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Foreign exchange reserves: analysis of size and currency diversification

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Abstract

This thesis analyses the size of the foreign exchange reserves across countries and attempts to find the determinants that could explain the differences in reserve levels. Factors such as the foreign exchange regime, country development level, current and capital accounts balance, as well as the fuel-exporter status, are all important predictors of reserve size. The results provide evidence that broad money and trade openness are the most relevant variables to explain the level of reserves relative to GDP. Moreover, we also analyse the currency composition of reserves in order to explain the factors behind their diversification. This thesis introduces a new diversification measure, which investigates the concentration between the five main international currencies. We find that larger reserve portfolios tend to be more diversified, while countries with stricter exchange regimes have more concentrated portfolios.

Keywords

Foreign exchange reserves, currency composition of reserves, size of international reserves, diversification, foreign exchange regime.

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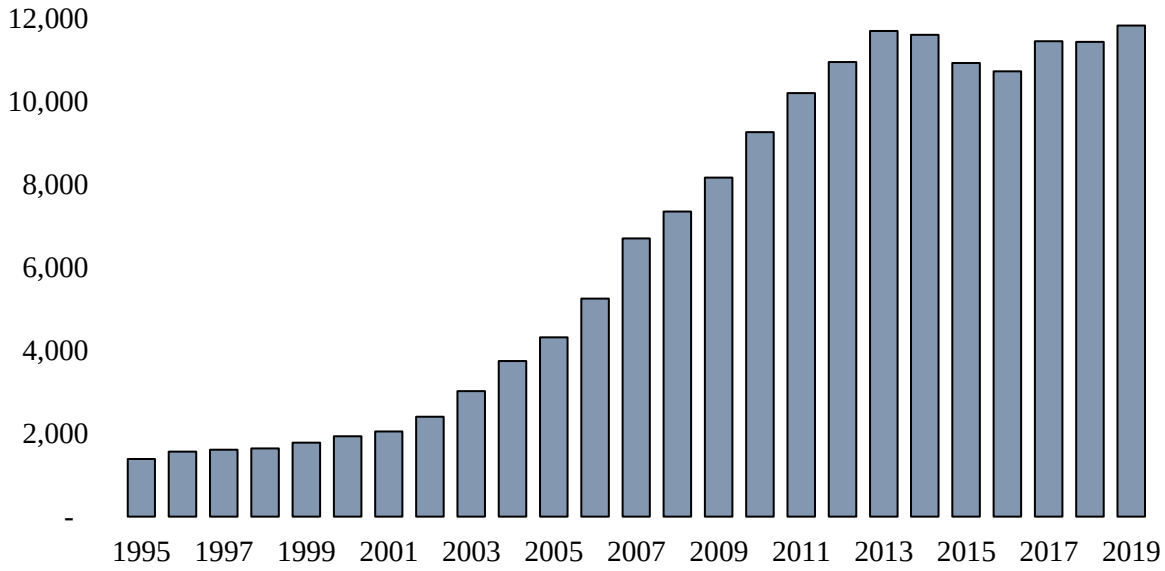
List of abbreviations

AE	Advanced Economies
AREAER	Annual Report on Exchange Arrangements and Exchange Restrictions
BIS	Bank of International Settlements
Bn	Billions
BOP/IIP	Balance of Payments and International Investment Position Statistics
COFER	Currency Composition of Official Foreign Exchange Reserves
CNY	Chinese Renminbi
EUR	Euro
EMDE	Emerging Market and Developing Economies
Fed	U.S. Federal Reserve
FX	Foreign Exchange
GDP	Gross Domestic Product
GFC	Global Financial Crisis of 2007-2008
GNI	Gross National Income
IFS	International Financial Statistics
IMF	International Monetary Fund
IRFCL	International Reserves and Foreign Currency Liquidity
GBP	British Pound Sterling
JPY	Japanese Yen
LIDC	Low Income Developing Countries
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary Least Squares
pp	Percentage point
PRGT	Poverty Reduction and Growth Trust
SDR	Special Drawing Rights
ST	Short-Term
UK	United Kingdom
UN	United Nations
US	United States of America
USD	United States Dollar
WB	World Bank
WOE	World Economic Outlook

1 Introduction

The global development over the last decades has shown a clear trend in increasing demand for foreign exchange reserves under the control of governments and monetary authorities. These reserve assets, also referred to as international reserves or foreign exchange reserves, are a part of the country's balance of payments and serve various purposes such as prevention of currency crisis, support for international trade or as a tool for stabilizing the domestic currency. In theory, the reserve amounts should be lower for countries with floating exchange rate regimes as they do not have to keep the exchange rate stable in comparison with fixed regimes. After the collapse of Bretton Woods in the early 1970s, there has been a shift towards more flexible exchange rate regimes, but the expectations on reserve amounts have been the opposite to what is observable in the world now. As shown in Figure 1, countries not only have not diminished their reserves, but significantly increased their stocks – this trend goes against the theoretical indication and is often deemed inexplicable.

Figure 1: Development of the total amounts of reserves from 1995 to 2019 (bn USD)

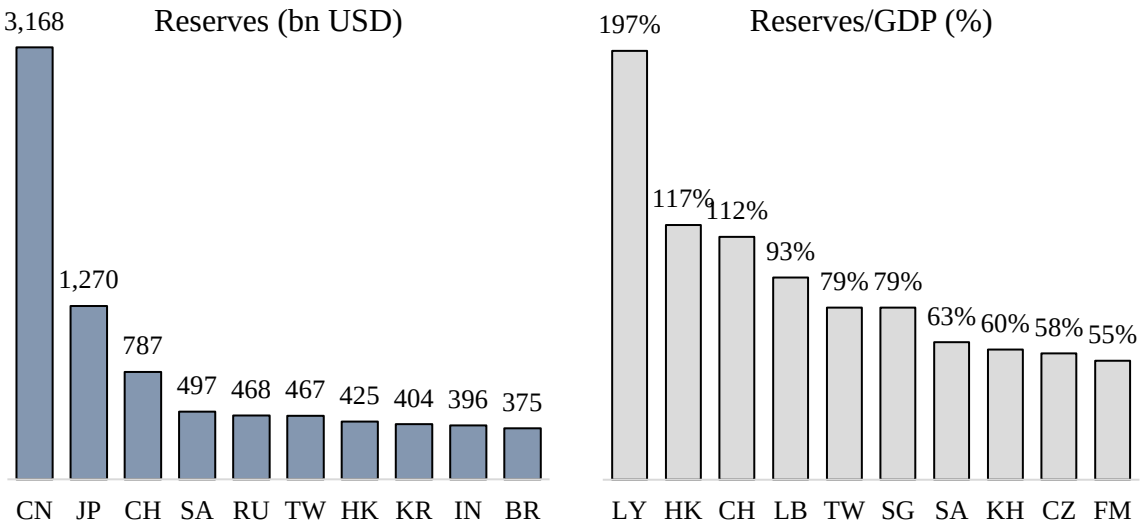


Source: IMF (COFER database), Author's calculation

In this thesis, we investigate the determinants behind the reserve accumulation from the cross-country point of view as well as the diversification of the currency composition of reserves. Our contribution to this topic is the extensive and updated analysis built on various cross-country characteristics such as the country's foreign exchange rate regime, development, fuel exports or current and capital accounts balance. Additionally, based on our assessment of literature, we introduce a new diversification measure that has not been previously used when analysing the currency composition of international reserves.

When inspecting reserve amounts across countries, substantial differences are observable in reserve size in different countries, and this holds for both, absolutely and relatively expressed reserves. Left-hand side of Figure 2 presents the top 10 countries with the largest amounts of reserves in 2018. China was by far the main foreign reserves holder in the world with more than 3 trillion USD, a stunning amount considering the second main holder, Japan, held less than half of China's reserves.

Figure 2: Top 10 reserve holders[1] in 2018 (absolute and relative terms)



Source: IMF, Author's calculation

Howbeit, we know that China is one of the main economies accounting for more than 15% of the world GDP. Therefore, when examining the reserve size in the context of the country size, measured as the country's GDP, the picture changes. Right-hand side of Figure 2 introduces the top 10 major reserve holders in the world in relative terms. In this case, Libya clearly dominates the ranking with reserve stocks almost twice its GDP size. Second and third positions are allocated to Hong Kong and Switzerland respectively, which hold reserves in a value larger than their respective GDP sizes.

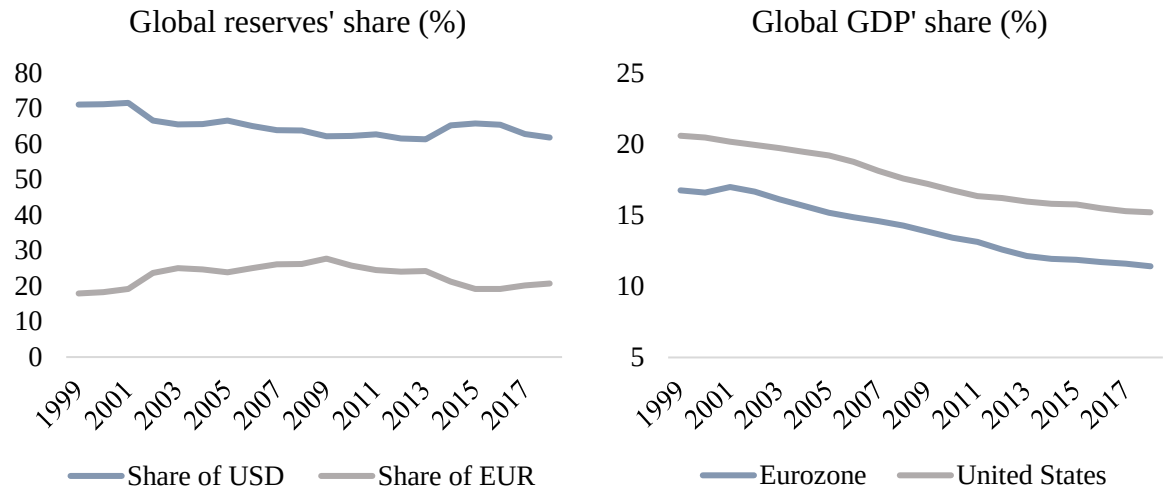
Traditional reserve adequacy benchmarks are based on the number of months that reserves can sustain imports, the proportion of broad money covered by the reserves, or the amount of reserves that could pay off the short-term external debt of the country[2]. However, the striking development in reserves is no longer possible to explain by these benchmarks. Many countries have accumulated such large reserve stocks that they have surpassed the conventional adequacy ratios by far.

The share of different currencies has been changing over the years. Some currencies ceased to exist, such as the Deutsche mark and the French franc after the introduction of the Euro; and new currencies have seen their importance and share increasing, such as the Chinese renminbi

[1] *Country codes are based on ISO 3166-1.*
[2] *More information about this topic is available in Section 2.4.*

(CNY)[3]. Despite some changes in the past, the American dollar (USD) has consistently held the lion's share of all the reserves ranging from 70% at the end of the 20th century to 61% at the end of 2019[4]. For the majority of countries, USD denominated investments are still dominating the central banks' reserves, while euro (EUR) assets are holding on to the second place. When comparing these two currencies, we could hypothesise whether their share in reserves is related to the issuing country's share in the global GDP. As illustrated in Figure 3, if this was the case, then EUR and USD reserve shares would be closer than currently observable, as GDP similarity suggests.

Figure 3: Currency and GDP share of US and Eurozone



Source: IMF, Author's calculation

As outlined, the reserve accumulation is not homogenous across countries and not even over time. There have been numerous attempts to explain the paradoxically increasing trend in reserve accumulation despite the opportunity of central banks to invest in higher yielding investments. This thesis is motivated by the topic of unprecedented reserve accumulation of the last decades too. It aims to add an updated perspective on the reserve situation, while simultaneously providing a comprehensive overview of numerous country-specific variations influencing the reserve size, together with potential triggers influencing the currency composition of the reserve assets.

Several authors have been trying to define the adequate amount of international reserves and factors driving their hoarding. Previous research has mainly focused on analysing emerging markets where the excessive reserve accumulation was recognized first, and/or the comparison with advanced economies. Other research have been centred around the drivers behind the currency composition of reserves. However, the sphere of examining additional cross-country differences among countries and the diversification of the currency composition of the portfolio has received less attention. Our thesis consolidates both of these aspects in one place. We build

[3]*Effective from October 2016, the IMF incorporated the CNY in the SDR basket. COFER database was consequentially updated to include a separate account for the currency instead of being reported under "other currency" reserves.*

[4] *Further details on the currency composition of the world international reserves can be found in Appendix A.*

our thesis on analysing the similarities and contrasts among different groups of countries, exploring whether there are any clear distinctions between these country-classes. Moreover, we add an analysis focused on the diversification of reserve portfolios across countries, where we introduce a new diversification index. Econometric models, panel data methods in particular, are used to analyse the drivers behind the accumulation and diversification of reserves. In order to account for the heterogeneity of countries in our sample, the fixed effects method is deployed.

The overall analysis is built on two subtopics as stated below:

i) Analysis of the relative size of reserves of various classes of countries based on their foreign exchange rate regime, development of the economy, fuel-related exports, and current and capital accounts balances, as well as a time comparison before and after crisis.
ii) Analysis of the diversification of the currency composition of reserves.

Given the points above, the main research question is defined as:

> *What are the determinants of the accumulation of foreign exchange reserves and the diversification of their currency composition?*

By doing a preliminary visual inspection of the data, it is clearly observable that emerging and advanced economies tend to hold relatively different amounts of reserves. The same explicit distinction can be found when comparing fuel-exporting and non-fuel-exporting economies, and countries with different foreign exchange rate regimes. The latter is also relevant in the portfolio diversification of the currency reserves. These findings suggest cross-country differences in the relative size of foreign exchange reserves and serve as a base for a further in-depth analysis in this thesis.

The structure of this thesis is as follows. Section 2 outlines the theoretical background and literature review of our analysis. Section 3 describes the methodology and models used in the thesis, together with an overview of chosen explanatory variables and their expectations, as well as the sources of data and potential limitations of the model. Section 4 states the estimation results from the analysed models and, finally, Section 5 summarises and makes the conclusions of our research.

2 Literature and Theoretical Review

In this section of our thesis, we introduce the terminology of foreign exchange reserves, outline the traditional and, also, novel motives behind reserve accumulation. Furthermore, we present how reserves are managed and the typical objectives pursued. As the last subchapter, we provide a comprehensive overview of the previous literature on the reserve size and currency composition of reserves.

2.1 What are foreign exchange reserves?

The IMF refers to foreign exchange reserves as international reserves or reserve assets, and it defines them as "those external assets that are readily available to and controlled by monetary authorities…Reserve assets must be foreign currency assets and assets that actually exist" (International Monetary Fund, 2009, p. 111).

From the definition of the International Monetary Fund (2009), the following is interpreted:

- *External assets*: they must be claims on non-residents, except for gold bullion, and be expressed in foreign currency.
- *Readily available*: assets must be liquid, that is, can be liquidated for cash quickly and without affecting its value significantly.
- *Controlled*: they must be under the effective control of the monetary authority, regardless of the ownership.
- *Monetary authority*: a central bank and other government institutions, or commercial banks, that carry out the operations assigned to a monetary authority.
- *Exist*: they need to be existing claims, what excludes lines of credit, swap agreements or other resources that do not constitute existing claims.

Foreign exchange reserves can be classified as: "…monetary gold, SDR holdings, reserve position in the IMF, currency and deposits, securities (including debt and equity securities), financial derivatives, and other claims (loans and other financial instruments)" (International Monetary Fund, 2009, p. 113). A summary of the classification and components of reserves, according to the IMF data template, can be found in Appendix B.

2.2 Exchange rate regime's influence on reserve size

The phenomenon of stable, or even increasing demand for reserves, has been discussed by various authors who tried to explain the drivers behind reserve accumulation. Heller and Khan (1978) are one of the first ones, who tried to evaluate the rising demand of reserves closely after the breakdown of the Bretton Woods system. Their explanation indicates that the relationship of higher reserves and floating regimes could be caused by the variability of the payment balances and related higher uncertainty.

Few years after Heller and Khan's paper, Frenkel (1983) provided another possible explanation to this paradox. His interpretation is that: "during the pegged rate regime the rate was adjustable rather than fixed and during the so-called floating rate regime the rate has been managed rather than free" (Frenkel, 1983, pp. 23-24). However, as Grimes (1993) argues, Frenkel's explanation is not sufficient given the fact that there are countries that formerly followed fixed regimes and now they changed to totally floating regimes. Grimes (1993) further believes that if two countries with different regimes have uniform reserve demands, then it must be due to: i) the trivial opportunity cost[5] of holding reserves in which situation there is no reason to decrease reserve holdings or ii) the high risk aversity of a central bank towards reserve shortfall[6].

A paper on emerging markets by Aizenman and Marion (2003) also demonstrates that a country holds more reserves even if the opportunity cost is high and they suggest that this is due to a great loss aversion of the country. Moreover, they add that not all the countries which have experienced a crisis will hold large reserves, and this can be attributable to strong preferences towards the current consumption or instable political situation and corruption.

Research done by Choi and Baek (2004) finds out that the relationship between the exchange rate regimes and reserves resembles a reversed U-shape, where the x axis marks the regimes from the least to the most restrictive and the y axis marks the reserves. This means that the highest amount of reserves is attributed to the mediocre regimes between hard pegs and free float. Another interesting finding is that completely fixed regime involves less reserves than the free float.

A paper written by Bastourre et al. (2009) indicates that the capital account liberalisation needs to be taken into account when examining the reserve hoardings. They state that the transition to more flexible regimes happened during the times of capital account liberalisation, which could possibly explain the surprising increases in reserves in those times. A situation akin to this arose again in 1990s when emerging economies were going through the capital account deregulation potentially clarifying the excessive reserve growth (Bastourre et al., 2009).

Pontines and Rajan (2011) have explored reactions of central banks in emerging Asian countries to detect how they managed the exchange rate volatility. They state that many bankers have tried to make the maintenance of the exchange rate as the main motive for the excessive

[5] *The higher the liquidity of the reserves held, the higher the opportunity cost for a central bank.*
[6] *The higher the risk aversion of a country, the closer the reserves of a country with the floating regime is to a country with fixed regime.*

reserve accumulation, however, if this was true, the reserve holdings would not change much on average; although the opposite is observable.

Akdogan (2020) states that there are differences between motives for accumulating reserves across countries; it can be due to foreign exchange interventions, as observed in China and other developing countries, or driven by a new precious resource in a country, as seen in Norway or Saudi Arabia. Furthermore, he provides an explanation behind the two-sided relationship between foreign exchange reserves and exchange rate: a) central banks are stocking up reserves to be able to use them in situations when they need to maintain their exchange rates; and b) the exchange rates change when a central bank sells or buys its foreign currency reserves.

2.3 Motives for holding and accumulating reserves

Obstfeld et al. (2010) question that a truly floating regime needs no reserves, but governments are not indifferent to the exchange rates, therefore they probably increase reserves. Considering that international reserves usually earn low or no interests (Osada, 2017) and the fact that there has been a shift towards more flexible exchange rate regimes, which theoretically does not require a country to hold any reserves, brings up a question: *what are the drivers behind accumulation of reserve assets?* To clarify this matter, the focus of the next pages is put on the two main groups of motives which have been developing simultaneously throughout the time. The first, *precautionary motive,* ties up the stock of reserves mainly with potential crisis scenarios affecting the economy, while the second, *mercantilist motive,* relates to the international trade.

2.3.1 Precautionary motives

Stockpiling reserves due to the fixed exchange rate regimes could be considered as a side effect of maintaining the domestic currency stabilised. However, countries have clearly chosen to hold reserves also for different purposes known as precautionary ones (Li & Rajan, 2005).

The precautionary motive was the primary reason for countries to maintain reserves till the turn of the millennium. This traditional motive of holding reserves has been examined by numerous authors throughout the history. It has started with Kenen and Yudin (1965), who indicate that the demand for reserves highly depends on the central bank's expectations of the magnitude and duration of disturbances that are likely to make the country's exchange rate unstable. It was followed by research of Heller (1966, p. 301) who establishes that the optimal level of foreign exchange reserves held for precautionary motives depends on: "(1) the cost of adjusting to an external imbalance; (2) the cost of holding liquid international reserves; and (3) the probability that there will actually be a need for reserves of a given magnitude", where the last motive is in line with the belief of Kenen and Yudin.

Green and Torgeson (2007) mention that the main reason to hold reserves for precautionary motives is to secure a country against currency crises. Additionally, they describe that other stimuli behind stockpiling the reserves are meant to:

- reduce volatility;
- serve as an anti-deflation tool;
- pay for day-to-day transactions;
- help banks with large liabilities in foreign currencies (central banks as a lender of last resort).

Reserve hoardings based on precautionary motives are associated with "exposure to sudden stops, capital flight and volatility" (Aizenman & Lee, 2007, p. 2). As Li and Rajan (2005) state, this insurance motive integrates both the prevention against crisis and management during crisis periods. Green and Torgeson (2007) add that the demand for reserves varies among the crisis and non-crisis motives, with the former demand typically surpassing the latter.

Cabezas and De Gregorio (2019) further divide the precautionary motive of accumulating reserves into two subcategories: i) self-insurance reserves used to finance imbalances in capital inflows and outflows, ii) comparative hoarding reserves acting as an indication of strength of a country and, therefore, a deterrent from speculating attack on the currency.

The rationale for a risk reduction of speculative attacks on the domestic currency is also mentioned in paper by Li and Rajan (2005), who note that building up high reserves is a signal of strong economy and it reduces the probability of the currency run. This speculative run on currencies (currency crisis) in countries with fixed exchange rate regime can be described as a speculation of investors who try to attack the domestic currency. The central bank can defend its currency in two ways: i) by increasing domestic interest rates or ii) by deploying its international reserves (Glick & Hutchison, 2011). The reasoning behind the first possible action is that the assets denominated in the domestic currency would become more interesting for investors to hold (Teimouri & Zietz, 2016). When a central bank decides for the second described action, it pays with the accumulated foreign exchange reserve, and faces the potential risk of running out of its stocks. Therefore, the higher the reserves are, the greater the ability of a country to withstand the speculative depreciation attacks and, also, prevent the country from possible credit crunch due to increasing interest rates (Arslan & Cantú, 2019; Glick & Hutchison, 2011; Teimouri & Zietz, 2016).

The times of distress for countries are not always related to only currency crises; countries stock up reserves for other types of emergency states. Sachs et al. (1996) show that low amounts of reserves are highly related to the occurrence of crisis and, consequently, adequately large reserves can fully counterbalance the weak fundamentals of an economy. On the other hand, Li and Rajan (2005) show that if a country has *hopelessly weak* fundamentals, there is no reserve amount which could possibly offset this weakness, i.e. policy reforms are necessary, crisis is unavoidable and no level of reserves could help a country like this. Choi and Baek (2006) also ascribed the hoarding of reserves to precautionary reasons. Their explanation of reserve accumulation is due to an increasing volatility of capital flows, which occurs

simultaneously with the liberalization of capital account, contributing to higher vulnerability of a country and higher frequency of financial crisis.

Findings of Choi and Strömqvist (2007) imply that rising reserves are a consequence of the capital account crisis which took place in the late 1990s in many emerging countries. Aizenman and Lee (2008) indicate that countries might accumulate reserves in an attempt to mitigate the likelihood of channelling the banking crisis to a currency one. Choi et al. (2009) explain that, due to information problems and frictions in the financial markets, countries coping with sovereign risk and high volatility in their capital flows have a large incentive to stock up reserves, and this holds even if a country has to increase its external debt. Steiner (2009) states that, if a country has previously gone through a balance of payment crisis, it will not consider the risk of openness in the same way as a country that has not experienced such crisis before. Furthermore, he adds that economies that have had their current and capital accounts opened for a longer time may act differently than those which have opened it quite recently. A model by Bastourre et al. (2009) confirms that the primary rationale for hoarding reserves is the precaution and it has not changed since 1960s.

A notable research done by Jeanne and Ranciere (2011) connects the optimal level of reserves with the probability of sudden stops, opportunity cost of reserves and risk aversion of consumers. They provide evidence that emerging economies stock up reserves when the times are good, and they decrease them in times of distress as a reaction to sudden stop risk[7].

Large reserve amounts can serve as a sign of the country's ability to pay off the external debt and, therefore, increase the availability of the international credit for a country (De Beaufort Wijnholds, 2013). Similar interpretation of this motive was described by Jones (2018) who explains that precautionary reserves can be perceived as a buffer against capital outflows, which could destabilise the domestic currency. The recent paper by Arslan and Cantú (2019) provides an evidence that countries which held relatively more international reserve during the GFC of 2008 underwent lower depreciations, which proves the initial idea.

There are many examples that prove that precautionary motive for holding reserves exists and, in case of not holding optimal amount of reserves, it can be a real risk for the economy. One of the last currency crises happened in Turkey in 2018, where the lira lost about 40% in the first half of the year. Another such example is the probably most famous currency attack, known as the "Black Wednesday", which occurred in the UK in September 1992 against the British pound.

2.3.2 Mercantilist motives

If the reserves are accumulated only for the precautionary motive, countries should stop piling them up once the optimal level is hit (Pineau et al., 2006). However, given the development in the last decades, the precautionary motive might not any longer justify the accelerating reserve stocks. Regressions based on the precautionary motive are more relevant for predicting the long-term reserve stocks, however, they highly underestimate the reserves held especially for

[7] *Based on their explanation, a sudden stop is a situation when a consumer can lose access to external credit.*

the emerging Asian countries (Aizenman & Marion, 2003). Therefore, another rationale of the large reserves has been introduced and it could be assigned to "the unintended consequence of large current account surpluses" Jeanne (2007, p. 39). This alternative motive, which has become more significant mainly after the crises of emerging countries at the turn of the century, is the monetary or mercantilist motive of holding reserves. Under this motive, countries accumulate reserves to follow the policy objectives associated with competitiveness of a country, growth stimulation and elimination of increasing commodity prices (Akdogan, 2020). According to Cabezas and De Gregorio (2019, p. 827) mercantilist reserves are "a by-product of an export-led growth strategy".

As Dooley, Folkerts-Landau, and Garber (2005 cited in Aizenman & Lee, 2008) state, the intention of a country holding excess reserves is based on their development strategy, which is built on supporting the growth of a country by undervaluing the domestic exchange rate. Aizenman and Lee (2007) are the first ones who tried to incorporate the importance of the mercantilist motive in the model after crises of 1997 and they express that reserve accumulation based on this motive is connected with real exchange rate depreciation and increasing export growth.

Jeanne (2007) finds that there is a positive relationship between reserve accumulation and the GDP growth rate. He adds that this is quite surprising given the fact that *high-growth developing countries* are supposed to import the external capital in order to fund their development. However, this result is in line with the mercantilist standpoint based on a concept of stimulating growth through depreciating domestic currency.

Choi et al. (2009) mention that holding reserves in foreign currencies can serve as an investment strategy tool for risk diversification in case of domestic currency being negatively correlated with the foreign ones.

Pontines and Rajan (2011) explain that the prevailing purpose for reserve stocking in Asian countries is mainly driven by the desire to keep their domestic currencies undervalued. As found in their research, emerging Asian countries have a bigger *fear of appreciation* than *fear of depreciation* and, therefore, the central bank responses are more substantial in case of currency appreciation. This might possibly indicate that these economies put more weight on the mercantilist motive of reserves holdings rather than the precautionary one.

The mercantilist motive is focused on the prevention of domestic currency's appreciation and, that way, ensuring external competitiveness and encouraging growth driven by exports through frequent interventions (Chiţu et al., 2019).

One of the countries that has been recently accused of devaluating its currency to gain a competitive advantage is China. In response to US' import tariffs on the country, the People's Bank of China let the currency depreciate and surpass the level of 7 Renminbi for 1 US dollar in August 2019 for the first time in more than a decade (Contractor, 2019).

One potential concern related to maintenance of competitiveness this way is the competitive accumulation of reserves by most of the countries. As Aizenman and Lee (2008) explain, stocking reserves encouraged by a short-term competitiveness of one country could cause other

countries starting to hoard reserves too in order to *keep up with the Joneses*. These actions would result in diminishing of the competitive advantage for all the countries and excessive reserve holdings (Aizenman & Lee, 2008). This herd behaviour is also described by Bastourre et al. (2009), who account for this aspect by including a variable capturing the share of countries from a specific region, which increased its reserves in the last period.

As the research shows, countries used to hold reserve mainly due to the precautionary motive of reserves; however, nowadays, the incentive has moved more towards the exchange rate and monetary motives (Arslan & Cantú, 2019). As Jeanne (2007) describes, the precautionary model would be plausible to explain the excess reserve hoardings, completely, only in case in which countries would estimate their expected costs, caused by capital account crisis, to more than 60 percent of its GDP. Considering that this is quite unrealistic assumption, authors have found significant evidence for the mercantilist motive (Cabezas & De Gregorio, 2019). Even though many have considered this motive plausible to explain current trends in hoardings reserves, it is apparent that precautionary motive is still the one that majority of the authors found as a primary rationale for reserve accumulation. Aizenman and Lee (2007) confirm the mercantilist motive is being statistically significant, but it is not economically significant to explain the reserve accumulation; the opposite holds for their precautionary model, which has bigger impact on reserves than the mercantilist stimuli. Similar result is obtained from research by Calvo et al. (2012), who find no evidence for the mercantilist type of reserve accumulation.

2.4 Foreign exchange reserve management

Whatever the reasons behind reserve accumulation are, it is certain that central bankers have the task of managing their portfolio of reserve assets. This brings us to the question of *how do they manage their foreign exchange reserves?* There are different opinions on what the best reserve adequacy metric is and, in this section, we define the main optimal-reserve-metrics presented in the literature and outline what we understand by reserve management.

As the International Monetary Fund (2004) explains, reserve management is a process securing that a country has an adequate level of foreign assets readily available for necessary intervention.

Typical objectives in reserve management are:

> support and maintain confidence in the policies for monetary and exchange rate management, including the capacity to intervene in support of the national or union currency; limit external vulnerability by maintaining foreign currency liquidity to absorb shocks during times of crisis or when access to borrowing is curtailed, and in doing so provide a level of confidence to markets that a country can meet its external obligations; demonstrate the backing of domestic currency by external assets; assist the government in meeting its foreign exchange needs and external debt obligations; and maintain a reserve for national disasters or emergencies (International Monetary Fund, 2004, p. 1).

Central banks build their reserve management around three main pillars: safety, liquidity and profitability; the first two purposes are the most important goals although each central bank can adjust these motives to its interest (International Monetary Fund, 2001). International Monetary Fund (2004) also points out that strategies should be consistent with monetary and exchange arrangements, as well as the management of external debt.

There are some traditional approaches of what is considered to be a good metric for reserve adequacy. For example, International Monetary Fund (2016) mentions:

- *Import coverage:* it indicates for how long a country could sustain its imports if a shock happened. It is more useful for those countries that have less open capital accounts and the typical benchmark is 3 months coverage.
- *Ratio of reserves to short-term external debt:* especially important metric for emerging markets with large short-term external debt. Greenspan (1999, n.p.) mentioned that "countries should manage their external assets and liabilities in such a way that they are always able to live without new foreign borrowing for up to one year". This idea became known as the *Greenspan-Guidotti rule* and the typical benchmark is 100% coverage of short-term debt.
- *Ratio of reserves to broad money*[8]*:* the typical ratio level is 5%, although 20% is the upper limit of a prudent range. It is a helpful ratio for those countries that have more open capital accounts and larger banking sectors in order to consider the risk of potential outflow of citizens' deposits.

Other metrics try to elaborate more on the complexity of foreign exchange reserve management and several combinations and optimal reserve models have appeared. The International Monetary Fund (2016) mentions the *expanded Greenspan-Guidotti rule* that represents the sum of the short-term debt and the current account deficit (when the current balance is negative) in order to reflect the full financing need of the following 12 months. Nevertheless, the IMF recommends an adaptation of this metric instead, which is based on the use of short-term debt minus the current account balance in order to account for the asymmetry in shocks between surplus and deficit countries. De Beaufort Wijnholds and Kapteyn (2001) propose that the level of reserve adequacy should cover the short-term external debt plus a fraction of broad money that could potentially flow out in a confidence crisis; this fraction would be higher for fixed rate regimes than floating ones. Jeanne and Ranciere (2006) present an optimal model of the reserve level, balancing the benefits of reserves to smooth sudden stops in capital flows and the opportunity costs of holding them.

As mentioned in International Monetary Fund (2015, p. 18), the IMF proposed a new reserve adequacy metric for emerging markets, *ARA EM*, that "comprises four components reflecting potential drains on the balance of payments", namely export income, broad money, short-term debt and other liabilities. They also give a set of pre-established weights for each component, that depends if the exchange regime is fixed or floating, and they explain that, if the reserves

[8] *Usually measured as M2 money supply.*

reach 100-150 percent of the metric, they can be treated as highly adequate for the precautionary motive.

Despite the reserve adequacy measures cited above, Jones (2018) considers that reserve management is mirroring private investors practices and central banks are not managing their portfolios for crisis environments; and, he concludes, that there is a current policy challenge in making good decisions in times of prosperity to help the economy when needed.

2.5 Currency composition of reserves

Another aspect of this thesis is an examination of currency composition of foreign exchange reserves. In general, USD is the main reserve currency, followed by EUR in the second place. This situation might be mainly related to the investment opportunities, credit risk and liquidity associated with government bonds issued by US and Germany (Berłowska et al., 2019). As Ito and McCauley (2020) state, the US share of the international trade has been decreasing, however, its share in international reserves has been very much stable. If we considered the international trade as a determinant for currency share in reserves, then EUR and USD shares should be much more equal than they are at the present time (Ito & McCauley, 2020).

As Brière et al. (2015) state, keeping most of its reserves in USD, in particular in short- and medium-term government bonds, has been a profitable strategy in times of decreasing interest rates. Howbeit, some central banks have already realised the potential risk related to increases of interest rates by the Fed, which would hurt USD denominated reserves. Therefore, these countries have decided to diversify its international reserves in order to mitigate the potential risk and earn higher returns than the yields of US assets (Brière et al., 2015). This approach is, for example, observable in the case of Poland, which has benefited from diversification in terms of higher yields on account of the different levels of returns in individual markets (Berłowska et al., 2019). Brière et al. (2015,p. 5) also state that the optimal strategy which reduces the risk is based on increasing shares of US government bonds and, simultaneously, "diversifying the portfolio into currencies weakly correlated with USD, such as GBP, AUD, and CAD."

Truman and Wong (2006) outline three types of diversification:

i) *Passive diversification:* in a situation when a reserve currency depreciates against the other currencies in a portfolio, the reserve amount in this depreciating currency would decrease while the rest of currencies would be increasing their values. A central bank does not intervene, yet allows the exchange rate variation to adjust the distribution of reserves (Wong, 2007). .

ii) *Active diversification:* a central bank, with regards to the currency depreciation, sells the investments in depreciating currency while rising its investments in other currencies. This causes the reserve value denominated in the depreciating currency to decline even more than in the first case and it can potentially escalate the ongoing trend of the currency depreciation.

iii) *Stabilizing diversification (portfolio rebalancing):* the central bank buys assets denominated in depreciating currency at the expense of other reserve currencies. This strategy causes the depreciating currency share to decrease less than in the scenario of passive diversification. A central bank intervenes against the ongoing trend in the market to keep the shares of all reserve currencies constant (Wong, 2007).

As already mentioned above, diversification is highly important mainly in times when interest rates are increasing, and if a country holds all reserves in one currency, it cannot possibly decrease the portfolio volatility (Brière et al., 2015). Due to these and various other reasons, the diversification of reserves has gained in popularity across countries. Considering the shift towards more diversified portfolios, Das et al. (2019) think that USD will lose its share against EUR and CNY reserves, although it will maintain the leading position for the future considering its natural advantages as liquidity or depth of capital markets.

For a currency to obtain the international currency status, it must fulfil various conditions. Chinn and Frankel (2007) introduce the following determinants:

i) *Patterns of output and trade:* it is beneficial for the home country of an international currency to have a big share of the international trade.

ii) *Financial markets:* the home country of an international currency should have an open, deep and well-developed financial market, which is free of controls.

iii) *Confidence in the value of the currency:* it is crucial that a reserve currency is stable, and its value does not change unpredictably.

iv) *Network externalities:* there is a bias when choosing a currency, i.e. a) when a currency has been widely used as a dominant foreign currency in the past, and b) when a currency is used widely among the individuals (importers, borrowers, …) ; therefore, it is more likely to be used as a reserve currency.

Berłowska et al. (2019) state that the choice of a currency to be included in the reserve portfolio is influenced by foreign exchange regime, geographical structure of the country's trade and, also, banking liabilities. These three items have served as primary variables for almost all research papers and the following inferences are made:

i) *Currency peg:* Beck and Rahbari (2008) find that a country with a currency anchored to another currency tend to hold reserves predominantly in this anchored currency. This result is in line with those provided by Eichengreen and Mathieson (2000), Beck and Weber (2011) or Ito and McCauley (2020).

ii) *International trade:* In case when foreign exchange reserves are seen as an insurance tool to protect the country against the risk of unavailability of foreign imports, the currency composition of these imports is relevant and influences the currency choice of reserves (Borio et al., 2008). The concept of Gopinath and Stein (2018) is that, when a country imports higher share of goods invoiced in USD, people will demand more safe claim denominated in USD.

iii) *External debt denomination:* According to Borio et al. (2008), if a country considers reserves mainly as a protection against the unavailability of the international financial markets, the currency composition of reserves is influenced by the denomination of foreign debt. Gopinath and Stein (2018) provide an evidence that, in situation when banks have more funds denominated in USD, a central bank tends to accumulate more USD reserves too. The same result is obtained by Aizenman et al. (2020) who examined this relationship from the key-currencies point of view. Ito and McCauley (2020) explain that this is due to the tendency to hold reserves in a currency that matches their cash flows**.** On the other hand, Beck and Rahbari (2008) find that the debt denomination does not influence the decision behind accumulating reserves in specific currencies.

Even though, all three determinants have been widely used to explain the currency composition of foreign exchange reserves, our analysis is highly constrained by the unavailability of data and therefore, only the international trade factor were fully utilised. Partially, the currency peg aspect is also included by accounting for differences between foreign exchange regimes.

2.6 Previous research on foreign exchange reserves

In the following section, we introduce a more specific and detailed overview of the previous research related to foreign exchange reserves. The objective is to summarise some of the utilised samples, models, dependent and independent variables of various authors. Considering the structure of our analysis, we distinguish between preceding literature on determinants of reserve size and currency composition of reserves.

2.6.1 Previous research on size of reserves[9]

Range of countries and periods utilised by previous researchers is a direct consequence of the availability of data. Some authors decided to analyse reserve of one specific country (Shijaku & Dushku, 2017), others focused on a particular group of countries, e.g. developing countries as Aizenman and Marion (2003) or Park and Estrada (2009). A clear trend in this sphere is to include as many countries as possible and analyse their reserve drivers. The sample size has been varying greatly mainly due to data availability – we can observe models built on 24 countries, as done by Arslan and Cantú (2019), expanding to almost double in case of Cabezas and De Gregorio (2019), or even to 100 countries as done by Cheung and Ito (2009). The biggest sample observed is deployed by Steiner (2009), who managed to gather data for 162 economies. We were able to collect data for more than 160 countries, however, due to data limitations of our explanatory variables, we make use of a maximum of 82 of them.

Even though majority of authors have focused on the static models for reserve analysis, there have been some researchers approaching this concept differently. As stated by Bastourre et al.

[9] *A summary of previous research done on the topic of size of reserves can be found in Appendix C.*

(2009), OLS fixed effect model is not sufficient when examining the reserve demand and they suggest considering a dynamic approach where the model uses a lagged value of the regressand as an independent variable. According to them, this method should solve the unrealistic assumption that a central bank adjusts its reserve amount straightaway after a change in any of the factors influencing the reserves. Similar conclusion is provided by Steiner (2009), who compares the static fixed effects panel model with a dynamic approach and he indicates that neglecting the dynamics can result in incorrect conclusions. Considering all previous research, we believe that using the static model is still the most suitable for this kind of analysis given the potential serious problems with endogeneity and bias in dynamic models. Moreover, bearing in mind the cross-country distinction among countries, the fixed effect method is preferred in comparison to the pooled regression in an effort to allow for different means across countries.

Moreover, most of the authors have used ratio of reserves over GDP to capture the relative size of reserves. We followed this concept and used reserve values rescaled with GDP size as our regressand. Another aspect to consider is whether gold reserves should be included or excluded from the reserves. Authors have not been unambiguous when constructing their models and there is no clear trend overtime which would explain their decisions. We chose to analyse the total reserve amounts and, therefore, control for gold reserves as a part of our overall dependent variable, as we believe that gold is a liquid asset that can be easily converted to cash.

The literature identifies relatively large scope of possible explanatory variables, which could influence reserves accumulation. In an effort to make the reserves' determinants more comprehensive, authors have been classifying them in various groups. Cheung and Ito (2009) divide their independent variables into three categories: traditional macro, financial and institutional variables. Other authors, as Cabezas and De Gregorio (2019) or Arslan and Cantú (2019), make a distinction among variables related to the precautionary and mercantilist motive of holding reserves. As far as we are aware, these authors utilised the widest range of dummy variables that we have found in the literature. We focus on those factors that are believed to explain the biggest variation of the relative reserve size, as well as a broad range of country-specific dummy variables. Our research might be the closest to Cheung and Ito (2009), although we incorporate the current and capital accounts balances from two perspectives, i.e. including a dummy variable and continuous variable; generally, this approach has not been widely used in the literature. Moreover, this thesis introduces a new model, which accounts for a country-specific crisis. To our knowledge, there has not been a paper considering specific crisis for individual countries when analysing the size of the reserves, yet they explored one specific crisis jointly for a group of countries, e.g. Asian crisis of 1990s or GFC (Arslan & Cantú, 2019; Cabezas & De Gregorio, 2019; Cheung & Ito, 2009).

2.6.2 Previous research on currency composition of reserves

Even though there have been numerous researchers working merely with publicly available data (Beck & Weber, 2011; Gopinath & Stein, 2018; Wong, 2007), most of them have collaborated quite extensively with various international institutions, such as the IMF or

regional reserve funds, allowing them to expand their analysis to confidential information on currency composition of reserves (Eichengreen & Mathieson, 2000; Ito & McCauley, 2020). As presented above, the size of the examined sample highly depends on the obtained database. The scope of the countries used has been varying from 15 up to 58 countries, the latter introduced by Ito and McCauley (2020) who stated that their dataset, covering 51% of world GDP, is probably the largest one aside COFER.

The approach of analysing the currency composition differs across authors. One group of researchers, including Beck and Weber (2011), Lu and Wang (2019), Ito and McCauley (2020) or Aizenman et al. (2020), analyse determinants of individual currency share on a country level, i.e. controlling for the country-specific currency breakdowns. These authors present a range of different independent variables, namely: return volatility, imports invoicing, imports share, currency anchor, co-movements of domestic currency with the reserve currency, external debt denomination, share of gold in total reserves and GDP share of the home country. Others analyse the aggregate currency share of the world reserves, as Eichengreen et al. (2016). Chinn and Frankel (2007) introduce further independent variables influencing the currency composition, as credibility, network effects, export volume, financial market depth and inflation rate. Some of them exploit the dynamic approach and additionally include the lagged dependent variable to account for persistence (Aizenman et al., 2020; Eichengreen et al., 2016). The third bigger group of authors focuses on the examination of diversification strategies and perform mean-variance efficiency analysis as Brière et al. (2015). They conclude that the diversification of reserves is highly important especially in times of increasing interest rates. Lu and Wang (2019) also use the mean-variance framework to examine the decision behind currency allocation. Moreover, as Beck and Rahbari (2008) analyse, the optimal currency shares are examined by applying a two asset minimum variance analysis where central banks choose between USD or EUR denominated investments.

As far as we know, this thesis introduces two new types of approaches related to the currency composition of international reserves. Firstly, we examine the relative changes between reserves denominated in USD and EUR, i.e. what influences the transfer of reserves from one currency to the other. Secondly, a diversification variable is introduced to capture how well reserve portfolios are diversified among the five main reserve currencies.

3 Methodology and Data

The third chapter of this thesis is dedicated to the methodological aspect of our research and is divided into two main parts following the structure of our analysis, i.e. size of reserves in Section 3.1 and currency composition of reserves in Section 3.2.

3.1 Methodology and Data: Size of reserves

The main pillar of our research is built on analysing the size of reserves among different countries and time periods. As a first thing, we introduce the model used for the analysis together with the variables employed, i.e. dependent, independent and dummy variables. After that, the data collection and the expected behaviour of these variables are presented.

3.1.1 Method and model specification

The analysis is built on a set of cross-sectional and time-series data, which includes 82 countries and spans across 20 years from 1999 to 2018. Panel data methodology is applied in order to analyse cross-sectional differences, as well as time-series. OLS estimation is used on a linear regression model accounting for fixed effects through dummy variables that represent different qualitative groups of countries and/or time periods. The fixed effects model, also known as the within estimator, is an econometric model used in panel data analysis, in which the average effects of each group is constant. Those groups can be cross-sectional and/or time-series, represented by dummy variables, generally giving different intercepts in estimated models for each category.

By performing an adjusted Chow test on our dataset, it is found that running a pooled regression is not appropriate in our panel data sample. Therefore, the analysis is built up on fixed effects, which allow for a cross-sectional heterogeneity that is naturally expected among countries.

The general econometric model can be specified as follow:

$$Res/GDP_{i,t} = \beta_1 + \beta_2(Trade/GDP_{i,t}) + \beta_3(M2/GDP_{i,t}) + \beta_4(DebtST/GDP_{i,t}) + \beta_5 Kaopen_{i,t} + \beta_6 Ln(GDPpc_{i,t}) + \beta_7 Dummy_{i,t} \quad (1)$$

3.1.2 Dependent variable

The dependent variable $Res/GDP_{i,t}$ is defined as a ratio between reserve assets and GDP for a country i at time t. Using a ratio, the amount of reserves takes into account the size of each economy and "make[s] the dependent variable stationary" (Obstfeld et al., 2010, p. 73). It is believed that using a unit-free ratio improves the results and the comparability across countries

and majority of the authors have used the relative reserves amounts as their dependent variables (see Appendix C).

In our analysis, the *reserves*, as stated above, are the *official reserve assets* as defined by the International Monetary Fund (2009), for which the data is extracted from the IMF website using two databases: IFS and IRFCL. Official reserve assets, as published in IFRCL, are composed of foreign currency reserves, IMF reserve position, SDRs, gold and other reserves. This corresponds to the section I.A of the Data Template (see Appendix B) and this definition of foreign exchange reserves is in line with the definition of gross reserves (Bahmani-Oskooee & Brown, 2002). The country values taken for this analysis are the reserves held by monetary authorities and central governments, excluding social security. Both IFS and IRFCL consist of observations measured in USD, which facilitates the comparability among countries, and its accounting principles are based on approximate market values. IFS database comprises the information on the size of reserves for 182 countries and it is the main source of data for this analysis. On the other hand, IRFCL provides a further breakdown to the mentioned subaccounts of the official reserve assets, however, limited to 83 countries[10]. IRFCL is also used to fill in some gaps in the IFS database where observations were missing; namely Hong Kong 2010 and Jordan 2017-2019. This was possible due to similarities between IFS and IFRCL databases, in which the reported values are comparable and possible to be interchanged (International Monetary Fund, 2020b).

The GDP data used in our analysis is measured in current prices. The reason behind taking current instead of constant prices is that reserves are reported in nominal (market) values and, dividing it by GDP in current prices, could partially remove the FX effect and give a more constant ratio. This data is obtained from the WEO database published by the IMF, where the GDP values are also reported in USD, simplifying the comparison among countries.

3.1.3 Independent variables

Trade openness

$Trade/GDP_{i,t}$ is defined as a ratio between the sum of exports and imports, and the GDP, for a country i at time t. This relation is commonly known as the *trade-to-GDP ratio* or *trade openness ratio*. The variable tries to explain whether more trading with partner countries is related to higher reserve amounts in order to finance the balance of payments, which is part of the mercantilist motive of holding reserves. Steiner (2009) states that the trade openness, as used in our model, is the most prevalent measure deployed among other authors. Shijaku and Dushku (2017) mention that the traditional version of this variable was based only on the imports; however, as also indicated by Steiner (2009), including exports in the analysis is important. This is due to the fact that exports create foreign exchange income, which is consequently used to fund country's imports; and this way we take the current account movements fully into the consideration (Shijaku & Dushku, 2017). Steiner also states that a

[10] *Moreover, IRFCL database contains the currency composition for some of the countries and it is the main data source for the analysis of the currency composition of reserves introduced in Section 3.2.*

country with more open economy is more vulnerable to external shocks and, therefore, the trade openness is assumed to have a positive relationship with reserves, i.e. $\beta_2 > 0$. Data on exports and imports is obtained from the BOP/IIP database available by the IMF.

Broad money (M2)

$M2/GDP_{i,t}$ is defined as a ratio between broad money, measured as M2, and GDP for a country i at time t. M2 is a monetary aggregate defined by the European Central Bank (2020) as the total amount of cash plus demand- and some time-deposits[11].

Obstfeld et al. (2010) consider M2 as the size of domestic financial liabilities that could potentially be converted into foreign currency in case of financial crisis. They suggest using M2 as a reserve adequacy benchmark considering that it has a higher explanatory value than other conventional drivers in the long run. Lane and Burke (2001) describe the M2/GDP ratio as a measure of financial depth and state that central banks should match the financial deepening with the rising of their foreign exchange reserves. Therefore, we expect that an increase in financial depth is followed by higher reserves, thus, $\beta_3 > 0$. Information on the broad money, as a percentage of GDP, is obtained from the World Bank. However, data for the eurozone countries is not available given the fact that they share a common currency. Due to this reason, countries of eurozone are dropped from the analysis.

External short-term debt

The International Monetary Fund (2016) considers the *Greenspan-Guidotti rule* as a traditional metric for reserve adequacy and states that it is the most used metric for emerging markets. In order to capture the application of this rule among countries, the variable $DebtST/GDP_{i,t}$ is defined as the amount of external short-term debt in relation to GDP, for a country i at time t.

This ratio determines the financial vulnerability of a country or the risk that domestic borrowers could face if foreign investors did not roll over their debts (Glick & Hutchison, 2011; Obstfeld et al., 2010). Commonly, larger amounts of debt mean higher probability of liquidity risk and financial crisis. Therefore, as a result of the precautionary motive, central banks can accumulate more reserves to offset this risk (Steiner, 2009). Consequently, the β_4 coefficient is expected to be positive.

Data on external debt is obtained from the World Bank database as the Gross External Debt Position, which is defined as the outstanding amount of liabilities that are borrowed by domestic residents from non-residents of a country (International Monetary Fund, 2014a). For the purpose of our analysis, the short-term debt for all the sectors and all the instruments is considered as the most relevant and this choice is based on the *Greenspan-Guidotti rule*.

[11] More specifically, these time deposits are meant to be overnight deposits, deposits with an agreed maturity of up to two years and deposits redeemable at notice of up to three months.

Kaopen

Chinn and Ito built up on their previous research from 2002, in which they examine "[t]he link between capital account openness, financial development, and legal/institutional environment" (Chinn & Ito, 2006, p. 3). They approach the matters "relevant to the sequence of liberalization between financial and goods cross-border flows and the sequence of development in banking and equity markets" (Chinn & Ito, 2006, p. 4). In this extended work, they have introduced the capital account index, Kaopen, as used in present. They argue that the measures of capital controls used traditionally, such as the ones used by the IMF in its AREAER, are not always successful to consider the capital controls' intensity, something that Kaopen tries to explain.

$Kaopen_{i,t}$ as used in our analysis represents the normalized Kaopen index for a country i at time t and serves as a measure of financial openness[12]. According to Aizenman and Lee (2007) or Arce et al. (2019), countries with more open capital accounts are more likely to hold larger reserves. Therefore, considering the previous research, we expect to obtain a positive coefficient of β_5.

Kaopen, also referred to as Chinn-Ito index, is obtained from a Portland State University blog where the data is available (Chinn & Ito, 2019). The normalized index is opted and, at the time of writing this paper, the index is available until 2017. However, given that our analysis spans up to 2018, estimations for the missing year of 2018 are inevitable. Considering that country indexes have been fairly constant over time and no significant changes are expected in the intensity of capital control from the year 2017 to the following one, observations for the missing year are extrapolated. This is performed in order to match the availability of other variables and to avoid losing further observations in the model. Countries with the same index over the last five years are assigned the same value also for 2018. In contrast, those countries whose index has changed, a weighted average of the previous five years is calculated assigning more weight to more recent periods in the following way: 41% to the value of 2017, 25% to 2016, 17% to 2015, 11% to 2014 and 6% to 2013[13].

Real GDP per capita

$Ln(GDPpc_{i,t})$ represents the natural logarithm of the real GDP per capita for a country i at time t. Following the econometric model estimated by Arslan and Cantú (2019), this variable is included in the regression to test if the income level of a country can influence the amount of reserves. According to Lane and Burke (2001), it should control for the development level in a state and Choi and Strömqvist (2007) describe it as a scaling factor capturing the size of international transactions of a country, which is positively related to the standards of living. Considering the research performed by Choi and Baek (2004), this variable should have an inverted U-shape with reserves, i.e. the poor and the wealthy countries should hold less reserves than the mid-income economies. According to the paper of Aizenman and Marion (2003), this

[12] *The larger the value of Kaopen, the higher the level of capital account openness.*

[13] *Weights are calculated using the exponential function λ^{α} where $\lambda = 0.41$ and $\alpha = [1, 1.5, 2, 2.5, 3]$ for each year [2017, 2016, 2015, 2014, 2013], respectively, and rounding the sum to the unit.*

variable has a positive impact on reserves over GDP. Building our expectation on their theory, the coefficient β_6 is expected to be positive.

Data on real GDP per capita is obtained from the World Bank database. Values are measured in constant 2010 US dollars and the reserve amounts are transformed to the log-values applying the natural logarithm. Real GDP per capita is log-transformed for two reasons: first, the distribution of real GDP per capita is right skewed and its log-transformation makes data more normally distributed; and second, it is more interesting to measure the impact that a percentual change in real GDP per capita has on the explained variable than a change in absolute terms.

3.1.4 Dummy variables

$Dummy_{i,t}$ is a vector of zero-one dummy variable that explains cross-sectional fixed effects for different categories of countries, which are grouped by aspects such as foreign exchange regime, country development, fuel-related exports, or current account balance. It is also used to explain time-series fixed effects when analysing changes in the dependent variable before and after crisis.

Exchange rate regime

Several authors agree that the exchange rate regime must be considered in order to explain country-specific factors (see Appendix C). Following the IMF classification in its AREAER, the countries are categorized into the following regimes: *hard peg, soft peg, floating and other managed*.

The classification of these regimes are built on the theory presented by Stone et al. (2008) and International Monetary Fund (2019a). Based on this literature, we summarise the exchange rate regimes as follows:

- *Hard peg:* when a country subordinates its monetary independence to a foreign currency, either by using a currency of another country, known as *formal dollarization* or *no separate legal tender*; or by fixing its currency to a foreign currency or a basket of currencies, known as *currency board.*
- *Soft peg:* when a country's currency is pegged to a foreign currency, or a basket of foreign currencies, and the country aims to keep a stable exchange rate. This classification includes regimes such as *conventional peg*, *pegged exchange rate within horizontal bands*, *stabilized arrangement*, *crawling peg* or *craw-like arrangement*.
- *Floating:* when a country's exchange rate is mainly determined by the market and the actions to target a specific level of exchange rate are not allowed or are very limited.
- *Other managed arrangement:* a residual category for arrangements that are not meeting the criteria to be included in any of the above stated categories.

The classification of exchange rate arrangements was extracted from the IMF AREAER database, which provides the *de facto* classification. It is believed that *de jure* arrangements,

i.e. the officially announced regimes, may differ from the actual ones and *de facto* classification is a better approximation of the reality. Next, countries have are assigned to the four previously described categories. The purpose is to explain whether the dependent variable behaves differently for countries with different FX regimes. Additionally, changes of exchange regime throughout the time are also considered in order to explain whether countries that have changed their regime have also significantly changed their reserves. List of countries and their exchange regimes can be found in Appendix D. Considering previous research, it is expected to find significant differences among hard pegs, soft pegs and floating regimes, with the latest regime holding the lowest reserves.

Country development

In order to account for the cross-country differences among more and less developed economies, countries in our model are divided into three groups according to the IMF classification: *Advanced Economies (AE), Emerging Market and Developing Economies (EMDE)* and *Low-Income Developing Countries (LIDC)*[14]. As suggested by Bastourre et al. (2009), the model should be expanded by including economic development of a country when analysing reserve hoardings.

As proved by Cheung and Ito (2009), there are significant differences between reserves and their demand factors in countries with different developments. They find that developing countries tend to hold more reserves than advanced economies. Choi et al. (2009) found that a country with better credit ratings tends to hold less reserves. Considering that advanced economies are more creditworthy than emerging ones, it could serve as an indirect explanation. Based on the previous research, it is expected that EMDE and LIDC are more likely to hold more reserves than AE in order to cope with the potential crisis in a better way, as well as the fact that AE have a stable banking system and the possibility to borrow in their domestic currencies (Obstfeld et al., 2010).

In order to classify the countries among AE, EMDE and LIDC, the WEO classification of the IMF is followed, which groups the economies based on the following factors: income level per capita, export diversification and degree of integration into the global financial system (International Monetary Fund, 2019b). To obtain the most correct results, changes between these groups are taken into account and any updates of the country classification are mirrored in our analysis. List of countries and their development level is available in Appendix D.

[14] *LIDC is a new IMF category since 2014 when 60 countries from EMDE group were excluded and reclassified based on their eligibility for PRGT and their GNI per capita below some threshold (International Monetary Fund, 2014b).*

Fuel-exporting

As described in Arslan and Cantú (2019), during a period of fuel price swings, fuel exporting countries increased their reserves to almost 80% of their GDP and, subsequently, downsized their hoardings when prices declined. Fuel-exporting economies usually sell their resources in USD or other main currencies. Thus, it is expected that they hold more foreign exchange reserves to balance their current account and face potential price changes in commodities, which is consistent with the mercantilist standpoint.

For the purpose of our analysis, countries are classified into two groups: fuel-exporting and non-fuel exporting economies, following United Nations (2019) classification, which defines an economy as a fuel exporter when its share of fuel exports in the total exports is larger than 20 percent. Overall, our dataset contains 17 fuel exporting nations listed in Appendix D.

Current and capital accounts balance

International Monetary Fund (2009, p. 216) establishes that "the sum of the current and capital account balances…is labelled as net lending (+)/net borrowing (-)". Eurostat (n.d.) details that the current and capital accounts' balance "represents the net resources that the total economy makes available to the rest of the world (if it is positive) or receives from the rest of the world (if it is negative)".

As Jeanne (2007) finds, reserve hoardings are significantly related to the current account surpluses. Economies that are mainly borrowers or mainly lenders might hold different amount of reserves, as some of them might have to be exchanged in order to finance the balance of payments' imbalances, which is related to the mercantilist motive.

Data on the current and capital accounts balance is obtained from the BOP/IIP dataset available from the IMF website. Based on the balance sign, each observation is allocated to the category of "borrower" (negative sign) or "lender" (positive sign) using dummy variables. Moreover, the data shows that countries tend to be either mainly borrowers or mainly lenders over time, with some changes that seem to occur temporarily. This aspect could distort our analysis since we believe that a country does not adjust the amount of reserves at short-term when the balance changes sign. Therefore, data is adjusted for countries whose balance sign has changed several times over the period of time analysed. Our approach considers the country as either borrower or lender according to the net position reported most of the periods. On the other hand, no adjustment is needed when a country does not change its balance sign or when it only happens once; the latter could indicate a change in trend, and we want to consider this option.

In order to measure the sensitivity that the current and capital accounts balance has on the level of reserves, we also apply the model replacing the dummy for a continuous variable, i.e. the current and capital accounts balance divided by the GDP of the country ($CCBalance/GDP$). Consequently, the equation for this specific analysis would be as presented in equation (2):

$$Res/GDP_{i,t} = \beta_1 + \beta_2(Trade/GDP_{i,t}) + \beta_3(M2/GDP_{i,t}) + \beta_4(DebtST/GDP_{i,t}) + \beta_5 Kaopen_{i,t} + \beta_6 Ln(GDPpc_{i,t}) + \beta_7(CCBalance/GDP_{i,t}) \quad (2)$$

Nor et al. (2008) give a good understanding of the relationship between current account and exchange rate. They state that the current account surplus tends to be related to the external inflows denominated in foreign currencies caused by the export-payments, which the domestic country receives, and these inflows might contribute to the appreciation of a domestic currency. McCauley (2003) mentions that the market intervention done to prevent the currency appreciation, and the associated loss of foreign demand, entails the growth of foreign exchange reserves. Therefore, we expect that larger positive current and capital accounts balance entails increasing reserves, thus, a positive coefficient for the variable $CCBalance/GDP$ and the dummy associated to net lenders.

Crisis

According to the precautionary motive, countries hold reserves in order to protect themselves against various negative shocks. If a country has had an experience with any type of crisis, this could potentially influence its reserve holdings, i.e. the risk aversity might be higher and, therefore, they might hold more reserves than a country which has not experienced any crisis in the past. Bastourre et al. (2009) mention that, if a country has defaulted in the past, it is expected to hold more reserves in general. We find of interest to analyse whether countries have learnt the lesson from their previous crises and increased their reserve holdings to successfully face upcoming instabilities.

Not all the countries have experienced the same kind of crisis, and if so, it did not even have to be at the same time. Therefore, in order to provide a more detailed analysis, we want to identify what crises our sample has suffered from and when. We make use of a database provided by Laeven and Valencia (2020) where country-specific crises are detailed.

Our goal is to analyse whether the occurrence of a crisis changes the amount of reserves of a country experiencing it. Thus, we start from our original model, stated in equation (1), and we adjust it to represent the first differences as presented in equation (3):

$$\Delta\, Res_{i,t} = \beta_1 + \beta_2\, \Delta(Trade/GDP_{i,t}) + \beta_3\, \Delta\left(M2/GDP_{i,t}\right) + \beta_4\, \Delta\left(DebtST/GDP_{i,t}\right) + \beta_5\, \Delta Kaopen_{i,t} + \beta_6\, \Delta Ln\left(GDPpc_{i,t}\right) + \beta_7\, DummyAfter_{i,t} \qquad (3)$$

Changes in the independent variables reflect the difference, in absolute terms, between the values of two periods[15]. The dependent variable is modified for this analysis with respect to its original shape. Using the ratio Res/GDP could give us artificially higher values due to potential declining denominator, even though no change would occur in the amount of reserves, i.e. GDP tends to decrease in reaction to worsening economic conditions. Thus, the relative change in the total amount of reserves is preferred, i.e. a new dependent variable is defined as ΔRes.

In order to better isolate the crisis effect, only those countries that have been hit by a crisis during our time frame are taken into account. This reduces the cross-sectional dimension of the sample to merely 23 countries (see Appendix D), but also reduces the distortion caused by countries that have not experienced any crises. Moreover, to obtain a more precise *before vs*

[15] *Original variables are ratios, indexes and logarithms so we find a subtraction the best way to measure a change.*

after crisis effect and reduce the potential noise from other periods, the time dimension of our sample is restricted to *three years preceding the start* and *three years succeeding the end of a crisis* occurred in a country. This way, there is a long enough period of time before the start of the crisis to see how the country was behaving, as well as a long enough period after the end of the crisis in which the country might have adjusted its reserves to desired levels.

$DummyAfter$ is a dummy variable accounting for fixed effects in time periods; in particular, it assigns a value of one to each of the three years succeeding the end of the crisis and a value of zero to each of the three periods preceding the start of it. Consequently, the crisis years and other time periods are excluded from our analysis.

According to the idea that countries react to crisis, we expect to find a significant dummy variable, what would indicate differences in the acquisition pattern of reserves before and after crisis. A positive sign would signal that countries react to crises by increasing the amount of reserves more than they did before, what would be in line with the precautionary motive.

3.2 Methodology and Data: Currency composition of reserves

The second part of our analysis is devoted to the currency composition of reserves. Firstly, we examine variables that could possibly explain the relative selection of EUR and USD in the currency composition of the world reserves; and secondly, a diversification measure is used to explain the diversification effect in the countries' currency composition of reserves. The structure of each analysis is similar to the previous subchapter, i.e. we introduce the model and variables used, together with the data sources and the expectations of the model.

3.2.1 USD-EUR spread in world reserves

USD is the main international currency and the one which represents the largest share of the world foreign exchange reserves. However, the eurozone has been gaining weight in the international trade and world's GDP, with some researchers as Chinn and Frankel (2007) stating that EUR has chances to even surpass USD as the main international currency. Wong (2007) finds that there is a high negative correlation between USD and EUR indicating that these two currencies are very good substitutes for each other. In this section, we examine the rationale behind why countries would increase their shares in one currency to the detriment of the other, in their implicit USD-EUR portfolio, i.e. we only account for variations between USD and EUR denominated assets.

Our analysis is based on the data obtained from COFER database, published by the IMF, where world reserve assets are broken down into currencies, although no information is provided at a country-level. We use the quarterly data from 1999 to 2019 and summed claims in USD and EUR in order to calculate the share of each currency in the USD-EUR portfolio. The difference in shares gives a spread, and its change over time is defined as the dependent variable of this

model, $\Delta CurrencySPD_t$[16]. COFER database provides data on both USD and EUR claims measured in USD units. In order to avoid changes in spread due to exchange rate effects, EUR claims measured in dollars are converted to euros taking the exchange rate at the end of the specific quarter and consequently converted back to dollars using a constant rate[17].

We formulate the following regression model in equation (4):

$$\Delta CurrencySPD_t = \gamma_1 + \gamma_2 \Delta EURUSD_t + \gamma_3 \Delta GDPSPD_t + \gamma_4 \Delta TradeSPD_t \qquad (4)$$

$\Delta EURUSD_t$ indicates the change in the exchange rate, in relative terms, between the currencies, measured as the value in USD of 1 unit of EUR[18]. It is believed that the relative appreciation or depreciation of the currencies can have a strong effect on building the USD-EUR portfolio. Exchange rate data is obtained from the financial data provider Investing.com.

US and eurozone economies may have a different growth that could potentially increase or decrease their attractiveness. As both markets grow at different speed, the spread of the real GDP growth is calculated, and it defines its change as the variable $\Delta GDPSPD_t$[19]. This variable would suggest which region is growing faster and, potentially, provide a motive for changing the weight of the portfolio towards either currency. OECD data for GDP growth is used.

As the mercantilist motive suggests, trade can also be an important reason to hold more or less reserves in a specific currency. We use data on trade for the US and the eurozone countries as the sum of their total imports and exports. These amounts are divided by the total sum of both regions and a relative weight of each currency zone is obtained. Consequently, the spread is calculated between them and its change represents the variable $\Delta TradeSPD_t$[20]. This variable measures whether trade is increasing more in one region than in the other and could be a reason for holding more reserves from the region increasing in its importance. We access the data on imports and exports from the IMF database.

3.2.2 Diversification effect

As Das et al. (2019) describe, fixed exchange rate regimes proved to be unsustainable and they were replaced by more flexible currency systems, which consequently shifted the purpose for holding reserves from the explicit exchange rate maintenance to rather financial stability management. This re-orientation was followed by changes in the central bank management "from pure liquidity management to a portfolio management approach with increased emphasis on capital preservation and return" (Das et al., 2019, p. 2). Countries manage their reserves as a portfolio of investments; some of them have a more diversified portfolio whereas others have the claims more concentrated in only a few currencies. In this section, we intend to explore the

[16] $\Delta CurrencySPD_t = CurrencySPD_t - CurrencySPD_{t-1}$
where $CurrencySPD_t = ShareUSD_t - ShareEUR_t$ *and* $ShareUSD_t + ShareEUR_t = 1$.
[17] *Our analysis has used the exchange rate as of 1999Q1.*
[18] $\Delta EURUSD_t = EURUSD_t - EURUSD_{t-1}$
[19] $\Delta GDPSPD_t = GDPSPD_t - GDPSPD_{t-1}$, *where* $GDPSPD_t = GDPgrowthUSD_t - GDPgrowthEUR_t$.
[20] $\Delta TradeSPD_t = TradeSPD_t - TradeSPD_{t-1}$ *where* $TradeSPD_t = ShareTradeUSD_t - ShareTradeEUR_t$ *and* $ShareTradeUSD_t + ShareTradeEUR_t = 1$.

factors that affect the diversification of reserve portfolios in different currencies and how their diversification differs among countries.

In order to explain the currency diversification of the country portfolios of reserves, we define our diversification measure (Div) as a variation of the commonly accepted measure of market concentration *Herfindahl-Hirschman Index (HHI)*. For a country i at time t, the share of each currency h on the total portfolio of SDR currencies is represented by $w_{i,t,h}$, where $h = [USD, EUR, JPY, GBP, CNY]$ and $\sum_h w_{i,t,h} = 1$. Thus, our diversification measure (Div) is defined as illustrated in equation (5):

$$Div_{i,t} = 1 - \sum_h w_{i,t,h}^2 \qquad (5)$$

In our analysis, Div represents a diversification index taking on values between 0 and 0.8[21]. When the portfolio is concentrated in only one currency, $Div = 0$; and when the portfolio is totally diversified across the five currencies in equal shares, $Div = 0.8$.

Data on currency composition of reserves is obtained from the IMF's IRFCL database. Even though COFER database contains the currency split of the aggregate amounts of reserves, the country-specific information is confidential. IRFCL database, on the other hand, provides the currency breakdown for some countries in its IRFCL guidelines in section *IV Memo Items*[22] (International Monetary Fund, 2013). Due to the limitation that only the breakdown of the five SDR currencies is available, our diversification analysis is constrained to these currencies. Given the fact that the domestic currency cannot be considered as a foreign exchange asset, we exclude the eurozone countries from the analysis in order to have a fairer Div measure. Our final sample is composed of 20 countries with quarterly observations from 2015Q3 to 2019Q4. List of countries that are part of this analysis can be found in the Appendix D.

We define our regression model[23] as introduced in equation (6):

$$Div_{i,t} = \alpha_1 Ln(Res)_{i,t} + \alpha_2 Ln(GDPpc)_{i,t} + \alpha_3 CVol_{i,t} + \alpha_4 DivTrade_{i,t} + \alpha_5 DummyFX_{i,t} \qquad (6)$$

$Ln(Res)_{i,t}$ is the natural logarithm of the total amount of official reserve assets of a country i at time t. Considering the common opinion in literature, we expect a positive coefficient, i.e. countries holding larger amounts of reserves tend to diversify their portfolio more.

We want to test if the size of the economy, measured as GDP, is relevant for diversification decisions. Larger economies might have more possibilities to diversify their portfolios; however, this variable was highly correlated with $Ln(Res)_{i,t}$, giving a correlation coefficient larger than 0.8 and implying a model suffering from multicollinearity. Therefore, GDP is dropped from the analysis considering $Ln(Res)_{i,t}$ as a better variable[24] to explain $Div_{i,t}$.

[21] *A wider variety of assets would provide a diversification index between 0 and 1.*
[22] *A sample of the template structure can be found in Attachment B.*
[23] *Regression model without intercept to avoid the 'dummy variable trap'.*
[24] *Decision was made by running a bivariate regression model in which log-reserves provided a better fit than GDP or log-GDP, measured as R2.*

$Ln(GDPpc)_{i,t}$ indicates the natural logarithm of the real GDP per capita of a country i at time t. We want to account for the income level of each economy and test whether it is relevant in the diversification of the reserve assets. More developed countries with higher incomes per capita could potentially have better access to wider options of assets associated with more diversification opportunities, thus a positive coefficient is expected.

Quarterly data on GDPpc is challenging to obtain. For instance, OECD reports some GDP per capita data on a quarterly basis, but it does not include all the countries in our analysis. Only annual data was found from other sources; therefore, our approach consists of using annual values, which we divide by 4 in order to approximate the quarterly values. The WB reports annual GDPpc in USD, but it does not cover all our time frame, i.e. values as of 2019. However, the IMF database is more up to date and we have decided to use it, although expressed in domestic currency, thus, a necessary translation to USD[25] is made in order to work with homogenous units. Foreign exchange rates are obtained from the publicly available financial data providers Yahoo Finance and Investing.com.

Diversification effect might be influenced by the perception of risk. We have seen, from the precautionary motives, that currency crises might be the most important crises related to reserve accumulation. Therefore, we define a variable, $CVol_{i,t}$, which represents the return volatility of currency-pair i at time t and is calculated as the standard deviation[26] of the domestic currency with USD. Using the domestic currency against the USD makes it possible to account for country-specific risks. Berłowska et al. (2019) indicate that holding reserves in a currency with the lowest volatility against the domestic currency strengthens the reserves' risk profile. As diversification is a well-known option to hedge for risks, a positive relationship is believed to exists, this is, larger currency volatility can imply more diversification.

As already introduced, the international trade is a foundation for the mercantilist motive and, therefore, plays an important role in reserve hoarding. In order to account for this determinant, our model defines a new variable $DivTrade_{i,t}$ which denotes the trade diversification quantified according to the equation (5). The weight $w_{i,t,h}$, in this situation, represents the share of the invoicing currency h in the five-SDR-currencies basket of trade for a country i at time t. To clarify, an increase in trade with US must be matched with a decrease in the trade's share of another currency region, such as the eurozone, Japan, UK and/or China. The purpose of including this variable is to examine whether more diversified trade could increase the diversification of reserve assets. Following the concept of Beck and Weber (2011), we use the sum of the imports and exports of the currency zone as a proxy of currency invoicing, i.e. imports and exports actually denominated in the currency zone specific currencies. Based on the data from Direction of Trade Statistic reported by the IMF, we calculate the share of trade in a currency h and the diversification variable is calculated. The more diversified trading should lead to more diversified reserves; thus, a positive coefficient is expected.

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[25] USD was selected as the measurement unit for the analysis given the fact that this is the most widely used currency in the world and it is also the reporting currency of the IRFCL database.

[26] Standard deviation is quantified from returns between currency pairs of the previous 63 days. The reason to choose 63 days specifically is to represent a quarter of yearly trading days, i.e. commonly accepted 252 trading days in a year.

The final variable of the model is a vector of dummy variables, $DummyFX_{i,t}$. It identifies the foreign exchange regime for a country i at time t, namely, *hard peg*, *soft peg* and *floating regimes*. According to the nature of the countries with stricter regimes, we expect them to hold a less diversified portfolio of reserve assets, which is more concentrated on the currency, or basket of currencies, that the regime follows. On the other hand, floating regimes are expected to have a more diversified assets as there is not an anchor to be tied up.

3.3 Limitations

Due to complexity of the research question, it is unavoidable to set some necessary boundaries. These are with respect to the explained and explanatory variables, time span of the observations and utilised databases. Considering the extensive number of possible explanatory variables, the focus is set on the few main ones, which are believed to explain the biggest variation in the reserve data. Therefore, we assume a model where omitted variables might be present.

The most challenging aspects of this thesis, which restrict our analysis, are the accessibility and consistency of the available data. This thesis relies only on publicly available data, which could potentially generate measurement errors and deteriorate the possible correct conclusions.

In order to get information on the foreign exchange reserves, the databases of the IMF are utilised. These databases restraint our analysis in more ways:

- IFS database includes data on the absolute amounts of reserves for the largest number of countries and periods, however, it does not contain any currency composition.
- IRFCL database also contains overall size of reserves, although for fewer countries than IFS. IRFCL, additionally, provides a limited scope of countries reporting their currency compositions - not all countries are represented, and availability of this data starts mainly from the end of 2015, when more countries have gradually started reporting currency breakdowns, although still constrained to only a small portion of all countries.
- Another sub-database of IRFCL includes the currency split between SDR and non-SDR currencies available from 2013 to 2016, while not providing further details for specific currency reserves.
- COFER database does not incorporate currency composition of specific countries given the fact that this information is confidential; otherwise, it includes merely the aggregate amounts of reserves.

In general, we have not found a database including all desirable data for the foreign currency reserves in order to span our analysis to all countries in the world for a period of several decades. In an effort to maximise the availability of the data, IFS and IRFCL databases are used simultaneously for the analysis of the reserve size. After a more comprehensive review of these two databases, it is discovered that values differ only slightly and within a reasonable

threshold[27] that made this pooling of data possible. Overall, it is possible to collect the international reserve data on more than 180 countries.

Another main limitation in the analysis of the reserve size comes with the availability of data on some explanatory variables. When looking for data to match our already obtained reserve amounts, information for various countries and years is missing. Numerous variables are not available for the early 90s, what makes us reduce the time frame to the current century, or more explicitly, from 1999 onwards. Consequently, an unbalanced panel data method is deployed. Some variables also pose restrictions on the eurozone countries. For instance, broad money is not reported on an individual basis, but merely on a group level, while the Chinn-Ito index is a country-specific measure and does not consider the eurozone as a whole. This stated, there is a necessity to drop all eurozone countries out of scope in order to use all defined variables. Given that some countries do not report, or information is not available, for some of the key variables, the scope of our cross-country analysis is reduced to a few more than 80 countries.

Another potential obstacle faced is related to the conversion of reserve amounts to USD. Considering the fact that each reporting entity coverts its reserves into USD separately, and that there are not specific exchange rates given by the IMF, it could potentially cause discrepancies in our analysis. The IMF only recommends, to its reporters, to use the market exchange rates of the year-end, but this could possibly differ across individual reporting countries (International Monetary Fund, 2020a). Same problem appears for some of the explanatory variables, which are obtainable merely in domestic currencies and, therefore, adjustments to a one common currency is necessary.

In addition to the above disclosed limitations, there are various constraints for the currency breakdown of reserves. In an effort to perform the reserve diversification analysis, we utilise quarterly data, which allows us to increase the number of observations to an adequate level. However, as a consequence of deploying quarterly data, other problems come on the scene, i.e. some of the explanatory variables are not available on a quarterly basis, but only on a yearly frequency.

One potential drawback of the USD-EUR spread analysis is the weight that big reserve holders might have in the overall reserve amounts. These countries could be changing their reserve composition independently of the global trend. For instance, even if most of the smaller reserve holders have been increasing their EUR reserves, but, at the same time, a big holder has been substantially decreasing its EUR share, the total aggregate data obtained from COFER might still indicate a reduction in EUR reserves (Wong, 2007).

With all this in mind, our work is constrained to the publicly available data. A greater scope of reporting countries and extended, or more frequent, time observations would have enriched our work further.

[27] *A threshold of 10% is introduced when comparing IRS and IRFCL databases, i.e. all data used in our analysis does not differ more than 10% across these two databases.*

4 Results and Analysis

This part is devoted to analysing the data collected and models applied that are described in the previous section. Firstly, we outline some univariate analysis from the samples obtained as a way to introduce some preliminary observations. Secondly, we analyse the size of reserves by applying the previously introduced models. And finally, we analyse the USD-EUR spread in the world reserves and the diversification effect in the currency composition of international reserve assets[28].

4.1 Descriptive statistics

Our data shows differences in the amount of reserves held by countries with various characteristics, which establishes a base for further analysis. In this part, we carry out a univariate analysis of the data collected to obtain some preliminary observations. It is introduced how countries – categorised based on their foreign exchange regimes, development, fuel exports or current and capital accounts balance – hold unambiguous amount of reserves in relation to their GDP. Countries are also analysed from the reserve adequacy perspective according to the three typical reserve adequacy measures: import coverage, reserves over M2 ratio, and short-term external debt coverage. Regarding currency composition of reserves, we present an outlook, extrapolating from our sample, on the main reserve holders for each currency and the diversification measure (Div) for a sample of countries.

Foreign exchange regime

Table 1 summarises reserves, in terms of GDP, and the three traditional reserve adequacy metrics for our sample in the year 2018[29], where it can be seen how apparent the differences are among foreign exchange regimes. Furthermore, Appendix E presents a visual overview of these metrics from 1999 to 2018.

Hard peg countries have the highest amount of reserves, in relation to their GDP. This might be due to the higher importance of interventions in the FX market in order to tie the domestic currency to its peg. This would be the case of a currency board regime. Reserves over GDP for

[28] *Section 4.1 was done using all the countries, time periods and observations for which specific data for the analysis was available. On the other hand, Section 4.2 and Section 4.3 were done using only observations for which all the key variables were available, thus, reducing the sample.*

[29] *In order to give an updated picture, tables in this section show the last year of our sample, i.e. 2018. We do not present the averages throughout the entire scope of time given that our panel sample is unbalanced, countries have changed the level of reserves significantly throughout the time and some have changed their classifications among different groups.*

hard peg regimes have been increasing in the last two decades from around 25% in 2000 to more than 70% in 2017. Soft peg comes second, peaking in 2009 to around 40%, while since then it has been decreasing down to 25% in 2018. This trend is opposite to the hard peg. Floating regime seemingly does not need a lot of reserves as the market is supposed to regulate the currency exchange rate and interventions are limited. They have barely surpassed 10% of the GDP for the last 20 years.

Table 1: 2018 statistics, FX regime[30]

Average values	**Hard peg**	**Soft peg**	**Floating**
Res/GDP (%)	67.8	24.7	11.1
Import coverage (months)	7.1	8.1	4.5
Res/M2 (%)	30.3	33.5	9.8
Res/DebtST (%)	39.1	82.3	23.0

Source: IMF, WB, Author's calculation

Analysing the eurozone[31] individually, it is found that countries held on average 9% of their GDP's value in reserves before entering the currency union and this amount dropped to 5% after the EUR was introduced. This difference, however, can mainly be explained by the transfer of reserves by the state members to the ECB, as it is stated in the Article 30 of the Statute of the European System of Central Banks and of the European Central Bank (2012, p. 242): "the ECB shall be provided by the national central banks with foreign reserve assets".

Returning back to our general analysis in Appendix E, the import coverage of countries with fixed currency regimes is higher in comparison to those with flexible regimes. This is consistent with our expectations. Examining the figure further, all of the countries held higher stocks of reserves than the rule of 3 months suggests. Soft peg regimes have covered more than 9 months of imports in most of the recent years, whereas floating regimes have been around the benchmark of 3 months and barely covering more than 4 months of imports. From the figures in the appendix, it is clear that hard and soft peg regimes held consistently more reserves over M2 than floating regimes did, exceeding the conservative benchmark of 20%, whereas floating regimes peaked in 2016 at 11%. It is also observable that hard and soft pegs have a higher coverage of short-term external debt than floating regimes. Although, all of them are below the 100% benchmark, with the exception of only 2 years since 1999 for soft peg regimes.

[30] *Excluding China as an outlier for import coverage, M2 and ST Debt metrics. China's effect on reserves over GDP is not significant to be excluded.*
[31] *Excluding Germany and France, whose currencies were part of the SDR basket before introducing EUR and their reserve holding have not changed significantly for the analysis.*

Country development

An overview of the four measures being discussed for the year 2018 is available in Table 2, where differences among development levels are presented.

Table 2: 2018 statistics, country development

Average values	**AE**	**EMDE**	**LIDC**
Res/GDP (%)	9.6	23.5	14.7
Import coverage (months)	3.9	10.6	4.6
Res/M2 (%)	7.9	19.3	25.8
Res/DebtST (%)	16.2	287.9	311.0

Source: IMF, WB, Author's calculation

As Appendix F shows, emerging markets tend to hold far more reserves in relation to the GDP than advanced economies. For instance, the average ratio of reserves over GDP for EMDE is more than double the size of AE, whose ratio has started exceeding 10% of GDP only in the last few years. Emerging markets also tend to have more import coverage than advanced or low-income economies. AE meet the 3-months benchmark on average whereas emerging markets exceeded 10 months for the last decade. However, there is a change in positions in reserves over M2 ratio; in this case, LIDC hold relatively more reserves to their M2 than EMDE. Low-income and emerging markets tend to exceed the benchmark of 20% broad money coverage whereas advanced economies are constantly below 10%. Similar result is obtained when the short-term external debt coverage ratio is analysed. EMDE and LIDC are constantly over the recommended 100% ratio known as *Greenspan-Guidotti rule*; nevertheless, AE have covered less than 18% or their external debt position during the last 20 years.

Fuel-exporting

Table 3 shows a summary of the average values for the year 2018 between fuel and non-fuel exporting economies.

Table 3: 2018 statistics, fuel-exporting

Average values	**Fuel**	**Non-fuel**
Res/GDP (%)	22.1	13.6
Import coverage (months)	10.3	5.7
Res/M2 (%)	26.9	11.1
Res/DebtST (%)	191.0	31.9

Source: IMF, WB, Author's calculation

Fuel exporters tend to hold relatively more reserves than the rest of the countries, something that can also be observed in Appendix G, where more details are presented. These fuel exporting countries tend to have higher reserves both in terms of imports and broad money. While fuel exporters have been reaching recommended levels of these two adequacy measures, the opposite applies for non-fuel exporting countries; these countries did not surpass the 20%

level of reserves over M2 in the last 30 years. In the case of reserves over short-term external debt, fuel-exporting countries also present a higher coverage. Non-fuel exporters have barely covered 30% of their short-term debt in the last years, whereas fuel-exporting economies have surpassed the 100%.

Current and capital accounts balance

Table 4 depicts the differences in the four discussed metrics between countries and periods with a negative balance (borrower position) and positive balance (lender position) for the year 2018. From our observations, it is clear that lender positions have, on average, more reserves than borrower positions. This argument is corroborated in Appendix H, where metrics are available for a broader time period.

Table 4: 2018 statistics, current and capital account balance

Average values	**Borrower position**	**Lender position**
Res/GDP (%)	6.0	26.5
Import coverage (months)	3.4	10.8
Res/M2 (%)	6.9	15.1
Res/DebtST (%)	17.0	92.1

Source: IMF, WB, Author's calculation

When examining the three adequacy ratios, we see that countries with lender positions surpassed the benchmark of 3-months import coverage by a great extent, holding more than 15 months of their imports in FX reserves. On the other hand, countries with borrower positions have started reaching this adequacy benchmark only in the last 10 years, while barely exceeding 5 months of their imports. An interesting observation is that both groups of countries had problems to achieve the levels of the two other recommended adequacy measures. While lenders managed to reach the 20% level of reserves over M2, at least from 2007 to 2014, borrowers generally held half of the reserves suggested by this measure. Even though, lender countries seem to be improving their debt coverage ratios in the last 4 years, borrower countries are far away from fulfilling this limit.

Currency composition

When building a portfolio of international reserves, USD is clearly the predominant currency chosen by most of the countries. Considering the availability of currency composition data for only 28 countries, it proves to be the case that 21 of them hold the majority of their reserves in USD denominated assets. On the other hand, only four countries maintain EUR as the main asset currency and the remaining three countries hold the most reserves in JPY; whereas no country in our sample hold the most of its reserves in either GBP or CNY. Table 5 shows the top five holders of each individual currency, relative to the size of their portfolio.

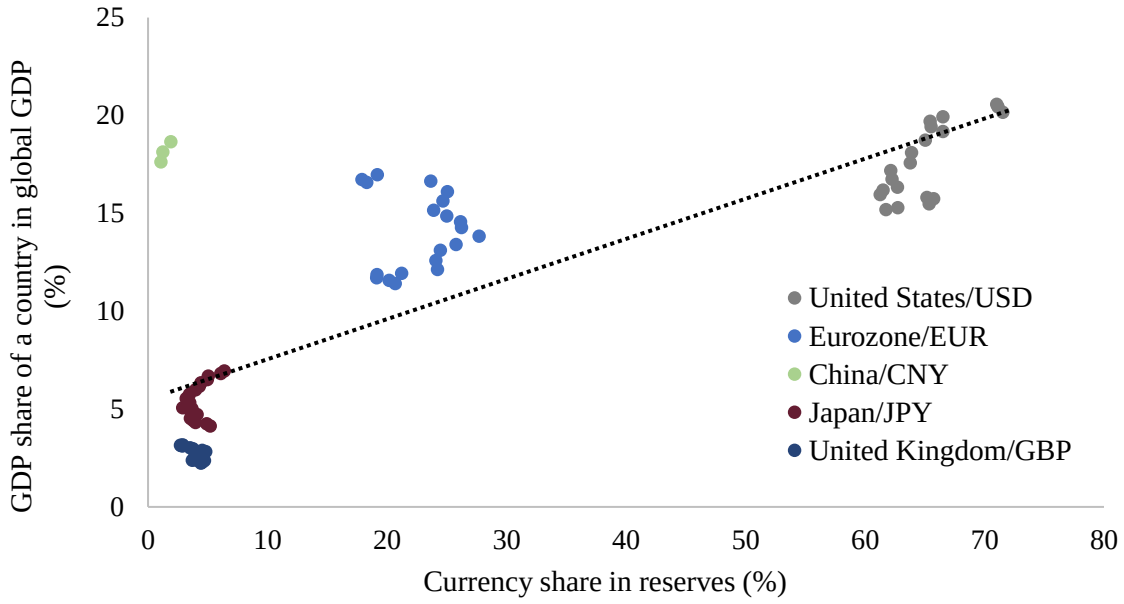
Table 5: Top 5 currency holders as of 2018 (% of total SDR reserves)

USD		EUR		JPY		CNY		GBP	
Ecuador	100	Bulgaria	100	Portugal	72	Portugal	9	Canada	11
Estonia	100	Croatia	87	Australia	67	Australia	4	Finland	11
Latvia	100	Morocco	61	Ireland	61	Ukraine	4	Moldova	11
Uruguay	97	Switzerland	43	Netherlands	43	Chile	3	Norway	8
Peru	97	Sweden	37	Finland	17	Peru	3	Switzerland	7

Source: IMF, Author's calculation

It has been suggested that a specific-currency share of reserves might follow the specific-currency issuer contribution to global GDP. Meaning that, if there is an inclining trend in US share of total GDP in the world, central banks might accumulate more USD denominated reserves. However, if we look at USD and EUR, there has been a declining trend for both US and eurozone GDP shares of the global GDP. Figure 4 shows the relationship between the currency's share in reserve assets and the GDP's share in the world for the five currencies that are part of the SDR basket. The United States and the eurozone have similar GDP share; however, their currencies have quite different shares in the breakdown of reserves. It is clearly visible that there is some non-linear relationship, otherwise EUR and USD would have more similar shares in reserves. The non-linear relationship was discovered by Chinn and Frankel (2007), who also made a prediction that if all the remaining eurozone members joined the Economic and Monetary Union (EMU) by 2020, then reserves in USD would be surpassed by EUR. As we know, this scenario has not come into realisation.

Figure 4: Non-linear relationship between currency shares and GDP

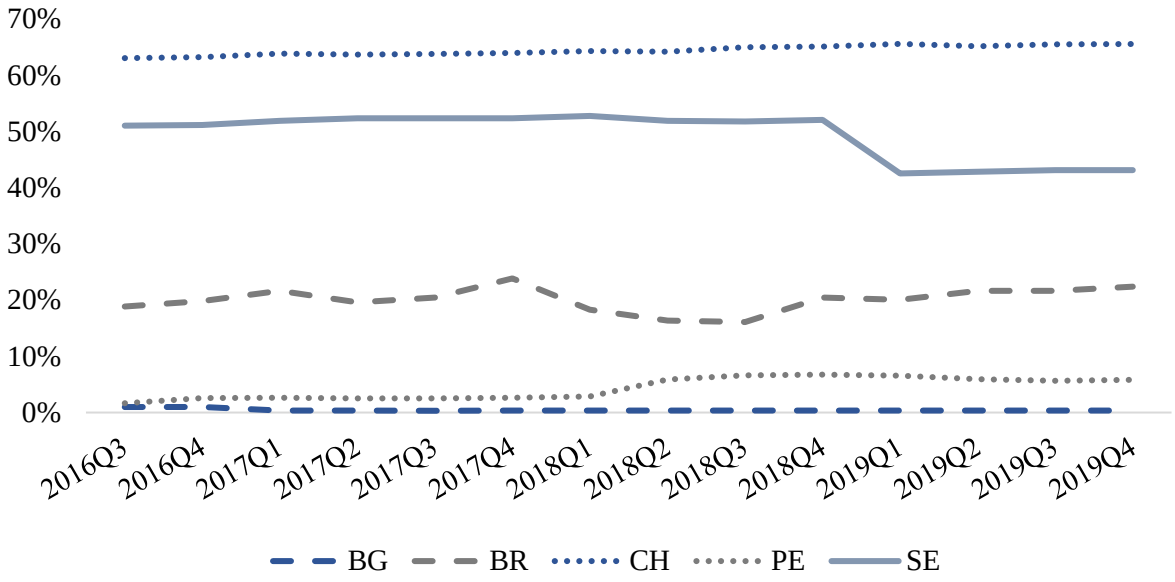


Source: IMF, Author's calculation

The diversification index (Div) can give us an idea of how diversified the reserve assets are among countries, in terms of currency composition. Figure 5 applies equation (5) to our sample of countries. As observable from the graph, Switzerland (CH) is the country with the most

diversified portfolio in our sample, with the Div value ranging between 63% and 66%. For instance, in 2019Q4, USD represented 38% of the swiss reserve assets, EUR 43%, JPY 11%, GBP 7% and CNY 1%. At the other extreme, Bulgaria (BG) is one of the countries with the most concentrated portfolio and Div is close to zero. EUR accounts for roughly 100% of the reserves, what can be explained by the country's hard peg regime with the anchor to euro.

Figure 5: Diversification (Div) of the currency composition of reserves across countries



Source: IMF, Author's calculation

4.2 Analysis: Size of reserves

In this part, we apply our regression models on the collected databases in order to explain the size of reserves, according to our specified variables, while taking into account the existence of cross-sectional and/or time-series effects according to the methodology specified in Section 3. A summary of descriptive statistics for the sample used can be found in Appendix I.

4.2.1 Foreign exchange regime

The model defined in equation (1) is estimated by setting the intercept to zero and including dummy variables to account for the foreign exchange regimes, i.e. *floating*, *hard peg* and *soft peg*. Moreover, the same regression equation, with an intercept, is estimated for each regime separately. Results for the full sample and subsamples are shown in Table 6.

In the full sample model (A), reserves over GDP can be explained by all the variables with a significance level of minimum 5%, except the external short-term debt variable, which is found insignificant. Moreover, based on R^2 result, this estimated model is able to explain 88% of the variability of the dependent variable. Estimation (B) analyses, exclusively, the sample of

countries with hard peg regimes and the results indicate that broad money and Kaopen index can explain the reserve holding for these countries at 1% significance level, whereas trade openness can do it at only 10%. When analysing the soft peg sample of countries (C), all the variables are found significant at 1% level, as opposite to the countries with floating regimes (D) for which the amount of external short-term debt and Kaopen index are not significant.

Table 6: Estimation results, foreign exchange regime

Dependent variable: Reserves/GDP				
	(A) **Full sample**	**(B)** **Hard peg**	**(C)** **Soft peg**	**(D)** **Floating**
Constant		-0.416	0.178***	0.191***
		(0.370)	(0.063)	(0.035)
Trade/GDP	0.189***	0.099*	0.101***	0.189***
	(0.007)	(0.056)	(0.023)	(0.009)
M2/GDP	0.119***	0.242***	0.198***	0.082***
	(0.008)	(0.059)	(0.020)	(0.011)
DebtST/GDP	0.009	0.067	0.081***	0.004
	(0.007)	(0.062)	(0.025)	(0.007)
Kaopen	0.026**	0.175***	0.074***	-0.012
	(0.011)	(0.058)	(0.019)	(0.013)
Ln (GDPpc)	-0.029***	0.028	-0.026***	-0.022***
	(0.004)	(0.046)	(0.007)	(0.004)
Floating, dummy	0.204***			
	(0.030)			
Hard peg, dummy	0.175***			
	(0.031)			
Soft peg, dummy	0.216***			
	(0.029)			
Number of countries[32]	79	6	43	52
Number of observations	917	73	247	597
R^2	0.88	0.94	0.65	0.54
R^2, adjusted	0.88	0.94	0.65	0.54

*Standard errors in parentheses. *, **, *** indicates significance at the levels 10%, 5%, 1%.*

Source: Author's calculation

The $M2/GDP$ ratio is detected to be the most important determinant of relative reserves; it has a significant and positive impact in all the exchange regimes, indicating that a broader monetary base implies a larger holding of reserves to prevent the potential capital outflows. This is consistent with the study of Cabezas and De Gregorio (2019) or Lane and Burke (2001) who state that financial deepening should correspond to the increasing levels of reserves. More

[32]*Numbers of countries in sub-samples do not add up to the full sample because: a) countries with 'other managed' exchange regimes were excluded from the analysis due to the low number of countries available in our sample and the little importance this residual regime has for our analysis; b) some countries have changed their FX regime throughout the time and, therefore, they were included in more than one regime category – only those observations with specific regime are a part of the specific regime category.*

concretely, a 1 pp increase in the $M2/GDP$ ratio would raise the level of reserves over GDP from 0.08 pp in floating regimes (D) to more than 0.24 pp for hard pegs (B). When we look at the full sample result from a bit different perspective, a one standard deviation raise in $M2/GDP$ from its sample mean[33] would cause the dependent variable to increase by 6.1 pp.

The trade openness variable is also significant in all four regressions. Based on research done by Lane and Burke (2001) and Choi and Baek (2006), this variable is the most important determinant of reserve demand for a country. However, given only the 10% significance in the hard peg sample of countries, our model ranks the $Trade/GDP$ ratio as the second most important variable. Its coefficient is positive, in line with our expectations, and its interpretation suggests that 1 pp raise in $Trade/GDP$ would increase $Reserves/GDP$ ratio between 0.1 pp and 0.2 pp depending on the exchange rate regime.

The Kaopen index seems to have a significant impact on stricter regimes. Among these countries, the less capital restrictions often come with higher amount of reserves. This result is in line with the theory of Aizenman and Lee (2007) who signify that if a capital account regime is more liberal, it is directly linked to increasing amounts of reserves.

The external short-term debt seems to be relevant only for countries with soft peg regimes for which it has a positive coefficient. This indicates that reserves for these countries subsidise for the foreign capital in case of sudden stops as suggested by Steiner (2009). For the soft peg sample, an increase of 1 pp in the level of $DebtST/GDP$ would increase $Reserves/GDP$ in about 0.08 pp. When it comes to the insignificant results, our model is not an exception. Papers by Obstfeld et al. (2010) or Cabezas and De Gregorio (2019) also conclude no impact of ST debt on reserves. Moreover, Obstfeld et al. (2010) attempt to clarify why this traditional adequacy criteria fails to explain the reserve accumulation. They hypothesise: the usual argument for higher reserves related to higher external debt is built on an idea that the potential negative shock is caused by sudden stops in exports of domestic assets abroad; however, it is necessary to keep in mind that the same balance-of-payments shock can happen when citizens of the home country suddenly start importing foreign assets.

Looking at real GDP per capita, its coefficient is negative for the samples where the variable is found significant, which differs from our initial expectations and indicates that richer countries do not hold as much reserves as poorer countries do. However, according to the model of Choi and Baek (2004), this variable is ambiguous when it comes to the relationship with reserve amounts. They state that richer countries could potentially accumulate more reserves, but on the other hand, these countries are less sensitive to crises and speculation attacks, therefore, they do not need such large reserve stocks. Nevertheless, our results differ from Steiner (2009), who finds that this variable does not have any significant effect on reserves. The interpretation of the coefficient suggests that, if the $GDPpc$ increases by 1%, it reduces the reserves over GDP between 0.022 pp and 0.026 pp, depending if the regime is floating or soft peg, respectively.

[33] *Sample mean 0.73 and std dev 0.51. For further details on descriptive statistics of variables see Appendix I.*

In order to check if the dummy variables are significantly different from each other, we run the regression crossing the regimes, that is, the intercept represents one of the regimes and the others are represented by their dummy variables. Our results are shown in Table 7 and indicate that hard peg is significantly different from floating and soft peg regimes at 5% level, whereas floating and soft peg regimes are not significantly different.

Table 7: Cross-regime significance in FX regimes

	P-values
Floating vs Hard peg	0.03
Floating vs Soft peg	0.11
Hard peg vs Soft peg	0.00

Source: Author's calculation

From Table 6 we see that the dummy variable for a hard peg regime has a lower value than floating and soft peg. This is neither in line with our expectations nor with the standard prediction already mentioned in the literature review. It is commonly thought that countries with floating regimes should hold the least amounts of reserves because the exchange rate can freely alter and, therefore, they do not have such incentives to maintain high reserve amounts. The results obtained from our model are identical to the theory of Choi and Baek (2004), who identified a reversed U-shape relationship between reserve amounts and the exchange rate regimes of a country. Steiner (2009) also finds that countries with fixed regimes hold lower amounts of reserves than those with less strict regimes, howbeit, his findings indicate lower reserves for medium exchange rate systems than for the flexible regime, which is opposite to the results of Choi and Baek. Nevertheless, we see that combining the regimes into a fixed effects model is not a good predictor for the hard peg sample of countries. In fact, when inspecting the unconditional average value of $Reserves/GDP$ for these subsamples individually, we see that the average amount for the hard peg regime is 37.8%, while only 23.2% for the soft peg and 18.4% for the floating regime. This is in line with the previous research performed, for instance, by Bahmani-Oskooee and Brown (2002), who state that central banks of countries with pegged regimes are required to intervene in order to sustain a fixed exchange rate, thus, indicating a higher demand and higher holdings of international reserves; as well as Chiţu et al. (2019, p. 40), who mentions that countries with more flexible exchange rate regimes need less reserves since "the exchange rate can act as a buffer and help absorb external shocks". Consequently, the specific estimations in (B), (C) and (D) are better models to explain the dependent variable.

A further analysis is carried out in order to test if countries, whose *de facto* exchange regime has changed over the time period of our analysis, have altered their relative amounts of reserves significantly. In order to do so, we consider the change in variables and introduced dummy variables to represent all possible combinations of changes across regimes. The idea of the model is to test whether the change in the dependent variable is because of the change in FX regime or the other explanatory variables. The estimation results, in Exhibit J1, suggest that the change in the explained variable, for this specific sample, is mainly due to the change in broad money and real GDP per capita. Only a movement from the soft peg regime to the other managed regimes could explain the reduction in reserves over GDP at a 10% significance level.

4.2.2 Country development

In order to analyse the cross-country differences among states with different development backgrounds, we introduce a dummy variable for each category of development (AE, EMDE, LIDC). The variable real GDP per capita is dropped to avoid multicollinearity as we are aware of the fact that emerging markets have lower GDP per capita than advanced economies and, simultaneously, higher than low income countries, thus, we want to avoid accounting for the same explanatory variable twice. This is related to the theory presented by Choi and Strömqvist (2007) who state that GDP per capita has a positive correlation with the living standards. A model with three dummy variables is run with no intercept for the full sample (A), as well as three additional regressions with intercepts for each development category as presented in columns (B), (C) and (D).

Table 8: Estimation results, country development

Dependent variable: Reserves/GDP				
	(A) **Full sample**	**(B)** **AE**	**(C)** **EMDE**	**(D)** **LIDC**
Constant		-0.009	-0.009	-0.073***
		(0.034)	(0.012)	(0.027)
Trade/GDP	0.171***	0.231***	0.061***	0.260***
	(0.008)	(0.011)	(0.014)	(0.028)
M2/GDP	0.138***	0.098***	0.183***	0.315***
	(0.009)	(0.012)	(0.013)	(0.032)
DebtST/GDP	0.026***	-0.002	0.128**	-0.513***
	(0.007)	(0.009)	(0.058)	(0.124)
Kaopen	0.025**	-0.106***	0.066***	-0.031
	(0.011)	(0.037)	(0.011)	(0.025)
AE, dummy	-0.137***			
	(0.015)			
EMDE, dummy	-0.037***			
	(0.009)			
LIDC, dummy	0.019			
	(0.013)			
Number of countries	82	16	51	16
Number of observations	982	257	617	108
R^2	0.87	0.86	0.38	0.66
R^2, adjusted	0.87	0.85	0.38	0.65

*Standard errors in parentheses. *, **, *** indicates significance at the levels 10%, 5%, 1%.*

Source: Author's calculation

Closer inspection of Table 8 shows that the trade openness and broad money variables are significant at 1% level for all the samples. Based on the obtained R^2, the full sample (A) model can explain 87% of the relative reserve level. For the development-specific regressions, the explanatory power is much smaller for the EMDE subsample (0.38) than for AE (0.86). There is an important difference in the effect that trade openness has on the level of reserves for

EMDE, on one side, and AE and LIDC, on the other side. An increase of 1 pp in $Trade/GDP$ would cause a raise in $Reserves/GDP$ of 0.06 pp for EMDE, whereas more than 0.23 pp for AE and LIDC. In general, as explained by Choi and Baek (2004) or Steiner (2009), the higher the trade openness, the higher the exposure to external shocks and, for that reason, the higher the reserves to protect the country. In the case of $M2/GDP$, the country development can be also influential in its effect. An increase of 1 pp in the level of M2 over GDP could increase the relative reserve amounts in about 0.1 pp for AE, whereas almost double in EMDE and more than 0.3 pp in LIDC.

Moreover, it is observable that the external short-term debt seems to have no significant impact on relative reserves of AE. On the other hand, $DebtST/GDP$ is significant for LIDC and EMDE, although the coefficients' signs differ among these subsamples. One potential explanation could be that LIDC are more indebted than EMDE and, in that case, LIDC might have problems to accumulate and (consequently hold) the desired amounts of reserves. This deviation from the expected positive relationship among countries is mentioned by Steiner (2009). When looking specifically at the LIDC subsample, results are in line with Lane and Burke (2001), who also find this negative relationship for developing economies indicating that more indebted economies tend to hold lower amount of reserves as proportion of their GDP. The same inference is found by Steiner (2009), who speculates: a central bank might decide to sell its reserves and use it as an internal funding in an effort to substitute the external financing and meet the domestic demand for the foreign credit.

Looking at the financial openness measure, $Kaopen$, we find a positive coefficient for the EMDE. This result proves that developing countries necessitate more reserves if they are more integrated financially with the rest of the world. A positive relationship for developing economies is also found by Obstfeld et al. (2010) and Cheung and Ito (2009). As they state, this result highlights the precautionary motive of holding reserves, in which case, a country holds more reserves if it has a more open capital account to protect itself against the unfavourable capital outflows.

Table 9: Cross-country significance in country development

	P-values
AE vs EMDE	0.00
AE vs LIDC	0.00
EMDE vs LIDC	0.00

Source: Author's calculation

In order to analyse cross-sectional variations in countries of different developments, new regressions are run across development classifications. For each regression, the intercept now represents one of the development groups, whereas the other classifications are represented by dummy variables. This analysis is helpful to see whether there are any significant differences among country developments. As observable from Table 9, there are significant variations in reserve over GDP holdings among all development categories at 1% level of significance.

The general picture which emerges is that, on average and conditional to the same explanatory variables, LIDC[34] hold more reserves than EMDE, whereas AE holds the least (see Table 8). This is in line with the theory presented by Steiner (2009), who explains that the relationship between the foreign exchange reserves and country development level is positive, but only in case when the real level of reserves is the same as the desired one, otherwise the relationship is ambiguous. Additionally, Steiner (2009) summarises two reasons of reserve demand for less developed countries as: i) limited opportunities to access the international capital market, complicating the funding of balance of payments' imbalances and, therefore, developing countries are interested in holding reserves as a replacement of private foreign capital; ii) the likelihood of crisis for developing countries is much higher. As Choi et al. (2009) explains, it is easier for AE to access the international capital market and, therefore, there is a lower interest for stocking international reserves when they can invest in foreign asset with higher yields. As suggested by Bastourre et al. (2009), middle-income countries are more likely to suffer from financial crisis and they cannot use their exchange rate to soak up these shocks and, therefore, they gather reserves as a prevention against sudden stops. This is in line with the precautionary motive of protecting themselves against unpleasant sudden stops in capital flows. Bastourre et al. (2009) also state that, under assumption of the ability of poor countries to produce surpluses of balance of payments, they do not prioritize hoarding reserves over their other objectives. Furthermore, Choi and Baek (2004) and Bastourre et al. (2009) present the inverted U-shape relationship between the country's income level and international reserves. This would mean that "reserve holdings should increase with the standard of living from low-income to mid-income level, but thereafter decrease as income moves up to high level" (Choi & Baek, 2004, p. 9). However, our results do not match their theory.

4.2.3 Fuel-exporting

Model in this section is estimated with an intercept while adding one dummy variable to represent the fuel-exporting economies. Regression is also run for each subsample. As we can see from Table 10, the dummy variable is significant at 5% level and its coefficient is positive, indicating that fuel-exporting countries tend to hold 2.3 percentual points more reserves in relation to its GDP than non-fuel exporting economies, given everything else equal.

Our estimation results are both in line with the expectations and with the previous research on this topic. As Lane and Burke (2001) state, countries with high temporary income from fuel related business tend to accumulate more reserves. Calvo et al. (2012) describe that fuel-exporting countries have different objectives for holding international reserves aside the precautionary stimuli, such as stockpiling the oil-profits received in order to smooth out the inter-temporal oil consumption over time. This said, it is apparent that fuel producing countries tend to hold more reserves than considered optimal from the precautionary point of view.

Trade openness and broad money are, again, the main explicative variables and both significant at 1% for all samples. The influence of trade openness is higher in non-fuel exporting economies, where an increase of 1 pp in its level could be related to an increase of almost 0.2

[34] *LIDC dummy's coefficient can be interpreted as zero given the null hypothesis of insignificance is not rejected.*

pp in the level of reserves over GDP. Broad money, on the other hand, has a higher influence for fuel-exporting economies, that is, expanding the $M2/GDP$ ratio by 1 pp could increase the level of reserves over GDP by around 0.27 pp.

Table 10: Estimation results, fuel-exporting

Dependent variable: Reserves/GDP			
	(A) **Full sample**	**(B)** **Fuel-exporting**	**(C)** **Non-fuel exporting**
Constant	0.206*** (0.031)	-0.006 (0.163)	0.192*** (0.030)
Trade/GDP	0.184*** (0.008)	0.131*** (0.050)	0.195*** (0.007)
M2/GDP	0.124*** (0.008)	0.269*** (0.050)	0.109*** (0.008)
DebtST/GDP	0.012* (0.007)	-0.307** (0.142)	0.011* (0.006)
Kaopen	0.018 (0.011)	-0.037 (0.044)	0.017 (0.011)
Ln (GDPpc)	-0.029*** (0.004)	0.000 (0.018)	-0.027*** (0.004)
Fuel-exporting, dummy	0.023** (0.009)		
Number of countries	82	17	65
Number of observations	982	183	799
R^2	0.68	0.19	0.77
R^2, adjusted	0.67	0.16	0.77

*Standard errors in parentheses. *, **, *** indicates significance at the levels 10%, 5%, 1%.*

Source: Author's calculation

The external short-term debt variable seems to be significant at least at some significance level for all regressions in Table 10. However, its effect is negative for fuel-exporting economies and positive for non-fuel exporters. As stated by Lane and Burke (2001), the relationship between reserves and debt is not unambiguous. Kaopen, on the other hand, is not significant at all for any of the samples and this is in line with results of Arslan and Cantú (2019) who also do not identify that the financial openness variable has any impact on reserves of fuel exporters.

GDP per capita does not seem to affect the reserve holding of fuel-exporting economies. Nevertheless, it is significant at 1% level for non-fuel countries and its sign is negative, signifying that the richer non-fuel exporting economies hold relatively less reserves than their poorer peers. To be more precise, the coefficient suggests that a 1% increase in $GDPpc$ could decrease the level of $Reserves/GDP$ in about 0.027 pp.

4.2.4 Current and capital accounts balance

In order to analyse the effect of the current and capital accounts balance on the level of reserves, we use two approaches, whose results are presented in Table 11. The first is based on a fixed effects model and the use of dummy variables (columns A, B and C), which helps us to see whether net borrowers and net lenders are significantly different in terms of relative reserves. The second approach is based on adding a continuous variable, $CCBalance/GDP$, to see the sensitivity that the balance has on the level of reserves (column D).

Table 11: Estimation results, current and capital accounts balance

Dependent variable: Reserves/GDP				
	(A) Full sample, dummy	**(B) Net lender sample**	**(C) Net borrower sample**	**(D) Full sample, continuous**
Constant	0.277***	0.418***	0.261***	0.268***
	(0.031)	(0.074)	(0.033)	(0.032)
Trade/GDP	0.172***	0.158***	0.136***	0.178***
	(0.007)	(0.016)	(0.011)	(0.007)
M2/GDP	0.106***	0.099***	0.117***	0.119***
	(0.008)	(0.012)	(0.014)	(0.008)
DebtST/GDP	0.020***	0.059***	-0.011	0.009
	(0.007)	(0.016)	(0.008)	(0.007)
Kaopen	0.014	-0.049	0.032***	0.017
	(0.011)	(0.031)	(0.010)	(0.011)
Ln (GDPpc)	-0.036***	-0.039***	-0.032***	-0.033***
	(0.004)	(0.009)	(0.004)	(0.004)
Net lender, dummy	0.065***			
	(0.008)			
CCBalance/GDP				0.309***
				(0.051)
Number of countries[35]	82	38	63	82
Number of observations	982	333	649	982
R^2	0.69	0.77	0.33	0.69
R^2, adjusted	0.69	0.77	0.32	0.68

*Standard errors in parentheses. *, **, *** indicates significance at the levels 10%, 5%, 1%.*

Source: Author's calculation

Following the methodology explained in previous sections, regression (A) is estimated with an intercept, using a dummy variable whose value is 1 for countries (and time periods) that are mainly net lenders (positive current and capital accounts balance), and 0 when they are mainly borrowers (negative balance). The result of the dummy variable indicates that there is a significant difference between countries classified as mainly borrowers and mainly lenders, as it is also clear in Appendix H. Regressions (B) and (C) are the individual estimations for each

[35] *Because some countries can be lenders and borrowers in different periods, as already explained in Section 3, the number of countries in sub-samples (B) and (C) does not add up to the number of countries in full sample (A).*

of both subsamples, i.e. net lenders and net borrowers. The results of the second approach, shown in column (D), imply that the continuous variable $CCBalance/GDP$ has a positive and significant coefficient at 1% level, what indicates that higher positive balances are associated with higher level of reserves. This is in line with the previous research and expectations of increasing reserves in countries with larger positive balances (see Section 3).

Trade openness and broad money have a significant effect for all the samples and their positive signs are in line with expectations, i.e. countries that trade more and have larger M2 monetary base tend to hold relatively higher reserve amounts. An increase of 1 pp in $M2/GDP$ would cause about 0.1 pp increase in the dependent variable across all samples; and the same raise in trade openness would have a positive impact on the $Reserves/GDP$ between 0.14 pp and 0.18 pp, depending on the sample. Another perspective of interpretation could be through the standard deviation of the full sample (A), i.e. if the $Trade/GDP$ ratio increases from its sample mean by one standard deviation[36], the dependent variable would increase by almost 11 pp.

GDP per capita is another variable that is significant at 1% level for all the samples. Their coefficients' signs are negative, which is in line with our findings from other estimations presented previously. It can be understood that a 1% increase in the level of GDP per capita is associated with a decrease in $Reserves/GDP$ between 0.03 pp and 0.04 pp.

4.2.5 Crisis

A first difference model, presented in Table 12, has been estimated according to equation (3) for countries that have experienced a crisis since 1999. As already mentioned in the methodology section, in order to distinguish the periods before the start of the crisis from periods after the crisis ends, a dummy variable is introduced. The result shows that, at 10% significance level, there is a difference between reserves held by a country three years before a crisis occurred and three years after it ended. Its positive coefficient indicates that countries increase their reserves after the crisis more than they did before the crisis started, i.e. their risk aversion is higher and, consequently, countries want to accumulate more reserves to protect themselves against the negative outcomes of crises. However, there is another perspective on these results, which needs to be considered. As it is known, countries use their reserves to fight the crisis and, therefore, when the crisis is over, the growth rate of reserve accumulation might be higher in order to increase the reserve amounts back to the pre-crisis levels. This could potentially indicate that countries did not actually change the level of reserves after the crisis in comparison to the pre-crisis level, but only increased it back to the desired levels.

Moreover, changes in reserve amounts seem to be additionally explained by differences in broad money ratio, Kaopen and GDP per capita, which are all significant at 1% level. For instance, an increase of 1 pp in the level of $M2/GDP$ would raise our dependent variable by approximately 2.5 pp.

[36] *Sample mean 0.88 and std dev 0.63. For further details on descriptive statistics of variables see Appendix I.*

Table 12: Estimation results, country-specific crisis

Dependent variable: Change in Reserves	
	(A) **Country-specific crisis sample**
Constant	-0.087 (0.062)
Change Trade/GDP	-0.026 (0.436)
Change M2/GDP	2.542*** (0.645)
Change DebtST/GDP	0.045 (0.104)
Change Kaopen	1.187*** (0.309)
Change Ln (GDPpc)	4.880*** (1.060)
3-years after, dummy	0.113* (0.066)
Number of countries	23
Number of observations	126
R^2	0.29
R^2, adjusted	0.26

Standard errors in parentheses. *, **, *** *indicates significance at the levels 10%, 5%, 1%.*

Source: Author's calculation

Even though we find some variables significant, the overall explanatory power of this method is quite low, i.e. based on the obtained R^2, the model explains only 26% of variations in the dependent variable.

Additionally, we explore a more general picture and examine whether the great financial crisis of 2008 has made central bankers increase the relative size of their reserves. This variation of the crisis analysis allows us to expand the sample of countries in comparison with the previous model. In order to do so, we use our original dependent variable Res/GDP and included a dummy variable to represent the periods after the GFC. This way, we are able to account for the time-series fixed effects in our model. Exhibit J2 represents the output of the regression and it indicates that the dummy is significant at 1% level. Thus, there has been an overall increase in the relative size of reserves after the crisis of about 4.4 percentual points, given everything else equal. The value of R^2 shows that 68% of the variance of the dependent variable can be explained by running this model.

4.3 Analysis: Currency composition of reserves

In this part, we analyse the currency composition of reserves in order to explain: i) the choice between USD and EUR in the currency composition of reserves at world level; ii) the diversification effect of country-specific portfolios by currency.

4.3.1 USD-EUR spread in world reserves

Equation (4) is estimated in order to explain the factors behind the movements of the spread between reserves denominated in USD and EUR. Results are presented in Table 13. Furthermore, we also carry out an estimation by introducing a lag of the independent variables to check whether there could be a delay in the relationship, but the lagged variables were not significant, therefore, they are not included in our model.

Table 13: Estimation results, USD-EUR spread in world reserves

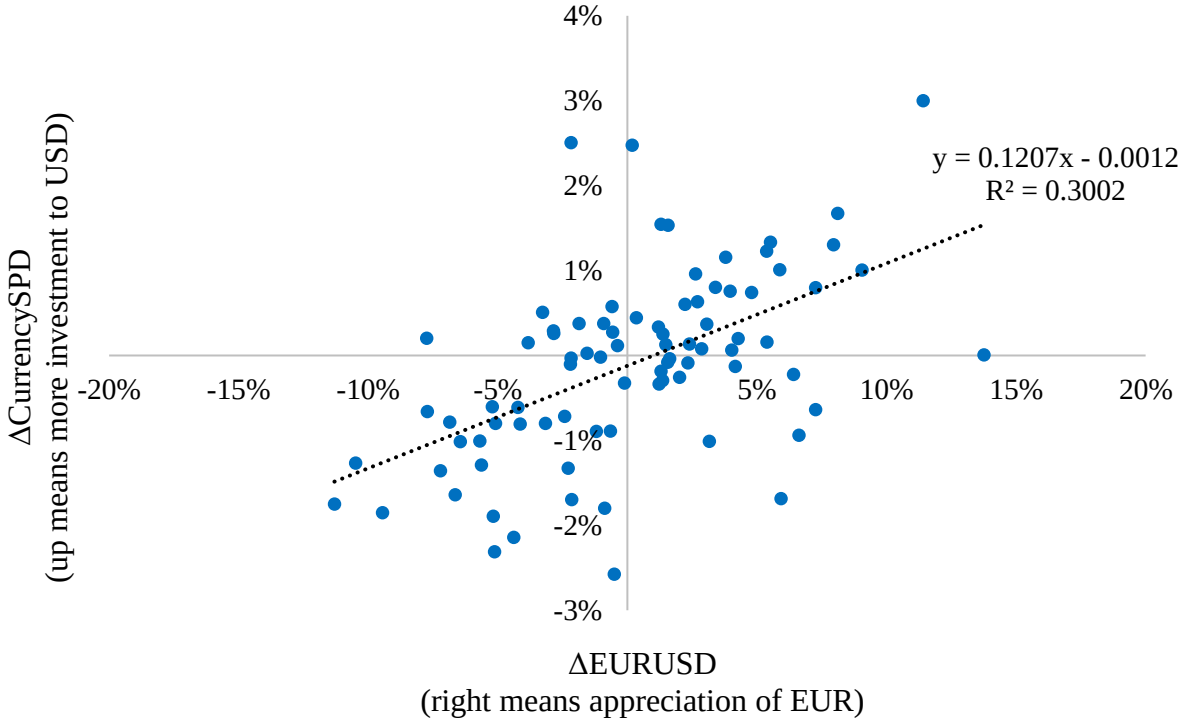
Dependent variable: ΔCurrencySPD	
	(A) **1999Q1 - 2019Q4**
Constant	-0.001
	(0.001)
ΔEURUSD	0.116***
	(0.024)
ΔGDPSPD	-0.058
	(0.121)
ΔTradeSPD	-0.029
	(0.080)
Number of observations	83
R^2	0.30
R^2, adjusted	0.28

*Standard errors in parentheses. *, **, *** indicates significance at the levels 10%, 5%, 1%.*

Source: Author's calculation

As observable from Table 13, the independent variables in our model are able to explain no more than 30% of the variance of the dependent variable and only the change in the exchange rate is significant. If the value of the euro increases by 0.01 dollars, the spread will change about 0.12 pp in favour of the USD. A visual depiction of the relationship between changes in the foreign exchange rate and the change in spread of currencies can be seen in Figure 4. An appreciation of EUR, against USD, is usually followed by increasing weight of USD reserves. As described by Truman and Wong (2006), this could possibly be explained by the stabilising diversification concept, which indicates that countries rebalance their portfolios in order to keep the weights in individual currencies as initially set.

Figure 4: Change in USD-EUR spread in reserves with respect to changes in FX rate



Source: Author's calculation

4.3.2 Diversification effect in currency composition

Equation (6) is estimated including a dummy variable for each of the three possible foreign exchange regimes in the sample: *floating*, *soft peg* and *hard peg*. Results obtained from these regressions are presented in Table 14.

Even though the common opinion is that diversification increases with higher reserves, Beck and Weber (2011) find the opposite. They state that this argument would hold only in case when reserves would be accumulated for different purposes than the precautionary motive. However, we find a positive and significant relationship between the amount of reserves and diversification, what is in line with our expectations and most of the research results, such as the one from Aizenman et al. (2020). They examined the *big four currencies* and found evidence for the so-called scale effect, which is interpreted as: the higher the reserve holdings, the higher the diversification. In our model, an increase of 1% in the total amount of reserves can be associated with 0.04 pp increase in the diversification measure.

A positive and significant result is also found for GDP per capita: 1% raise in GDP per capita can explain up to 0.05 pp increase in Div. This result implies that richer countries diversify their portfolio more than countries with lower incomes.

Table 14: Estimation results, diversification effect in currency composition

Dependent variable: Diversification effect (Div)	
	(A) **Currency sample**
Ln (Res)	0.041*** (0.006)
Ln (GDPpc)	0.048*** (0.007)
CVol	-1.602 (1.351)
DivTrade	-0.335*** (0.135)
Floating, dummy	-0.792*** (0.135)
Soft peg, dummy	-0.924*** (0.128)
Hard peg, dummy	-1.212*** (0.132)
Number of countries	20
Number of observations	229
R^2	0.90
R^2, adjusted	0.89

*Standard errors in pa*rentheses. **, **, *** indicates significance at the levels 10%, 5%, 1%.*

Source: Author's calculation

The diversification of trade, however, gives a significant result but opposite to what we expected. Expectations were that a more diversified trade with countries issuing SDR currencies would encourage the diversification of the reserve portfolio, but the opposite is found in our model. Our results for this variable do not agree with most of the research carried out so far. Eichengreen and Mathieson (2000) express that the more the country trades with a specific currency zone country, the greater the probability of holding higher reserve amounts in this specific SDR-currency. Furthermore, according to Beck and Weber (2011), the expected relationship is that, the higher the import share with a country, the lower the transaction costs in the country-specific currency and, therefore, an increase in the reserve share of this currency. Moreover, Aizenman et al. (2020) confirm that countries which have more trade with US, UK, eurozone or Japan, accumulate more reserves in these currencies.

Our measure of currency volatility is found to be insignificant. A higher currency volatility, as a measure of risk, was expected to possibly encourage countries to broaden their diversification; however, this theory does not hold in our model. This insignificant result is in line with the outcome obtained by Lu and Wang (2019), who also find no significance in this variable.

Another aspect of the analysis is to examine whether there are significant distinctions in the diversification effect between the exchange rate regimes. This is done by comparing the p-

values of additional regressions, where the intercept stands for one regime, while the other two regimes are represented by dummy variables. As presented in Table 15, these differences are significant. Consequently, we can conclude that the hard peg is the least diversified regime, whereas floating regime is the most diversified. On average, countries with the least restricted regimes tend to have their diversification indexes higher by 42 pp[37]. These results are in line with our expectations. We anticipated that countries with very strict regimes and currency anchors would hold larger proportion of the total reserves in the currency they are anchored to. This is, moreover, in line with the research performed by Eichengreen and Mathieson (2000), Beck and Rahbari (2008), Beck and Weber (2011) or Ito and McCauley (2020), who all have the same inference related to the currency peg and diversification of reserves.

Table 15: Cross-country significance in FX regime (currency composition)

	P-values
Floating vs Hard peg	0.00
Floating vs Soft peg	0.00
Hard peg vs Soft peg	0.00

Source: Author's calculation

[37] *From Table 14: coefficient of hard peg is deducted from the floating regime, i.e. -0.792 - (-1.212) = 0.42*

5 Conclusion

The purpose of this thesis was to examine what the different determinants of reserve accumulation are and what influences the diversification of their currency composition. The primary focus was set on the cross-country analysis of reserve size. This was mainly based on differences between countries of different foreign exchange regimes, development levels, fuel exports, current and capital accounts balance and, lastly, country-specific crises. Moreover, we introduced a model with a new diversification measure, which examines the reserve concentration among the five SDR currencies in the central bank's portfolio.

The analysis of the size of foreign exchange reserves, measured as the level of reserves over GDP, recognised the broad money and trade openness as the best explanatory variables. The former, measured as the level of M2 over GDP, was always significant at 1% level and had a positive coefficient for all subsamples. This is in line with the theory that countries want to be protected against sudden capital outflows. The latter, measured as the sum of imports and exports in relation to GDP, also influenced the level of reserves significantly and positively. Our expectation that more international trade is a reason for larger reserve holding were met. On the other hand, the external short-term debt variable – part of the traditional reserve adequacy metrics – was not in line with our expectations. Its significance was not proven for some of the subsamples and, moreover, its coefficient was negative for some of them, i.e. opposite to what the rule suggests. Similar results were obtained from the financial openness index, titled as Kaopen, where we found significance only for some subsamples. GDP per capita, when significant, resulted in a negative coefficient, indicating a major tendency towards poorer countries holding larger reserves.

As expected, our sample showed differences for relative reserves size across countries with varying foreign exchange regimes, i.e. the stricter the regime is, the higher the level of reserves. Cross-country differences were also found among countries of different level of development, i.e. LIDC hold the largest relative amounts of reserves, followed by EMDE, whereas AE holding the lowest reserves. Another model, focusing on countries identified as fuel- or non-fuel exporters, found that fuel exporters held significantly larger amounts of reserves over GDP than the non-fuel economies. The current and capital accounts balance analysis indicated another important explanation for differences in reserves holding across countries, both from the perspective of continuous variable as well as the dummy used to differentiate between net lender and net borrower countries. Results suggested that, the higher and the more positive the balance, the higher the level of reserves over GDP.

Time-series dimension was also considered in our analysis, particularly the effect that a crisis might have on the level of reserves, as it is known that one of the motives for reserves holding is to mitigate the effect of crisis. Using a first difference model and a dummy variable to distinguish between the three years prior to a crisis and the three years after its end, we found

increasing reserves amounts after the crisis. Moreover, using more extensive sample and analysing the level of reserves before and after the GFC, we found that the relative amount of reserves has been significantly higher after 2008.

When investigating the currency composition of reserves on a global scale, we found that the appreciation of EUR against USD was followed by a portfolio rebalancing from EUR to USD. Furthermore, we analysed how currency portfolios of reserves were diversified across countries and we found a significant and positive effect in the absolute amount of reserves and the GDP per capita. This indicates that richer countries with larger reserve portfolios tend to diversify their reserve assets more. Moreover, our results indicated that the more diversified the trade of a country is, the less diversified their reserve portfolios are. An interesting finding was that the currency volatility does not have a significant impact on diversification, what goes against our expectations, as we believed that diversification and risk go hand in hand. The estimation results also suggested that foreign exchange regimes are a factor for the diversification of reserves, i.e. countries with floating regimes have the most diversified reserves whereas hard peg countries have the most concentrated portfolios. This is in line with our expectations: hard peg countries have obligations to match their reserves to a specific currency, while countries with floating regimes are flexible enough to diversify risks and profitability.

Further research on the foreign exchange reserves topic could be looked at from various perspectives. Our vision and suggestion would be to keep deploying the cross-sectional and time series data simultaneously in order to get more accurate inferences. A natural progression of this thesis could be to incorporate different explanatory variables for reserve size analysis such as: opportunity cost of holding reserves, credit ratings of a country directly serving as sign of default history, political factors, as well as a lagged dependent variable or its volatility. As another subject of the potential future research, we see the unfortunate crisis caused by the Covid-19 outbreak in 2020, which could serve for a time-series analysis or an event study. The currency composition of reserves is a highly interesting area to be examined, however, it is heavily influenced by the data limitations of consolidated databases. To cope with this issue, it is possible to collect data from annual reports of scarce number of central banks. This, however, carries another complication as: each central bank has its own reporting standards varying in gross/net amounts or items included in the total amounts of reserves. Moreover, this process of collecting data could bring up a discussion on the self-selection bias in the data collection. Assuming that a breakdown of more currencies is available, a further study could investigate the diversification among these currencies, not limited to the five as used in our analysis. Furthermore, another study following up on our USD-EUR spread analysis could examine the drivers behind the movements across any other additional reserve currencies, without restricting it to only two. Additionally, the future research could look at whether there are different determinants driving reserves of a specific currency.

We identified a need for better data availability for a potential future research. Higher number of countries disclosing their currency composition could provide a more precise and representative analysis. Considering the current trend towards a higher transparency in reporting, we believe a more comprehensive databases will be available in the future, allowing future researchers to establish a greater degree of accuracy on this matter.

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Appendix

Appendix A: Currency Composition of World Reserves

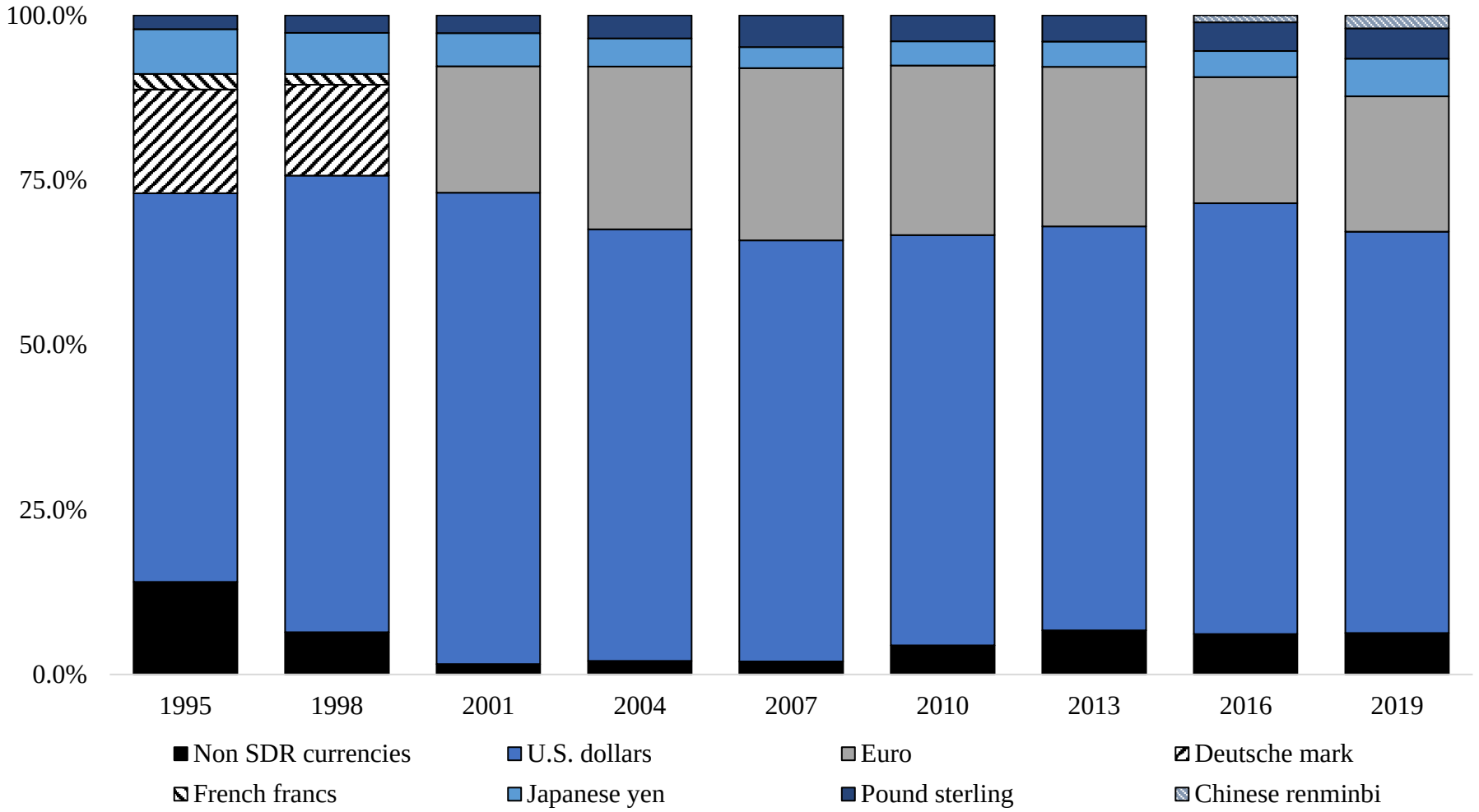
Exhibit A1: Historical development of shares in reserves allocated to different currencies

World allocated reserves (%)	**1995**	**1998**	**2001**	**2004**	**2007**	**2010**	**2013**	**2016**	**2019**
US dollars	59.0	69.3	71.5	65.5	63.9	62.2	61.3	65.4	60.9
Euro	0.0	0.0	19.2	24.7	26.1	25.8	24.2	19.1	20.5
Japanese yen	6.8	6.2	5.0	4.3	3.2	3.7	3.8	4.0	5.7
Pound sterling	2.1	2.7	2.7	3.5	4.8	3.9	4.0	4.3	4.6
Chinese renminbi[38]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	2.0
Other currencies	4.9	4.5	1.3	1.9	1.8	4.3	2.8	2.3	2.6
Canadian dollars[39]	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.9	1.9
Australian dollars[39]	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.7	1.7
Swiss francs	0.3	0.3	0.2	0.2	0.2	0.1	0.3	0.2	0.2
Netherlands guilders	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deutsche mark	15.8	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECUs	8.5	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
French francs	2.4	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: IMF, Author's calculation

[38] *Before 2016 included within "Other Currencies" category*
[39] *Before 2012 included within "Other Currencies" category*

Exhibit A2: Allocated foreign exchange reserves by currency – comparison of SDR and non SDR currencies



Source: IMF, Author's calculation

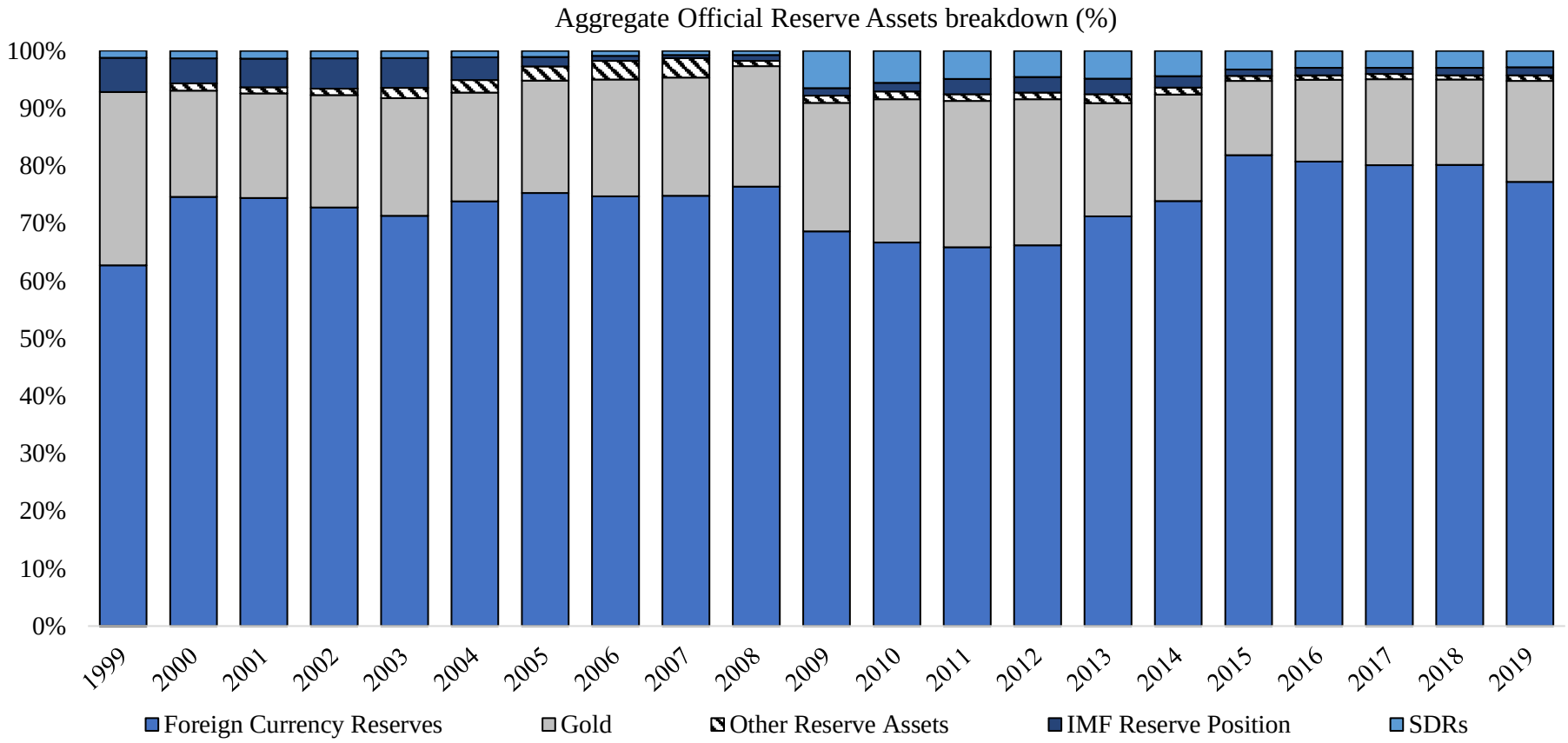
Appendix B: Reserves Data Template

Section I of Reserves Data Template	
I	**Official Reserve Assets and Other Foreign Currency Assets**
I.A	**Official Reserve Assets**
I.A1	Official Reserve Assets, Foreign Currency Reserves (in Convertible Foreign Currencies)
I.A2	IMF Reserve Position
I.A3	SDRs
I.A4	Gold (Including Gold Deposits and, If Appropriate, Gold Swapped)
I.A5	Other Reserve Assets (Specify)
I.B	**Other Foreign Currency Assets (Specify)**

Section IV of Reserves Data Template	
IV	**Memorandum Items Currency Composition of Reserves (by Groups of Currencies)**
IV.A	**Currencies not in SDR Basket**
IV.B	**Currencies in SDR Basket**
IV.B1	Denominated in Chinese Yuan
IV.B2	Denominated in Euros
IV.B3	Denominated in Japanese Yen
IV.B4	Denominated in UK Pound Sterling
IV.B5	Denominated in US Dollars

Source: Reserve Data Template (IMF), Author's Calculation

Notes: For simplicity and clarity, the above tables are only a part of the original Section I and IV of Reserves Data Template.



World Official Reserve Assets (%)	1999	2001	2003	2005	2007	2009	2011	2013	2015	2017	2019
Foreign Currency Reserves	62.7	74.4	71.3	75.3	74.8	68.6	65.9	71.2	81.8	80.1	77.2
IMF Reserve Position	5.9	4.9	5.2	1.7	0.5	1.3	2.6	2.7	1.1	1.1	1.4
SDRs	1.3	1.4	1.3	1.1	0.7	6.5	4.9	4.9	3.3	2.9	2.9
Gold	30.2	18.2	20.4	19.6	20.6	22.4	25.4	19.7	12.9	14.9	17.5
Other Reserve Assets	0.0	1.1	1.8	2.5	3.3	1.2	1.2	1.5	0.8	0.9	1.0

Source: IRFCL database (IMF), Author's Calculation

Appendix C: Literature overview

Author (year)	Sample		Variables similar to our approach							Other variables (not exclusive)
	Countries	Time period	Dependent variable	Trade	Financial depth (2)	External debt	Financial openness (3)	GDP per capita	Additional CC and TS analysis	
Lane and Burke (2001)	102	1981-1995	Ln (Res/GDP)	x	x	x	x	x	FU(4), FX(4)	Population, Volatility of export revenues
Aizenman and Marion (2003)	122	1980-1996	Ln (Res/GDP deflator) (1)	x				x		Political corruption, Population, Exchange rate volatility
Choi and Baek (2004)	137	1980-2000	Ln (Res) (1)	x			x	x	FX(4)	Opportunity cost, GDP, Export volatility
Choi and Baek (2006)	46	1980-1999	Ln (Res) (1)	x			x		DEV	Opportunity cost, Political Corruption, GDP growth
Choi and Strömqvist (2007)	60	1980-2003	Res/GDP (1)	x	x		x	x	DEV	Opportunity cost, Population, Exchange rate volatility, Credit rating, GDP growth
Cheung and Ito (2009)	100	1975-2005	Res/GDP	x	x	x	x	x	FX(4), DEV, FU(4) Crisis(4), Geographic(4)	Population, Opportunity cost, Reserve volatility, Corruption, Political stability
Bastourre et al. (2009)	139	1973-2003	Ln (Res/GDP)	x			x	x	Shift 1990(4)	Opportunity cost, Financial volatility
Steiner (2009)	162	1975-2003	Res/GDP (1)	x		x	x	x	FX(4)	Lagged Y variable, Opportunity cost, External volatility

Author (year)	Sample		Variables similar to our approach							Other variables (not exclusive)
	Countries	Time period	Dependent variable	Trade	Financial depth (2)	External debt	Financial openness (3)	GDP per capita	Additional CC and TS analysis	
Park and Estrada (2009)	130	1980-2004	Reserves	x				x	Only EM analysis	Population, Export volatility, Exchange rate volatility
Choi et al. (2009)	60	1980-2005	Res/GDP (1)	x		x	x		DEV	Population, Exchange rate volatility, Credit rating
Obstfeld et al. (2010)	134	1980-2004	Ln (Res/GDP)	x	x	x	x	x	FX(4) , AE(4)	Population, Exchange rate volatility
Shijaku and Dushku (2017)	1	1999-2012	Ln (Res)	x	x	x				Opportunity cost, M3, GDP
Arslan and Cantú (2019)	24	1980-2016	Ln (Res/GDP)	x	x		x	x	GFC, Asian crisis, FU, Geography	Population, Exchange rate stability, Current Account vulnerability
Cabezas and De Gregorio (2019)	52	2000-2013	Ln (Res/GDP) (1)	x	x	x	x		FX(4), GFC	Opportunity cost, Terms of Trade, Exchange rate volatility, Export volatility, GDP growth

Notes:

(1) Excluding gold
(2) Represented as M2/GDP in our analysis
(3) Represented as Kaopen in our analysis
(4) Model includes a dummy variable
CC: Cross-country
DEV: Country development
EM: Emerging markets
FU: Fuel-exporter
FX: Foreign exchange regime
TS: Time-series

Appendix D: List of countries

Code	Country Name	Development	Fuel Exporter	FX regime
AL	Albania	EMDE	Non-fuel	Floating
AM	Armenia	EMDE	Non-fuel	Floating
AR	Argentina[1]	EMDE	Non-fuel	Floating
AU	Australia[2]	AE	Fuel-exporter	Floating
BD	Bangladesh	LIDC	Non-fuel	Soft peg
BG	Bulgaria[2]	EMDE	Non-fuel	Hard peg
BO	Bolivia	LIDC	Fuel-exporter	Soft peg
BR	Brazil[1], [2]	EMDE	Non-fuel	Floating
BY	Belarus[1]	EMDE	Fuel-exporter	Other
CA	Canada[2]	AE	Non-fuel	Floating
CH	Switzerland[1], [2]	AE	Non-fuel	Floating
CL	Chile[2]	EMDE	Non-fuel	Floating
CM	Cameroon	LIDC	Fuel-exporter	Soft peg
CN	China	EMDE	Non-fuel	Soft peg
CO	Colombia	EMDE	Fuel-exporter	Floating
CR	Costa Rica[2]	EMDE	Non-fuel	Soft peg
CZ	Czech Republic	AE	Non-fuel	Floating
DK	Denmark[1]	AE	Non-fuel	Soft peg
DM	Dominica	EMDE	Non-fuel	Hard peg
DO	Dominican Republic	EMDE	Non-fuel	Soft peg
DZ	Algeria	EMDE	Fuel-exporter	Other
EC	Ecuador[1], [2]	EMDE	Fuel-exporter	Hard peg
EG	Egypt(1)	EMDE	Fuel-exporter	Soft peg
GB	United Kingdom[1]	AE	Non-fuel	Floating
GE	Georgia[2]	EMDE	Non-fuel	Floating
GT	Guatemala	EMDE	Non-fuel	Soft peg
HK	Hong Kong	AE	Non-fuel	Hard peg
HR	Croatia[2]	EMDE	Non-fuel	Soft peg
HU	Hungary[1]	EMDE	Non-fuel	Floating
ID	Indonesia	EMDE	Fuel-exporter	Soft peg
IL	Israel[2]	AE	Non-fuel	Floating
IN	India	EMDE	Non-fuel	Floating
IS	Iceland[1]	AE	Non-fuel	Floating
JM	Jamaica[1]	EMDE	Non-fuel	Soft peg
JO	Jordan	EMDE	Non-fuel	Soft peg
JP	Japan	AE	Non-fuel	Floating
KG	Kyrgyz Republic	LIDC	Non-fuel	Other
KH	Cambodia	LIDC	Non-fuel	Other
KR	Korea	AE	Non-fuel	Floating
KZ	Kazakhstan[1]	EMDE	Fuel-exporter	Floating
LC	St. Lucia	EMDE	Non-fuel	Hard peg
LK	Sri Lanka[1]	EMDE	Non-fuel	Soft peg
MA	Morocco[2]	EMDE	Non-fuel	Soft peg
MD	Moldova[1], [2]	LIDC	Non-fuel	Floating

Code	Country Name	Development	Fuel Exporter	FX regime
MG	Madagascar	LIDC	Non-fuel	Floating
MK	North Macedonia	EMDE	Non-fuel	Soft peg
MN	Mongolia	LIDC	Fuel-exporter	Floating
MU	Mauritius[(2)]	EMDE	Non-fuel	Floating
MX	Mexico	EMDE	Non-fuel	Floating
MY	Malaysia	EMDE	Non-fuel	Floating
NA	Namibia	EMDE	Non-fuel	Soft peg
NI	Nicaragua	LIDC	Non-fuel	Soft peg
NO	Norway[(2)]	AE	Fuel-exporter	Floating
NP	Nepal	LIDC	Non-fuel	Soft peg
NZ	New Zealand	AE	Non-fuel	Floating
PE	Peru[(2)]	EMDE	Non-fuel	Floating
PG	Papua New Guinea	LIDC	Fuel-exporter	Soft peg
PH	Philippines	EMDE	Non-fuel	Floating
PK	Pakistan	EMDE	Non-fuel	Soft peg
PL	Poland	EMDE	Non-fuel	Floating
PY	Paraguay	EMDE	Fuel-exporter	Other
RO	Romania	EMDE	Non-fuel	Floating
RU	Russian Federation[(1)]	EMDE	Fuel-exporter	Floating
RW	Rwanda	LIDC	Non-fuel	Soft peg
SA	Saudi Arabia	EMDE	Fuel-exporter	Soft peg
SB	Solomon Islands	LIDC	Non-fuel	Soft peg
SC	Seychelles[(2)]	EMDE	Non-fuel	Floating
SE	Sweden[(1), (2)]	AE	Non-fuel	Floating
SG	Singapore	AE	Non-fuel	Soft peg
SL	Sierra Leone	LIDC	Non-fuel	Other
SR	Suriname[(1)]	EMDE	Non-fuel	Soft peg
SV	El Salvador	EMDE	Non-fuel	Hard peg
TH	Thailand	EMDE	Non-fuel	Floating
TJ	Tajikistan[(1)]	LIDC	Non-fuel	Soft peg
TN	Tunisia	EMDE	Non-fuel	Soft peg
TR	Turkey[(1)]	EMDE	Non-fuel	Floating
TT	Trinidad and Tobago	EMDE	Fuel-exporter	Soft peg
UA	Ukraine[(1), (2)]	EMDE	Non-fuel	Floating
UG	Uganda	LIDC	Non-fuel	Floating
US	United States[(1)]	AE	Non-fuel	Floating
UY	Uruguay[(1), (2)]	EMDE	Non-fuel	Floating
ZA	South Africa[(1)]	EMDE	Non-fuel	Floating

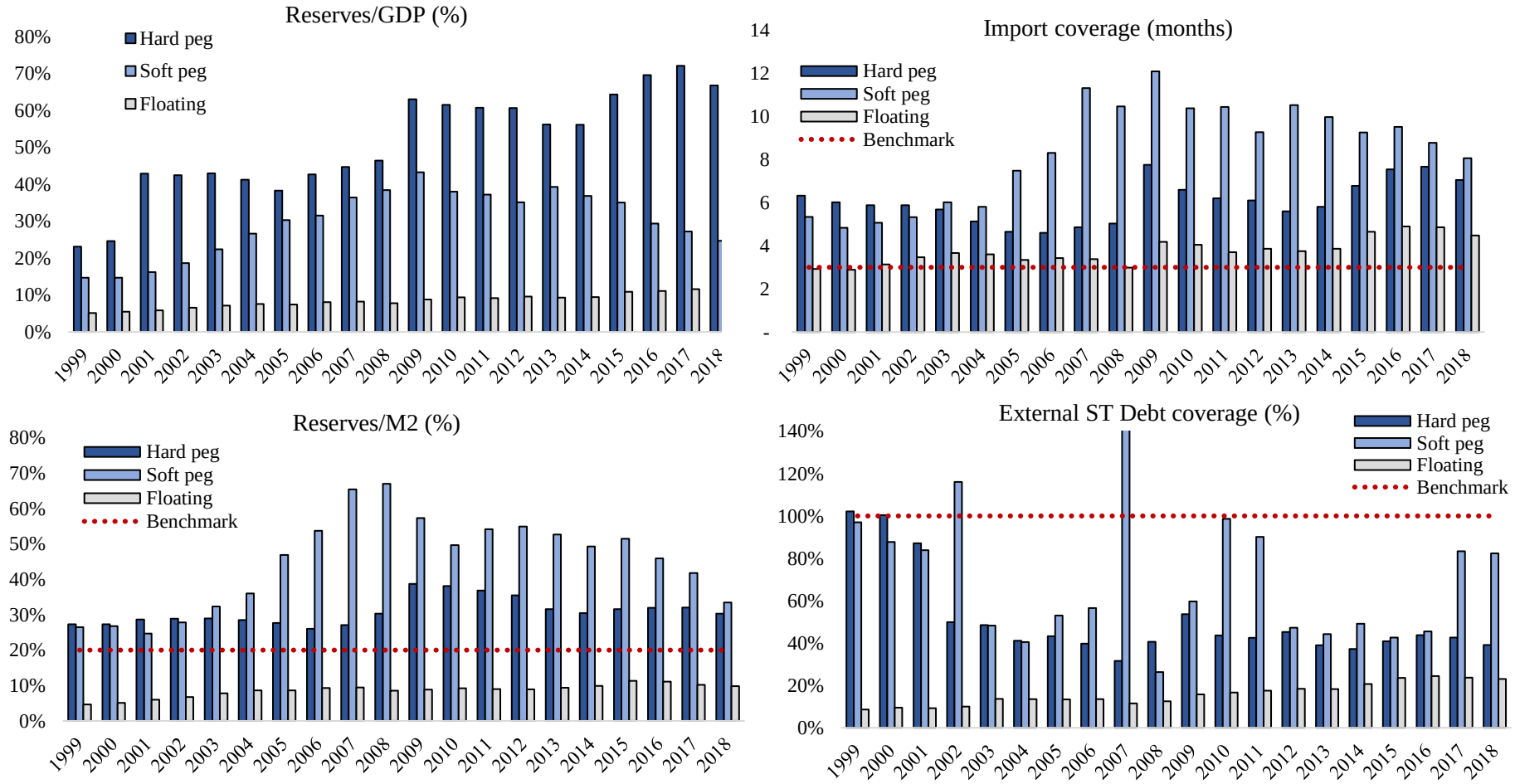
Source: Author's calculation from the IMF data

Notes:

(1) Countries used for Before vs After crisis analysis, i.e. countries which have experienced any type of crisis between 1999 and 2018.

(2) Countries used in currency composition analysis.

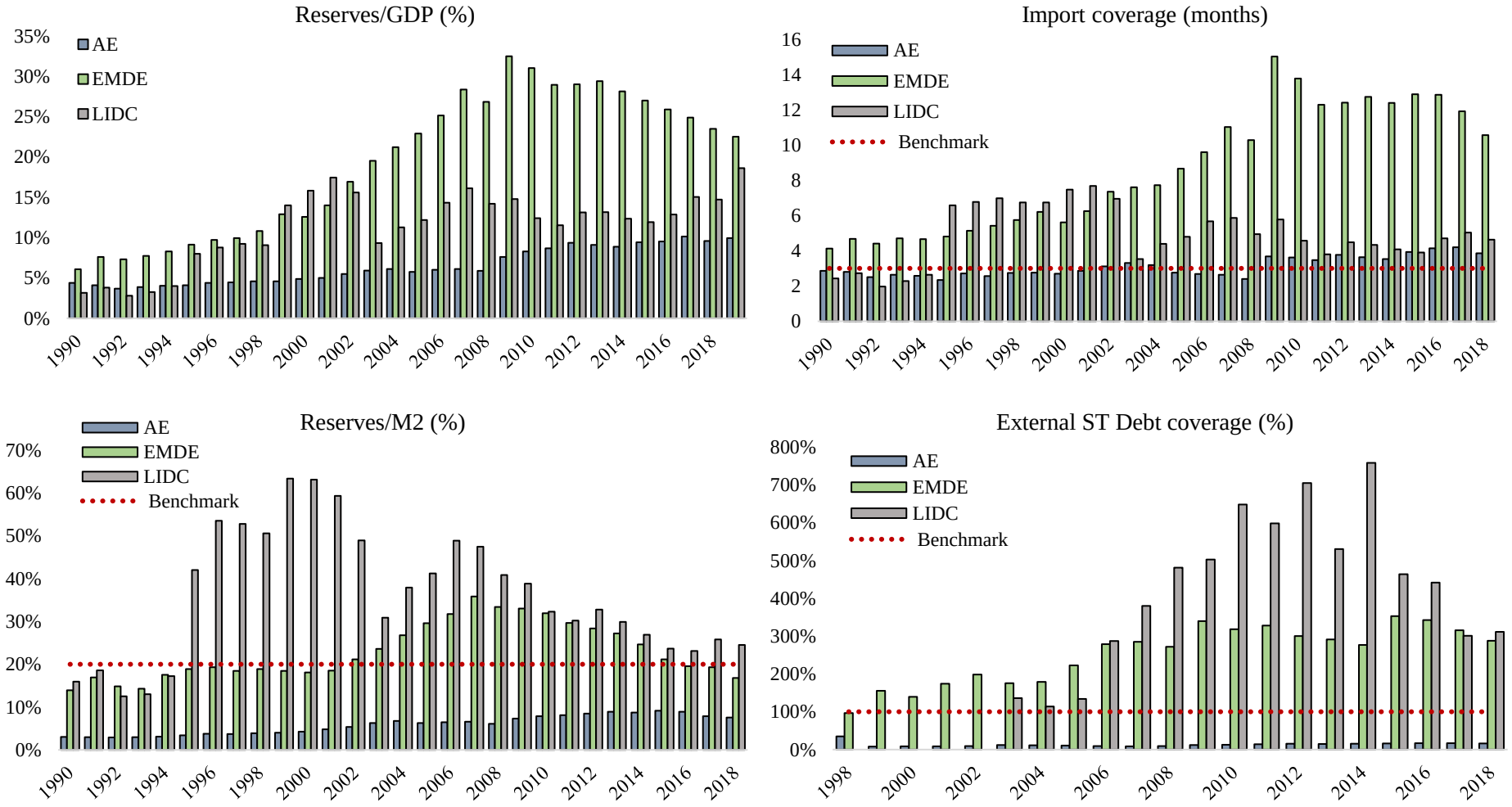
Appendix E: Exchange rate comparison[40]



Source: IMF, WB, Author's calculation

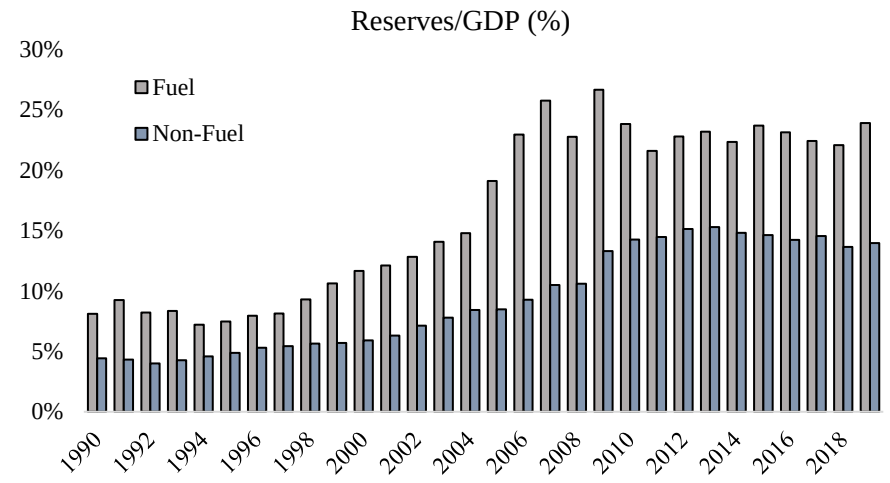
[40] *Excluding China as an outlier for import coverage, M2 and ST Debt metrics. China's effect on reserves over GDP is not significant to be excluded.*

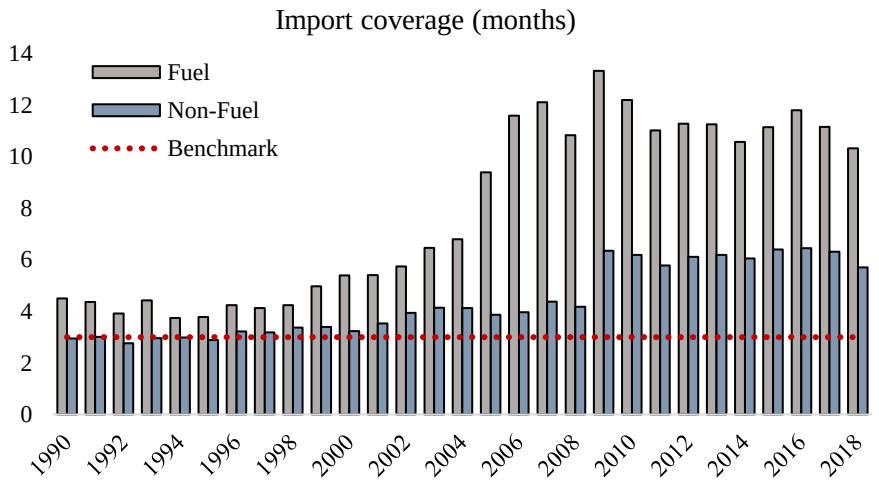
Appendix F: Country development comparison

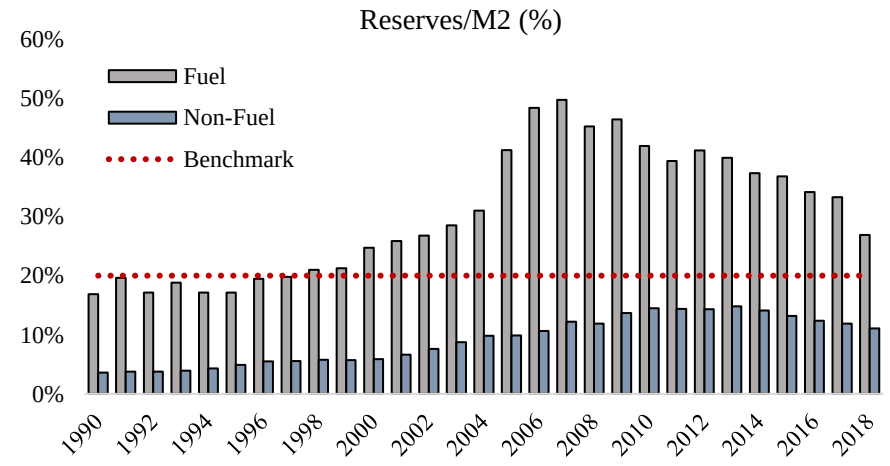


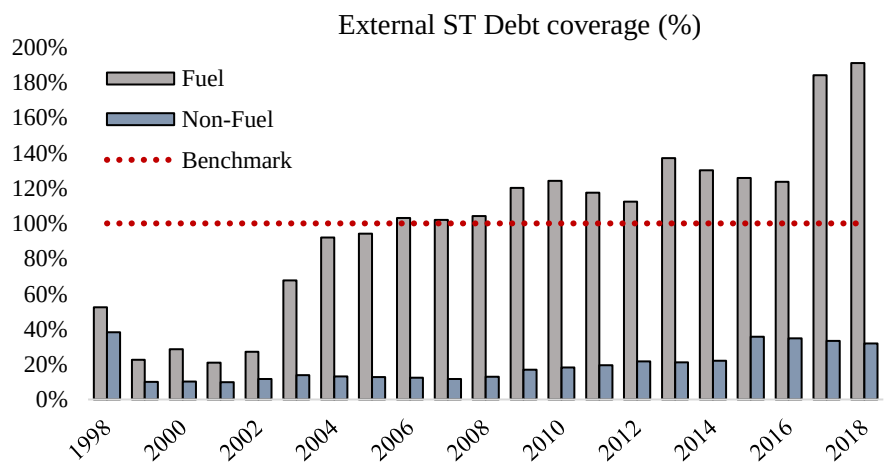
Source: IMF, WB, Author's calculation

Appendix G: Fuel-exporting comparison



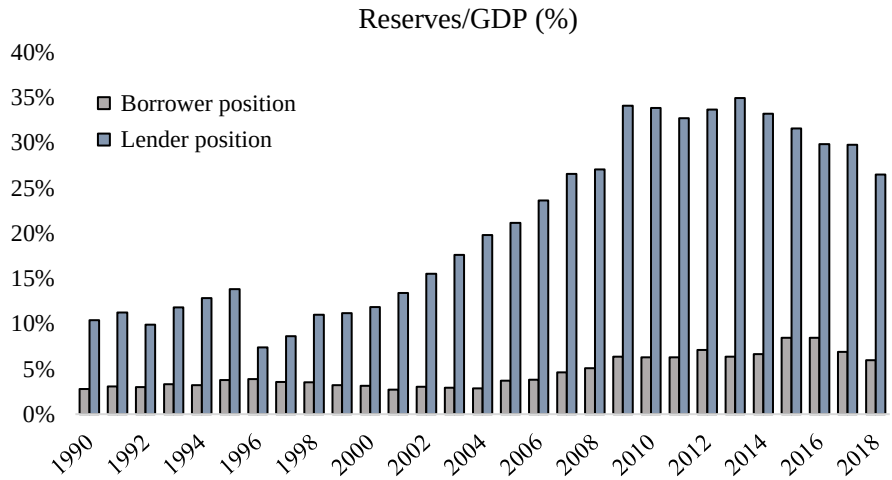


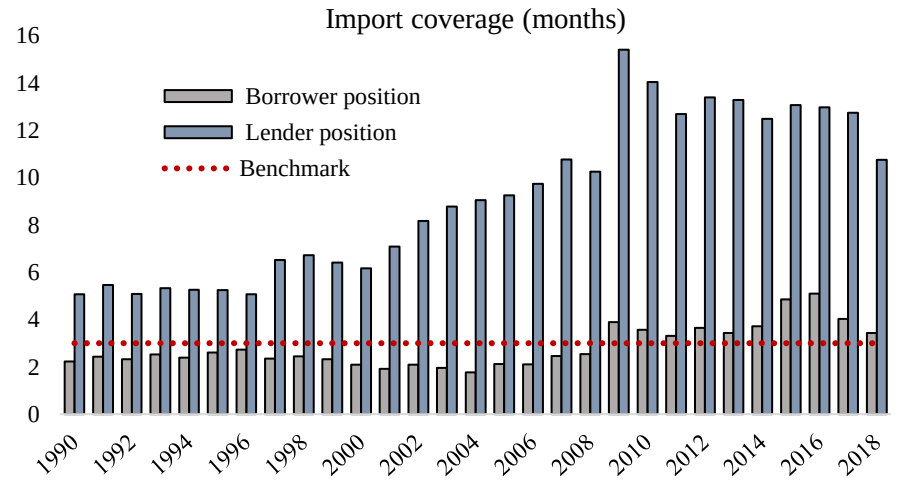


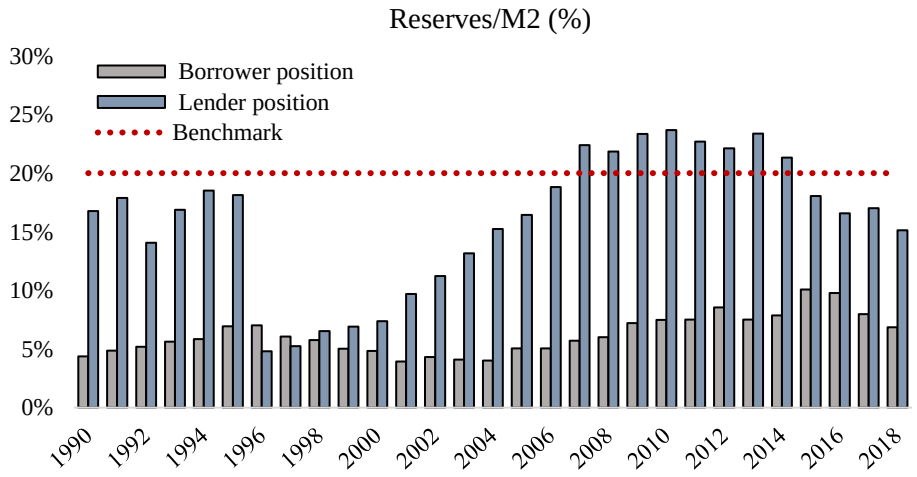


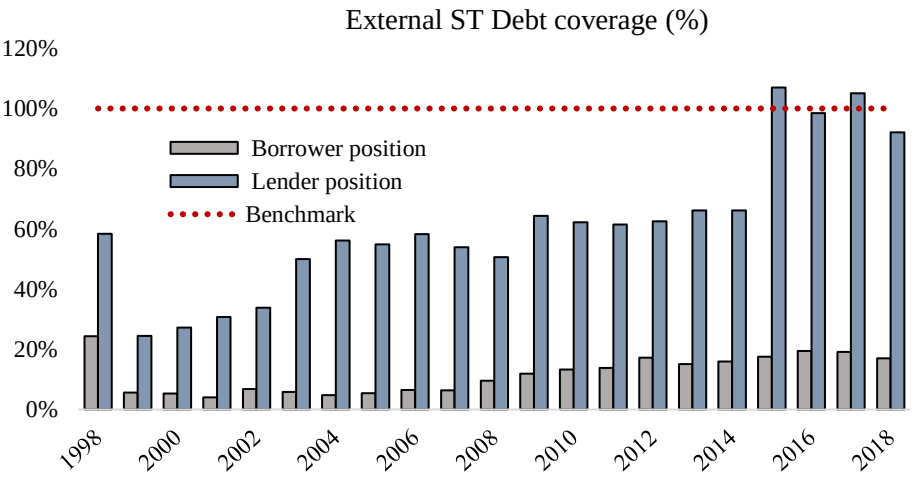
Source: IMF, WB, UN, Author's calculation

Appendix H: Current and capital accounts balance comparison









Source: IMF, WB, Author's calculation

Appendix I: Descriptive statistics of reserve size analysis

Sample:

Number of countries	82
Max number of observations	982

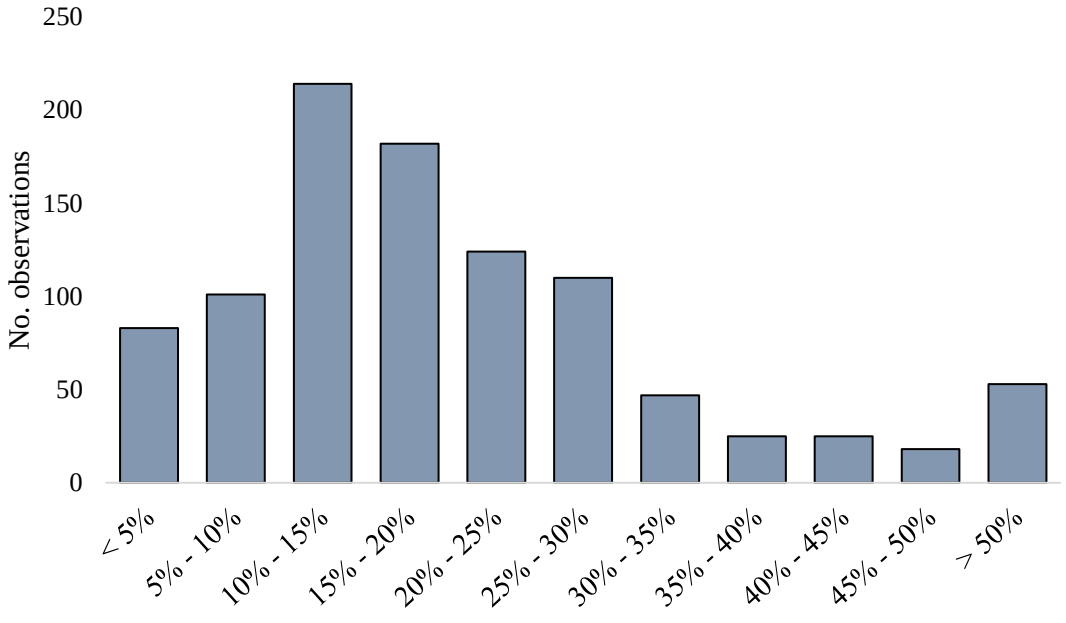
Descriptive statistics of the main variables:

	Res/GDP	Trade openness	M2/GDP	DebtST/GDP	Kaopen	GDPpc
Mean	0.22	0.88	0.73	0.33	0.63	16,898.11
Std Dev	0.19	0.63	0.51	0.71	0.35	20,101.30
Max	1.26	4.43	3.96	5.01	1.00	92,077.57
Min	0.00	0.21	0.11	0.00	0.00	457.83

Correlation among the main variables:

	Res/GDP	Trade openness	M2/GDP	DebtST/GDP	Kaopen	LN GDPpc
Res/GDP	1.00	0.77	0.57	0.54	0.16	0.10
Trade openness	0.77	1.00	0.46	0.65	0.21	0.18
M2/GDP	0.57	0.46	1.00	0.52	0.24	0.43
DebtST/GDP	0.54	0.65	0.52	1.00	0.27	0.47
Kaopen	0.16	0.21	0.24	0.27	1.00	0.48
LN GDPpc	0.10	0.18	0.43	0.47	0.48	1.00

Distribution of observations based on Res/GDP (%) ratio:



Source: Author's calculation

Appendix J: Other estimation results

Exhibit J1: Estimation results, countries changing FX regime

Dependent variable: Change in Reserves/GDP	
	(A) **Change in regime**
Constant	0.010***
	(0.003)
Change Trade/GDP	-0.001
	(0.026)
Change M2/GDP	0.241***
	(0.048)
Change DebtST/GDP	0.019*
	(0.011)
Change Kaopen	0.017
	(0.025)
Change Ln (GDPpc)	-0.229***
	(0.062)
Float to Soft peg, dummy	0.008
	(0.010)
Float to Other, dummy	-0.011
	(0.015)
Soft peg to Float, dummy	0.007
	(0.010)
Soft peg to Other, dummy	-0.027*
	(0.016)
Other to Float, dummy	-0.019
	(0.022)
Other to Soft peg, dummy	0.000
	(0.012)
Number of countries	30
Number of observations	386
R^2	0.12
R^2, adjusted	0.10

*Standard errors in parentheses. *, **, *** indicates significance at the levels 10%, 5%, 1%.*

Source: Author's calculation

Exhibit J2: Estimation results, Great Financial Crisis

Dependent variable: Reserves/GDP			
	(A) Full sample, 1999-2018	**(B) Before crisis, 1999-2007**	**(C) After crisis, 2008-2018**
Constant	0.155***	0.222***	0.175***
	(0.032)	(0.047)	(0.038)
Trade/GDP	0.183***	0.180***	0.183***
	(0.007)	(0.011)	(0.009)
M2/GDP	0.114***	0.064***	0.130***
	(0.008)	(0.012)	(0.010)
DebtST/GDP	0.013*	0.016	0.013
	(0.007)	(0.010)	(0.009)
Kaopen	0.016	0.016	0.020
	(0.011)	(0.016)	(0.014)
Ln (GDPpc)	-0.025***	-0.028***	-0.024***
	(0.004)	(0.005)	(0.005)
After crisis, dummy	0.044***		
	(0.008)		
Number of countries	82	50	82
Number of observations	982	278	704
R^2	0.68	0.77	0.66
R^2, adjusted	0.68	0.76	0.66

*Standard errors in parentheses. *, **, *** indicates significance at the levels 10%, 5%, 1%.*

Source: Author's calculation