[-0.93526]	[-0.37852]	[0.00073]	[-1.70743]	[-5.63326]	[0.73855]
D[USIND_PRO(-2)]	0.137051	0.020283	-0.286993	-11.17505	-0.076327	-0.265638	0.287623
	[1.53028]	[0.43631]	[-1.38815]	[-0.86772]	[-1.64870]	[-2.36860]	[0.29312]
D[USIND_PRO(-3)]	0.043645	0.008585	0.253227	1.421731	0.002422	0.011723	0.087568
	[0.57920]	[0.21949]	[1.45571]	[0.13120]	[0.06217]	[0.12423]	[0.10606]
D[USINT(-1)]	-0.008731	0.003366	0.038631	-1.181042	-0.000495	-0.005209	0.465421
	[-0.89599]	[0.66556]	[1.71740]	[-0.84288]	[-0.09818]	[-0.42689]	[4.35945]
D[USINT(-2)]	0.023745	-0.007515	-0.037364	1.144587	-0.013165	-0.015852	-0.048999
	[2.41324]	[-1.47139]	[-1.64501]	[0.80896]	[-2.58829]	[-1.28658]	[-0.45451]
D[USINT(-3)]	0.013723	-0.001232	0.002255	-0.674184	0.007976	-0.021221	-0.074012
	[1.45484]	[-0.25151]	[0.10356]	[-0.49702]	[1.63575]	[-1.79647]	[-0.71611]
C	-0.001551	0.008542	0.003254	0.752784	0.007313	0.009813	-0.013635
	[-0.31749]	[3.36949]	[0.28864]	[1.07192]	[2.89667]	[1.60455]	[-0.25482]

Table A3 : Outcome of VEC Granger Causalty / Block Exogeneity Wald Test

Dependent variable: D(LNEXR)

Excluded	Prob.
D(SLMONEY)	0.1858
D(SLIND_PRO)	0.0795
D(SLINT)	0.3971
D(USMONEY)	0.2013
D(USIND_PRO)	0.2290
D(USINT)	0.0147

Dependent variable: D(SLMONEY)

Excluded	Prob.
D(LNEXR)	0.4683
D(SLIND_PRO)	0.4223
D(SLINT)	0.5921
D(USMONEY)	0.5671
D(USIND_PRO)	0.5530
D(USINT)	0.4532

Dependent variable: D(SLIND_PRO)

Excluded	Prob.
D(LNEXR)	0.7377
D(SLMONEY)	0.6903
D(SLINT)	0.2227
D(USMONEY)	0.7180
D(USIND_PRO)	0.0081
D(USINT)	0.2338

Dependent variable: D(SLINT)

Excluded	Prob.
D(LNEXR)	0.9655
D(SLMONEY)	0.1349
D(SLIND_PRO)	0.8361
D(USMONEY)	0.7801
D(USIND_PRO)	0.5779
D(USINT)	0.7914

Dependent variable: D(USMONEY)

Excluded	Prob.
D(LNEXR)	0.9919
D(SLMONEY)	0.9593
D(SLIND_PRO)	0.1794
D(SLINT)	0.1322
D(USIND_PRO)	0.1470
D(USINT)	0.0245

Dependent variable: D(USIND_PRO)

Excluded	Prob.
D(LNEXR)	0.0256
D(SLMONEY)	0.8626
D(SLIND_PRO)	0.5071
D(SLINT)	0.0458
D(USMONEY)	0.0000
D(USINT)	0.0661

Dependent variable: D(USINT)

Excluded	Prob.
D(LNEXR)	0.3219
D(SLMONEY)	0.9687
D(SLIND_PRO)	0.7861
D(SLINT)	0.0000
D(USMONEY)	0.9757
D(USIND_PRO)	0.9066

From Where Does it Come?
An Analysis of Currency Market Volatility in Sri Lanka

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Abstract

Exchange rate volatility is a key concern of policy makers. Existing literature has identified a large set of variables as the determinants of exchange rate volatility. However, it is argued that there are common shocks that underlie the co-movements of large time series used in such studies. Using the latent factor approach, which is naturally structured to identify such common shocks, this paper disentangles the unconditional volatility of six currencies expressed against the Sri Lankan rupee into common, numaraire and idiosyncratic factors to identify the sources of currency market volatility in Sri Lanka during the period from 2002–2012. Specifically, this paper attempts to investigate whether the volatility of currency market in Sri Lanka stems from domestic currency market specific sources or external sources. Care is taken to distinguish the effects on intervention and non-intervention days. Empirical results suggest that currency market volatility in Sri Lanka is primarily externally sourced. Prior to the financial crisis, policy makers are found to have been primarily focused on mitigation of the volatility coming from the US currency market, whereas during the crisis this was expanded to include volatility emanating from European currency markets in what may be characterised as an attempt to minimise Sri Lanka's exposure to global events at the time. However, the policy change introduced in early 2012 by limiting the Central Bank intervention in the foreign exchange market can be identified as an effective policy measure which has reduced exchange rate volatility arises in the domestic currency market.

Keywords: Exchange Rate Volatility, Latent Factor Model, Sri Lanka

JEL Classification: C38, C51, F31, G15

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1. Introduction

Exchange rate volatility is a key concern of policy makers. Excessive volatility in the foreign exchange market can impair the smooth functioning of the financial system and economic performances as the exchange rate has a strong influence on foreign trade, capital flows and economic development. Therefore, policy makers tend to adopt various policies to curb excess volatility in exchange rate movements.

Understanding the causes of exchange rate volatility provides valuable insight for policy makers to design appropriate measures or intervention strategies in mitigating a country's vulnerability to risk in periods of uncertainty. Moreover, identifying the sources of exchange rate volatility is important, as maintaining a competitive and stable exchange rate is necessary for promoting private investment, domestic and foreign, needed to meet the growth and development targets in the country. Although a voluminous of scholarly articles can be found on exchange rate volatility, there is no consensus in the literature on the factors which affect exchange rate volatility, either by individual country or across panels (Abdalla, 2012; Canales-Kriljenko and Habermeier, 2004). Existing studies identify a number of factors which contribute to the volatility of exchange rate. These factors include, but are not limited to, level of output, openness of an economy, domestic and foreign money supplies, exchange rate regime, policy intervention, inflation, interest rates, central bank independence, income and external shocks (Stančík, 2009).

A careful investigation of the factors influencing exchange rate volatility reveals that the dynamic behaviour of exchange rates broadly stems from two factors; (*i*) factors unique to the domestic currency market, and (*ii*) factors which spill-over from currency market interdependencies. The latter is viewed as external factors. Introducing the so-called "meteor shower" hypothesis, Engle *et al*. (1990) have suggested that volatility spills-over, rather than remaining in one market. Although the majority of the existing studies focuses on investigating the determinants of exchange rate volatility, the individual characteristics of exchange rate returns and the degree of the impact of each of these variables, only a handful of studies attempts to disentangle exchange rate volatility to identify the contribution of domestic currency market related factors and external factors. Diebold and Nerlove (1989), Mahieu and Schotman (1994), Dungey (1999) and Dungey and Martin (2004) are exceptions. This paper aims to fill that gap in literature.

The objective of this paper is to decompose the volatility of bilateral exchange rates of a selection of Sri Lanka's trading partner currencies, expressed against the Sri Lankan rupee, into factors unique to domestic currency market and external factors to investigate the sources of domestic currency market volatility in Sri Lanka.[1] The motivation of

1 The term "domestic factors" is used in this paper to represent factors uniquely attributed to the domestic currency market and the term "external" is used to represent factors which do not uniquely stem from the domestic currency market.

this paper is the fact that the effective mitigation of exchange rate volatility depends on understanding its sources. Dungey (1999) put forward this idea by suggesting that national monetary authorities can only play a limited role in reducing exchange rate volatility, while maintaining a floating exchange rate regime, if such volatility is primarily stemmed from external sources. Conversely, economic costs associated with exchange rate volatility could potentially be mitigated by appropriate policy measures, if the volatility of exchange rate is primarily originated from domestic currency market related sources as domestic sources of such volatility are more likely to be amenable to policy initiatives of the domestic monetary authority.

The empirical investigation of this paper is based on the latent factor structure of exchange rate movements proposed by Diebold and Nerlove (1989) and Mahieu and Schotman (1994).[2] In economics, factors are defined as common shocks that underlie the co-movements of the large number of economic time series (Bai and Ng, 2006, p.1). As in the latent factor model literature, these factors are not directly observable (Dungey and Martin, 2004; Heston and Rouwenhorst, 1995). In fact, the identfication of key variables for existing studies on exchange rate volatility is somewhat *ad hoc*, mainly because it is impossible to incorporate all the variables that may affect dynamic features of exchange rate movements. To overcome this problem some studies such as Bai and Ng (2006); Verdelhan (2012) and Engel *et al*. (2012) have tried to identify whether there is commonality in the empirical characteristics of exchange rate returns. This provides a justification for the use of a small set of latent factors as in Diebold and Nerlove (1989); Engle *et al*. (1990); Kose *et al*. (2003); Mahieu and Schotman (1994); Ng *et al*. (1992) and Dungey *et al*. (2005) to specify a parsimonious multivariate model of time varying volatility. That is, latent factor analysis can be used to summarize a rich data set with a simpler underlying structure.

The way that the latent factor model can be specified and estimated to decompose exchange rate volatility is explained in detail in Dungey (1999), the closest to this paper. However, the current paper is different to earlier work in the area of interest in two ways. First, the current paper mainly focusses on disentangling exchange rate volatility of a set of Sri Lanka's trading partner currencies into domestic currency market related factors and external factors, which has not been studied previously. Second, the current paper takes foreign exchange intervention by the Central Bank of Sri Lanka into account, by separately modelling the dynamic behaviour of currencies involved with the Sri Lankan rupee for days on which the Central Bank intervenes in the domestic foreign exchange

2 The other method that is used widely to decompose exchange rate volatility is the Vector Auto-Regression (VAR) Analysis, and the use of VARs to model dynamics of exchange rate movements is well published (Berument and Pasaogullari, 2003; Ito and Sato, 2008; Karras *et al*., 2005; Odusola and Akinlo, 2001).

market and for days on which there is no intervention. Previous studies such as Diebold and Nerlove (1989); Engle *et al*. (1990) and Dungey *et al*. (2005) have not considered this phenomenon when decomposing exchange rate volatility.[3] However, this study does not formally model currency market intervention in Sri Lanka.[4]

The analytical framework consists of modelling each exchange rate return series as a linear combination of three factors, as in Engle *et al*. (1990); Heston and Rouwenhorst (1995) and Dungey (1999): a common factor that impacts upon all exchange rate returns, a numeraire factor that is uniquely associated with the numaraire currency, and an idiosyncratic factor that captures the variations in a specific currency market. The currencies examined in this paper are euro (EUR), the British pound (GBP), the Japanese yen (JPY), the US dollar (USD), the Indian rupee (INR) and the Pakistan rupee (PKR), all against the Sri Lankan rupee (LKR). The latent factor model of panel of exchange rate returns is estimated through Generalised Method of Moments (GMM) for the period prior to the current financial crisis, January 2002 – June 2007, and for the crisis period, July 2007 – August 2012. The empirical investigation is further extended by decomposing exchange rate volatility during the period from February–August 2012 to identify the impact of the changes introduced to the exchange rate policy in Sri Lanka in February 2012, by limiting the Central Bank intervention in the domestic foreign exchange market to allow for more exibility in determining the exchange rate.

Empirical results reveal that exchange rate volatility mainly stems from the factors external to the domestic currency market in Sri Lanka. Except for the decomposition of the US dollar/Sri Lankan rupee exchange rate volatility on non-intervention days in the pre-crisis period, at least 70 per cent of total volatility of the currency market is explained by external factors – that is by common and idiosyncratic factors. Exhibiting that the domestic monetary authority can do little in reducing volatility when the contribution of external factors is large, domestic currency market volatility is larger when the Central Bank intervenes either by buying or selling US dollars. Overall, the volatility decomposition of intervention day models in both periods suggests that policy response of the Central Bank of Sri Lanka mainly aims volatility spills-over from external factors rather than factors which are unique to the domestic currency market. During the pre-crisis period, this response was rested on US currency market specific factors, but the response in the crisis period was mainly aimed at US dollar and euro specific factors. The latter can be viewed as a response to the recent financial crisis and the ensuing debt problems in the US and Europe.

3 Not considering currency market intervention by monetary authorities in existing studies may be due to lack of availability of data or intervention is not very frequent in the countries studied.

4 See Fry-McKibbin and Wanaguru (2013) for an application of the latent factor specification in modelling currency market intervention.

Re-running the model for the period from February 2012 – August 2012, this paper finds that the contribution of the domestic currency market related (numaraire) factors is considerably larger during this period when the Central Bank does not intervene. The contribution of the numaraire factor, however, has decreased significantly as the Central Bank intervenes in the foreign exchange market. This, not only suggests that the Central Bank has been able to mitigate the impact of domestic currency market related factors, but also indicates that the current exchange rate policy stance is appropriate in the context of reducing the contribution domestic factors made to the total volatility of the Sri Lankan rupee. However, the adequacy of data for this sub-period remains a concern.

The rest of the paper is organized as follows. Section 2 develops the latent factor model of exchange rate returns. Section 3 presents GMM methodology used in the analysis. Section 4 discusses the statistical properties of data, while Section 5 presents empirical results. Section 6 concludes.

2. The Model

This section specifies a latent factor model of exchange rate returns, distinguishing between non-intervention days and intervention days. Latent factor analysis, which originated in psychometrics, is a statistical method applied to explain the variability among observed and correlated variables in terms of a fewer number of unobserved variables. These unobserved variables are called factors. In other words, the latent factor model identifies the common shocks that underlie the co-movements of large time series, thus allowing the variations in a set of observed variables to reflect the variations in fewer unobserved variables. Using latent variables helps in reducing the dimensionality of data by aggregating a large number of variables in a model to represent an underlying concept and making it easier to understand data. Therefore, applying the latent factor methodology to investigate the factor structure of the dynamic nature of exchange rate volatility provides a parsimonious and convenient way of representing data, whilst implicitly taking into account all the disturbances affecting the set of exchange rate returns included in the model. All the factors are assumed to be independent latent stochastic processes with zero means and unit variances. This facilitates the decomposition of unconditional volatility of exchange rate returns according to the contribution that each of the factors makes to overall volatility.

The non-intervention day model is specified assuming that the volatility of exchange rate returns can be captured through a "common" factor, which affects all foreign exchange markets simultaneously; a "numaraire" factor which captures variations unique to the numaraire currency, here the Sri Lankan rupee; and "idiosyncratic" factors which are specific to each foreign exchange market in a particular country.[5]

The intervention day model is also built with the same assumptions, but the effect of each factor on each exchange rate return, as given by the factor loadings, is allowed to change through the formal modelling of structural breaks as in Fry-McKibbin and Wanaguru (2013). This treatment allows capturing changes in external and domestic dependence structures among the exchange rate returns such as possible high volatility which may be prevalent on the days that the Central Bank of Sri Lanka chooses to intervene (Fry-McKibbin and Wanaguru, 2013).

Denoting the percentage change in the exchange rate between currency i, and the numeraire currency, x, on non-intervention days (NI) at time t as $R^{NI}_{i,x,t}$, the model of exchange rate volatility can be presented as a linear combination of three factors given by:

$$R^{NI}_{i,x,t} = \lambda^{NI}_{i,x} W_t + \eta^{NI}_{x} N_t + \nu^{NI}_{i,x} C_t \qquad (1)$$

where, $i = EUR, GBP, INR, JPY, PKR$ and USD.

In matrix form, the model of exchange rate returns can be expressed as:

$$\begin{bmatrix} R^{NI}_{EUR,x,t} \\ R^{NI}_{GBP,x,t} \\ R^{NI}_{INR,x,t} \\ R^{NI}_{JPY,x,t} \\ R^{NI}_{PKR,x,t} \\ R^{NI}_{USD,x,t} \end{bmatrix} = \begin{bmatrix} \lambda^{NI}_{1} & \eta^{NI}_{x} & \nu^{NI}_{1,x} & 0 & 0 & 0 & 0 & 0 \\ \lambda^{NI}_{2} & \eta^{NI}_{x} & 0 & \nu^{NI}_{2,x} & 0 & 0 & 0 & 0 \\ \lambda^{NI}_{3} & \eta^{NI}_{x} & 0 & 0 & \nu^{NI}_{3,x} & 0 & 0 & 0 \\ \lambda^{NI}_{4} & \eta^{NI}_{x} & 0 & 0 & 0 & \nu^{NI}_{4,x} & 0 & 0 \\ \lambda^{NI}_{5} & \eta^{NI}_{x} & 0 & 0 & 0 & 0 & \nu^{NI}_{5,x} & 0 \\ \lambda^{NI}_{6} & \eta^{NI}_{x} & 0 & 0 & 0 & 0 & 0 & \nu^{NI}_{6,x} \end{bmatrix} \begin{bmatrix} W_t \\ N_t \\ C_{1,t} \\ C_{2,t} \\ C_{3,t} \\ C_{4,t} \\ C_{5,t} \\ C_{6,t} \end{bmatrix} \qquad (2)$$

5 Several alternative model structures with other possible factors such as regional and market factors were considered in the preliminary stage of the empirical investigation. However, computationally the models with these specifications did not work in this study.

The term W_t represents the common factor that affects all exchange rate returns, but with different parameter loadings for each currency return. The loading parameter of the common factor is denoted as $\lambda_{i,x}^{NI}$. The term N_t captures shocks specific to the numaraire currency. The impact on each currency is fixed and given by η_x^{NI} . Imposing no arbitrage condition and presenting the exchange rates relative to a common numeraire, here the Sri Lankan rupee, leads to the loading parameter η_x^{NI} to be fixed, reducing the parameterisations (Dungey, 1999). The set of idiosyncratic factors which capture country specific effects in currency market is given by C_t , with factor loading $\nu_{i,x}^{NI}$. The intervention day model is slightly different to the non-intervention day model as it is assumed that the Central Bank intervenes in the foreign exchange market as a consequence of higher excess volatility in the foreign exchange market. As in Fry-McKibbin and Wanaguru (2013), this phenomenon is captured through introducing structural breaks in modelling the factor structure of exchange rate volatility. Therefore, the dynamics of exchange rate returns for intervention days (I) takes the form:

$$R_{i,x,t}^{I} = (\lambda_{i,x}^{NI} + \lambda^{I})_{i,x} W_t + (\eta_x^{NI} + \eta_x^{I}) N_t + (\nu_{i,x}^{NI} + \nu_{i,x}^{I}) C_t, \tag{3}$$

In matrix form, the model of exchange rate returns can be expressed as:

$$\begin{bmatrix} R_{EUR,x,t}^{I} \\ R_{GBP,x,t}^{I} \\ R_{INR,x,t}^{I} \\ R_{JPY,x,t}^{I} \\ R_{PKR,x,t}^{I} \\ R_{USD,x,t}^{I} \end{bmatrix} = \begin{bmatrix} (\lambda_1^{NI} + \lambda_1^{I}) & (\eta_x^{NI} + \eta_x^{I}) \\ (\lambda_2^{NI} + \lambda_2^{I}) & (\eta_x^{NI} + \eta_x^{I}) \\ (\lambda_3^{NI} + \lambda_3^{I}) & (\eta_x^{NI} + \eta_x^{I}) \\ (\lambda_4^{NI} + \lambda_4^{I}) & (\eta_x^{NI} + \eta_x^{I}) \\ (\lambda_5^{NI} + \lambda_5^{I}) & (\eta_x^{NI} + \eta_x^{I}) \\ (\lambda_6^{NI} + \lambda_6^{I}) & (\eta_x^{NI} + \eta_x^{I}) \end{bmatrix} \begin{bmatrix} W_t \\ N_t \end{bmatrix} +$$

$$\begin{bmatrix} (\nu_{1,x}^{NI} + \nu_{1,x}^{I}) & 0 & 0 & 0 & 0 & 0 \\ 0 & (\nu_{2,x}^{NI} + \nu_{2,x}^{I}) & 0 & 0 & 0 & 0 \\ 0 & 0 & (\nu_{3,x}^{NI} + \nu_{3,x}^{I}) & 0 & 0 & 0 \\ 0 & 0 & 0 & (\nu_{4,x}^{NI} + \nu_{4,x}^{I}) & 0 & 0 \\ 0 & 0 & 0 & 0 & (\nu_{5,x}^{NI} + \nu_{5,x}^{I}) & 0 \\ 0 & 0 & 0 & 0 & 0 & (\nu_{6,x}^{NI} + \nu_{6,x}^{I}) \end{bmatrix} \begin{bmatrix} C_{1,t} \\ C_{2,t} \\ C_{3,t} \\ C_{4,t} \\ C_{5,t} \\ C_{6,t} \end{bmatrix} \tag{4}$$

The zero mean assumption constraints any intercept term in Equations (1) and (3). The unit variance assumption makes all covariances between the latent factors interpretable as correlations. Therefore, using Equation (1), the unconditional volatility of currency returns on non-intervention days can be expressed as the variance:

$$VAR(R_{i,x,t}^{NI}) = E[(R_{i,x,t}^{NI})^2] = (\lambda_{i,x}^{NI})^2 + (\eta_x^{NI})^2 + (\nu_x^{NI})^2 \tag{5}$$

The unconditional volatility of currency returns on intervention days can be given by:

$$VAR(R^I_{i,x,t}) = E[(R^I_{i,x,t})^2] = (\lambda^{NI}_{i,x} + \lambda^I_{i,x})^2 + (\eta^{NI}_x + \eta^I_x)^2 + (\nu^{NI}_{i,x} + \nu^I_{i,x})^2 \qquad (6)$$

A useful description of the unconditional volatility of exchange rate returns given in Equations (5) and (6) is these equations allow to decompose the effects of shocks into common, numaraire and idiosyncratic components. The total decomposition of exchange rate volatility on intervention days can be re-expressed using Equation (6) as a proportion of the contribution of each factor as follows:

$$\text{Contribution of the common factor} = \frac{(\lambda^{NI}_{i,x} + \lambda^I_{i,x})^2}{(\lambda^{NI}_{i,x} + \lambda^I_{i,x})^2 + (\eta^{NI}_x + \eta^I_x)^2 + (\nu^{NI}_{i,x} + \nu^I_{i,x})^2} \qquad (7)$$

$$\text{Contribution of the numaraire factor} = \frac{(\eta^{NI}_{ix} + \eta^I_x)^2}{(\lambda^{NI}_{i,x} + \lambda^I_{i,x})^2 + (\eta^V_x + \eta^I_x)^2 + (\nu^{NI}_{i,x} + \nu^I_{i,x})^2} \qquad (8)$$

$$\text{Contribution of the idiocyncratic factor} = \frac{(\nu^{NI}_{i,x} + \nu^I_{i,x})^2}{(\lambda^{NI}_{i,x} + \lambda^I_{i,x})^2 + (\eta^{NI}_x + \eta^I_x)^2 + (\nu^{NI}_{i,x} + \nu^I_{i,x})^2} \qquad (9)$$

Similarly, the proportionate contribution of each factor on non-intervention days can be presented using Equation (3), but suppressing the structural break terms. This presentation allows the unconditional volatility of the exchange rate returns of each currency expressed against the Sri Lankan rupee to be decomposed into domestic and external factors: the first and the third terms of Equations (5) and (6), the λ and ν terms, to represent the contributions of external factors, and the second term, η, to represent the contribution of the factors unique to domestic currency market.

3. Methodology

The latent factor model of exchange rate volatility is estimated through the Generalized Method of Moments (GMM). GMM provides a unified framework for inference in econometrics to obtain consistent and asymptotically normally distributed estimators of the parameters. Existing literature has identified GMM as a method that provides a solution to the problems of simultaneity bias, omitted variable bias and reverse causality. Additionally, GMM estimators are robust to failures of ‘auxiliary distributional’ assumptions that are not needed to identify key parameters (Wooldridge, 2001:87). Another important feature of this methodology is that it is generally better under Heteroskedasticity, and allows the parameters to be over-identified (Cragg, 1983; Wooldridge, 2001).

The estimation procedure is based on computing the unknown parameters by equating the theoretical moments of the model to the empirical moments of the data in both the non-intervention day model and the intervention day model. The non-intervention day model is jointly estimated with the intervention day model. Therefore, the entire model consists of 42 theoretical moments of which [6 * (6+1)] / 2 = 21 comes from the non-intervention day model while the remainder comes from the intervention day model. There are 26 unknown parameters to estimate.

The objective function of the GMM estimator:

$$S(\theta) = X'_{NI}(\theta)V_{NI}(\theta)^{-1}X_{NI}(\theta) + X'_{I}(\theta)V_{I}(\theta)^{-1}X_{I}(\theta) \tag{10}$$

is minimized accounting for both non-intervention days and intervention days. The term θ in Equation (10) is the parameter vector. The weighting matrices, $V_{(.)}(\theta)$, are corrected for possible Heteroskedasticity in the moment conditions (Hamilton, 1994; Newey and West, 1987). An optimal weighting matrix can be obtained for a GMM analysis subject to the set of population moment conditions (Wooldridge, 2001). The GMM estimators are obtained by iterating both the parameters and weighting matrices until the convergence of the empirical and theoretical moments. $X_{(.)}(\theta)$ are the vectors containing the differences between the empirical moments and the theoretical moments, and are given by:

$$\begin{aligned} X_{NI}(\theta) &= vech(\Omega_{NI}(\theta)) - vech(\Psi_{NI}(\theta)\Psi'_{NI}(\theta)) \\ X_{I}(\theta) &= vech(\Omega_{I}(\theta)) - vech(\Psi_{I}(\theta)\Psi'_{I}(\theta)) \end{aligned} \tag{11}$$

where $\Omega_{(.)}(\theta)$ and $\Psi_{(.)}(\theta)\,\Psi'_{(.)}(\theta)$ are the empirical and theoretical variance-covariance matrices, respectively, which are defined as:

$$\Omega_{\tau}(\theta) = \frac{1}{T_{\tau}} \sum_{t \epsilon T_{\tau}} \varepsilon_t(\theta))\varepsilon'_t(\theta)) \text{ where } \tau = NI, I \tag{12}$$

and

$$E[\varepsilon_t(\theta)\varepsilon'_t(\theta)]_{t\epsilon T_{\tau}} = \Psi_{(\tau)}(\theta)\Psi'_{(\tau)}(\theta) \text{ where } \tau = NI, I \tag{13}$$

Finally, it is desired to check for the adequacy of the model using an over-identifying restrictions test as the number of theoretical moment conditions is greater than the number of empirical moment conditions in the model. Usually, the over-identifying restrictions are tested using Hansen's *J*–static to test the null hypothesis that the model is correctly specified. The *J* test is given by:

$$J(\theta) = T\,S(\theta) \qquad (14)$$

where T is the total number of observations in the full model given by $T = T_{NI} + T_I$. Here, $J(\theta)$ converges to the $X^2_{p\text{-}q}$ distribution asymptotically, with p number of moment conditions and q number of parameters. If over-identifying restrictions are rejected, it suggests that the variables included in the model fail to satisfy the orthogonality condition.

4. Data Description

The data consists of high frequency daily observations of bilateral exchange rates of the euro, the British pound, the Japanese yen, the Indian rupee, the Pakistan rupee and the US dollar, expressed against the Sri Lankan rupee, over the period from January 01, 2002 to August 30, 2012. All the data are obtained from the Central Bank of Sri Lanka. The selection of currencies depends on Sri Lanka's major trading partners, who follow floating exchange rate regimes. Additionally, the euro, the British pound, the Japanese yen and the US dollar represent advanced foreign exchange markets, whilst the Indian rupee and the Pakistan rupee represent emerging markets. An increase in the value of the exchange rate indicates an appreciation of the Sri Lankan rupee against other currencies.

Daily exchange rates of the selection of currency pairs are shown in Figure 1, and the summary statistics are presented in Table 1. The continuously compounded exchange rate returns [$R_{i,t} = ln\,(e_{i,t}) - ln\,(e_{i,t-1})$] are depicted in Figure 2. The outliers in the euro on March 1 and 2, 2005, and in the Pakistan rupee on July 31 and August 01, 2003 as depicted in Figure 2 are removed using dummy variables in the empirical analysis. All the return series are standardized to have zero mean and unit variance to facilitate convergence in the estimating procedure.

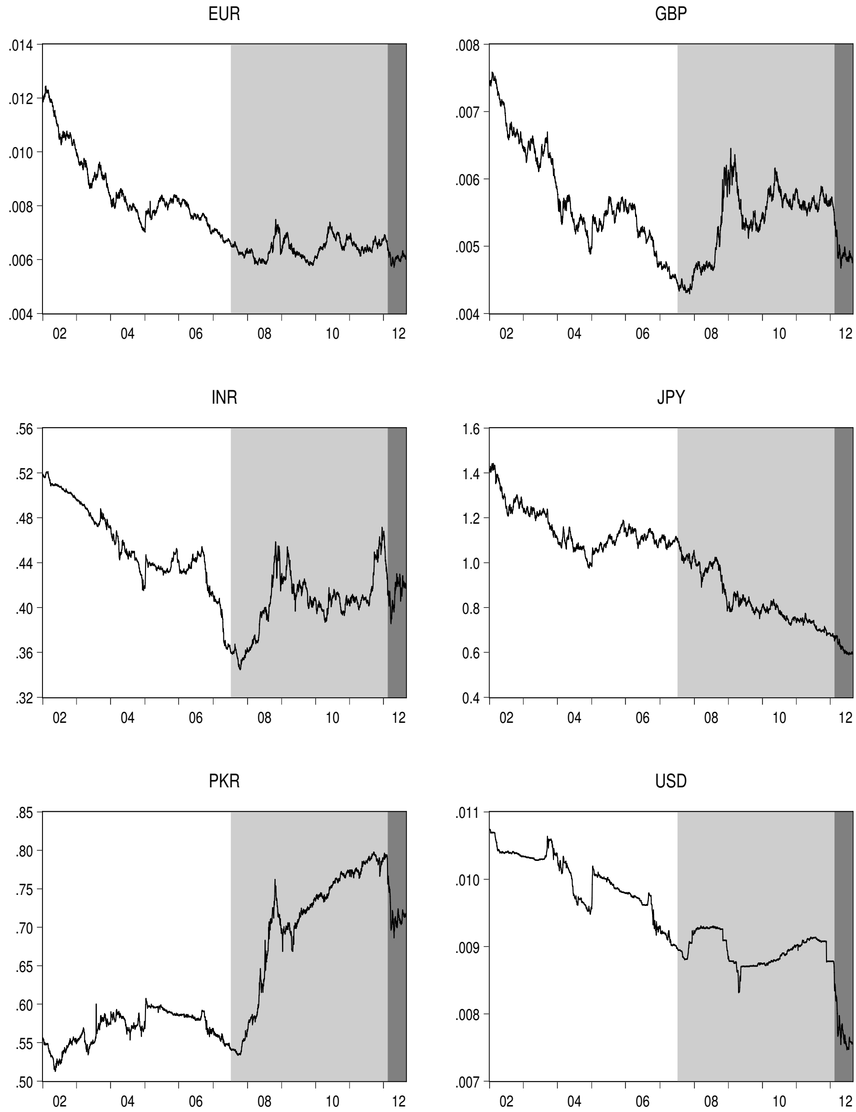

Figure 1:

Daily Exchange Rates of the euro, the British pound, the Indian rupee, the Japanese yen, the Pakistan rupee and the US dollar against the Sri Lankan rupee, January 2002 – August 2012. An increase in the value of the exchange rate indicates an appreciation of the Sri Lankan rupee. The shaded area indicates the period of global volatility from July 02, 2007 – August 30, 2012, while the dark shaded area represents the period from February 2012 – August 2012 – the period after changing the exchange rate policy stance.

Source : Central Bank of Sri Lanka

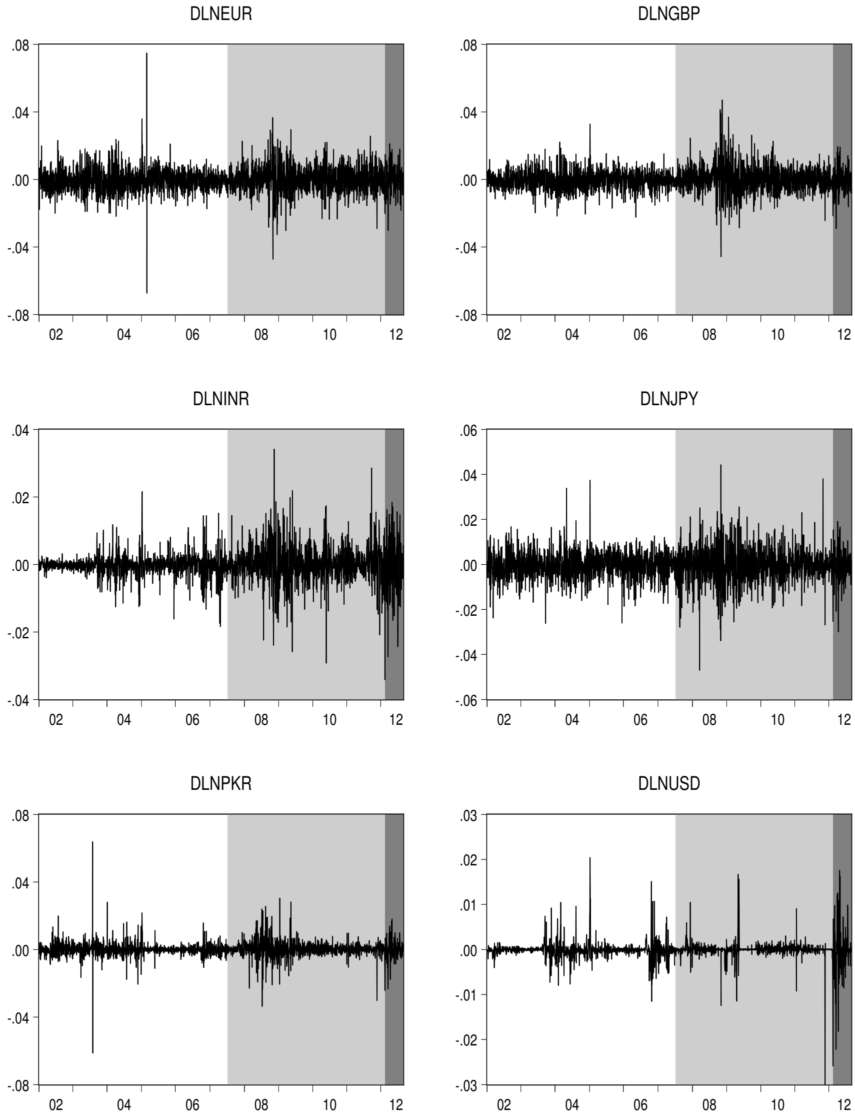

Figure 2:

Daily Exchange Rate Returns of the euro, the UK pound, the Indian rupee, the Japanese yen and the US dollar against the Sri Lankan rupee, January 2002 – August 2012. An increase in the value of the exchange rate indicates an appreciation of the Sri Lankan rupee. The shaded area indicates the period of global volatility from July 02, 2007 – August 30, 2012, while the dark shaded area represents the period from February 2012 – August 2012 – the period after changing the exchange rate policy stance.

Source : Central Bank of Sri Lanka

Table 1

Summary of Descriptive Statistics of Exchange Rates, expressed against the Sri Lankan Rupee: Jan 01, 2002 – Aug 30, 2012

Stat	Pre-crisis priod (Jan 01, 2002 – June 29, 2007)						Crisis period (July 02, 2007 – Aug 30, 2012)					
	EUR	GBP	INR	JPY	PKR	USD	EUR	GBP	INR	JPY	PKR	USD
All days												
	No. of observations: 1325						No. of observations: 1262					
Mean	0.009	0.006	0.455	1.153	0.569	0.010	0.006	0.005	0.397	0.871	0.679	0.009
Max	0.012	0.008	0.521	1.442	0.607	0.011	0.007	0.006	0.472	1.109	0.798	0.009
Min	0.007	0.004	0.363	0.975	0.513	0.009	0.006	0.004	0.345	0.675	0.534	0.008
Std dev.	0.001	0.001	0.036	0.095	0.020	0.000	0.000	0.001	0.029	0.122	0.090	0.000
Skewness	1.005	0.498	-0.158	0.982	-0.499	-0.455	0.457	-0.169	0.057	0.179	-0.404	-0.108
Kurtosis	3.242	2.398	2.713	3.628	2.388	2.354	2.796	1.616	2.308	1.563	1.601	2.107
Non-intervention days												
	No. of observations: 542						No. of observations: 489					
Mean	0.009	0.006	0.456	1.147	0.569	0.010	0.006	0.005	0.396	0.862	0.689	0.009
Max	0.012	0.008	0.521	1.441	0.603	0.011	0.007	0.006	0.453	1.099	0.795	0.009
Min	0.007	0.005	0.363	0.975	0.513	0.009	0.006	0.004	0.345	0.682	0.534	0.008
Std dev.	0.001	0.001	0.035	0.095	0.021	0.000	0.000	0.001	0.022	0.114	0.084	0.000
Skewness	1.012	0.513	-0.068	0.993	-0.558	-0.533	0.550	-0.306	-0.448	0.317	-0.540	-0.426
Kurtosis	3.235	2.412	2.544	3.600	2.461	2.391	2.790	1.567	2.697	1.536	1.802	2.558
Intervention days												
	No. of observations: 783						No. of observations: 773					
Mean	0.009	0.006	0.453	1.161	0.568	0.010	0.006	0.005	0.398	0.877	0.673	0.009
Max	0.012	0.008	0.521	1.442	0.607	0.011	0.007	0.006	0.472	1.109	0.798	0.009
Min	0.007	0.004	0.363	0.988	0.514	0.009	0.006	0.004	0.345	0.675	0.534	0.009
Std	dev.	0.001	0.001	0.038	0.095	0.020	0.000	0.000	0.001	0.032	0.126	0.093
Skewness	0.993	0.484	-0.236	0.983	-0.414	-0.340	0.393	-0.082	0.107	0.095	-0.313	0.143
Kurtosis	3.224	2.359	2.804	3.678	2.278	2.315	2.789	1.643	1.974	1.563	1.493	1.660

Some of the existing literature explicitly model heteroskedasticity through a generalized autoregressive conditional heteroskedasticity, in order to capture the volatility clustering phenomenon that can be observed in high frequency financial time series. This paper, however, does not focus on specifying GARCH conditional volatilities on the factors structured in Section 2 as it leads to an over parameterised model. Instead, possible heteroskedasticity is controlled in accomplishing the model through GMM.

5. Results

This section disentangles the exchange rate volatility as per the factor model Equations (5) and (6) discussed in Section 2. Section 5.1 presents the decomposition of exchange rate volatility during the pre-crisis period, whilst Section 5.2 presents the same for the crisis period. In both cases, the results are reported distinguishing non-intervention days and intervention days. Also, it is worth mentioning that the Central Bank of Sri Lanka intervenes by absorbing and supplying US dollars, expecting to impact upon other foreign currency rates through cross currency exchange rate movements.

5.1 Pre-crisis period

The decomposition of exchange rate volatility of the six exchange rates, expressed against the Sri Lankan rupee, is presented in Table 2. Disentangling exchange rate volatility into common, numaraire and idiosyncratic factors allows policy makers to understand the influence of domestic and external factors on overall exchange rate volatility as discussed in Section 2. The *J*–test is satisfied with a value of 34.22 and a *p*–value of 0.705. The number of degrees of freedom is 16.

As it can be seen in Table 2, volatility in exchange rates is mainly driven by the external factors (common and idiosyncratic factors), rather than the factors which arise in the domestic foreign exchange market. The only exception is the US dollar/ Sri Lankan rupee exchange rate during non-intervention days, where 51 per cent of the total volatility is attributed to the numaraire factor. The conclusion that the volatility is primarily externally sourced can be seen contrary to the general perception of the rupee exchange rate movements in Sri Lanka as it is believed that the exchange rate responds primarily to domestic market conditions such as availability and demand for foreign exchange. However, in this study, word "external" refers to factors which are not uniquely associated with the domestic foreign exchange market, hence it does not necessarily refer to international factors. Nevertheless this emphasizes the need for further investigations in this field of study as even this general perception is not validated through any quantitative analysis thus far. The large contribution of the numaraire factor to the volatility of the US dollar/Sri Lankan rupee exchange rate during the pre-crisis period under no intervention reflects the fact that the US dollar/Sri Lankan rupee exchange rate is independently determined while the exchange rate against other currencies are determined by applying the US dollar/Sri Lankan rupee exchange rate to their cross rates against the US dollar, as most of the transactions in the foreign exchange market are in US dollars.

Table 2

Volatility Decomposition during the Pre-crisis Period, in per cent

	Common	Numaraire	Idiosyncratic
Non-intervention days			
EURO	61.618	2.317	36.065
GBP	71.129	2.465	26.406
INR	1.823	3.682	94.495
JPY	34.511	2.542	62.947
PKR	0.024	5.228	94.747
USD	9.182	51.034	39.784
Intervention days			
EURO	37.586	28.616	33.798
GBP	38.892	28.042	33.066
INR	2.497	30.107	67.396
JPY	14.280	28.030	57.689
PKR	2.929	17.569	79.502
USD	3.262	35.703	61.035

Note: Volatility decomposition is based on the contribution to the total volatility.
Exchange rates are expressed against 1 unit of the Sri Lankan rupee.

It is also clear that more than 60 per cent of volatility of the euro/Sri Lankan rupee and British pound/Sri Lankan rupee exchange rate returns is due to the common factor in the non-intervention days, whilst more than 94 percent of Indian rupee/Sri Lankan rupee and Pakistan rupee/Sri Lankan rupee volatility stems from the idiosyncratic factors. With the exception of the Japanese yen, the common factor plays a large role in volatility of the currencies that represent advanced countries on non-intervention days. In the case of emerging market currencies, a considerable component of exchange rate volatility is attributed to the factors unique to their own foreign exchange markets. The contribution of the common factor to the volatility of these currencies is considerably small. However, capturing the contribution of domestic currency market specific factors which are transmitted through the US dollar/Sri Lankan rupee exchange rate remains an issue here.

The volatility decomposition of the intervention days provide some insight about the foreign exchange market in Sri Lanka. The most interesting observation here is the volatility of the US dollar/Sri Lankan rupee exchange rate return, where 61 percent of overall volatility comes from the US dollar market (idiosyncratic US dollar factor). Noting that the Central Bank of Sri Lanka intervenes only by absorbing or supplying US dollars, the volatility decomposition of the US dollar/Sri Lankan rupee in non-intervention days and intervention days suggests that the Central Bank intervenes in the foreign exchange market when the US foreign exchange market is highly volatile. This result, in fact, is in line with Fry-McKibbin and Wanaguru (2013), in which they have expressed the exchange rate as the amount of Sri Lankan rupees per unit of the US dollar.[6]

Although the contribution of the factors uniquely attributed to the domestic foreign exchange market (numaraire factor) to the overall volatility of the US dollar/Sri Lankan rupee exchange rate has decreased on intervention days compared to that of the non-intervention days, the contribution of the numaraire factor to all other currencies considered in the model is larger even if the Central Bank intervenes in the market. The relatively large contribution of domestic currency market specific factors to other currencies may be attributed to the higher variance of the US dollar/Sri Lankan rupee exchange rate. The variance of the US dollar/Sri Lankan rupee exchange rate is higher on intervention days compared to that of the non-intervention days and this variance seems high enough to make a relatively higher contribution to the variance of other bilateral exchange rates.

5.2 Crisis period

The factor model of exchange rate returns is re-run in this section for the crisis period and the results are presented in Table 3. As in the pre-crisis period model, this model also satisfies the *J*–test with a value of 26.74 and a *p*–value of 0.144 with 16 degrees of freedom.

The results indicate that the volatility of all exchange rate returns, including the US dollar/Sri Lankan rupee rate, in both the non-intervention and intervention regimes stems from external sources. The contribution of the factors attributed to the domestic currency market is 20 per cent in the euro/Sri Lankan rupee and the US dollar/Sri Lankan rupee exchange rates, but less than 4 per cent in all other cases.

6 Although one can interpret relatively higher contribution of the US dollar market as simply a reflection of reduced contribution of domestic factors as a result of intervention, Fry-McKibbin and Wanaguru (2013) have shown that intervention absorbs only a small portion of the volatility that is attributed to the domestic factor.

Table 3

Volatility Decomposition during the Crisis Period, in per cent

	Common	Numaraire	Idiosyncratic
Non-intervention days			
EURO	44.499	19.792	35.709
GBP	42.101	3.179	54.720
INR	11.281	3.144	85.575
JPY	3.213	3.522	93.266
PKR	0.063	2.556	97.381
USD	3.010	19.962	77.038
Intervention days			
EURO	38.789	13.312	47.898
GBP	66.386	11.808	21.806
INR	8.650	12.937	78.413
JPY	10.265	13.122	76.613
PKR	0.524	15.372	84.105
USD	0.038	13.931	86.030

Note: Volatility decomposition is based on the contribution to the total volatility. Exchange rates are expressed against 1 unit of the Sri Lankan rupee.

Notably, the factors uniquely associated with all currency markets except for the euro market tend to affect the respective currencies by explaining more than 50 percent of their volatilities in non-intervention days. Except for the case of the Indian rupee, the magnitude of this influence is larger compared to the results reported for the pre-crisis period. These results provide evidence of the increased volatility in foreign exchange markets around the world after 2007. Although, the volatility in the Indian foreign exchange market related factors is smaller than the non-intervention day results reported for the pre-crisis period, it still exceeds 85 per cent of total volatility of the Indian rupee/Sri Lankan rupee exchange rate returns.

During the intervention days, the contribution of the idiosyncratic US and Euro foreign exchange market related factors have increased, suggesting that the Central Bank has responded to the volatility increase in these foreign exchange markets in the face of the recent US and euro based crises. The volatility decomposition also reveals that the contribution of the numaraire factors of the US dollar/Sri Lankan rupee and the euro/Sri Lankan rupee returns have decreased compared to the non-intervention day volatility. Together, these results suggest that the Central Bank of Sri Lanka tries to shield its domestic foreign exchange market against possible adverse effects coming from crisis originated countries. Though it is debatable whether a country, especially a small open economy like Sri Lanka, can curb externally sourced volatility effects by adjusting domestic policies, the Sri Lankan Central Bank's action can be interpreted as a way of preventing the spread of the effects of the crisis in to the foreign exchange market in Sri Lanka.

As a diagnostic test, the significance of the structural break terms introduced to the model for the crisis period were tested using the Wald test and all the structural break parameters were found to be jointly significant with F-test of 2084.23 (with p–value of 0.000).

5.3 The period after changing the policy stance

The exchange rate policy in Sri Lanka has not changed much since the introduction of the floating exchange rate regime in January 2002. Although the Central Bank of Sri Lanka followed the floating exchange rate since 2002, it reserved the right to intervene in the foreign exchange market either to build up the country's stock of international reserves or to curb excess volatility in the market as is the convention in any central bank who follow the floating exchange rate policy. History shows that the central bank has intervened in the foreign exchange market frequently until 2012. However, the Central Bank decided,

Table 4

Volatility Decomposition in the Period after February 2012, in per cent

	Common	Numaraire	Idiosyncratic
Non-intervention days			
EURO	7.200	25.088	67.712
GBP	14.264	34.726	51.009
INR	43.877	23.964	32.159
JPY	13.146	45.483	41.371
PKR	5.480	62.004	32.517
USD	5.617	55.544	38.839
Intervention days			
EURO	27.188	6.762	66.050
GBP	17.711	6.681	75.608
INR	37.781	8.745	53.475
JPY	33.246	7.847	58.907
PKR	81.495	7.271	11.234
USD	60.702	6.142	33.156

Note: Volatility decomposition is based on the contribution to the total volatility.
Exchange rates are expressed against 1 unit of the Sri Lankan rupee.

on February 09, 2012, to limit its intervention in the domestic foreign exchange market to allow more flexibility in determining the exchange rate.

This section re-runs the factor model of exchange rate returns for the period from February 09 to August 30, 2012 to identify the contribution of each factor to the total volatility of exchange rate returns of the six bilateral exchange rates after limiting intervention by the Central Bank. Results are reported in Table 4. The estimated model satisfies the *J*– test with *p*–value of 0.948.

The volatility decomposition reported in Table 4 is strikingly different from the crisis period results reported in Table 3. The euro/Sri Lankan rupee and the British pound/Sri Lankan rupee exchange rate volatility on non-intervention days now stems from factors uniquely attributed to the European and the UK currency markets, reflecting the higher exchange rate volatility in the currency markets in the Euro area that spills-over to the other currency markets. The percentage contributions of the idiosyncratic factor of all other currency markets on non-intervention days are lower than the contribution of the crisis period. Notably, most of the volatility of the Indian rupee/Sri Lankan rupee exchange rate comes from factors common to all currency markets.

The percentage contributions of the numeraire factor to the total volatility of all the exchange rate pairs in the model on non-intervention days play an important role after the change in exchange rate policy in Sri Lanka. This suggests that the volatility of the foreign exchange market during this period is mainly driven by shocks which stem domestically. Specially, the numaraire factor accounts for 56 per cent and 62 per cent in US dollar/Sri Lankan rupee and Pakistan rupee/Sri Lankan rupee exchange rate volatility, respectively.

Decomposition of exchange rate volatility on intervention days is clearly different to the decomposition results reported in both the pre-crisis and crisis periods. Most interestingly, it is observed that the contribution of the factors unique to the domestic foreign exchange market (numaraire factor) decreases as the Central Bank intervenes in the currency market. Further, the factors common to all currency pairs in the model (common factor) now play a major role in the volatility decomposition of the US dollar/Sri Lankan rupee and Pakistan rupee/Sri Lankan rupee exchange rate volatilities. For all other currency pairs, factors unique to the respective currency markets make the highest contribution to the exchange rate volatility. Most importantly, the sizable contribution of the factors uniquely associated with the European and the UK currency markets (idiosyncratic euro and GBP factors) are higher, reflecting the higher currency and financial market volatility which prevails in the European region.

The volatility decomposition on intervention days highlights some important insights. First, the results clearly show that the Central Bank of Sri Lanka has changed its exchange rate policy stance. Specially, intervention does not aim volatility uniquely associated with the US currency market. Further, these results suggest that the new policy stance which is following by the Central Bank has been able to curtail the shocks which originate domestically. More than 90 per cent of the currency market volatility on intervention days is now attributed to the shocks coming from external factors. This implies that the recently adopted exchange rate policy stance is appropriate in curtailing the effects of domestic factors. These results, in turn, suggest that the Central Bank has to change its policy stance towards the foreign exchange market from time to time, in line with developments in the foreign exchange markets. However, further research is needed to assess robustness of these findings as the empirical analysis is limited to a relatively short period.

6. Concluding Remarks

Decomposition of exchange rate volatility to identify the magnitude of the contribution of external factors and factors unique to the domestic currency market to overall volatility of the exchange rate return is a cluttered area of international finance. This paper attempted to fill that gap in the literature using high frequency data on six currencies namely euro, the British pound, the Indian rupee, the Japanese yen, the Pakistan rupee and the US dollar, all expressed against the Sri Lankan rupee. The period considered was extended from January 2002 to August 2012. This period was divided into two periods: the pre-crisis period which covered the period from January 2002 to June 2007, and the crisis period which covered the period from July 2007 to August 2012. An additional empirical investigation is carried out for the period from February 2012 to August 2012, to capture the impact of the structural change after limiting foreign exchange intervention by the Central Bank of Sri Lanka. A latent factor model, which is considered as a parsimonious way of modelling common shocks that underlie the co-movements of large time series was applied as the empirical methodology. The model was accomplished through GMM, distinguishing days on which the Central Bank intervenes and does not intervene in the foreign exchange market.

The factor structure allowed disentangling unconditional exchange rate volatility into three factors; two factors attributed to external shocks and one factor attributed to the domestic currency market. This paper offers empirical evidence that the volatility of exchange rate returns in Sri Lanka is mainly driven by externally sourced shocks. The empirical results for both the pre-crisis and crisis periods suggest that the Central Bank of Sri Lanka mainly responds to externally sourced factors rather than factors uniquely associated with the domestic foreign exchange market. Specifically, the Central Bank's focus is the volatility that comes from major currency markets. The Central Bank's policy response was mainly aimed at the idiosyncratic US currency market related factors during the pre-crisis period, and to the idiosyncratic euro and US currency market factors during the period related to the recent financial crisis. The latter suggests that the Central Bank has attempted to shield its currency market against the shocks coming from the two crisis originating countries' currency markets. However, it would be more interesting if it identifies whether this higher contribution of the idiosyncratic euro and US factors is merely a spill-over effect or mainly driven by contagion effect, which appears only in crisis periods. This is left for future research. Both the pre-crisis analysis and the crisis period analysis reveal that the Central Bank can play only a limited role as the volatility of the exchange rate is mainly attributed to external factors. Despite the fact that the crisis in the Euro area is still evolving, the current exchange rate policy stance introduced at the beginning of 2012 has had the effect of reducing volatility that stems from domestic currency market related sources.

This paper highlights some important policy implications for central banking practice in Sri Lanka and, potentially, other small open economies. The Central Bank of Sri Lanka has limited scope in mitigating exchange rate volatility when such volatility comes from external sources. Specifically, frequent intervention in the foreign exchange market does not seem to absorb volatility unique to the domestic currency market in such circumstances. Instead, intervening in the foreign exchange market when its volatility is mainly driven by domestic factors (isolated intervention) is shown to be more effective.

This study stands as an early attempt in applying the latent factor model to decompose exchange rate volatility in Sri Lanka. Therefore, it emphasizes the need for further research in this line of study. Although the latent factor model overcomes the issues related to conditioning on observed data to identify the sources of exchange rate volatility, which, in turn stands as a limitation of this methodology as it does not identify the role of any particular observed variable. Though challenging, research to overcome this limitation would be a significant contribution in the field of international finance.

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