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Falk Hendrik Laser and Jan Weidner

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Currency Compositions of International Reserves and the Euro Crisis

Falk Hendrik Laser* Jan Weidner†

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Abstract: During recent years, central banks have increased the levels of their international reserves at an unprecedented pace. In this paper, we introduce new country-specific reserve data and examine determinants of the composition of international reserves. Using a dataset of 36 countries (and the euro area) for the years from 1996 to 2016, we identify currency pegs and trade patterns as determinants of currency compositions. Our results emphasize the importance of transaction motives for the composition of currency reserves. The euro crisis appears to have been a setback for the euro, which temporarily seemed to challenge the US dollar as the most important international reserve currency and potentially impacted the determination of international reserve compositions.

JEL: E58, F31, G01

Keywords: International reserves, central banks, euro crisis.

*Goethe University Frankfurt Graduate School of Economics, Finance and Management (GSEFM) and Technische Universität Darmstadt, Department of Law and Economics, Address: Hochschulstraße 1, 64289 Darmstadt, Germany, E-Mail: laser@vwl.tu-darmstadt.de, Declarations of interest: none

†German Federal Ministry for Economic Affairs and Energy, Address: Scharnhorststraße 34-37, 11019 Berlin, Germany, E-Mail: jan.weidner@outlook.com, Declarations of interest: none

1 Introduction

Only recently the European Commission presented ambitious plans for a stronger role of the common European currency in the world as expressed by its president Jean-Claude Juncker in his State of the Union Address (Juncker, 2018). Moreover, a recent press release of the European Commission mentions concrete measures, for instance the promotion of the euro (EUR) as a means of payment in key strategic sectors such as energy markets or the establishment of an integrated European instant payment system suitable for strengthening the EUR in international currency reserve markets (European Commission, 2018). Given the mixed performance of the EUR with regard to its perceived stability during the euro crisis and its decreasing relative importance as an international reserve currency, it is difficult to assess the prospects of success measured against these ambitions (Maggiori et al. (2019) and The Economist (2019)).

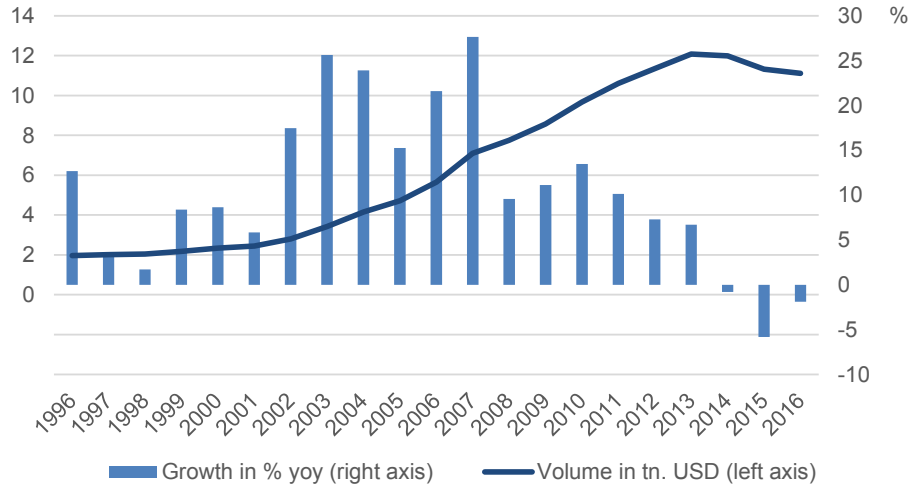
It is not only since Mr. Juncker's announcement that international reserves have been of considerable interest for both academics and policy makers. International currency reserves not only increasingly play an important role for international currency markets and exchange rates but also more broadly in terms of geopolitics and the global economy. During recent years, holdings of international reserves have grown at an extremely fast pace, as shown by Figure 1. According to the IMF International Financial Statistics (IFS) international reserves have seen nearly a sevenfold increase over the last two decades and have grown from 1.6tn US dollars (USD) in 1996 to 10.7tn USD in 2016 (International Monetary Fund, 2016b).[1] This development has largely been driven by a small group of countries, as the ten biggest holders of reserves account for 70% of worldwide international reserves. China and Japan alone managed around 39% of worldwide international reserves in 2016.[2]

The academic literature dealing with international reserves can broadly be separated

[1] In its Balance of Payments Manuel, the IMF defines international reserves as "those external assets that are readily available to and controlled by monetary authorities for meeting balance of payments financing needs, for intervention in exchange markets to affect the currency exchange rate, and for other related purposes (such as maintaining confidence in the currency and the economy, and serving as a basis for foreign borrowing)"(International Monetary Fund, 2007).

[2] Table A1 in the appendix reports the ten biggest holders of international reserves in 2016, of which seven are located in Asia.

Figure 1: Volume of international reserves (in trillion USD)



Notes: The line (left axis) corresponds to aggregated worldwide international reserves volumes without gold. The bars (right axis) display respective year-over-year growth rates. [Please use colors in print.]
Source: IMF International Financial Statistics.

into research questions concerning what determines the size of a country's overall reserve holdings and those concerning a country's drivers for its currency composition. We focus on the latter. While empirical examinations of currency compositions are hampered by limited access to relevant IMF data on country-specific reserve compositions, we compile a new dataset based on all countries publicly disclosing their data.

Making use of country-specific data, we test the relevance of transaction motives in determining currency compositions. Transaction motives with respect to the currency compositions of foreign exchange reserves refer to bolstering a country's preparedness for potential foreign exchange interventions, current account interventions, or temporary import financing. Our main findings suggest that currency compositions of international reserves under central bank management are influenced by currency pegs and trade patterns. Thus we are able to confirm previous academic findings (see Heller and Knight (1978), Dooley et al. (1989), Eichengreen et al. (2000) and recently Aizenman et al. (2019)). Unlike these papers, we place more focus on the specific role of the EUR, which since its introduction has been considered a serious competitor to the USD on international currency reserve markets by some. For instance, Bergsten (1997) calls the EUR the new rival to the USD and expects the establishment of a 'bipolar currency regime' and

Chinn and Frankel (2008) describe scenarios in which the EUR will replace the USD as the main international reserve currency.

In particular, we aim to disentangle the impact of the euro crisis on the euro's role as an international reserve currency. Splitting the sample into pre-crisis and crisis subsamples, we analyze the effect of the crisis on the determinants of currency compositions. We identify a significant and negative impact of the euro crisis on EUR holdings across countries. Additionally, our findings suggest that the euro crisis impacted on the effect of the determinants of currency compositions, rendering proxies for bilateral economic interdependence more relevant. We cautiously interpret this as a setback for the EUR as an international reserve currency. In a final exercise, we use our model to predict currency compositions of the three most important non-disclosing holders of international reserves, China, Japan, and Saudi Arabia.

The structure of this paper is as follows. In section 2, we address the related literature. In section 3, we present our data and descriptive findings. Section 4 is dedicated to analyzing determinants of country-specific reserve compositions, the role of the euro crisis and provides predictions of currency shares for non-disclosing countries. In section 5, we summarize and discuss our findings.

2 Literature

We present the related literature in two subsections. The first covers contributions analyzing the general level of international reserve holdings, the second focuses on contributions dealing with the composition of reserves.

2.1 Motives for International Reserve Holdings

The literature addressing the question of why countries hold international reserves identifies three main motives: A precautionary motive, a mercantilist motive, and an investment motive. In one of the earlier works discussing international reserves, Heller (1966) distinguishes between a precautionary, a speculative, and an investment motive

for holding international reserves. He finds precautionary motives to be the most relevant and derives the need to finance imbalances in a country's international accounts as the main rationale for holding reserves. Heller (1966) computes optimal reserve levels for 60 countries by minimizing the costs of adjustment to external imbalances and the costs of holding international reserves given a positive probability of having to adjust. Another contribution representing a precautionary motive stance is Calvo et al. (2012), which addresses the question of the optimal reserve level in the face of a sudden stop. The authors use a statistical model assuming that central bankers choose the desired reserve level of reserves by weighting the expected costs of a sudden stop against the opportunity costs of holding international reserves. They find that de-facto reserve levels were close to optimal on the eve of the Global Financial Crisis and do not find evidence for the mercantilist motive.

Dooley et al. (2003) are among the proponents of a mercantilist motive view and explain the accumulation of international reserves in Asia with export-led growth strategies. To them, the motive for holding international reserves is to influence the exchange rate to foster competitiveness (through undervaluation). Aizenman and Lee (2008) assess the importance of the mercantilist motive empirically and focus on developing countries from 1980 to 2000. They find that the precautionary motive better explains the accumulation of international reserves. They point out the high potential costs caused by a sudden stop.

Rodrik (2006), among others, views the high and increasing levels of international reserves as a protection against financial crises but raises the question of the related costs of these holdings, suggesting an investment motive. Due to the low level of interest earned on international reserves and the cost of foreign borrowing, Rodrik (2006) estimates an income loss of around 1 percentage point of GDP for developing countries.

Goldberg et al. (2013) provide an overview of the subject of international reserves, focusing on industrialized countries from a central bank perspective. They address, inter alia, the questions of why industrialized countries hold high levels of international reserves (e.g. manage exchange rates, "calm disorderly markets", "insure against liquidity losses

and disruptions to capital market access") and what are adequate levels of reserves.

2.2 Determinants of Currency Compositions

The previously discussed issue of why countries amass foreign exchange reserves is linked to the question of how central banks choose the currency composition of their foreign exchange reserves. On this subject, the literature mainly distinguishes between transaction and classical portfolio investment considerations. Transaction motives with respect to the currency composition of the foreign exchange reserve portfolio arise from the central bank's potential need to conduct foreign exchange interventions, current account interventions, or temporary import financing. The portfolio investment motive is characterized by a yield/risk trade-off. However, it is generally agreed upon that central banks exhibit a lower risk tolerance than private investors.

Empirical investigations in this field are often hampered by poor data availability. One important source is the IMF's COFER database (International Monetary Fund, 2016a). On very rare occasions, the IMF grants access to its confidential country-specific data. Three important contributions based on these data are closely related to our paper. Heller and Knight (1978) stress the importance of transaction motives. Using a panel of 76 countries for the period 1970-76, they find a relation between trade patterns and the exchange rate regime of a country with the currency composition of its foreign exchange reserves. Analyzing an updated version of the dataset, Dooley et al. (1989) confirm this finding for the years 1976-86. Additionally, they find that the denomination of a country's debt is related to the currency composition of this country's international reserves. Eichengreen et al. (2000), assessing a panel of 84 countries over the period 1979-96, find further evidence that trade flows, financial flows, and currency pegs are the principal determinants of a country's currency composition.

Other contributions are based on publicly accessible data. For instance, Wong (2007) extracts information from central bank annual reports on international reserves of 23 countries to analyze diversification. For the years 2000-2005, she finds evidence for net stabilizing interventions. This implies that central banks increase their foreign currency

shares as a response to devaluation and vice versa. In another study, Chinn and Frankel (2008) rely on aggregated COFER data for the years 1973-2007 and estimate a model using characteristics of the currency issuing country to explain shares of major currencies. They identify the relative size of the home country, a proxy for the relative size of the domestic trading place, and the exchange rate volatility of the respective currency as significant determinants. In two out of several possible scenarios the EUR is expected to surpass the USD (by 2015 and by 2022 respectively). Eichengreen et al. (2016) use data on aggregated currency compositions from 1947 to 2013 to investigate whether the breakdown of the Bretton Woods system had an impact on the above mentioned determinants. Including a measure of persistence, they find support for strong inertia in currency compositions and their determinants. Additionally, they suggest a smaller effect of the relative size of the home country's economy after Bretton Woods and weaker network effects.

Recently, Aizenman et al. (2019) have examined a possible regime change since the financial crisis concerning currency compositions and the demand for reserves. Using aggregated shares of the four largest reserve currencies they confirm previous findings that trade and debt denominated in the major reserve currencies drive reserve holdings of the major reserve currencies. Moreover, they find that higher reserve ratios relative to GDP and a shortage of global safe assets may have strengthened the concentration of the reserve holdings towards the major global currencies. Ito and McCauley (2019) observe a relation between the currency composition of reserves and the denomination of trade invoicing as well as with currency co-movements

On the theoretical side, one strand of the literature is concerned with modeling optimal currency composition according to a Markowitz-type portfolio problem, i.e. trading off expected return versus risk. In this sense, Ben-Bassat (1980) formulates the problem as minimizing the variance at a given return for a basket of import currencies. Using data from 1976 to 1980 and comparing optimal and actual currency compositions, he finds evidence for different roles of portfolio objectives across groups of countries. These are more relevant for developing countries and semi–industrial countries than for industrial

countries. Papaioannou et al. (2006) develop a mean-variance optimization framework including portfolio rebalancing costs and constraints mirroring a central bank's desire to hold some amount of currency reserves in the currency of its peg, of its main trading partners, and of its outstanding debt. They find that, once the dollar is assigned the status of the reference (risk-free) currency, optimal share as suggested by the model and actual shares match well. Observed EUR shares, however, exceed optimal shares. The authors explain this finding with the euro's partial use as an international reserve currency. Beck and Rahbari (2008) build a model embedding transaction motives to mitigate the effect of sudden stops into the minimum variance framework. They identify two separate rationales for currency compositions, these being classical portfolio objectives and hedging demands to counter effects of sudden stops. They argue that the importance of hedging demands decreases with declining debt to reserve ratios. Furthermore, they suggest that the USD is relatively more in demand than the EUR as a hedge against sudden stops in Latin America and Asia. Contrarily, in Emerging Europe the EUR appears to be the more relevant hedge currency. Beck and Weber (2011) consider optimal levels and the composition of international reserve level jointly in one model. In their contribution they refute the common belief that higher levels of international reserves necessarily come along with more diversification and attribute this to precautionary motives.

While the previously mentioned contributions focus on economic explanations of international reserve compositions, political factors also play a role. Only few would deny that the unique role of the USD as an international reserve currency, and thus the United States' so-called "exorbitant privilege", is also the result of its political weight in the world. For example, according to Posen (2008) foreign reserve holdings "depend as much on foreign policy as economics", while stressing the particular importance of security ties and pointing to high USD holdings of states as different as Saudi Arabia, Panama and Taiwan. Frankel (2012) states that from a historical perspective the status of an international reserve currency has been associated with political and military strength and prestige. Another recent contribution to the literature focusing on political factors is Eichengreen et al. (2017). In this piece of work, the authors explain countries' re-

serve currency preferences as a function of their dependence on the US for their security reasons.

3 Data and Descriptives

3.1 Data

Empirical work on the composition of international reserves has been somewhat limited by the discretion exercised by authorities in charge of reserve management. There are three main sources which provide insight into international reserves and its composition. The most general source is IMF's International Financial Statistics (IFS), comprising the overall reserve holdings of most countries in the world. The IMF's COFER database as another potential data source contains aggregated reserve holdings broken down by major international reserve currencies (International Monetary Fund, 2016a). It does not show individual reserve holdings and reporting is on a voluntary basis. Furthermore, of 145 reporting countries only 97 are listed by name on the IMF webpage. A third source consists of national data and is the foundation of this paper. To our knowledge, a total of 36 countries (plus the euro area) individually disclose the currency composition of their international reserves in different ways (mostly central bank annual reports). The advantage of this source is that it allows us to draw conclusions about the currency composition of worldwide total international reserves as well as about country-specific foreign reserve compositions. At the same time, this source is selective as the majority of central banks still prefer not to disclose currency compositions of their international

reserves.[3] [4]

The total volume of international reserves in our dataset accounts for more than one fifth of the total COFER reserves (22.2%) and for more than one fourth of the allocated COFER reserves (29.0%) in 2016. Table A2 in the appendix compares our dataset with both the IFS and COFER datasets of the IMF in terms of scope and level of aggregation. Table A3 in the appendix provides the coverage of countries of our data and the respective sources.

3.2 Descriptives

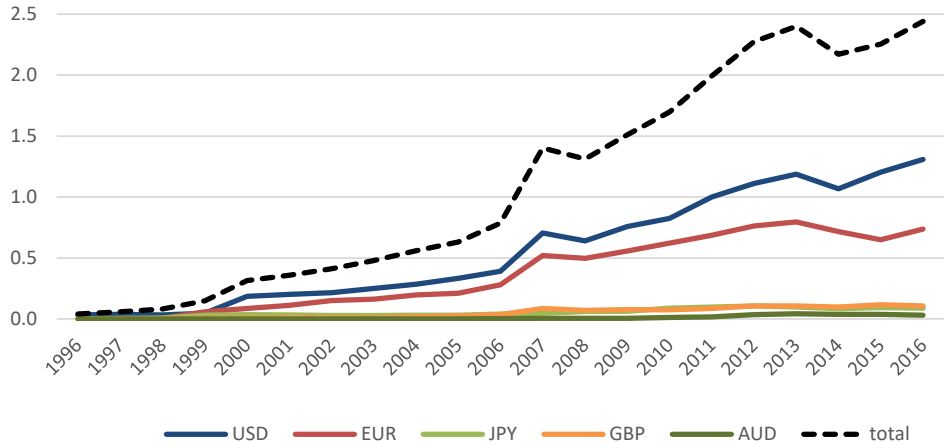
Our individual country data displays the same strong and parallel increase in international reserves and the domination of the USD over the last decade as shown by the IMF's International Financial Statistics and the IMF's COFER statistics. Figure 2 shows that the USD was able to successfully defend its positions as the world's main international reserve currency.

Our unbalanced panel consists of 23 countries from Europe (plus the euro area), six countries from the Americas, four countries from Asia, Mozambique as the only African country and Australia and New Zealand (Table A4 in the appendix lists all countries in our sample). Following the IMF World Economic Outlook classification, 21 countries (plus the euro area) are considered industrial countries and 15 are classified as emerging economies. Despite an overrepresentation of European countries, our sample includes countries from all regions of the world with a considerable variance in terms of economic

[3] To date, disclosure of currency compositions of international reserves is voluntary and left to the discretion of responsible authorities. For example, the non-binding IMF "Guidelines for Foreign Exchange Reserve Management" or the "Code of Good Practices on Transparency in Monetary and Financial Policies" promote more disclosure in the field of reserve management. We suppose that in the case of many, but not all, non-disclosing institutions either political considerations or fear of more unfavorable market conditions play a role. In a conference speech, former Bank of International Settlements Managing Director Malcom Knight summarized the trade-off between more or less disclosure from the point of view of an individual central bank as follows: "In general, disclosure of the level and composition of official reserve holdings has the virtue of improving public accountability regarding the management of public funds. But there is also a risk that opaque private portfolios might gain some, potentially lucrative, advantage over transparent public reserve portfolios" (Knight, 2006).

[4] Furthermore, in 2015, the IMF conducted an ad-hoc survey of its member states' foreign currencies holdings for 2013 and 2014 and published (aggregated) summary results. For a total of 130 responding monetary authorities it reveals which foreign currency assets were held by how many countries and at what size (International Monetary Fund, 2015).

Figure 2: Holdings in major reserve currencies (in trillion USD)



Notes: The graph shows aggregated reserve holdings for the five major currencies in our dataset. [Please use colors in print.]
Source: Own data (mostly annual reports of central banks, see Table A3).

development. Still, we are aware that we have to be cautious with regard to the generality of our results. The decision to disclose currency compositions might not be orthogonal to the mechanism driving currency compositions.

In total, our panel dataset contains the individual international reserve compositions of 36 disclosing countries (plus the euro area) and includes the eight major reserve currencies for different time spans between 1996 and 2016. In the euro area, both the national central banks and the European Central Bank (ECB) manage foreign reserves. In 2016, the ECB's international reserves were composed of around 83% USD-denominated and 17% JPY-denominated assets. The eight major currencies in our sample are the USD, the EUR, the Japanese yen (JPY), the Canadian dollar (CAD), the Chinese renminbi (CNY), the British pound (GBP), the Deutsche mark (DEM), the Swiss franc (CHF), and the Australian dollar (AUD). The entire (unbalanced) panel roughly contains 4,300 observations. In our empirical analysis, we will focus on the four most important international reserve currencies, the USD, the EUR, the JPY and the GBP which all have a substantial average share throughout the given time period.

In order to discuss a few trends, we observe developments for a total of 30 central banks which are consistently part of our panel for the period 2006-2016.[5] Our data

[5]This contrasts to our empirical analysis, for which we include the full sample.

shows the direction in which the percentage shares of the eight major reserve currencies have evolved. Data gaps prevent doing so for the other central banks of the sample. For instance, 16 countries increased the proportion of USD in their international assets, while 12 countries reduced their exposure to the USD. Only seven countries increased their EUR share and a total of 17 countries decreased their EUR share. This is partly due to some countries introducing the EUR, which implied that EUR-denominated assets are no longer considered part of their international reserves. For the period under review, the AUD and the CAD experienced increased demand as no country or only a few reduced their reserve assets (0 and 2 respectively) while many countries increased their reserve shares (11 and 8 respectively).

In terms of (unweighted) aggregated reserves in our sample, the share of the USD slightly increased from 52.8% to 53.6%, whereas the share of the EUR decreased from 33% to 30.2%. Shares of the AUD and the CAD increased from 0.1% to 1.6% and 0.4% to 2.1% respectively. The CNY, often regarded as the rising international reserve currency, was certainly no international reserve currency by 2006, but by 2015 it had become part of the official international reserves of Australia, Italy, and New Zealand even though its share of the total international reserves has so far remained negligible (0.1% in 2016). The JPY and the GBP have remained rivals for the position of the world's third international reserve currency, with shares fluctuating between 4% and 5%. Furthermore, it seems that countries increasingly diversify their foreign reserves portfolio. Indications hereof are a higher number of reserve currencies over time in our panel and also in the IMF COFER database, which was extended in the last years by the AUD, the CAD (both 2013), and the CNY (2016). Table 1 presents aggregated currency shares in our sample for all countries, industrial and emerging economies respectively and shows that the EUR and the GBP gained shares in the early stage after the introduction of the EUR, especially in emerging economies. Table A5 in the appendix reports country specific international reserve compositions.

In our empirical analysis we include as control variables dummies denoting currency pegs to the two main reserve currencies USD and EUR and variables measuring bilateral

Table 1: Share of currencies in total reserve holdings (percent)

Currency	1996	2000	2006	2010	2016
All countries					
US dollar	80.5	58.5	52.8	48.6	53.6
Euro	0.0	27.2	33.0	36.4	30.2
Japanese yen	3.5	11.0	5.0	5.3	3.6
British pound	0.1	2.1	3.8	4.5	4.4
others	15.9	1.1	5.4	5.2	8.2
Industrial countries					
US dollar	80.5	58.0	54.0	51.2	54.9
Euro	0.0	27.3	30.4	32.0	28.8
Japanese yen	3.5	11.3	6.0	8.0	5.0
British pound	0.1	2.2	3.9	2.3	4.0
others	15.9	1.2	5.7	6.5	7.3
Emerging economies					
US dollar	/	72.6	47.5	44.8	50.2
Euro	/	24.8	44.7	43.1	34.1
Japanese yen	/	1.2	0.1	1.1	0.0
British pound	/	0.7	3.7	7.7	5.4
others	/	0.7	4.0	3.3	10.3

Notes: This table presents aggregated currency shares for our sample for all countries, industrial countries and emerging economies.

Source: Own data (mostly annual reports of central banks, see Table A3).

economic dependencies between holding countries and the currency-emitting countries. We concretely proxy bilateral relations via trade, foreign currency public debt and liabilities in currency reserves of the private banking sector. Table 2 presents descriptive statistics for the main currency shares and the control variables. Further, Table A6 in the appendix reports the sources of our set of explanatory variables. In our sample, the USD on average exhibits the highest share with 46% followed by the EUR with 38%. Countries in our sample import substantially less from the US than from the euro area (8.6% vs. 29%), while external debt (59% vs. 26%) and liabilities (56% vs. 14%) are on average more likely to be denoted in USD than in EUR.

Table 2: Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max	N	N if = 0	N if = 1
USD	.46	.3	0	1	507	30	11
EUR	.38	.32	0	1	507	119	7
JPY	.048	.093	0	.57	507	247	0
GBP	.036	.063	0	.41	507	292	0
pegUSD	.033	.18	0	1	665	643	22
pegEUR	.18	.38	0	1	665	548	117
importsfromUSA	.086	.11	0	.68	764	21	0
importsfromEA	.29	.18	0	.79	767	21	0
importsfromJapan	.034	.036	0	.22	764	77	0
importsfromUK	.034	.028	0	.22	764	25	0
debtUSD	.59	.24	.011	.99	228	0	0
debtEUR	.26	.27	.00032	.97	176	0	0
debtJPY	.063	.098	0	.4	228	9	0
debtGBP	.0017	.0041	0	.024	228	113	0
liabilitiesUSD	.56	.26	0	.99	217	21	0
liabilitiesEUR	.14	.17	0	.64	223	92	0
liabilitiesJPY	.037	.044	0	.21	200	45	0
liabilitiesGBP	.061	.048	0	.19	197	38	0

Notes: This table displays descriptive statistics for the variables used in the empirical analyzes covering the years from 1996-2016. All variables except for the peg dummies are shares. Differences in the number of observations across variables result from different coverages across data sources.

Source: IMF Annual Report on Exchange Rate Arrangements and Exchange Rate Restrictions (AREAER), UN Comtrade Database, Eurostat, World Bank International Debt Statistics (IDS), Bank for International Settlements (BIS) Locational Banking Statistics (LBS) and own data (mostly annual reports of central banks, see Table A3).

4 Empirical Analysis

4.1 Model

We examine the determinants of currency compositions of international reserves following Dooley et al. (1989) and Eichengreen et al. (2000). To this end, we estimate the following panel model in different configurations:

$$\begin{aligned}\frac{A_{i,k,t}}{\bar{A}_{i,t}} =& \beta_0 + \sum_{s=1}^{2} \beta_{1,s} E_{i,s,t} + \sum_{k=1,k\neq i}^{4} \beta_{2,k} \left(\frac{IM_{i,k,t}}{\overline{IM}_{i,t}} \right) + \sum_{k=1,k\neq i}^{4} \beta_{3,k} \left(\frac{D_{i,k,t}}{\overline{D}_{i,t}} \right) \\ &+ \sum_{k=1,k\neq i}^{4} \beta_{4,k} \left(\frac{BC_{i,k,t}}{\overline{BC}_{i,t}} \right) + \mu_{i,t}, \qquad (1) \\ & i = 1, ..., n, k = 1, ..., 4, t = 1, ..., T, s = 1, 2.\end{aligned}$$

$A_{i,k,t}$ denotes the end-of-period reserves of country i in the reserve currency of country k at time t, $\bar{A}_{i,t}$ is the total end-of-period amount of foreign exchange reserves for country i at time t. Analogously for the other variables, a bar denotes the respective total volumes. $E_{i,s,t}$ represents a vector of two dummy variables indicating whether a country maintains a currency peg to the USD or the EUR respectively. $IM_{i,k,t}$ stands for imports to country i from reserve-currency country k at time t[6], $D_{i,k,t}$ for the amount of external debt and $BC_{i,k,t}$ for foreign currency claims on a country's banks. Finally $\mu_{i,t}$ denotes a country- and time-specific error term.

We estimate three models with a different set of independent variables separately for four reserve currencies as dependent variables. Our model specifications separately test for the effect of imports (Model A), foreign debt (Model B) and foreign currency claims (Model C) on currency reserves, while all models include currency peg dummies. As some covariates are not available for the entire set of countries in our sample, the number of observations strongly depends on the model we choose. Furthermore, as altering

[6]We decide to follow Beck and Weber (2011) and capture trade-related effects on the currency composition by including imports denominated in the reserve currency in the analysis. We reckon imports to be a preferable measure to exports for trade-related transaction motives as central banks might have to backstop import payments, for instance in the case of balance-of-payments crises.

the model also changes the composition of the countries in the sample, models cannot directly be compared with each other. The censored nature of the data (values for the dependent variable lie within the range of 0 and 1) makes the use of the Tobit estimator preferable (Beck & Weber, 2011). As compared to linear models, in non-linear models the interpretation of the coefficients is less intuitive, for which reason we provide estimates of the average marginal effects if necessary. Table B1 in the appendix reports country composition and number of observations across our model specifications.

4.2 Estimation

Exploiting the panel structure of the data, Table 3 presents the results from random effects Tobit estimations for Model A, which includes currency pegs and import variables as dependent variables. The actual magnitude of implied changes in currency holdings can be interpreted in the average marginal effects rather than in the coefficients. The coefficients typically overestimate the average marginal effects, especially for the JPY and the GBP regressions with a substantial amount of left-censored observations (i.e. currency share equal to 0). The coefficient of the USD peg is significantly positive in the regression for the USD and significantly negative in the regression for the EUR. On the contrary, the coefficient for the EUR peg is significantly negative in the USD regression and significantly positive in the EUR regression. We suspect a stronger impact of a USD peg to the USD share given a presumed different rationale of pegging to the USD. Pegging to the EUR might be more driven by historical ties with western European economies. For the case of eastern European countries, we consider the integration in western European value chains and the wish to join the euro area in the future explaining factors for an anchorage of a national currency to the EUR (however, joining the euro area in the future requires exchange rate stability in general and not increased levels of EUR reserve holdings in particular). The fact that several former French colonial countries in Africa have replaced pegs to the French franc with EUR pegs, when the latter was introduced, speak for this assumption of historical ties.

Indeed in the EUR regression the effect of the EUR peg is economically much less

pronounced when compared to the effect of the USD peg on USD holdings. Generally speaking, countries using a currency peg want to hold relatively larger reserves in the given currency in order to back the exchange rate to which they committed. At the same time, relative holdings of the other main currencies are reduced. The average marginal effect of the USD peg is 0.365. All other things equal, the introduction of a USD peg corresponds to an increase of the USD share by 36.5 percentage points. The peg to the EUR marginally increases EUR holdings by 4 percentage points.

Table 3: Estimation results: Model A, Tobit

	Dependent variable			
	USD	EUR	JPY	GBP
pegUSD	0.491***	-0.597***	0.028	0.016
	(0.066)	(0.056)	(0.029)	(0.038)
pegEUR	-0.235***	0.057**	0.006	-0.048***
	(0.030)	(0.028)	(0.014)	(0.015)
importsfromUSA	0.111	-0.365	0.351**	-0.139
	(0.276)	(0.272)	(0.137)	(0.144)
importsfromEA	-0.203**	-0.116	-0.049	-0.010
	(0.081)	(0.085)	(0.039)	(0.040)
importsfromJapan	-0.973*	-0.364	1.366***	0.238
	(0.565)	(0.471)	(0.237)	(0.333)
importsfromUK	-0.521	0.041	0.391**	0.437**
	(0.413)	(0.360)	(0.180)	(0.184)
Observations	468	403	486	468
Wald χ^2	167.86	161.06	74.52	18.11
Prob>Wald χ^2	0.000	0.000	0.000	0.006

Notes: This table displays the results of panel tobit regressions. The heads of the columns denote the respective dependent variables. Emitting countries are excluded for regressions featuring their domestic currencies. Standard errors are in parentheses. *** denotes significance at 1%, ** significance at 5% and * significance at 10%.

Concerning trade, we find a significantly negative coefficient for imports from the euro area in the USD regression but we do not find imports from the US to be significantly correlated to EUR shares. In terms of average marginal effects, a 1 percentage point increase of imports from the euro area is correlated to a decrease of 0.15 percentage points in the USD share. Imports from Japan and the UK have a significantly positive influence on the share of the JPY and the GBP, respectively. On average, a 1 percentage point increase in imports from Japan and the UK relate to increases of 0.44 and 0.14 percentage points of the JPY and GBP share respectively. Central banks might to some

degree be obliged to finance foreign trade with accumulated reserves (Soesmanto et al., 2015), thus rationalizing the finding that increased imports from the euro area or Japan reduce a central bank's propensity to hold USD relative to other currencies. Contrarily, we do not find imports from the US and the euro area to be associated with increases in the USD share and the EUR share respectively. Our interpretation is that the transaction motive seems to hold for the two large currencies in terms of the effect of currency pegs, but less so for trade patterns. For the two smaller reserve currencies JPY and GBP the trade relations with the emitting countries appear to be more relevant in terms of the accumulation of reserves.

Table 4 displays results for both Models B and C, incorporating debt and liabilities of domestic banks denominated in foreign reserve currencies respectively. We focus on regressions with the shares of the USD and the EUR as dependent variables. Using these alternative explanatory variables reduces the number of observations substantially as most countries in our sample are either not indebted in foreign currencies or do not report so. Similarly, for foreign currency liabilities the sample size is reduced compared to Model A. Column 1 shows that debts denominated in both USD and EUR have a significantly negative association with the USD share. Column 3 reports the same relationship for liabilities denominated in both main reserve currencies and the USD share respectively. The negative coefficients for debt and liabilities denominated in USD can be interpreted similarly to the insignificant effect of imports from the US on USD shares reported earlier. USD shares might not necessarily be driven by bilateral proxies of economic interdependence but instead by a premium stemming from its role as the prime reserve currency.

4.3 Robustness Checks

In this section, we discuss the robustness of our findings related to Model A. In order to control for country heterogeneity we employ in total three region fixed effects for the Americas, Europe and Asia. Adding country fixed effects overfits the model as the specification is not left with sufficient variation over time to identify the effects of our

Table 4: Estimation results: Models B and C, Tobit

	Dependent variable			
	USD	EUR	USD	EUR
pegUSD	0.000	-0.040	0.319*	-1.000
	(0.064)	(0.088)	(0.190)	(20.449)
pegEUR	-0.544***	0.626***	-0.060	0.040
	(0.137)	(0.138)	(0.056)	(0.056)
debtUSD	-0.556***	0.251		
	(0.161)	(0.214)		
debtEUR	-0.536***	0.311		
	(0.148)	(0.199)		
debtJPY	-0.357	0.417		
	(0.335)	(0.455)		
debtGBP	5.208	-2.039		
	(3.832)	(5.312)		
USDliabilities			-0.438***	-0.284
			(0.130)	(0.254)
EURliabilities			-0.432*	0.195
			(0.221)	(0.339)
JPYliabilities			0.825**	-0.214
			(0.343)	(0.415)
GBPliabilities			0.562	-0.095
			(0.428)	(0.555)
Observations	117	117	149	115
Wald χ^2	37.94	28.41	59.71	19.00
Prob>Wald χ^2	0.000	0.000	0.000	0.004

Notes: This table displays the results of panel tobit regressions of models B and C. The heads of the columns denote the respective dependent variables. Emitting countries are excluded for regressions featuring their domestic currencies. Standard errors are in parentheses. *** denotes significance at 1%, ** significance at 5% and * significance at 10%.

covariates. We present the results of estimating our benchmark Model A including region fixed effects in Table B2 in the appendix. In our benchmark models we normalize imports to 0 for imports from emitting countries in regressions analyzing the determinants of other currency shares (i.e. imports from the euro area are set to 0 for euro area countries in the USD regression). Doing so prevents further sample attrition, particularly in the USD, JPY and GBP regressions as euro area countries are retained in the sample. As a robustness check we add currency emission fixed effects to our benchmark model. The regressions from Model A are estimated including a dummy for the United States, the UK and one dummy for all euro area countries. We present the results of this specification in Table B3 in the appendix. The results for these two alterations remain qualitatively very similar compared to our benchmark model.

Additionally, we alter estimation methodologies for sensitivity analyzes. We confront the results of the Tobit approach with results of random effects OLS panel regressions and Seemingly Unrelated Regressions (SUR) pioneered by Zellner (1962). SUR appear to be a plausible choice as by definition there is a dependence between the respective currency shares (shares add up to 1). Concretely, SUR allows the estimation of a system of equations with correlated error terms. Taking into account such correlations increases efficiency compared to the estimation of separate equations using OLS. For instance, Soesmanto et al. (2015) advocate the use of the SUR technique when examining determinants of international reserve holdings of the Reserve Bank of Australia (RBA). We focus on comparing the results from the different regression techniques for the two main currencies USD and EUR and for our main Model A.

Table B4 in the appendix contrasts the results for regressions explaining the USD share. The system of equations we estimate with the SUR estimator consists of three linear equations explaining the USD share, the EUR share and the aggregated share of all remaining currencies. By subsuming all other currencies in one share we want to reduce the number of coefficients to be estimated and focus on explaining the choice between the two leading currencies. For USD shares in Model A, OLS and SUR estimates broadly confirm our findings from Tobit estimations. In the regressions from all three methodo-

logies, coefficients of the currency pegs are economically relevant and highly significant. The previous finding of trade not being decisive in the accumulation of USD shares is confirmed in the SUR regression which even features a negative coefficient on imports from the US. Coefficients on other trade variables, however, are intuitive. Unlike the other regressions, the SUR regression results yield negative and statistically significant estimates on imports from all other three reserve currency countries, suggesting the relevance of trade patterns. Table B5 in the appendix compares the results across regression techniques for the EUR. Similarly to the USD regressions, the qualitative results concerning the relations between currency pegs and currency shares are supported in the two alternative regressions techniques. Further, the SUR regression yields supportive results for the impact of trade patterns on the accumulation of the EUR currency share as the coefficient on imports from the euro area is positive and statistically significant.

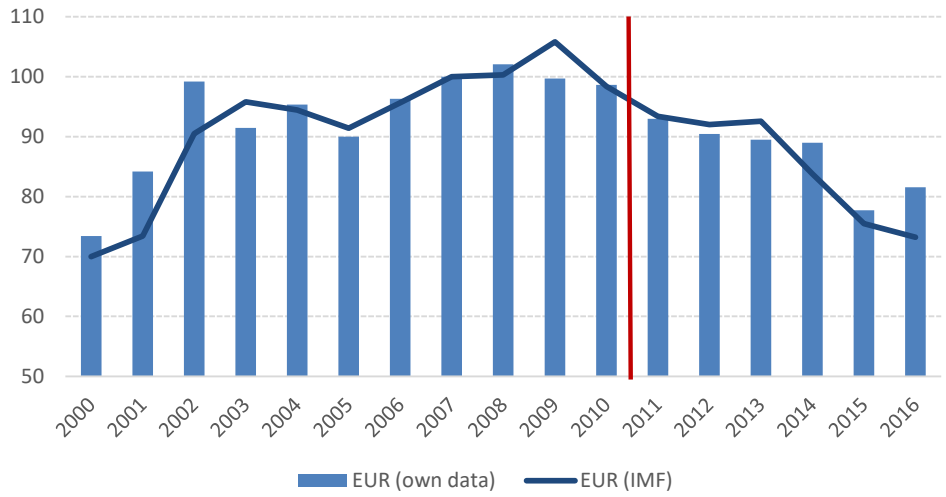
In sum, results are mostly robust for currency peg and trade variables and can explain international reserve compositions reasonably well. Models B and C acknowledge the importance of international debt and international bank claims but present mixed results. In the following sections, we rely on our baseline Model A as a workhorse model.

4.4 Effect of the Euro Crisis on Euro Holdings

In the first decade after the introduction of the common European currency, the EUR share experienced a steady increase in international reserve holdings. The outbreak of the euro crisis in 2010 marked a turning point, as since then the EUR share has constantly lost ground. IMF COFER data document a peak in 2009 with a share of 28% of total allocated foreign reserves. Our more eurocentric data suggest the year 2008 was already a break date and document a EUR share in total foreign reserves of nearly 38% for that year. In both data sets, the EUR shares have decreased by 9 and 8 percentage points, respectively, since the respective peak years. Not surprisingly, scenarios of the EUR surpassing the USD as the world's main reserve currency usually date from the years prior to the euro crisis (see Chinn and Frankel (2008)). Figure 3 illustrates the initially increasing and subsequently decreasing importance of the EUR as an international reserve currency, with

2007 as a base year (2007=100). In terms of the euro's share in international reserves, 2015 was the currency's temporary nadir according to our data since 2001.

Figure 3: EUR share in total reserves



Notes: IMF COFER. This graph shows the EUR share in international reserves according to our data (bars) and to the IMF COFER data (line). 2007 is defined as base year (=100%) to illustrate the parallel evolution. The vertical red line separates the sample into pre-crisis and post-crisis subsamples. [Please use colors in print.]
Source: IMF COFER, own data (mostly annual reports of central banks, see Table A3).

We use Chow tests to verify a structural break for EUR shares triggered by the euro crisis in 2010. To further examine effects of the euro crisis, we add a crisis dummy to capture a direct effect and interaction terms to capture an indirect effect to the baseline regression (see Table 5). Crisis years are marked by a dummy variable (1 for all years after 2010, 0 otherwise). Interaction terms are constructed as products of the dummy variable and the six independent variables of the baseline regression. We find a significant and negative coefficient for the crisis dummy in columns 2 and 3, which traces the reduction in EUR holdings post-2010. The coefficient of -0.08 in column 2 corresponds to a marginal reduction of EUR shares of around 6 percentage points. Interestingly, the interaction terms of the crisis dummy and covariates displayed in columns 3 and 4 suggest that channels based on transaction motives are strengthened after the euro crisis. For instance, the effect of a currency peg to the USD is more positive, the effects of imports from the US and the UK are more negative and the effect of imports from the euro area are

more positive after the crisis. For the latter, note that the total effect of imports from the euro area after the crisis is still negative and insignificant. Yet, the tendency for estimates after the crisis suggests the interpretation that the euro crisis has damaged the attractiveness of the EUR on international reserve markets, causing a flight to quality out of the EUR. Consequently, after the crisis currency shares of the EUR might be explained more by transaction motives rather than stemming from the status of being a prime reserve currency.

Table 5: Estimation results with crisis interactions

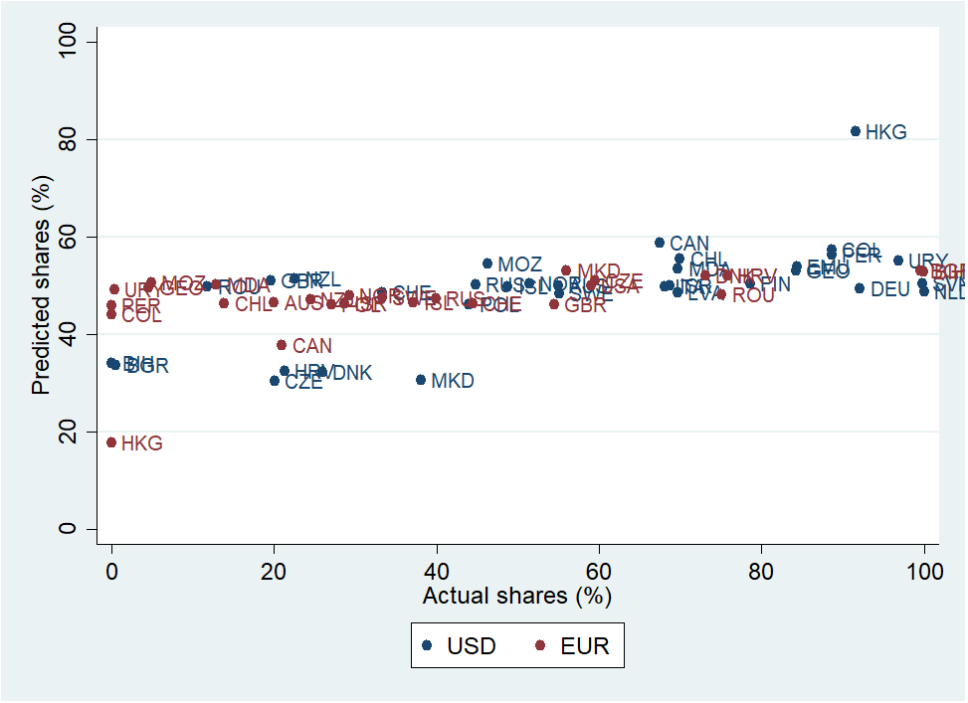
	Dependent variable = EUR shares			
	(1)	(2)	(3)	(4)
pegUSD	-0.597***	-0.535***	-0.579***	-0.590***
	(0.056)	(0.054)	(0.057)	(0.054)
pegEUR	0.057**	0.090***	0.071**	0.066**
	(0.028)	(0.027)	(0.029)	(0.028)
importsfromUSA	-0.365	-0.413*	-0.423*	-0.527**
	(0.272)	(0.246)	(0.246)	(0.239)
importsfromEA	-0.116	-0.092	-0.107	-0.246***
	(0.085)	(0.078)	(0.078)	(0.078)
importsfromJapan	-0.364	-1.780***	-1.678***	-1.768***
	(0.471)	(0.483)	(0.488)	(0.469)
importsfromUK	0.041	-0.060	-0.097	1.462***
	(0.360)	(0.339)	(0.340)	(0.445)
Crisis		-0.080***	-0.090***	-0.035
		(0.011)	(0.013)	(0.040)
Crisis x pegUSD			0.104**	0.108**
			(0.053)	(0.053)
Crisis x pegEUR			0.032	-0.017
			(0.025)	(0.026)
Crisis x importsfromUSA				-0.237**
				(0.098)
Crisis x importsfromEA				0.176**
				(0.088)
Crisis x importsfromJapan				-0.376
				(0.602)
Crisis x importsfromUK				-2.127***
				(0.428)
Observations	403	403	403	403
Wald χ^2	161.06	229.42	236.99	300.85
Prob>Wald χ^2	0.000	0.000	0.000	0.000

Notes: This table displays the results of panel Tobit regressions with random effects for the EUR using interactions with a euro crisis dummy which is one for 2011 and all subsequent years. Regressions exclude the euro area and its member states as issuers of the EUR. Standard errors are in parentheses. *** denotes significance at 1%, ** significance at 5% and * significance at 10%.

4.5 Actual and Model Predicted Currency Compositions

In this section, we confront model predicted and actual currency shares. We restrict ourselves to the two main international reserve currencies the USD and the EUR and make use of our baseline model, i.e. Tobit-type panel regressions with currency pegs and import shares. Figure 4 plots predicted and actual shares for both currencies for 2016. The majority of shares predicted for the USD and the EUR lie in the range between 40 and 60%. The model provides a reasonable fit on average as it is capable of assigning larger currency shares for those countries featuring larger actual shares. The correlation coefficients between actual and predicted shares are 0.64 for the USD and 0.48 the EUR respectively. Comparing actual to predicted currency shares further reveals interesting patterns about the fit of our model. The parsimony of the model does not capture country idiosyncrasies driving extreme choices (i.e. currency shares close to 0 or 1) in currency compositions. For instance, an important number of Latin American countries seemingly have a strong preference for holding USD-denominated assets while EUR shares are regularly larger than predicted in neighboring countries of the euro area. Potentially, other factors beyond trade patterns and currency pegs, such as geopolitical factors, are relevant for these countries. Further, many emitting countries exhibit large holdings of the respective other main currency, including the US with a large share in EUR-denominated assets due to a missing choice between two rivaling currencies.

Figure 4: Actual and model predicted shares of USD and EUR (2016)



Notes: This table displays model predictions and corresponding actual values for USD shares (blue) and EUR shares (red) by country for 2016. For prediction we use our benchmark model with pegs and imports as explanatory variables (Model A). [Please use colors in print.]
Source: Own data (mostly annual reports of central banks, see Table A3).

Lastly, we predict currency compositions of the three largest - non-disclosing - reserve holders China, Japan, and Saudi Arabia, which together account for nearly 45% of world-wide international reserves in 2016 (see Table A1). Substituting respective import shares and currency pegs into our baseline estimation equation for USD, EUR, JPY and GBP we obtain the following predicted shares. For China, our model predicts a composition of its international reserves of 39% USD, 37% EUR, 11% JPY and 7% GBP assets. The model further suggests that Japanese international reserves are invested to 47% in USD, to 40% in EUR and to 7% in GBP. For Saudi Arabia, the US peg translates itself via an economically significant coefficient into a highly USD-dominated, predicted reserve composition, despite lively trade with the euro area. The predicted foreign reserves portfolio consists of 63% USD, 13% EUR, 11% JPY and 8% GBP-denominated assets.[7]

[7]We normalize our predictions such that currency shares for each country sum to unity. We do so by assuming a constant currency share of 8.5% for currencies other than USD, EUR, JPY and GBP, which is the average for the disclosing countries in 2016, and by assigning the remaining 91.5% to the four main

For the three countries of interest, these estimation results are difficult to compare to actual compositions about which little is known. Nevertheless, possible bands within which currency shares may fluctuate can be derived from statements by economists and analysts. For China, estimates assume a USD share between 60% and 70% of its international reserves, a EUR share between 20% and 30%, and JPY and GBP shares together between 5% and 10% (see Hu et al. (2010), pp. 8-9, Morrison and Labonte (2013), p. 5, Wildau (2014), Neely (2017), p. 1).[8] For Japan, a high USD share in the country's international reserves appears realistic. For instance, Wong (2007) is among the few committing herself to an, in our opinion, plausible USD share between 83% and 89%. For Saudi Arabia, which is regularly among the largest holders of foreign reserves, market observers assume central bank foreign reserves to be denominated almost exclusively in USD (Torchia, 2015). Bearing in mind the challenge of predicting extreme currency shares and the role of political factors which our model omits, our predictions seem to follow broadly the tendencies of USD dominance for these three countries.

5 Conclusions

In this paper, we examine determinants of the composition of international reserves and aim to disentangle the impact of the euro crisis on currency compositions. We compile a new dataset based on publicly available central bank data on international reserves to overcome the lack of comprehensive data in this area. Relating these data to a selection of country-specific factors reveals that trade patterns and currency pegs are primary determinants of foreign currency holdings. Our analysis suggests the importance of transaction motives in determining the composition of currency shares. In particular, we find correlations between currency pegs and imports. Thus, we can confirm findings from papers based on access to confidential IMF data (see Heller and Knight (1978), Dooley et al. (1989) and Eichengreen et al. (2000)). We also examine other possible determinants.

currencies based on our model predictions.

[8] Concerning the impact of the euro crisis on Chinese EUR holdings, Wang and Freeman (2013) write that "the European sovereign debt crisis has not produced a significant reduction in the share of China's holding of euro assets, but it may have discouraged any increase".

Foreign debt and international bank claims appear to play a role in the composition of foreign currency holdings, but our results are mixed.

We further show that the euro crisis caused a break in the rising relative significance of EUR holdings. In pre-crisis years and since the EUR introduction in 1999, the EUR was able to establish itself as the world's second reserve currency after the USD and was even considered a rival to the USD as the world's main international reserve currency. Since 2010, however, EUR shares have been declining by trend. Additionally, the euro crisis potentially strengthened transaction motives for the determination of EUR shares, which we cautiously interpret as a setback for the EUR as a rival the USD as the main international reserve currency.

Additionally, this paper argues that a simple model can, on average, explain currency compositions reasonably well, whereas deviations from predicted shares in some cases suggest that additional factors such as geopolitical factors might play a role. We use our model to predict currency shares for China, Japan, and Saudi Arabia, the largest - non-disclosing - reserve holding countries. Our model predicts USD dominance in these countries' reserve holdings.

The development of international reserves remains of growing general interest for academics and policy makers due to its relevance for currency markets, exchange rates, geopolitical factors and the global economy as a whole. Academic research can further contribute to explain both recent and future dynamics in this field.

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Appendix

A. Data and Descriptive Statistics

Table A1: Ten biggest holders of international reserves (2016)

Rank	Country	International reserves (in bn USD, 2016)	Cumulated share of worldwide total	Percent increase 2010-2016	Percent increase 2005-2016
1	China	3,010.5	28.1%	-5.4%	182.3%
2	Japan	1,158.3	38.9%	-5.2%	32.4%
3	Switzerland	634.9	44.9%	134.2%	1,599.3%
4	Saudi Arabia	526.0	49.8%	0.1%	134.3%
5	Taiwan	434.,2	53.8%	12.6%	63.1%
6	Hong Kong	386.1	57.4%	35.4%	190.0%
7	Korea	361.7	60.8%	21.3%	51.7%
8	Brazil	356.8	64.1%	3.9%	319.0%
9	India	336.6	67.3%	28.0%	97.8%
10	Russia	308.0	70.2%	-30.2%	4.3%

Notes: The table shows international reserves volumes without gold for the ten major holding countries.
Source: IMF International Financial Statistics.

Table A2: Data availability on the composition of international reserves (2016)

	IMF International Financial Statistics (IFS)	IMF Currency Composition of Foreign Exchange Reserves (COFER)	Individual country data (own compilation)
Countries (total)	191	149 (97 names disclosed)	37
Industrial countries	38	39	22
Developing countries	153	58	15
Total international reserves (2016)	10.7tn USD	10.7tn USD	2.4tn USD
Breakdown of total by currency	no	yes	yes
Breakdown of currencies by country	no	no	yes
Frequency of data	monthly/quarterly	quarterly	annual

Notes: IFS volumes are presented according to the international liquidity statistics data selection and exclude gold. IMF COFER volumes correspond to the "total foreign exchange reserves" data selection. The table represents 2016 values.
Source: IMF IFS, IMF COFER, Wooldridge (2006), own data (mostly annual reports of central banks, see Table A3).

Table A3: Data sources reserve holdings

Country	Years	Source
Australia	1997-2016	Annual Report
Bosnia	2001-2016	Annual Report
Bulgaria	2000-2016	Annual Report
Canada	2001-2016	Report on the Management of Canada's Official International Reserves
Chile	2005-2016	Annual Report
Colombia*	2009-2016	Foreign Reserves Management Report
Croatia	2001-2016	Annual Report
Czech Rep.	1999-2016	Annual Report
Denmark	2006-2016	Annual Report
Euro area	2006-2016	Annual Report
Finland	2001-2016	Annual Report
Georgia	1998-2016	Annual Report
Germany	2000-2016	Annual Report
Hong Kong	2000-2016	Annual Report
Iceland	2007-2016	Annual Report
Israel	2011-2016	Foreign Exchange Reserves Annual Report
Italy	2005-2016	Annual Report
Latvia	2005-2016	Annual Report
Lithuania	1993-2010	Annual Report
Macedonia	2010-2016	Annual Report
Moldova	2011-2016	Annual Report
Mozambique	2007-2016	Annual Report
Netherlands	2002-2016	Annual Report
New Zealand	2011-2016	Annual Report
Norway	1998-2016	Annual Report
Peru	2000-2016	Annual Report
Philippines	2011-2013	Annual Report
Poland	2004-2015	Annual Report
Romania	2005-2016	Annual Report
Russia	2007-2016	Annual Report
Slovak Rep.	1999-2008	Balance of Payments Statistics
Slovenia**	1995-2016	Annual Report
Sweden	1999-2016	Annual Report
Switzerland	1996-2016	Annual Report
UK	1997-2016	UK International Reserves and Foreign Currency Liquidity Template
USA	1999-2016	U.S. International Reserve Position (Treasury)
Uruguay	2004-2016	IMF SDSS Reserve Template

Notes: This table reports the sources for the data we collect on country specific reserve holdings. "Annual Report" refers to the annual reports of a country's central bank. * denotes gap in 2010, 2012, 2014. ** denotes gap in 2007.

Table A4: Sample composition

	Europe		Americas	Asia	Australia and Oceania	Africa
Industrial countries	Czech Rep.	Lithuania	Canada	Hong Kong	Australia	
	Denmark	Netherlands	USA	Israel	New Zealand	
	Euro Area	Norway				
	Finland	Slovakia				
	Germany	Slovenia				
	Iceland	Sweden				
	Italy	Switzerland				
	Latvia	UK				
Emerging economies	Bosnia	Moldova	Chile	Georgia		Mozambique
	Bulgaria	Poland	Colombia	Philippines		
	Croatia	Romania	Peru			
	Macedonia	Russia	Uruguay			

Notes: The table shows the composition of our sample. We have data for 23 countries in Europe plus the euro area. The further distribution across continents is: Americas (6), Asia (4), Australia and Oceania (2) and Africa (1). In terms of economic development our sample includes 21 industrial countries and the euro area and 15 emerging economies following the IMF World Economic Outlook classification in 2016.
Source: Own data (mostly annual reports of central banks, see Table A3).

Table A5: Country specific international reserve composition (shares in %)

	USD		EUR		JPY		GBP		others	
Country	2006	2016	2006	2016	2006	2016	2006	2016	2006	2016
Australia	45.0	55.0	45.0	20.0	10.0	5.0	0.0	5.0	0.0	15
Bosnia	0.0	0.1	99.9	99.9	0.0	0.0	0.0	0.0	0.0	0.0
Bulgaria	0.6	0.5	99.4	99.5	0.0	0.0	0.0	0.0	0.0	0.0
Canada	53.4	67.4	45.3	21.0	1.3	1.4	0.0	10.2	0.0	0
Chile	71.0	69.9	24.9	13.9	0.0	0.0	0.0	0.0	4.1	16.2
Colombia*	85.0	88.6	12.0	0.0	3.0	0.0	0.0	0.0	0.0	11.4
Croatia	14.5	21.3	85.5	75.8	0.0	0.0	0.0	0.0	0.0	2.9
Czech Rep.	35.6	20.1	55.3	59.5	4.4	3.0	4.8	1.3	0.0	16.1
Denmark*	15.2	26.0	71.8	73.0	0.0	0.0	7.1	0.0	6.0	0.9
Euro area*	83	84.3	0.0	0.0	17	15.7	0.0	0.0	0.0	0.0
Finland	44.7	78.6	0.0	0.0	6.4	8.2	40.4	13.3	8.5	0.0
Georgia	76.5	84.2	23.3	4.6	0.0	0.0	0.0	0.0	0.2	11.2
Germany	98.2	92.1	0.0	0.0	1.8	4.7	0.0	0.0	0.0	3.2
Hong Kong	87.0	91.6	0.0	0.0	0.0	0.0	0.0	0.0	13.0	8.4
Iceland*	20.9	48.8	67.5	37.2	1.3	3.0	7.0	10.7	3.3	0.4
Israel	/	68.7	/	28.6	/	0.0	/	2.7	/	0.0
Italy	61.4	68.1	0.0	0.0	8.7	14.7	26.5	9.2	3.4	8.0
Latvia	40.0	69.6	50.0	0.0	20.0	0.0	0.0	17.7	0.0	12.7
Lithuania	0.0	/	100.0	/	0.0	/	0.0	/	0.0	/
Macedonia	/	38.1	/	56.0	/	0.0	/	0.0	/	5.9
Moldova	/	69.7	/	12.9	/	0.0	/	17.2	/	0.2
Mozambique*	65.8	46.3	15.1	4.9	0.0	0.0	7.0	2.3	12.1	46.6
Netherlands	100	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	25.2	22.6	23.3	24.5	5.3	6.0	10.4	13.4	35.8	33.5
Norway	32.1	51.4	40.4	29.2	0.0	8.0	12.4	7.4	15.1	4.0
Peru	82.2	88.6	15.1	0.0	0.0	0.0	0.0	10.4	2.7	0.9
Philippines*	/	78.8	/	5.0	/	10.0	/	0.0	/	6.2
Poland	45.0	44.0	40.0	27.0	0.0	0.0	15.0	0.0	5.0	29.0
Romania	27.2	11.8	68.8	75.1	0.0	0.0	0.0	0.0	4.0	13.2
Russia	47.0	44.8	42.4	39.9	0.8	0.0	9.8	9.5	0.0	5.8
Slovak Rep.	27.3	/	72.7	/	0.0	/	0.0	/	0.0	/
Slovenia	14.4	99.8	71.5	0.0	0.0	0.0	0.0	0.0	14.0	0.2
Sweden	30.0	55.0	50.0	33.3	0.0	0.0	10.0	3.9	10.0	7.7
Switzerland	32.8	33.3	47.0	44.4	5.1	6.6	10.1	6.6	5.0	9.1
UK	20.5	19.6	73.6	54.5	3.3	6.3	0.0	0.0	2.6	19.6
USA	0.0	0.0	61.2	59.0	38.9	41.0	0.0	0.0	0.0	0.0
Uruguay	98.6	96.8	1.3	0.4	0.0	0.0	0.0	0.0	0.0	2.8

Notes: This table reports shares of country specific reserve holdings. If currency shares are unavailable for a specific year, we report the nearest data available (max. ± 2 years). This is marked by *.

Source: Own data (mostly annual reports of central banks, see Table A3).

Table A6: Explanatory variables

Variable	Description	Scale	Source
Peg	Hard or soft peg to reserve currency according to IMF classification of exchange rate regimes.	Dummy variable	IMF Annual Report on Exchange Rate Arrangements and Exchange Rate Restrictions (AREAER)
Imports	Ratio of imports from currency issuing country to total imports	% value	UN Comtrade Database and Eurostat
Foreign currency debt	Ratio of external long-term public debt denominated in the respective reserve currency to total external public debt	% value	World Bank International Debt Statistics (IDS)
Liabilities to foreign banks	Ratio of liabilities of the domestic banking sector to foreign banks denominated in the respective reserve currency to total liabilities	% value	Bank for International Settlements (BIS) locational banking statistics (LBS)

Notes: This table reports the data sources for the explanatory data used throughout the empirical analysis.

B. Estimation

Table B1: Model specifications

Model	Explanatory variables	Countries included	N
A	pegUSD, pegEUR, importsfromUSA, importsfromEA, importsfromJapan, importsfromUK	Australia, Bosnia, Bulgaria, Canada, Chile, Colombia, Croatia, Czech Republic, Denmark, Euro Area, Finland, Georgia, Germany, Hong Kong, Iceland, Israel, Italy, Latvia, Lithuania, Macedonia, Moldova, Mozambique, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Romania, Russia, Slovakia, Slovenia, Sweden, Switzerland, United Kingdom, United States, Uruguay	403-486
B	pegUSD, pegEUR, debtUSD, debtEUR, debtJPY, debtGBP	Bosnia, Bulgaria, Colombia, Georgia, Macedonia, Moldova, Mozambique, Peru, Philippines, Romania, Russia	117
C	pegUSD, pegEUR, liabilitiesUSD, liabilitiesEUR, liabilitiesJPY, liabilitiesGBP	Australia, Canada, Chile, Denmark, Finland, Germany, Hong Kong, Italy, Netherlands, Norway, Philippines, Russia, Sweden, Switzerland, United Kingdom, United States	115-149

Notes: The table shows the country composition of the regression samples and the number of observations across different models. Differences in the number of the observations within models result from omitting the respective emitting countries.

Table B2: Estimation results: Model A including region fixed effects, Tobit

	Dependent variable			
	USD	EUR	JPY	GBP
pegUSD	0.474***	-0.582***	0.029	0.019
	(0.067)	(0.056)	(0.029)	(0.037)
pegEUR	-0.232***	0.049*	0.005	-0.051***
	(0.030)	(0.027)	(0.015)	(0.015)
importsfromUSA	-0.373	0.007	0.326**	-0.031
	(0.318)	(0.263)	(0.148)	(0.160)
importsfromEA	-0.151*	-0.210**	-0.055	-0.025
	(0.085)	(0.083)	(0.042)	(0.042)
importsfromJapan	-0.821	-0.113	1.427***	0.228
	(0.580)	(0.467)	(0.244)	(0.334)
importsfromUK	-0.243	-0.149	0.393**	0.389**
	(0.422)	(0.356)	(0.182)	(0.186)
Observations	468	403	486	468
Wald χ^2	182.11	192.47	75.00	22.33
Prob>Wald χ^2	0.000	0.000	0.000	0.008

Notes: This table displays the results of panel tobit regressions. The heads of the columns denote the respective dependent variables. Regional dummies for the Americas, Europe and Asia are included in the regressions but not reported in this table. Emitting countries are excluded for regressions featuring their domestic currencies. Standard errors are in parentheses. *** denotes significance at 1%, ** significance at 5% and * significance at 10%.

Table B3: Estimation results: Model A including currency emission fixed effects, Tobit

	Dependent variable			
	USD	EUR	JPY	GBP
pegUSD	0.553***	-0.594***	0.028	0.031
	(0.057)	(0.057)	(0.028)	(0.034)
pegEUR	-0.127***	0.059**	0.012	-0.022
	(0.028)	(0.028)	(0.015)	(0.015)
importsfromUSA	0.374	-0.374	0.295**	-0.116
	(0.246)	(0.271)	(0.121)	(0.146)
importsfromEA	-0.100	-0.113	-0.041	-0.012
	(0.072)	(0.085)	(0.038)	(0.042)
importsfromJapan	-0.645	-0.391	1.296***	0.510
	(0.486)	(0.474)	(0.226)	(0.324)
importsfromUK	-0.847**	0.058	0.430**	0.367**
	(0.356)	(0.360)	(0.177)	(0.176)
Observations	468	403	486	468
Wald χ^2	387.47	162.59	95.10	.
Prob>Wald χ^2	0.000	0.000	0.000	.

Notes: This table displays the results of panel tobit regressions. The heads of the columns denote the respective dependent variables. Emitting countries are excluded for regressions featuring their domestic currencies. Currency emitting dummies for the US, the UK and one dummy for all euro area countries are included in the regressions but not reported in this table. Standard errors are in parentheses. *** denotes significance at 1%, ** significance at 5% and * significance at 10%.

Table B4: Comparison of estimation results: Model A (USD)

	Tobit	OLS	SUR
pegUSD	0.491***	0.450***	0.245***
	(0.066)	(0.174)	(0.001)
pegEUR	-0.235***	-0.234***	-0.271***
	(0.030)	(0.086)	(0.001)
importsfromUSA	0.111	0.103	-0.076***
	(0.276)	(0.331)	(0.013)
importsfromEA	-0.203**	-0.220	-0.081***
	(0.081)	(0.262)	(0.004)
importsfromJapan	-0.973*	-1.007	-0.447***
	(0.565)	(1.069)	(0.018)
importsfromUK	-0.521	-0.527	-0.847***
	(0.413)	(0.640)	(0.014)
Observations	468	468	385
Wald χ^2	167.86	27.67	
Prob>Wald χ^2	0.000	0.000	

Notes: This table displays the results of panel tobit, random effects OLS and SUR regressions with the USD as the dependent variable. The heads of the columns refer to the respective estimation technique. All regressions exclude the US as emiting country. The SUR regression omits all emitting countries. The system of equations estimated with SUR consists of the three linear equations explaining the USD share, the EUR share and the aggregated share of all remaining currencies respectively. Standard errors are in parentheses. *** denotes significance at 1%, ** significance at 5% and * significance at 10%.

Table B5: Comparison of estimation results: Model A (EUR)

	Tobit	OLS	SUR
pegUSD	-0.597***	-0.535***	-0.323***
	(0.056)	(0.202)	(0.025)
pegEUR	0.057**	0.079*	0.494***
	(0.028)	(0.046)	(0.015)
importsfromUSA	-0.365	-0.502	0.024
	(0.272)	(0.458)	(0.249)
importsfromEA	-0.116	-0.022	0.203***
	(0.085)	(0.097)	(0.046)
importsfromJapan	-0.364	-0.582	0.508
	(0.471)	(0.802)	(0.320)
importsfromUK	0.041	0.054	2.442***
	(0.360)	(0.527)	(0.352)
Observations	403	403	385
Wald χ^2	161.06	20.68	
Prob>Wald χ^2	0.000	0.002	

Notes: This table displays the results of panel tobit, random effects OLS and SUR regressions with the EUR as the dependent variable. The heads of the columns refer to the respective estimation technique. All regressions exclude the euro area countries as emiting country. The SUR regression omits all emitting countries. The system of equations estimated with SUR consists of the three linear equations explaining the USD share, the EUR share and the aggregated share of all remaining currencies respectively. Standard errors are in parentheses. *** denotes significance at 1%, ** significance at 5% and * significance at 10%.

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