The Costs of Foreign Exchange Intervention
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Abstract

Central Banks around the world increasingly intervene in the foreign exchange market for a variety of reasons, such as maintaining exchange rate stability. In fact, research shows that central banks can lean against the macroeconomic policy trilemma through maintaining reserves and intervening in the foreign exchange market, and secure policy space. However, securing this policy space can come at substantial cost. In particular, there are substantial costs associated both with building and holding reserves of foreign exchange and using reserves to intervene in the foreign exchange market. This paper seeks to estimate the costs of foreign exchange intervention undertaken by central banks around the world, and examine how these costs are affected by country characteristics. In particular, the paper examines the variation of the costs between advanced and developing countries, and the effect of policy tools on these costs. The paper also makes policy recommendations for mitigating the costs of foreign exchange intervention.

1 Introduction

Central Banks regularly intervene in the foreign exchange markets. One of the most common forms of foreign exchange intervention is sterilized sale and purchase of international reserves by Central Banks. There is evidence to suggest that interventions increasingly take the form of purchases of foreign exchange reserves (Fratzscher et al., 2016; Levy Yeyati, 2008). For instance, Fratzscher et al. (2016) find that, in the 33 countries examined, central banks intervened in the foreign exchange market on 19.1% of the trading days between 1995 and 2011; of these, interventions took the form of purchases of foreign currency on 76.1 % of the trading days. Their findings are consistent with other studies that document extensive central bank activity in the foreign exchange markets (Dominguez and Frankel, 1993; Menkhoff, 2013).

The trilemma of international economics states that it is only possible to maintain two of the following three policy objectives in an economy: fixed exchange rates, open capital account, and independent monetary policy. However, holding foreign exchange reserves allows central banks to weaken the constraints of the policy trilemma. As is described above, holding reserves can be used to act against undesirable movements of the exchange rate and cushion against the effects of volatile capital flows, among other things. Therefore, reserve holdings allow countries to lean against the trillema (Ilzetzki et al., 2017; Aizenman et al., 2010; Steiner, 2017).

Consequently, there has been an unprecedented increase in the accumulation of foreign exchange reserves in Central Banks around the world. Moreover, this accumulation is especially pronounced in developing countries and emerging market economies. However, as is demonstrated in this paper, the cost of maintain foreign exchange positions is significant. This paper measures the cost of maintaining foreign exchange reserves by central banks, and documents its variation across countries. It also discusses the determinants of this variation across countries.

The rest of this paper is organized as follows. Section 2 briefly reviews the existing literature on reasons for reserve accumulation, extent and determinants of reserve accumulation and cost of reserve accumulation and foreign exchange intervention. Section 3 lays out the definition of cost on which the analysis is based. Section 4 outlines the data used. Section 5 documents the extent of reserve accumulation and estimates the cost of foreign exchange intervention, while Section 6 discusses the potential determinants of these costs. Based on this, Section 7 outlines the empirical model and the results, and Section 8 discusses the results.

2 Literature Review

In the heyday of neoliberal restructuring all over the world, especially since the 1990s, openness of the external account was considered the order of the day. Governments were expected to reduce their intervention in markets and allow the market determination of all prices, including the exchange rate. Capital controls were considered an impediment to market discovery and a hurdle that needed to be overcome in order to achieve financial and economic development. Therefore, intervention in the foreign exchange market by central banks was considered an inefficient ineffective tool of maintaining undervalued exchange rates for the purposes of export promotion or the pursuit of mercantilist objectives. The established wisdom that market fundamentals would eventually make foreign exchange interventions unsustainable in the long run, and anticipating this, market forces would make it ineffective in the short run. The skepticism regarding foreign exchange intervention also stems from the sheer size of the foreign exchange market: it is the largest financial market in the world (Fratzscher et al., 2016). Therefore, the size of interventions is dwarfed by the volume and size of transactions that take place in a particular currency in the foreign exchange market.

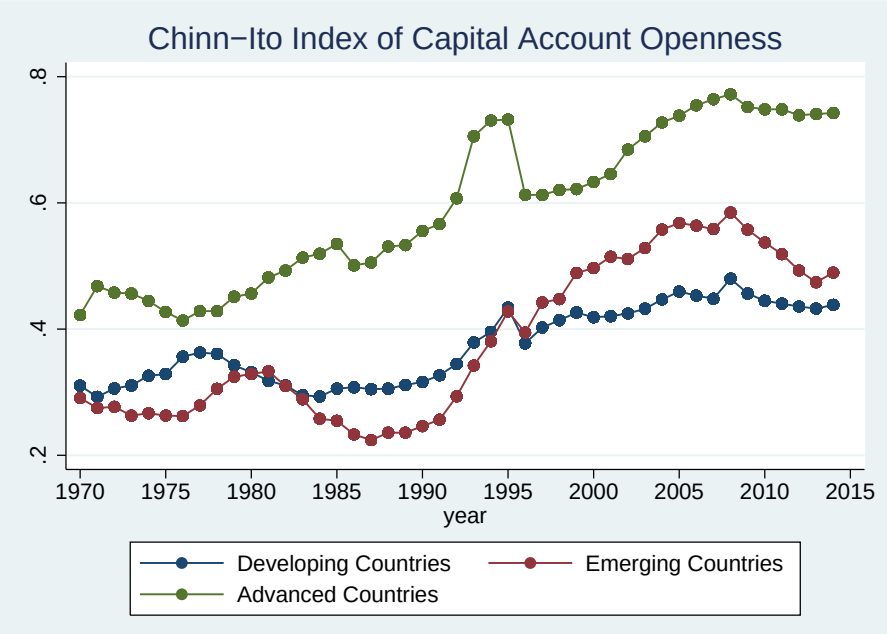
However, evidence suggests that foreign exchange interventions by central banks can be highly effective. For instance, Dominguez and Frankel (1993) find that intervention by the Federal Reserve and the Bundesbank was effective in moving the exchange rate in the desired direction in the mid-1980s. Adler et al. (2011) focus on Latin American economies to find that interventions can slow the pace of appreciation of the exchange rate. However, these effects decrease with the degree of capital account openness and are more effective in the context of already overvalued exchange rates. Fatum and Hutchison (2003) provide evidence that sterilized intervention affects the exchange rate in the short run. Menkhoff (2013) surveys the literature on exchange rate interventions and argues that foreign exchange intervention often has an impact on exchange rate level and volatility in emerging market economies. Fratzscher et al. (2016) argue that intervention has been effective tool for smoothing the path of exchange rates and in stabilizing the exchange rate in countries with narrow bank regimes. It is also effective in affecting the level of exchange rate in flexible exchange rate regimes when interventions are large and have been publicly announced. Blanchard et al. (2015) find that official reserve intervention can stem pressures of currency appreciation in the face of capital inflows in emerging market economies. Therefore, the current consensus in the intervention literature seems to be that foreign exchange interventions can be effective for a variety of exchange rate related policy objectives.

In addition, official reserve holdings can provide a buffer against a freely falling currency in the event of a sudden stop or reversal in capital flows. Bussière et al. (2015)

find that pre-crisis levels of reserves and capital controls are associated with higher economic growth as they are both used to buffer against external shocks. Holding of international reserves equal to at least the value of short term external debt reduces the annual probability of a country experiencing a share reversal in capital flows, which can precipitate and external debt and/or currency crisis, by 10 percentage points (Rodrik, 2006). Moreover, a rise in reserve holdings often lowers the cost of private debt and equity capital (Feldstein, 1999). To some extent, reserve holdings have substituted for capital controls (Ilzetzki et al., 2017). Reserve accumulation is considered a by-product of a shift to the trilemma configuration towards greater capital mobility (Steiner, 2017) engendered by financial globalization. Therefore, reserve holdings can be considered insurance against the costs of sudden stops and reversals in capital flows.

Perhaps unsurprisingly, accumulation of reserves has increased substantially with the increasing liberalization of the capital account around the world since 1990 (Rodrik, 2006) and the East Asian crisis in 1997 (Aizenman and Lee, 2005; Aizenman et al., 2010). Capital account openness as measured by the Chinn-Ito index has increased for all groups of countries examined (Figure 1).[1]

Figure 1: Capital Account Openness (Chinn-Ito Index) over time



Source: Author's calculations based on Chinn and Ito (2006)

Accumulation of reserves has also been pronounced in Asian economies since the Asian financial crisis. For instance, between 2000 and 2004, China, Japan, Korea,

[1]While the country classification into developing and advanced countries is based on the *World Economic Situation Prospects* of the UN, the classification as emerging economies is more ambiguous. Here, countries are classified based on the country classification used in Chinn and Ito (2006).

Malaysia, and Taiwan increased their holding of international reserves by 262 percent, 133 percent, 107 percent, 124 percent, and 126 percent, respectively (Cheung and Ito, 2009). Similarly, Bussière et al. (2015) argue that the rate of reserve accumulation has partly been a response to crisis experienced in emerging market economies in the recent past. Countries that used more reserves in the past during crises rebuilt their reserve pool at a faster rate as compared to others in the aftermath of crises, with the rate of accumulation eventually slowing down. However, the decrease in the rate of reserve accumulation can be attributed to the decline in the rate of increase of short-term external debt (Bussière et al., 2015). Cheung and Ito (2009) show that the explanatory power for traditional trade-related variables in explaining reserve accumulation is decreasing over time, while that of financial variables related to external financing has increased. They also show that, ceterus paribus, developed economies can afford to hold fewer reserve assets as compared to developing economies if faced with the same conditions. Obstfeld et al. (2010) argue that reserve accumulation is a key tool for managing financial stability in a globalized world and show that reserve growth in a broad panel of developing and developed economies is correlated with financial openness, financial development,and exchange rate policy. Dominguez (2012) shows that, during the global financial crisis, reserve accumulation was higher in countries with sovereign wealth funds, lower for countries that drew on Federal Reserve Swap Lines, higher in countries with higher short-term external debt as a proportion of GDP, higher for countries that experienced higher export growth, and lower for countries with a higher interest rate differential.

While the literature documenting the extent of reserve accumulation, and the reasons for it is extensive, the literature on the cost associated with it is quite limited, perhaps due to the perception that these costs are marginal and of second order importance (Adler and Mano, 2016). Nonetheless, (Rodrik, 2006) approximates this cost for different country groups (developed, developing, and emerging) assuming different spread levels, and finds that the social opportunity cost of excess reserves stood at about 1 percent of GDP of developing economies as of 2004. However, (Rodrik, 2006) does not use actual spreads for calculating costs and does not account for currency depreciation. (Levy Yeyati, 2008) argues that the literature on the cost of reserve accumulation overestimates the cost as it does not consider the benefits of reserve accumulation in the form of the reduced probability of crisis and the reduced borrowing costs. Therefore, (Levy Yeyati, 2008) argues that the marginal cost of reserve accumulation is typically overestimated by about 50 percent. Nonetheless, this study also does not calculate the total costs being incurred ex-post given the levels and accumulation of reserves across counties. Adler and Mano (2016) is, to the author's knowledge, the only study that systematically estimates the marginal and total costs of reserve accumulation for a set of 73 developed and developing economies during 2012-13, and find that ex-ante marginal cost incurred by the median emerging market economy was in the inter-quartile range of 2–5.5 percent

per year, and total costs in the range of 0.3–0.9 percent of GDP per year. Moreover, about 20 percent of the countries in their sample incurred greater than 1 percent of their GDP in sustaining foreign exchange reserve assets per year over the sample period. This study follows their method, and extends the period and sample of analysis.

3 Definition of Cost

However, this insurance against sudden stops and reversals of capital flows is an expensive proposition. Foreign exchange reserves are typically held in the form of highly liquid safe assets, such as sovereign bonds of some developed nations, especially short term US Treasury securities. However, the cost of acquiring these reserves is typically much higher than the return on these safe assets. Therefore the cost of foreign exchange intervention is the cost of maintaining a given foreign exchange reserve position.

In order to consider operations that are strictly foreign exchange transactions and not monetary policy actions, the literature on foreign exchange interventions typically consider sterilized interventions by the Central Bank. A sterilized foreign exchange intervention is one in which the central banks substitutes between foreign and domestic assets on its balance sheet. Therefore, if the central bank purchases (sells) foreign exchange, it typically also sells (purchases) domestic assets such as government bonds through open market operations, so as to leave the monetary base and monetary policy rate unchanged.

Formally, the change in a central banks net foreign asset position, ΔNFA due to a foreign exchange operation is

$$\Delta NFA = \Delta MB - \Delta NDA \tag{1}$$

where ΔMB is the change in the monetary base and ΔNDA is the net domestic asset position of the central bank (Adler and Mano, 2016). If the intervention is fully sterilized,

$$\Delta NFA = -\Delta NDA \tag{2}$$

Adler and Mano (2016) argue that the extent of sterilization of the official reserve operation is irrelevant from the perspective of the opportunity cost of foreign exchange intervention. For instance, in the case of a reserve purchase, the extent of the operation that is unsterilized and results in an expansion of the monetary base carries the higher

forgone interest that could be earned for the central banks from holding domestic assets. Therefore, the marginal cost of the operation would be the opportunity cost of increasing the foreign exchange reserve asset position of the Central Bank, measured by deviations from uncovered interest parity:

$$MC_{k,t+1} = \frac{1 + i_{k,t}}{1 + i_t^*} \frac{S_{k,t+1}}{S_{k,t}} - 1 \tag{3}$$

where $i_{k,t}$ is the nominal interest rate on the domestic government assets, i_t^* is the nominal interest rate on the reserve asset, and $S_{k,t}$ is the exchange rate expressed as the units of local currency per unit of foreign currency. Taking logarithms on both sides of equation 3,

$$\begin{aligned} mc_{k,t+1} &= ln(1 + MC_{k,t+1}) \\ &= ln(1 + i_{k,t}) - ln(1 + i_t^*) + ln(S_{k,t+1}) - ln(S_{k,t}) \\ &\approx (i_{k,t} - i_t^*) - \Delta s_{k,t+1} \end{aligned} \tag{4}$$

where $\Delta s_{k,t+1}$ is the log change in exchange rate from time t to $t + 1$.

The total cost of foreign exchange intervention is thus

$$TC_{k,t+1} = MC_{k,t+1} \times NFA_{k,t} \tag{5}$$

Since most central banks are quasi-government bodies that typically transfer their surpluses to the government, this total costs is the quasi-fiscal cost of foreign exchange intervention.[2]

4 Data

The data related to reserve holdings and external debt is from the International Financial Statistics produced by the IMF, World Development Indicators produced by the World Bank, and OECDstat. [3] In addition, data on capital account openness is based on the index created by Chinn and Ito (2006). This index is a composite of a variety of factors

[2]This formulation assumes that there is no maturity mismatch between reserves and debt (Levy Yeyati, 2008).

[3]However, in order to accurately calculate the cost, this paper will be revised with estimations based on data on official reserve transactions from central banks itself for the subsets of countries for which it is available.

that determine the degree of capital account openness based on the Annual Report on Exchange Arrangements and Exchange Restrictions. Data on the the countries that have access to swap arrangements and/or are members of regional financial arrangements has been taken from Scheubel and Stracca (2016). A complete list of variables used and their sources are listed in Appendix I.

The classification of countries into advanced and developing is based on the classification of the United Nations Conference on Trade and Development (UNCTAD). The classification of countries into emerging markets is slightly trickier as UNCTAD and other multilateral organizations do not classify countries as emerging market economies. It seems more to be a matter of convention and varies from study to study. For the purposes of this paper, the classification of Chinn and Ito (2006) is used. The complete list of countries studied and their classifications are listed in Appendix II.

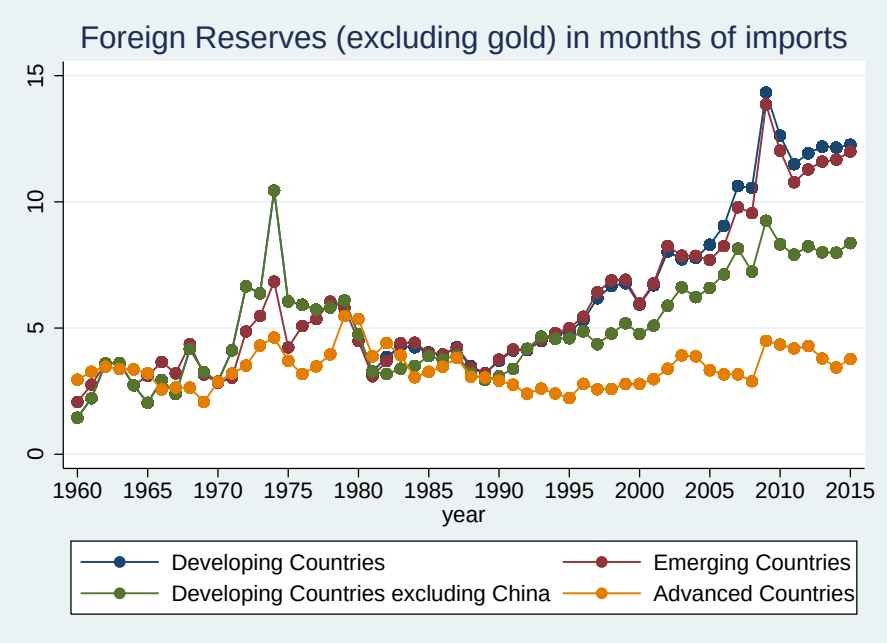
5 Extent and Cost of Foreign Exchange Intervention

Even during the heyday of neoliberal restructuring of external accounts, it was recognized that maintaining liquidity is the "key to financial self-help." Countries that hold substantial internationally liquid foreign currency reserves and/or a ready source of foreign currency loans were considered to be less likely to experience a speculative currency attack (Feldstein, 1999). As a rule of thumb, it is considered good practice for central banks to maintain reserves worth three months of imports. However, central banks have been holding reserves far in excess of the three month convention (Figure 2). In particular, Figures 2 and 3 show that there is a marked upward trend in the reserve holdings of developing and emerging economies since the 1990s. Essentially, central banks were expected to maintain international reserves equal to the value of the country's debt that is due within a year. Figure 4 shows that central banks in almost all emerging market economies were holding reserves greater than the short term external debt of the country by 2004, in sharp contrast to 1990. This is the Guidotti-Greenspan-IMF rule (Rodrik, 2006). Interestingly, the level of reserves in terms of months of imports has remained quite stable around the 3-month mark for advanced countries.

Based on the definition of quasi-fiscal costs in Section 3, the trends in the costs of foreign exchange intervention can be observed in Figure 5.[4] As mentioned previously, the cost of foreign exchange intervention has been estimated as the deviations from uncovered interest parity. This quasi-fiscal cost of holding reserves calculated based on the spread between short-term sovereign bonds and US Treasury Securities. Since no interest is received on reserves held in the form of gold, these are excluded in the

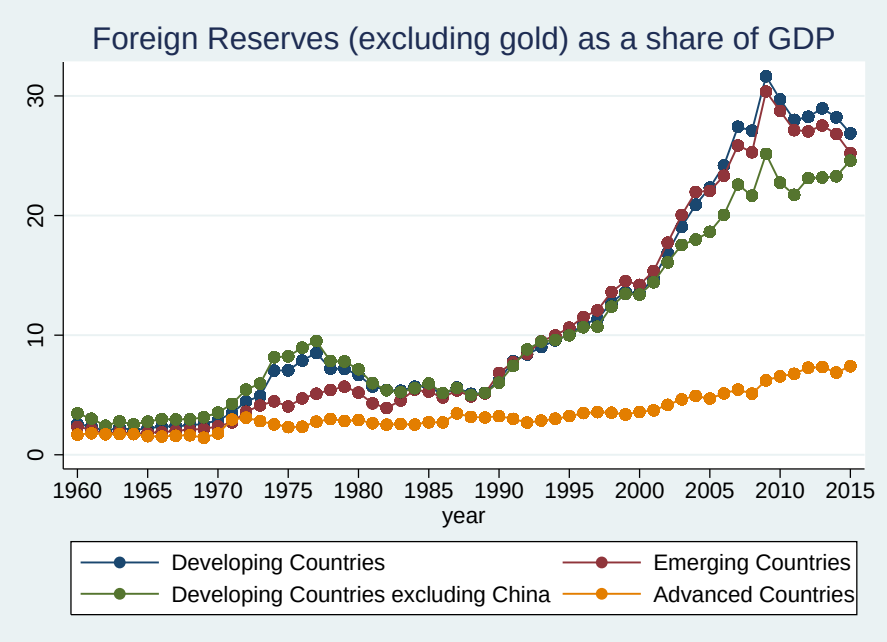
[4]The holding of reserves to conform to the Guidotti-Greenspan rule of thumb are excluded from total reserves for the purposes of calculation of the costs of holding reserves.

Figure 2: Foreign Reserves (excluding gold) in months of imports



Source: Author's calculations

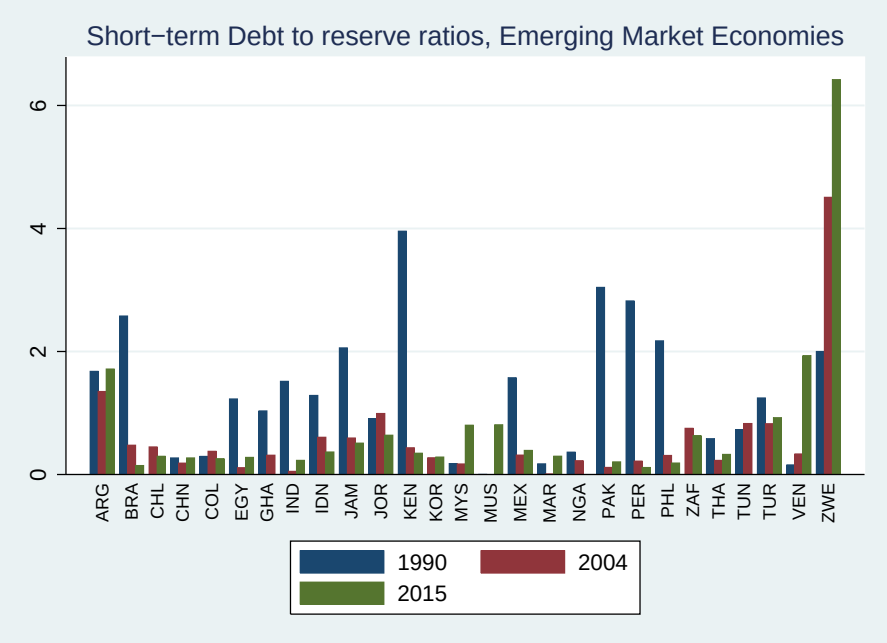
Figure 3: Foreign Reserves (excluding gold) as a share of GDP



Source: Author's calculations

calculation of costs of holding reserves. While appreciation in the price of gold can be considered a return on reserve holdings, they are excluded in the estimation of costs in Figure 5. This is unlikely to significantly affect the cost estimate since an increasing

Figure 4: Short-term Debt to reserve ratios, Emerging Market Economies



Source: Author's calculations

proportion of reserves are being held in the form of non-gold assets at least in developing and emerging economies. However, as is evident from Figure 6, about 50 % of reserves of advanced economies are held in the form of gold reserves.

6 Factors that determine Reserve Accumulation and its Cost

6.0.1 Country Group

In 2014, EMEs and developing economies incurred at least a cost of 0.91 percent and 0.86 percent of their GDP, respectively, for holding excess reserves. Table 1 shows the summary statistics of the costs incurred by year by developing countries. The average understates the magnitude of the costs incurred by some countries; therefore, table 1 also lists the maximum cost incurred in any given year after 1990 and the country incurring it. Figure 7 shows the histogram of the distribution of quasi-fiscal costs incurred by developing countries in 2014. Nearly 62 percent of developing countries incurred non zero costs, and about 16 percent spent greater than 1 percent of their GDP in holding foreign exchange reserves in 2014.

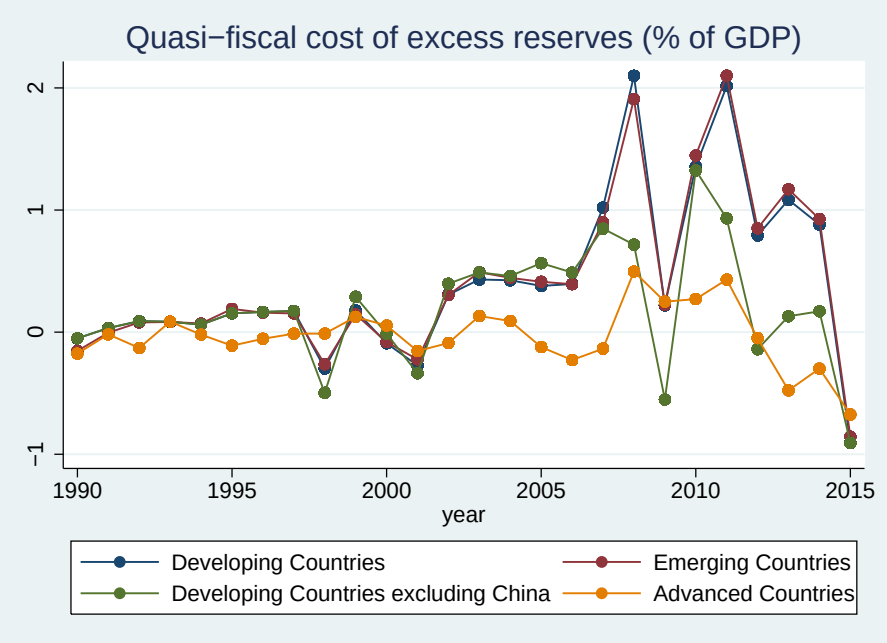
The magnitudes of the costs are not insignificant. For instance, in 2000, the Gov-

Table 1: Summary Statistics-Quasi-fiscal cost of Foreign Exchange Reserves of Developing Countries

Year	**Mean**	**Standard Deviation**	**Maximum**	**Country incurring Maximum cost**
1990	0.166	0.903	4.282	Zambia
1991	0.071	0.582	2.944	Jamaica
1992	-0.005	0.647	1.838	Nigeria
1993	-0.176	0.739	1.766	Guyana
1994	0.002	0.639	2.809	Malawi
1995	-0.051	0.778	1.526	Hungary
1996	-0.229	0.996	1.381	Guyana
1997	-0.096	0.482	0.832	Lesotho
1998	-0.229	1.089	1.589	Lao
1999	0.017	0.812	4.502	Indonesia
2000	0.010	0.562	2.634	Ghana
2001	-0.084	0.574	1.229	Turkey
2002	0.163	0.745	2.795	Czech Republic
2003	0.249	1.342	4.621	Malta
2004	0.159	0.845	2.057	Albania
2005	0.106	0.558	2.051	Yemen
2006	0.127	0.464	2.203	Yemen
2007	0.469	1.240	9.321	Iraq
2008	0.489	1.404	6.568	Iraq
2009	-0.142	1.467	2.863	Lebanon
2010	0.480	0.963	4.075	Lesotho
2011	0.621	1.058	4.399	Iceland
2012	0.072	0.897	2.849	Lebanon
2013	0.169	0.809	2.771	Lebanon
2014	0.063	0.578	2.956	Lebanon
2015	-0.839	2.177	2.831	Lebanon
Total	0.083	1.004	9.321	Iraq

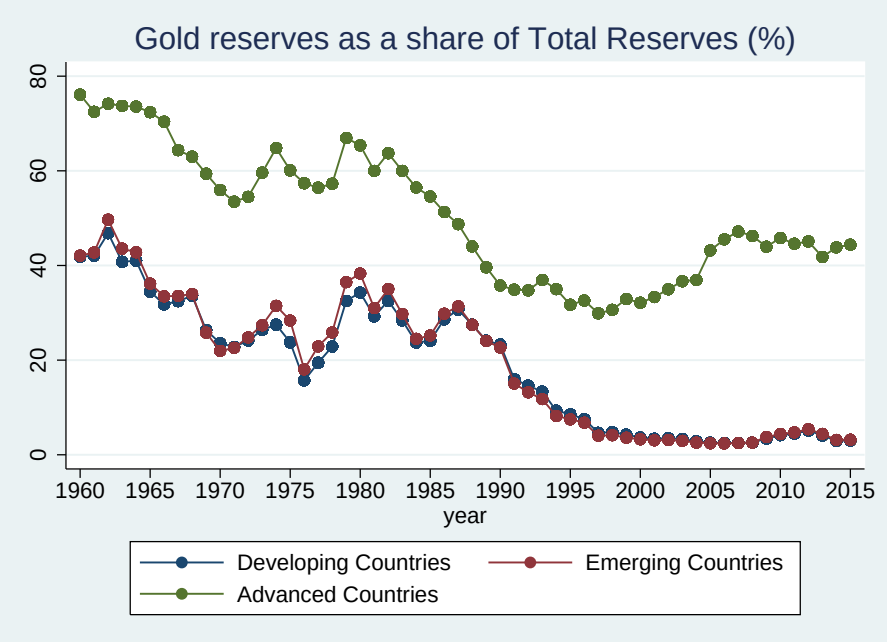
Source: Author's calculations

Figure 5: Quasi-Fiscal Cost of Excess Reserves (% of GDP)



Source: Author's calculations

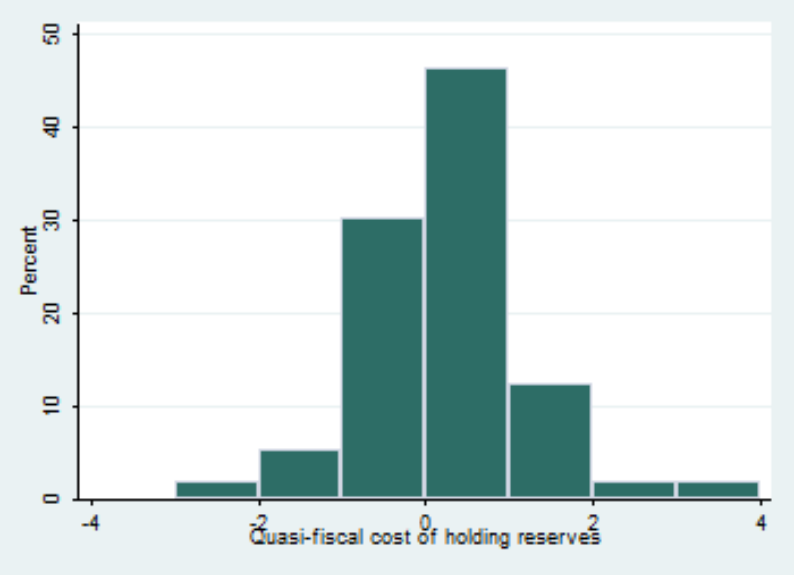
Figure 6: Gold reserves as a share of Total Reserves (%)



Source: Author's calculations

ernment of Ghana spent 1.5 percent of its GDP on healthcare, but incurred nearly 4.3 percent of its GDP in conducting foreign exchange intervention. In 2010, government expenditure on education in Lebanon was 5.5 percent, which is comparable to the cost

Figure 7: Histogram of Quasi-fiscal cost of developing countries in 2014



it incurred on foreign exchange intervention reserves (4.3 percent). In the middle of a severe financial crisis, the Icelandic economy spent 4.5 percent of its GDP on foreign exchange intervention.

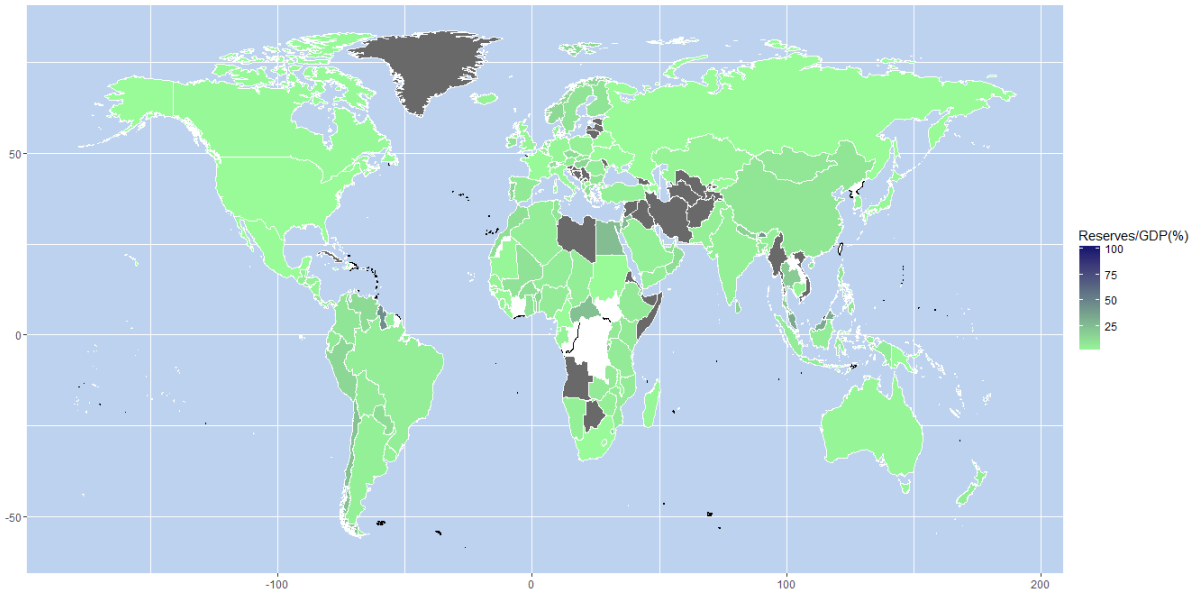
Once again, it is interesting to note that advanced economies are on average incurring close to zero quasi-fiscal costs over the period under consideration. Clearly, this is partly because advanced countries are holding a higher share of their reserves in the form of gold as opposed to foreign currency assets and partly because central banks in these countries do no hold significant excess reserves. However, these near-zero costs are interesting especially since, on average, the advanced economies have more open capital accounts (Figure 1).

6.0.2 Capital Account Openness

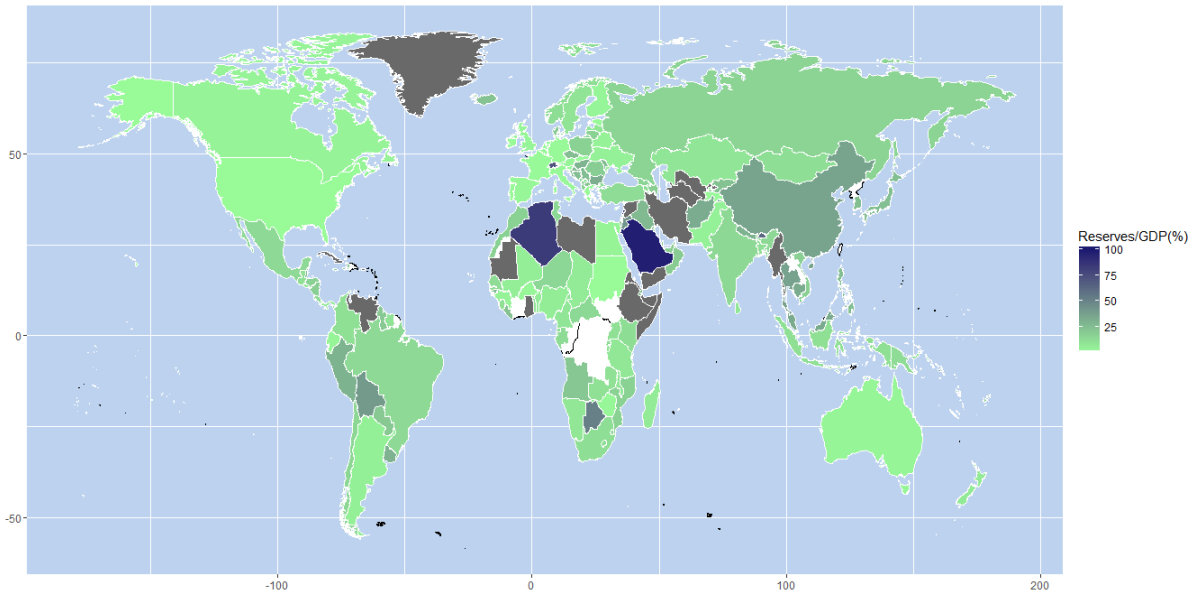
In addition to the disparity between the cost incurred by emerging and developing economies as a group and advanced economies as a group, there is also significant variation within these groups. In 2014, the Reserves to GDP ratio varied from 1.8 % in Slovenia to about 113 % in Hong Kong. Official reserve interventions can be seen as a substitute for capital controls (Steiner, 2017; Ilzetzki et al., 2017). From Figures 8 and 9, we can see that both the reserves to GDP ratio in several countries in the world and the degree of capital account openness has increased between 1994 and 2014. The darker the shade in Figure 8 and 9, the higher is the reserve to GDP ratio and degree of capital account openness of the economy, respectively. However, it is not immediately apparent if countries with more open capital accounts have higher reserve accumulation

Figure 8: Reserves to GDP ratio, 1994 and 2014

(a) 1994



(b) 2014

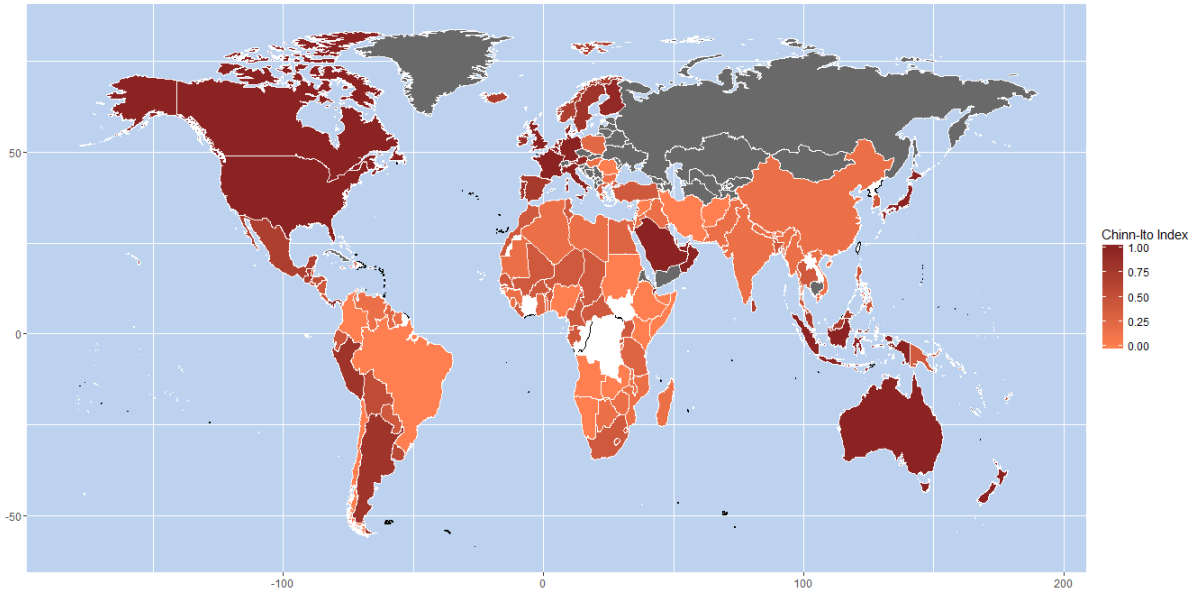


Note: Countries are shaded gray if data was not available

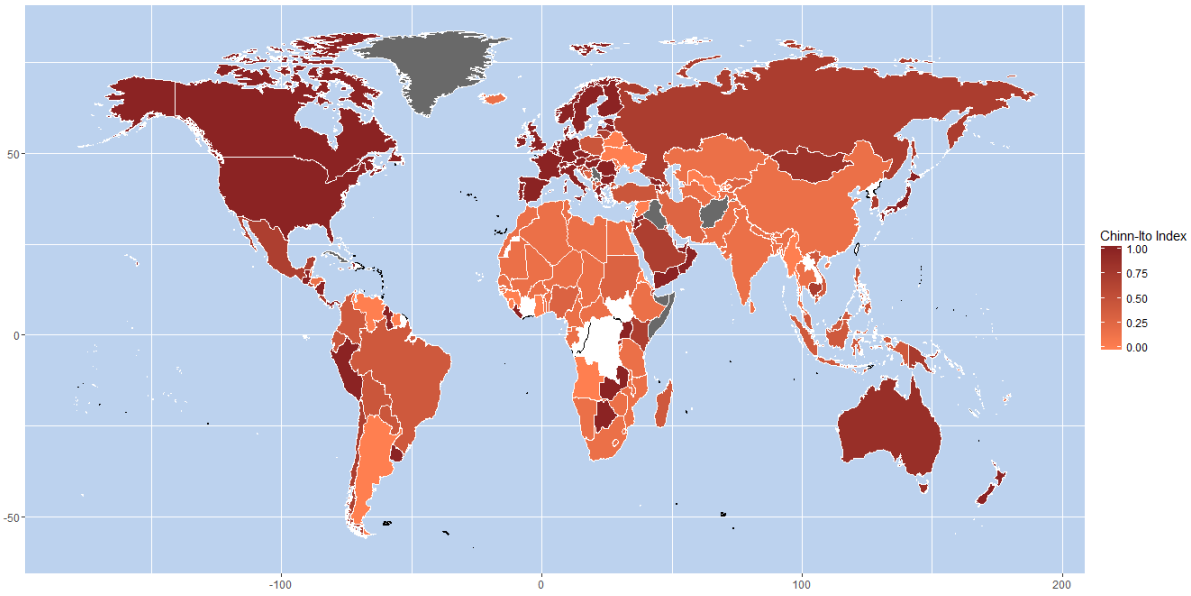
and higher costs of foreign exchange intervention.

Figure 9: Capital Account Openness, 1994 and 2014

(a) 1994



(b) 2014



Note: Countries are shaded gray if data was not available

6.0.3 Trade and Financial Variables

The size of a country's trade and exchange rate volatility is likely to affect the extent of foreign exchange intervention. However, in their exploration of the determinants of reserve holdings, Obstfeld et al. (2010) compare whether trade related or financial variables offer a better explanation the accumulation of reserves. They argue that financial motives have always been an important motivation for the accumulation of reserves as an adverse shock to the balance of payments can arise from domestic deposit holders moving their assets abroad. In other words, in addition to sudden stops and share reversals of capital flows, capital flight is associated with domestic financial instability, and therefore domestic financial stability is an important consideration as regards reserve accumulation. The central bank can stem the depreciation pressure in this event using its reserves. Obstfeld et al. (2010) argue that since the extent of the flight of capital out of domestic bank deposits depends on the size of M2 or the broad money supply, its size should play a role in determining the size of the reserve holdings of the central bank. Consequently, the size of M2 should play a role in determining the cost of foreign exchange intervention.

Additionally, the nature of the exchange rate regime is likely to have an impact on the size of reserve holdings. Have a pegged or de facto pegged exchange rate would require central banks to sell foreign exchange to stem pressures on the currency to depreciate and absorb foreign exchange to stem pressures on the currency to appreciate. Therefore, central banks in economies with pegged exchange rates are likely to hold higher reserves.

6.0.4 International Lender of Last Resort

It is also interesting to note that this system is consistently less expensive for advanced countries (Figure 5). And this is despite the case that, on average, advanced economies are likely to have more open capital accounts than developing economies (Figure 1). Why has this been the case? Feldstein (1999) argues that the only way to maintain private lending in an economy and increase credit is to ensure that lenders are reasonably sure of receiving a return on their investment. This can be done through ensuring the availability of some form of collateral. International reserves provide one form of collateral. However, a credible international lender of last resort to which borrowers could turn to in the event of financial distress eliminates the need for such collateral. While some institutions have historically functioned as international lenders of last resort at specific historical moments, in general there is no such consistent international lender of last resort. However, there are several institutional mechanisms through which the provision of an international lender of last resort is mimicked in times of financial distress. One such institutional arrangement is swap lines between central banks of

several advanced economies. The role of these swap lines was exceptionally important during the current financial crisis. However, these facilities are not available, in general, to developing countries and emerging economies. Therefore, the quasi-fiscal costs of holding reserves can potentially be mitigated by the extension of these institutional arrangements to developing countries, or creation of parallel arrangements between developing countries. To this end, several developing countries and emerging economies have formed regional agreements and mechanisms such as the Chiang Mai Initiative (CMIM), The Latin American Reserve Fund (FLAR), Arab Monetary Fund (ArMF), and the New Development bank and Contingent Reserve Arrangements of the BRICS countries (Grabel, 2015).

7 Empirical Model and Results

In order to get a preliminary idea of the importance of these factors on the accumulation of reserves, a random effects regression model is estimated[5].

$$Y_{it} = \alpha + \beta \times X_{it} + u_{it}$$

$$u_{it} = \mu_i + v_{it}$$

where the vector X_{it} includes the following variables, following Obstfeld et al. (2010).

- Advanced country dummy variable *advanced* (Section 6.0.1).
- Normalized Chinn-Ito index of capital account openness, *ka_open* (Section 6.0.2).
- Exchange Rate Peg dummy variable, *peg*, where 1 is a pegged exchange rate and 0 indicates a non-pegged exchange rate (Section 6.0.3).
- Logarithm of the ratio of total trade (exports to imports) to GDP, *logtrade* (Section 6.0.3).
- Exchange Rate Volatility calculated as the standard deviation of the monthly percentage change in exchange rate against the dollar over the current year, *evol* (Section 6.0.3).
- Logarithm of the share of M2 in GDP, $logm2$ (Section 6.0.3).
- Year Specific dummies

[5]The random effects model was estimated since the coefficients are meant to compare across countries. The suitability of the model as compared to the fixed effects model or a pooled OLS regression is also confirmed by the Hausman Test and Lagrange Multiplier test, respectively

The dependent variables are log of the share of reserves in GDP and the cost of foreign exchange intervention as defined in Section 3. The results are shown in column 1 and 2 of table 2. The results show that, as per the limited financial stability model suggested by Obstfeld et al. (2010), reserve accumulation is higher in countries with greater capital account openness, lower in countries with higher exchange rate volatility, and higher in countries with greater trade as a share of GDP. All these results are significant at the 5 percent level of significance. However, countries with higher M2 as a share of GDP and advanced economies do not have significantly different reserve accumulation as compared to countries with lower M2 as a share of GDP and developing countries, respectively [6]. As regards costs of foreign exchange intervention, counterintuitively, advanced economies incur higher costs of foreign exchange intervention, while countries with higher exchange rate volatility incur lower costs. Both these correlations are significant at the 5 percent level of significance. Countries with greater financial openness and with pegged exchange rates incur higher costs, while countries with higher M2 and trade as a share of GDP incur lower costs. However, these coefficients are not statistically significant.

Therefore, the model is then supplemented with other important indicators discussed in Section 6:

- Historical currency crisis dummy, *histcc*, where the variable takes the value 1 if the country has experienced a currency crisis in the past (Section 6.0.3).
- RFA is a binary variable that takes the value 1 if the country is a member of a Regional Financial Arrangement and 0 otherwise (Section 6.0.4).
- $Swap$ is a binary variable that takes the value 1 if the country's central bank has historically had a swap line with another central bank and 0 otherwise (Section 6.0.4).
- $Fedswap$ is a binary variable that takes the value 1 if the country's central bank has historically had a swap line with the Federal Reserve and 0 otherwise (Section 6.0.4).
- $ECBswap$ is a binary variable that takes the value 1 if the country's central bank has historically had a swap line with the European Central Bank and 0 otherwise (Section 6.0.4).
- $BOEswap$ is a binary variable that takes the value 1 if the country's central bank has historically had a swap line with the Bank of England and 0 otherwise (Section 6.0.4).

[6] This difference can be because this paper uses a random effects model, while Obstfeld et al. (2010) use a fixed effects model. As mentioned previously, the theoretical motivation and specification tests suggest that the random effects model is suitable.

Swap lines with the Federal Reserve, the European Central Bank, and the Bank of England are considered as most global trade is invoiced in these currencies, the dollar being the most prominent among them by a large margin Ilzetzki et al. (2017).

The results are presented in columns 3 and 4 of Table 2. Once again, counter-intuitively, advanced economies hold fewer reserves, but incur higher costs relative to developing economies. Countries with greater capital account openness are associated with a higher reserves to GDP ratio that is significant at the 1 percent level of significance. However, while higher greater capital account openness is associated with higher costs, the coefficient is not statistically significant. Countries with pegged exchange rates have higher reserves and higher costs. Countries that have experienced currency crises in the past unsurprisingly hold higher reserves and incur higher cost of foreign exchange intervention. However, the coefficient associated with cost is not significant. Even though significant progress has been made in the development of a number of RFAs, membership of one is not associated with statistically significant lower accumulation of reserves or lower costs. Similarly, having access to swap lines from other central banks, while being associated with lower reserve accumulation, is associated with statistically significantly higher costs. Swap lines with the Bank of England and the European Central Bank are associated with lower reserve accumulation and lower costs; however, the coefficients are not statistically significant. Interestingly, access to a Federal Reserve Swap line reduces reserve accumulation and the associated costs. The cost coefficient is statistically significant at the ten percent level.

8 Access to International Lender of Last Resort

It is not surprising that access to Federal Reserve swap line is associated with lower reserve accumulation and the costs associated with it. In a globalized economy, having access to a Federal Reserve Swap line effectively allows countries other than the United States to backstop a run on their currency by being willing to prop up a falling currency by selling dollars. In some instances, simply reaching an agreement with the Federal Reserve can calm speculative attacks and stem the tide of outward capital flight. A Federal Reserve Swap line means that the de facto International Lender of Last Resort, the issuer of the global reserve currency, stands behind the currency of the country in question. However, not all countries have, historically, had access to the International Lender of Last Resort in this form. This is particularly noteworthy since multilateral organizations such as the International Monetary Fund have not been very effective in playing the role of the International Lender of Last Resort.

In the context of the British banking system in the 19th century, Bagehot (1873) argued that, in order to avoid a financial crisis in the face of a bank run and prevent a

Table 2: Determinants of Reserve Holdings and Cost of Foreign Exchange Intervention

	(1) Reserves	(2) Cost	(3) Reserves	(4) Cost
advanced	-0.179	0.355**	-0.0500	0.375***
	(0.108)	(0.010)	(0.662)	(0.009)
ka_open	0.236**	0.177	0.289***	0.216
	(0.045)	(0.230)	(0.009)	(0.159)
peg	0.0181	0.227	0.0406	0.267*
	(0.706)	(0.140)	(0.379)	(0.087)
evol	-0.0399***	-1.935**	-0.0409***	-1.926**
	(0.002)	(0.014)	(0.001)	(0.016)
logm2	0.0520	-0.115	0.0754**	-0.131
	(0.118)	(0.268)	(0.030)	(0.253)
logtrade	0.665***	-0.186	0.662***	-0.213
	(0.000)	(0.136)	(0.000)	(0.106)
histcc			0.313**	0.0196
			(0.014)	(0.864)
rfaindicator			0.0143	0.0345
			(0.845)	(0.810)
histswap			-0.0575	0.583**
			(0.606)	(0.012)
histfedswap			-0.291	-0.564*
			(0.125)	(0.056)
histecbswap			-0.305	-0.406
			(0.139)	(0.117)
histboeswap			0.411	-0.0339
			(0.303)	(0.941)
Constant	-5.826***	0.257	-5.790***	0.264
	(0.000)	(0.619)	(0.000)	(0.636)
N	5114	2398	5114	2398
R^2	0.2967	0.2534	0.2805	0.2353

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

shortage of liquidity, the lender of last resort or the monetary authority should provide unlimited and automatic credit to any party with good collateral (McDowell, 2017). However, in general, no individual central bank can serve as central banks for the global financial system. McDowell (2017) defines the International Lender of Last Resort as "an actor that is prepared to respond to international financial crises by providing credit to illiquid institutions in foreign jurisdictions when no other actor is willing or able" (McDowell, 2017). In lender of last resort operations, time is of the essence, as in the absence of timely injection of liquidity, a liquidity crisis can quickly morph into a solvency crisis. In this regard, the IMF has been inadequate as an international lender of last resort as it is moves slowly only to often provide inadequate liquidity to financial systems in distress. However, in several instances, institutions in the United States have provided liquidity to foreign governments for the purposes of managing financial crises in the post-War period. Specifically, the Exchange Stabilization Fund of the US Treasury and the swap lines extended by the Federal Reserve has historically functioned as an international lender of last resort. Between 1980 and 2000, institutions in the United States effectively acted as the lender of last resort on 40 different occasions for about 20 countries (McDowell, 2017).

However, the United States has not uniformly provided the international lender of last resort facility uniformly. McDowell (2017) argues that the institutions that can function as the international lender of last resort in the United States, which are the Exchange Stabilization Fund of the US Treasury and the swap lines of the Federal Reserve in this analysis, have only done so for foreign governments to prevent the collapse of their financial systems only insofar as the potential collapse of these financial systems jeopardizes the stability of the US financial system. This is not surprising since neither of these institutions has a mandate of stabilizing the global financial system. However, these institutions, specifically the Federal Reserve is likely to be the most effective stabilizer of the global financial system since it has the power to create the global reserve currency, that is, the US dollar. The importance of access to these institutions is not only indicated in the preliminary analysis in section 6, but also in the literature. For instance, (Bordo et al., 2014), find that during the Bretton Woods era, the mere announcement of an increase in the available credit under a pre-existing swap line stemmed the speculative sales of a deficit country's currency, even if the increased credit line was not actually drawn upon.

Specifically, the international lender of last resort facility has mostly been extended to advanced nations. Insofar as some developing countries have been recipients of assistance from the institutions that can function as international lender of last resort, the assistance has been less robust as compared to that received by advanced nations. The Central Bank swap lines provided to the central banks of advanced nations were very large: in most instances, the size of the swap exceeded 50 percent of actual reserves.

In the case of the European Central Bank, the size of the swap was larger than the size of the reserves held. However, for developing economies, the size of the swap never exceeded more than 50 percent of the reserves held (Obstfeld et al., 2009).

Being excluded from this institutional network of lender of last resort operations partly explains the large accumulation of reserves and the cost associated with it. This suggests that the trends described in the paper are not inevitable and can be avoided by, among other things, including emerging markets and developing economies in the access to the lender of last resort facility.

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A Appendix I: Details of Variables Used

Variable	Description	Source
Reserves/GDP	Total Reserves Excluding Gold, US Dollars as a percentage of Nominal GDP in current US dollars	International Financial Statistics
Reserves(including gold)/GDP	Total Reserves including gold, US Dollars, as a percentage of Nominal GDP in current US dollars	International Financial Statistics
Total Reserves in months of imports	Total Reserves including gold divided by average monthly imports	International Financial Statistics
Short-term Debt to Reserve Ratio	Short Term Debt of maturity of one year or less as a share of total Reserves including gold	International Financial Statistics
Interest Rate	Interest rate on short-term government securities, percent per annum	International Financial Statistics
Exchange Rate Volatility, *evol*	Standard Deviation of the monthly percentage change in exchange rate against the dollar over the current year	International Financial Statistics
M2/GDP	Share of broad money as a share of GDP	International Financial Statistics
Trade to GDP	$\frac{Export+Import}{GDP}$	World Development Indicators
Chinn-Ito Index	Chinn-Ito index of capital account openness normalized between 0 (completely closed capital account) and 1 (completely open capital account)	Chinn and Ito (2006)
Peg	Exchange Rate Peg Dummy variable, where 1 is a pegged exchange rate and 0 is unpegged exchange rate	Shambaugh (2004)
Historical currency crisis *histcc*	Dummy variable that takes the value 1 if country has experienced a currency crisis during 1960–2014, 0 otherwise	Scheubel and Stracca (2016)
RFA	Membership in Regional Financial Arrangement. 1 if member of any RFA, and 0 otherwise	Scheubel and Stracca (2016)

Swap	Indicates whether country has historically (1960–2014) had swap line from a central bank or multilateral swap agreement. 1 if swap agreement, 0 otherwise	Scheubel and Stracca (2016)
Fed Swap	Indicates whether country has historically (1960–2014) had swap line from the Federal Reserve. 1 if swap agreement, 0 otherwise	Scheubel and Stracca (2016)
ECB Swap	Indicates whether country has historically (1960–2014) had swap line from the ECB. 1 if swap agreement, 0 otherwise	Scheubel and Stracca (2016)
BOE Swap	Indicates whether country has historically (1960–2014) had swap line from the BOE. 1 if swap agreement, 0 otherwise	Scheubel and Stracca (2016)

B Appendix II: Country Classification

Emerging Market Economies		
Argentina	Bahrain	Bangladesh
Botswana	Brazil	Chile
China	Colombia	Côte d'Ivoire
Ecuador	Egypt	Ghana
Hong Kong	India	Indonesia
Israel	Jamaica	Jordan
Kenya	South Korea	Malaysia
Mauritius	Mexico	Morocco
Nigeria	Oman	Pakistan
Peru	Philippines	Saudi Arabia
Singapore	South Africa	Sri Lanka
Thailand	Trinidad & Tobago	Tunisia
Turkey	Venezuela	Zimbabwe
Non-Emerging Developing Economies		
Aruba	Afghanistan	Angola
Algeria	Antigua & Barbuda	American Samoa
Barbados	Bahamas	Belize
Benin	Bhutan	Bolivia
Brunei Darussalam	Burkina Faso	Burundi
British Virgin Islands	Cameroon	Cambodia
Cape Verde	Cayman Islands	Central African Republic
Chad	Comoros	Costa Rica
Curacao	Cuba	Democratic Republic of Congo
Djibouti	Dominica	Dominican Republic
El Salvador	Equatorial Guinea	Eritrea
Ethiopia	Fiji	French Polynesia
Gabon	Gambia	Grenada
Guam	Guatemala	Guinea-Bissau
Haiti	Honduras	Kiribati
Kuwait	Lao	Lebanon
Lesotho	Liberia	Libya
Macao	Madagascar	Maldives
Mali	Malawi	Marshall Islands
Mauritania	Micronesia	Mongolia
Mozambique	Namibia	Nauru

New Caledonia	Niger	Nicaragua
Nepal	Palau	Panama
Papua New Guinea	Paraguay	Qatar
Republic of Congo	Rwanda	Saint Kitts & Nevis
Saint Lucia	Saint Vincent and the Grenadines	São Tomé & Príncipe
Samoa	Senegal	Seychelles
Sierra Leone	Solomon Islands	Somalia
Suriname	Swaziland	Syria
Tanzania	Timor Leste	Togo
Tonga	Uganda	United Arab Emirates
Uruguay	US Virgin Islands	Vanuatu
Vietnam	Yemen	Zambia
Advanced Economies		
Andorra	Albania	Armenia
Australia	Austria	Azerbaijan
Belgium	Bulgaria	Bosnia & Herzegovina
Belarus	Canada	Channel Islands
Croatia	Cyprus	Czech Republic
Denmark	Estonia	Faroe Islands
Finland	France	Georgia
Gibraltar	Greece	Greenland
Hungary	Iceland	Ireland
Isle of Man	Italy	Japan
Kazakhstan	Kosovo	Kyrgyz Republic
Latvia	Liechtenstein	Lithuania
Luxembourg	Macedonia	Malta
Moldova	Monaco	Montenegro
Netherlands	New Zealand	Norway
Poland	Portugal	Romania
Russia	San Marino	Serbia
Sweden	Switzerland	Tajikistan
Turkmenistan	Ukraine	United Kingdom
United States	Uzbekistan	

Note: The classification into "Emerging Market Economies" is based on Chinn and Ito (2006), while the classification into "Developing Economies" is based on 2014 Classification by the United Nations, which can be found here. The remaining countries are classified as "Advanced Economies"