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The currency composition of foreign exchange reserves

by Hiro Ito and Robert N McCauley

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Keywords: foreign exchange reserves, international currency; key currency; currency zones; invoicing of trade, currency of international debt, foreign exchange reserve management

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The currency composition of foreign exchange reserves

Hiro Ito and Robert N McCauley¹

Abstract

This paper analyses the factors that govern the choice of the currency composition of official foreign exchange reserves. First, we introduce a new panel dataset on the key currencies in foreign exchange reserves of about 60 economies in the 1999-2017 period. Second, we show that the currency composition of reserves relates strongly to the co-movement of the domestic currency with key currencies and the currency invoicing of trade. These factors represent attributes of the dollar or the euro rather than of the United States or the euro area. They exert about equal effects on the currency composition of foreign exchange reserves. We demonstrate that these findings are robust to a host of other possible factors.

Keywords: foreign exchange reserves, international currency; key currency; currency zones; invoicing of trade, currency of international debt, foreign exchange reserve management

JEL classification: E44, E58, F14, F31

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1. Introduction

The Great Financial Crisis (GFC) of 2007-08, the rise of the Chinese renminbi (RMB), and the euro debt crisis all revived debate on what makes for an international currency. The debate continues. The US dollar (USD) predominates; the euro (EUR) runs a distant second. Since 2014, the RMB's rise has reversed in some aspects, but its share of foreign exchange (FX) reserves has edged up since it joined the International Monetary Fund's (IMF's) Special Drawing Rights (SDR) basket in 2015 and the number of central banks that hold it continues to rise (Yi (2018)).

The US dollar continues to predominate. This puzzles scholars like Chinn and Frankel (2007) who seek to explain its predominance in FX reserves with US variables, such as its GDP.² The US GDP share in world GDP has trended moderately down for decades. In particular, the US economy at market prices accounted for 29% of the world total in 1975, but only 24% in 2017. Similarly, the US share of global trade has shown a declining trend (Graph 1). If one takes the size of the US economy, its international trade or its bond market's size to explain the dollar's share, the dollar's and euro's FX reserve shares should almost be running neck and neck (Lu and Wang (2019, p 25)). Instead, the share of the USD in total FX reserves at 63% remains way ahead of the EUR at a mere 20%.

Some recent work on the dollar, however, has looked beyond the US economy to the global use of key currencies. Regarding the dollar as a unit of account in international trade (Table 1, northwest corner, UP), Gopinath (2015) has pointed to the dollar's outsized role in the invoicing of half or more of international trade. Gopinath and Stein (2018a,b) have found that the currency of trade denomination lines up with the cross-section of the currency denomination of FX reserves.

International currency uses			Table 1
	Unit of account	Means of exchange	Store of value
Private	Trade invoicing (UP)	Vehicle currency FX mkt (MP)	Inter'l debt denomination (SP)
Official	Anchor currency (UO)	Intervention currency (MO)	FX reserve denomination (SO)

Sources: Cohen (1971) and Kenen (1983), as adapted by the authors.

Regarding the dollar or the euro as an anchor for other currencies (Table 1, southwest corner, UO), Ilzetzki et al (2019) have found that about 70% of the currencies of the world by country GDP shares show less volatility against the US dollar than against any other key currency. Allowing economies to straddle key currency zones, Ito and McCauley (2019) have found that for 40 years, what they dub the "dollar zone" has produced a fairly consistent 50-60% of world GDP (Graph 1).³

² Chinn and Frankel (2007, 2008) ascribe the dollar's high share of reserves to the size of the US economy in an inductively non-linear relationship. This allows FX reserves in dollars to amount to more than twice those held in euros while the economy of the United States is only a third larger than that of the euro area.

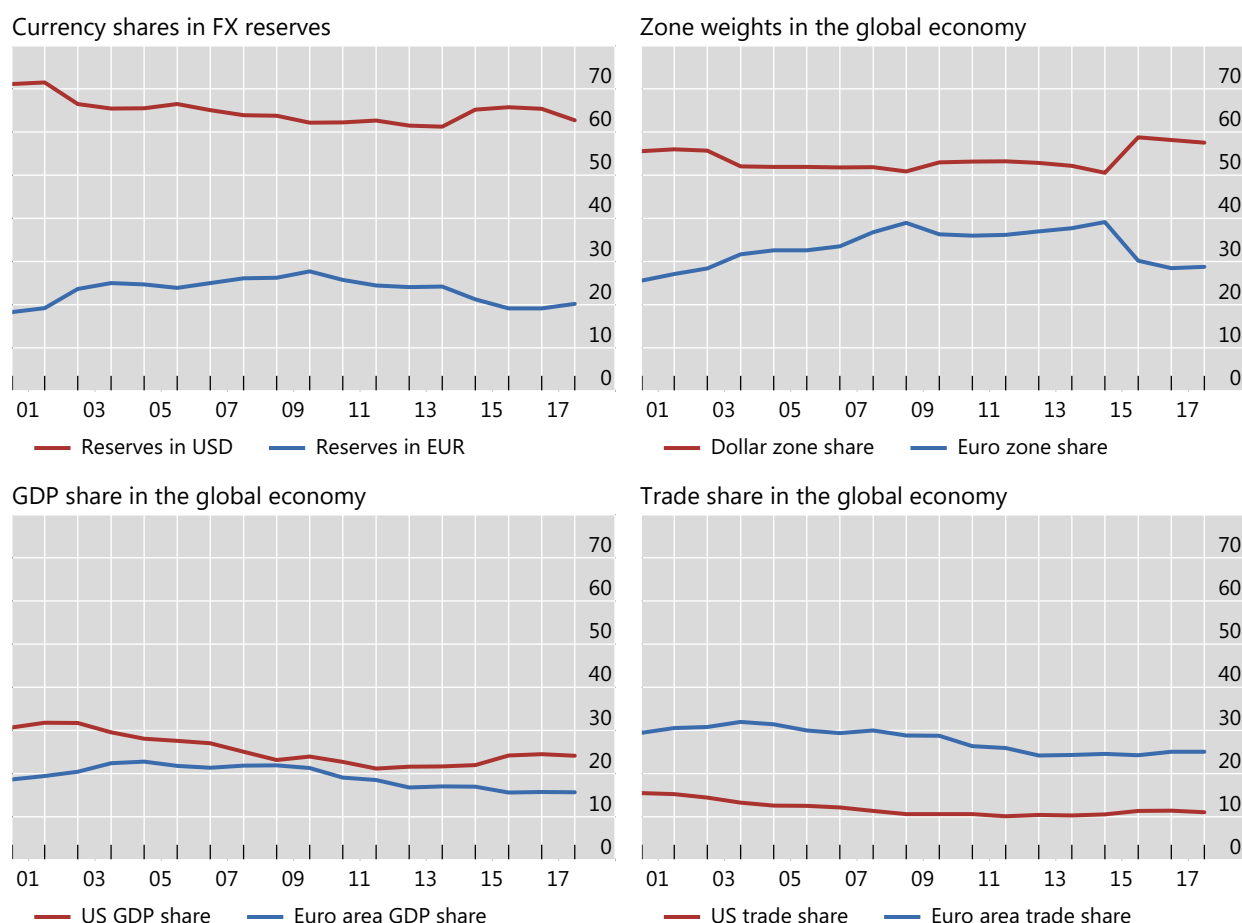
³ Below, using the inductive technique of Haldane and Hall (1991) and Frankel and Wei (1996), we divide economies among currency zones according to the co-movement of their currencies. An economy forms part of the dollar zone not only if its currency is dollar-pegged, but also if its floating currency varies less against the dollar than against euro or yen. See Kawai and Akiyama (1998, 2000),

True, the euro's influence has extended east in Europe (ECB (2014) and Ferrari (2019)), to commodity currencies, and even to emerging Asia (McCauley and Shu (2019)). However, Asia's fast growth has offset the euro's spread, given the dollar linkage of Asian currencies. The domestic currency's co-movement with the dollar lines up with the cross-section of the dollar share of FX reserves (McCauley and Chan (2014)).

Size of currency zones, GDP, trade, and shares in FX reserves, 2000–2017

In per cent

Graph 1



Sources: IMF, Currency Composition of Official Foreign Exchange Reserves (COFER) and International Financial Statistics; World Bank, World Development Indicators; authors' calculations.

This study contributes by introducing a new dataset on the currency composition of FX reserves. To date, a small sample has impeded the ability to distinguish the influence of trade invoicing and currency anchoring (Ito et al (2015)). The IMF's currency composition of official FX reserves (COFER) data generally disclose only aggregates for the entire world, advanced economies, and "emerging and developing economies". We collect data from central banks' annual reports, financial statements, and other publicly available information and construct a dataset for 58 economies in the 1999-2017 period. These data allow us to observe reserve management over time for individual economies. Our dataset provides us with a sample size between those

McCauley and Chan (2014), BIS (2015), Ito and Kawai (2016), Lu and Wang (2019), Ferrari (2019) and Ito and McCauley (2019). Tovar and Nor (2018), who use much the same technique as we do, find the dollar zone share of world GDP to be about 60%.

of extant small-sample studies ((McCauley and Chan (2014), Ito et al (2015), Gopinath and Stein (2018b) and Lu and Wang (2019)) and the dated but near-exhaustive IMF studies (Heller and Knight (1978), Dooley et al (1989) and Eichengreen and Mathieson (2000)).

Using this dataset, we find in both the cross-section and the panel that the greater the co-movement of the domestic currency with the dollar (euro), the higher its dollar (euro) share of official reserves. Other research on the currency composition of reserves has not analysed co-movement with key currencies except in the polar case of currency pegs (Dooley et al (1989) and Eichengreen and Mathieson (2000)). We also find in smaller samples that, the higher share of exports is dollar-denominated, the higher the dollar share in FX reserves. This finding confirms those of Gopinath and Stein (2018b) and Lu and Wang (2019) in a broader multivariate setting.

We find that the dollar's role as unit of account and as anchor in the FX market exert about equal effects on the share of the dollar in FX reserves and that, taken together, these two factors account for the bulk of the variance in the dollar's share. In particular, we find that a one standard deviation increase in the dollar zone weight raises the dollar share of reserves about as much as a one standard deviation increase in the dollar share in trade invoicing.

We also examine the role that another factor plays in the choice of currencies in FX reserves, namely, the currency denomination of stocks of international bank and bond debt. The positive relationship to the dollar reserve share also holds for the dollar share of external debt (Table 1, northeast corner, SP). However, we interpret this result with caution because both the FX reserve and the debt share respond to trade invoicing and currency co-movement. In addition, we test for the impact of trade with the United States or euro area and find that this bilateral variable adds little in the presence of the dollar or euro variables. Likewise, a larger share of dollar trading in the domestic FX market against the domestic currency (Table 1, north central entry, MP) leads to a larger share of USD in FX reserves, but leaves intact our main findings.

What is the implication of our main finding that economies with currencies that co-move with the dollar against other key currencies hold more dollar reserves? It is that the stability of the dollar share of FX reserves in aggregate despite the shrinking global share of the US economy or US trade reflects the surprisingly stable half or more of global GDP produced in the dollar zone – the zone where the dollar plays a dominant anchor role. In this zone, a reserve composition that favours the dollar produces more stable returns in terms of the domestic currency (Annex 1).

The remainder of this paper is structured as follows. Section 2 introduces our dataset on the currency composition of FX reserves and provides summary statistics. Section 3 explains how we estimate the currency zone weights, describes the variables for currency shares in trade invoicing and in debt stocks and charts bivariate relationships between these variables and the currency share in FX reserves. Section 4 discusses the results from a panel data analysis on the determinants of the USD and EUR shares in FX reserves. Section 5 reports robustness checks. Section 6 concludes.

2. Data on currency shares in foreign exchange reserves

The question of what makes for an international currency is a fundamental one in international finance. Among its different roles as summarised by Cohen (1971) and Kenen (1983), FX reserves play an important role as an official store of value, reflecting monetary and trade policy. While different aspects of an international currency have been investigated, data availability has limited study on the determinants of the currency composition of FX reserves of individual countries.

As noted, the IMF publishes its COFER data for the entire world, the group of industrialised economies, and that of emerging and developing economies, generally not for individual countries. Heller and Knight (1978), Dooley et al (1989), and Eichengreen and Mathieson (2000) have used individual countries' data from the COFER database. Others have more recently exploited limited public data (ie from central banks) on the currency shares (McCauley and Chan (2014), Ito et al (2015) and Gopinath and Stein (2018a), which possibly suffer from self-selection bias.

To overcome the data constraint, we have gone through annual reports, financial statements, and other relevant materials of central banks across the world and collected data on the currency composition of FX reserves of individual countries. Since reserve-management styles vary across central banks (Borio et al (2008)), the style of reporting the currency composition of FX reserves varies. Some central banks report the currency composition of (gross) foreign assets (ie, assets denominated in foreign currencies). Others find it more appropriate to report the currency of foreign currency exposure that is based on net foreign assets, or net FX positions.

For example, the Swedish Riksbank's on-balance sheet assets mainly consist of euro and US dollars. To achieve its desired currency composition, the Riksbank in effect converts some of its dollar holdings into Norwegian kroner using forwards, selling dollars at future value dates for Norwegian kroner. Hence, the Riksbank reports the composition of currency exposure by incorporating such FX forwards and foreign liabilities into gross financial assets. Such exposure better reflects the country's reserve management. Indeed, the Riksbank's reports of the currency composition of FX reserves (ie, that of gross foreign assets) to the IMF's COFER may well differ from its report on the composition of currency exposure (based on net foreign assets).⁴

We collect the currency composition of currency risk exposure whenever the information is available. For those central banks that do not report such currency composition, we look at the disaggregation of (gross) foreign assets by currency in the financial statements. When we calculate the currency shares of FX reserves, we exclude gold and SDRs.

For the data for Latin America, we have collaborated with the Latin American Reserve Fund (FLAR, its Spanish acronym). FLAR collected data on the currency shares in FX reserves and trade invoicing for 9 Latin American countries.

This helped to expand the dataset in Ito et al (2015) to 58: 13 advanced economies; 45 "emerging and developing economies", as defined by the IMF. By region we have 10 Asian-Pacific; 12 African and Middle Eastern; 6 Western European; 17 Eastern European and Central Asian; and 12 Western Hemisphere (see Annex 2). We exclude issuers of the key currencies: the United States, the euro area, and Japan.

⁴ In this (and other?) case(s), the dollar share of FX reserves reported in the COFER dataset may be inflated.

East Asian emerging market economies (EMEs) tend not to publish their reserves' currency compositions. That said, in the summer of 2019, China's State Administration of Foreign Exchange (SAFE) (2019) reported in its 2018 annual report the share of USD in the country's FX reserves for 1995 (79%) and 2014 (58%).

Coverage of the data on currency shares in FX reserves in percent Table 2

	World	Excluding the key currency issuers*	Excluding key currency issuers and China
GDP	51.4	74.7	65.6
FX reserves	63.4	73.7	61.8

Note: *The key currency issuers refer to the United States, the euro area, and Japan.

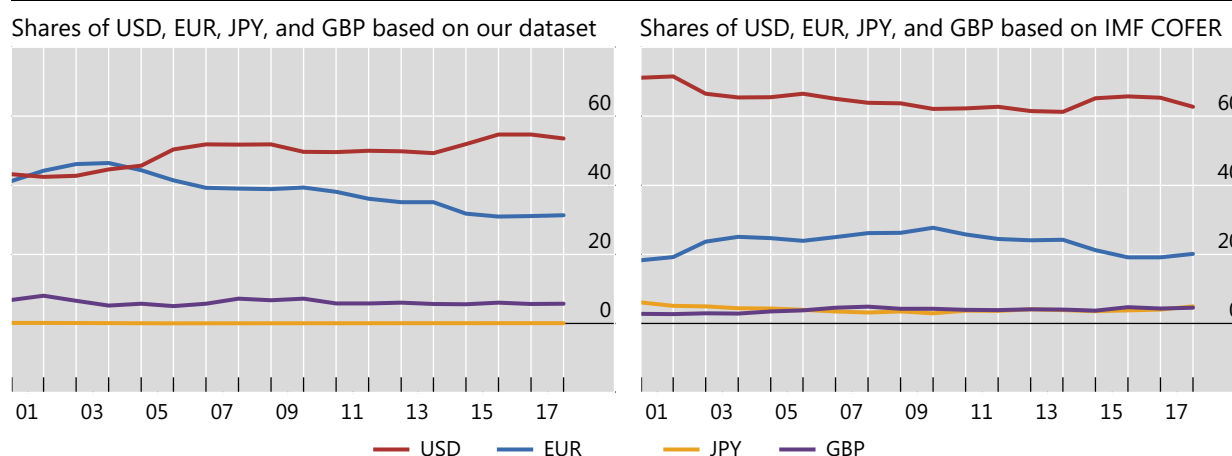
Source: Authors' calculations.

Outside the COFER database, our dataset of the currency shares in FX reserves is probably the largest in the literature. The economies included account for 51.4% of world GDP (Table 2). Removing the GDP of the key currency issuers (ie, the US, the euro area, and Japan) from world GDP, the coverage rate rises to 74.7%. Excluding not only the key currency issuers but also China, the largest reserve holder, our dataset still covers 65.6% of the rump of world GDP. Similarly, in terms of the world's total FX reserves, our sample cover 63.4% of the world's total, 73.7% excluding the key currency issuers and 61.8% excluding also China.

Our dataset on currency shares in FX reserves vs. the IMF COFER data, 2000–2017

In per cent

Graph 2



Sources: IMF, Currency Composition of Official Foreign Exchange Reserves (COFER); authors' calculations.

Our aggregate USD and EUR shares demonstrate a waning European selection bias in disclosure of currency weights (Graph 2).⁵ While the IMF COFER shows the USD share has been on a slightly declining trend in the 60-70% range, it starts in our dataset from low levels (ie, 40-45%), and rises in the late 2000s and the mid-2010s.

⁵ Graph 2, left-hand panel, and Graph 3 exclude China, the world's largest FX reserve holder, because the country's USD share is only available for one year (2014). Including the country's observation would create a small bump in 2014 though it would not alter the temporal profile of the USD share.

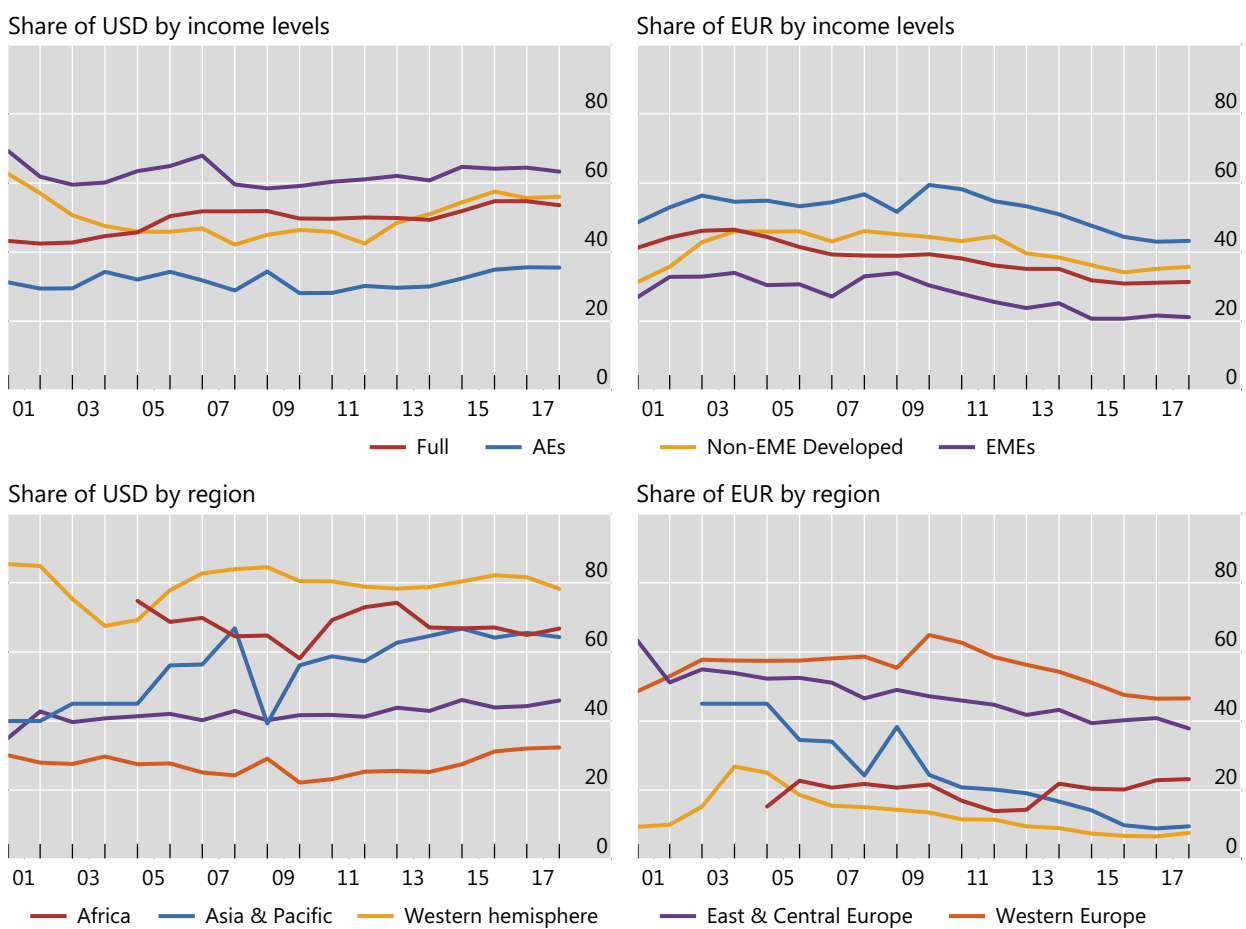
The contrast between our data and the COFER data arise mainly because our dataset, especially in the early years, over-represents European countries that tend to disclose their reserve currency composition. Our **lower** USD share also arises from our exclusion of Japan and the euro area, whose reserves well exceed US reserves, and which hold **high** shares (90%?) of USD in their FX reserves.

Across income groups, EMEs have held persistently **high** USD shares in their reserves (Graph 3, top left-hand panel). Non-EME developing countries do not have as **high** USD shares as EMEs do. AEs hold **lower** USD shares on average, which reflects that many are (non-euro area) European countries in Northern and Western Europe.

Dollar and euro shares in FX reserves by income and region, 2000–2017

In per cent

Graph 3



Source: Authors' calculations.

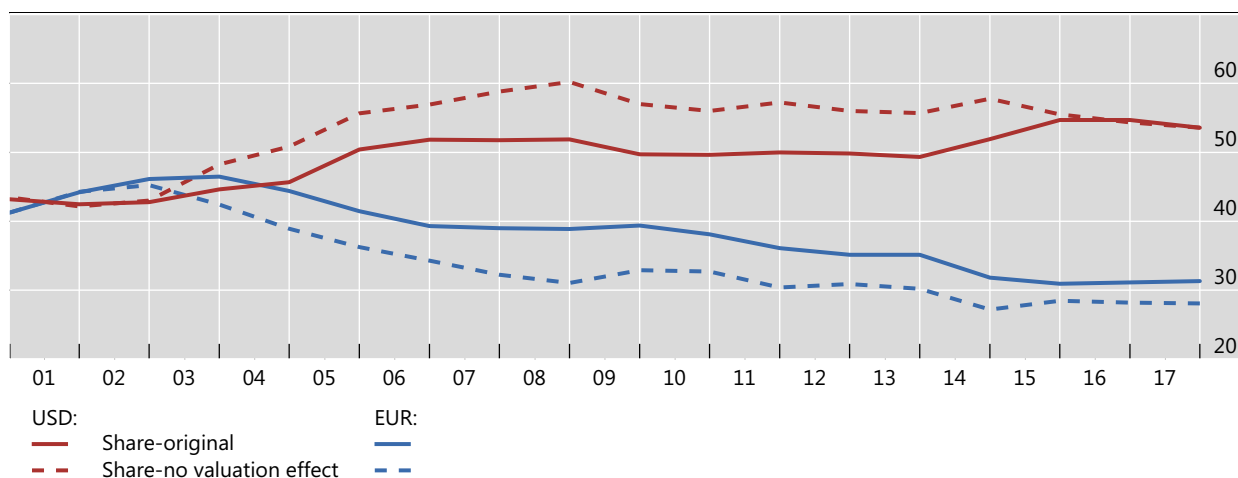
Across regions, countries in the West Hemisphere (ie, Canada and Latin American countries) hold persistently **high** USD shares, followed by African and Asian economies (Graph 3, bottom left-hand panel). By contrast, the EUR share is **high** for Western and East and Central European countries (bottom right-hand panel). The moderate declining trend of the EUR is observable across the geographical groups.

The rising trend of the USD in our sample is even more evident if we redraw Graph 2, left-hand panel, at constant, 2000 exchange rates (Graph 4). The USD share (red solid line) would have risen even more in the 2000s (red dotted line) had the dollar not experienced a trend depreciation then.

Share of USD and EUR in FX reserves with and without valuation effects

In per cent

Graph 4



Source: Authors' calculations.

3. Currency zone weights and currency denomination of trade and debt stocks

A central bank whose currency is anchored to a key currency, whether owing to policy or market forces, tends to hold FX reserves in this key currency that have a relatively stable value in domestic currency. And, an economy that invoices its international trade in a key currency tends to hold FX reserves in this currency that match its cash flows. And, an economy that holds external debt in a key currency tends to hold FX reserves in this currency that match cash flows. This section charts these bivariate relationships.

To be sure, different roles of money reinforce one other (Krugman (1984)). An economy that invoices its trade in a key currency, tends to borrow in this same currency, and to conduct policy to lend stability to the exchange rate against it. It naturally holds this same key currency in its FX reserves. Currency co-movement may be the starting point. Historical cases like Japan and Sweden in the 1930s suggest that the decision to stabilise the exchange rate against a key currency leads to the investment of FX reserves in the same currency (McCauley and Chan (2015)).

3.1 Currency weights

Previous studies using confidential IMF data acknowledged the importance of exchange rate arrangements, but only in polar form. Heller and Knight (1978) show that a country that pegs its currency to a key currency, tends to hold a large portion of its FX reserves in that key currency. Dooley et al (1989) and Eichengreen and Mathieson (2000) followed suit by using dummies for pegs. This restricts to extreme cases a test of the connection between currency anchoring and reserve composition. The insight that the way a managed or free-floating currency trades against the key currencies guides the choice of the currency denomination of reserves is new to our work.

Thus, we first estimate how much each currency co-moves with the USD, EUR and JPY. Our choice of these currencies is a prior that reflects their pre-eminent turnover in the Central Bank Triennial Survey of Foreign Exchange and Over-the-Counter Derivatives Activity (BIS (2016)).

The co-movement of currencies arises from exchange rate policy, monetary policy and underlying trade relations (McCauley and Shu (2019)). Policy fixes the Hong Kong dollar and the Bulgarian lev to the dollar and the euro, respectively. Policy also governs the Singapore dollar, managing it against its trade-weighted basket. The authorities may intervene in the market less systematically to stabilise the dollar exchange rate, as in Dooley et al (2004). In addition, a central bank may set its policy interest rates off of those of a major central bank in a way that stabilises the exchange rate (Hofmann and Bogdanova (2012); Hofmann and Takáts (2015)). For instance, the Norges Bank explicitly discusses the spread of its policy rate over that of the ECB, and the kroner shares most of the euro's moves against the dollar. Trading relations also matter: the Mexican peso and the Polish zloty co-move with their neighbours' currencies, the dollar and euro, respectively.

We estimate the key currency weights for each currency for each time period using a method based on Haldane and Hall (1991) and Frankel and Wei (1996).⁶ The estimated weights indicate the extent that an economy belongs to each zone.

Specifically, we estimate the following:

$$\Delta e_t^{i/\$} = \alpha_i + \beta_{i\text{€}t} \Delta e_t^{\text{€}/\$} + \beta_{i\text{¥}t} \Delta e_t^{\text{¥}/\$} + \varepsilon_{it} \quad (1)$$

Here, $e_t^{i/\$}$ is the bilateral exchange rate of home currency i , against the dollar (USD); $e_t^{h/\$}$ on the right-hand side of the equation is the exchange rate of the euro or yen against the dollar. The movement of each currency against the dollar on the left-hand side reduces to a weighted average of the movements of the euro and yen against the dollar on the right-hand side, leaving a residual of idiosyncratic movement. Thus, $\hat{\beta}_{iht}$, the estimated coefficient on the rate of change in the exchange rate of key currency h vis-à-vis the US dollar in period t , represents the weight of currency h in the behavioural basket. The dollar's weight is taken as $\hat{\beta}_{i\$t} = 1 - (\hat{\beta}_{i\text{€}t} + \hat{\beta}_{i\text{¥}t})$. For a currency pegged to the US dollar (eg the Hong Kong dollar), $\sum_{h=1}^H \hat{\beta}_{ih} = 0$ and $\hat{\beta}_{i\$t} = 1$. Similarly, for a currency pegged to the euro (eg the Bulgarian lev), $\hat{\beta}_{i\text{€}t} = 1$. When the Russian authorities stabilised the rouble against a dollar-euro basket with 45% euro (ECB (2013, p 67)), the estimated betas were both about one-half.

We estimate weights for the currencies of each of our sample economies over rolling windows of 36 months. Hence, the coefficients $\hat{\beta}_{iht}$ vary over time at the monthly frequency. We exclude monthly observations of any currency that depreciates by 10% or more against the dollar to prevent outliers during currency crises from producing spurious weights.^{7,8}

⁶ Haldane and Hall (1991) analysed sterling during Bank of England management and free floating, while Frankel and Wei (1996) sought to discover weights in an undisclosed official basket. See also Bénassy-Quéré et al (2006), Ito and Kawai (2016), Kawai and Akiyama (1998, 2000) and Kawai and Pontines (2016).

⁷ Similarly, Ilzetzi et al (2019) exclude countries where annual inflation reaches 40%.

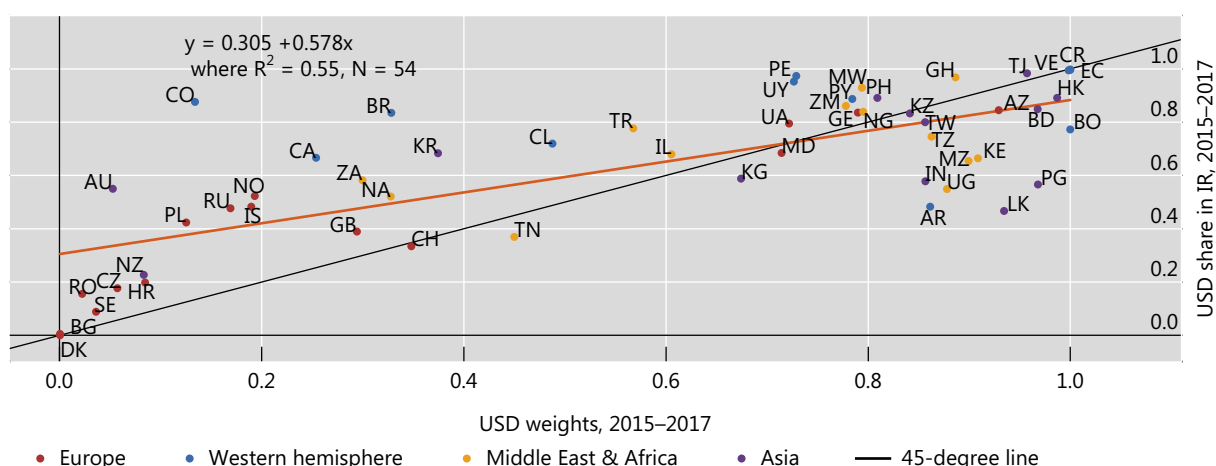
⁸ We convert the monthly weights into annual weights as follows. We take any significantly negative $\hat{\beta}_{iht}$ to be a missing value, and a statistically insignificant negative $\hat{\beta}_{iht}$ to be zero. Likewise,

We find that a currency's dollar zone weight is positively correlated with the dollar share in the country's FX reserves (Graph 5). Broadly, central banks in Latin America, Africa and the Middle East heavily weight the dollar, with which their currencies move. Several Latin American economies, notably Colombia and Brazil, hold more USD-denominated FX reserves than their currencies recently lowish dollar weights might suggest. The USD shares in Western and central European economies' reserves and USD weights are low, whereas those of central Asian economies are high.

The slope of the least squares line (in yellow in Graph 5) is not 1 (45-degree black line), as would be the case if reserve managers on average chose the dollar weight to minimise the variance of their portfolios in domestic currency. Instead, the estimated slope closer to one half points to some departure from the minimum variance portfolio, perhaps in some cases to raise expected returns. Departure from the minimum variance portfolio poses political economy risks to central banks. They might bask in praise when the dollar is weak, but more likely endure tough questions when it is strong. At the limit, losses on FX reserves could require fiscal support with implications for central bank autonomy (Del Negro and Sims (2015); Schanz (2019)).

Dollar zone weight and USD share of FX reserves, 2015–17

Graph 5



Source: Authors' calculations.

3.2 Invoicing of trade in key currencies

Dollar trade invoicing encourages exporters (especially commodity exporters) to borrow dollars to hedge and importers to borrow dollars for working capital. Servicing dollar debts tilts trading towards the dollar, encouraging reserve managers to hold dollars.

We use the dataset of Ito and Chinn (2015) and Ito and Kawai (2016), expanded to include currency shares in Latin America⁹ and updated to recent years. The initial

we take any $\hat{\beta}_{iht}$ that is significantly greater than one to be a missing value, and a $\hat{\beta}_{iht}$ that is insignificantly greater than one to be one. Once estimated betas outside the unit interval are thereby censored to zero or one or taken to be missing values, the average of the months becomes the annual observation. See Ito and McCauley (2019) for details.

⁹ We thank FLAR for its generous cooperation.

larger than 1. The goodness of fit is 35%, suggesting that the US trade share is a so-so proxy for the USD share in export invoicing.¹² For euro export invoicing regressed on the trade share with the euro area, the coefficient is a similar 1.2 and the goodness of fit is higher at 73%, suggesting that trade with the euro area is a pretty good proxy.

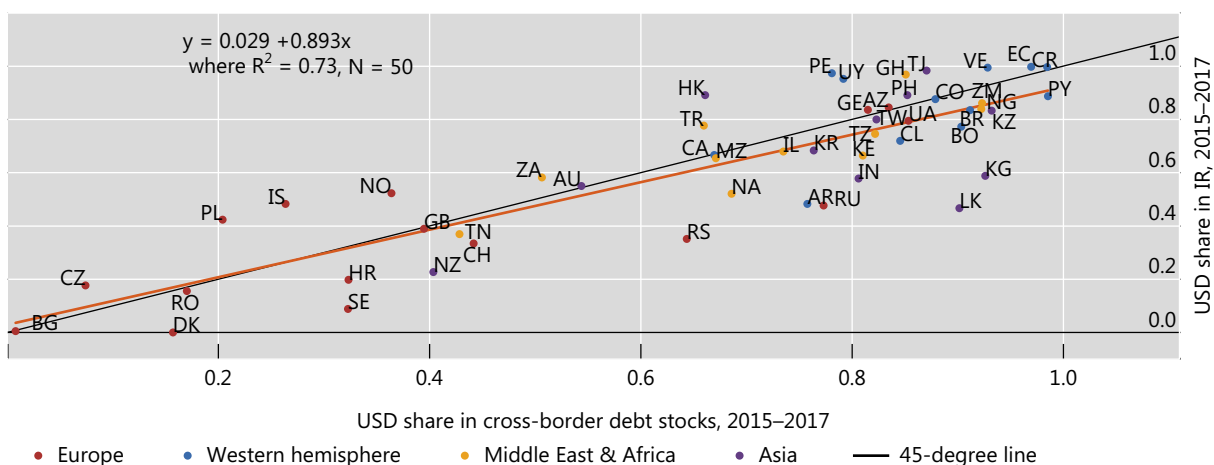
Graph 6 right-hand panel illustrates the link between the US trade share and the USD share in foreign reserves is much looser; only 9% of the variation of the USD shares in foreign reserves can be explained by the US trade shares in the 2015-2017 period. Although it may not be a perfect proxy, we still show the estimation results from the model that includes the US (or euro area's) trade share instead of the USD (EUR) share in export invoicing. Doing so allows us to conduct robustness tests with larger samples and accordingly higher degrees of freedom.

3.3 Debt stocks in key currencies

A country with debt denominated in a key major currency may also hold its FX reserves in that currency. Again, this can hedge cash flows, in this case debt service (Dooley (1987)).¹³ We measure the dollar and euro share of debt stocks as the weighted average of their shares in international debt securities and in cross-border bank loans. For the former, we use BIS data on international debt securities by nationality, and for the latter, BIS international banking data by location.¹⁴

USD share in international debt stocks and in FX reserves, 2015–17

Graph 7



Source: Authors' calculations.

Updating, broadening and confirming McCauley and Chan (2014), Graph 7 shows that the dollar FX reserve share rises one percentage point for each percentage point

¹² Ito and Chinn (2015) find qualitatively similar results in a multivariate estimation, though the magnitudes of the estimates are much smaller. Ito and Chinn (2015) also show that the EUR share in export invoicing is much more correlated with the share of the euro area as an export destination in total exports.

¹³ Cohen (2005) and Ito and Rodriguez (2015) analysed key-currency shares in international debt.

¹⁴ The BIS international banking data report 47 countries' assets vis-a-vis more than 190 countries. For data on international bank liabilities, we use the bank loans of the reporting countries vis-à-vis the sample countries.

higher dollar share in external debt. That is, the estimated coefficient at .89 is insignificantly different from one while the goodness of fit is also high at .73. However, the very strength of this relationship raises questions. Don't the firms, banks and governments that contract the debt to international banks and bondholders optimise on the liability side much as FX reserve managers do on the asset side? Despite wide use of this "explanatory" variable in the literature, we eschew it on the grounds that it is too close to what we want to explain.

4. Estimation

We have seen that the share of the US dollar in FX reserves holding lines up with currency co-movement with the dollar, and dollar invoicing of trade and dollar-denominated international debt. Do the bivariate relationships hold in a multivariate setting? Our dataset on the currency composition of foreign reserves is rich enough for us to conduct a panel data analysis.

4.1 Observations of currency shares in different aspects of international currency

While the FX reserve composition may be relatively stable for advanced economies, EMEs may experience changes in the underlying drivers and thus change their currency composition. Furthermore, reserve managers may manage their reserves cautiously when these are demanded for precautionary reasons, but with an eye on returns if reserves accumulate as a side effect of policies to nurture the traded goods sector (Aizenman and Lee (2007)).

Graph 8 charts the development of the share of the US dollar or the euro in FX reserves, currency weight, and export invoicing for four countries in the period 1995 – 2017. Based on these graphs and others for which we cannot spare space, we make 5 observations.

First, among the four variables, generally, the currency shares in export invoicing appear to be the least variant, while the currency weights are the most variant, with the variance of currency shares in FX reserves somewhere in-between.

Second, some countries, such as those in Latin America (except for the large ones), East Asia, Oceania, and Central Asia, are persistently dollar-oriented economies, with all three USD shares scoring high values consistently throughout the sample period. The Philippines is representative.

Third, many Eastern European economies transformed into euro-oriented economies, reflecting dramatic changes in their economic systems and structures after the demise of the Soviet bloc in the early 1990s. These economies have integrated themselves to varying degrees into the European Union. Their currencies' orientation in the mid-1990s toward the dollar or baskets giving substantial weights to the dollar (McCauley (1997)) tended to give way to orientation toward the euro as regional economic integration deepened. Poland is representative.

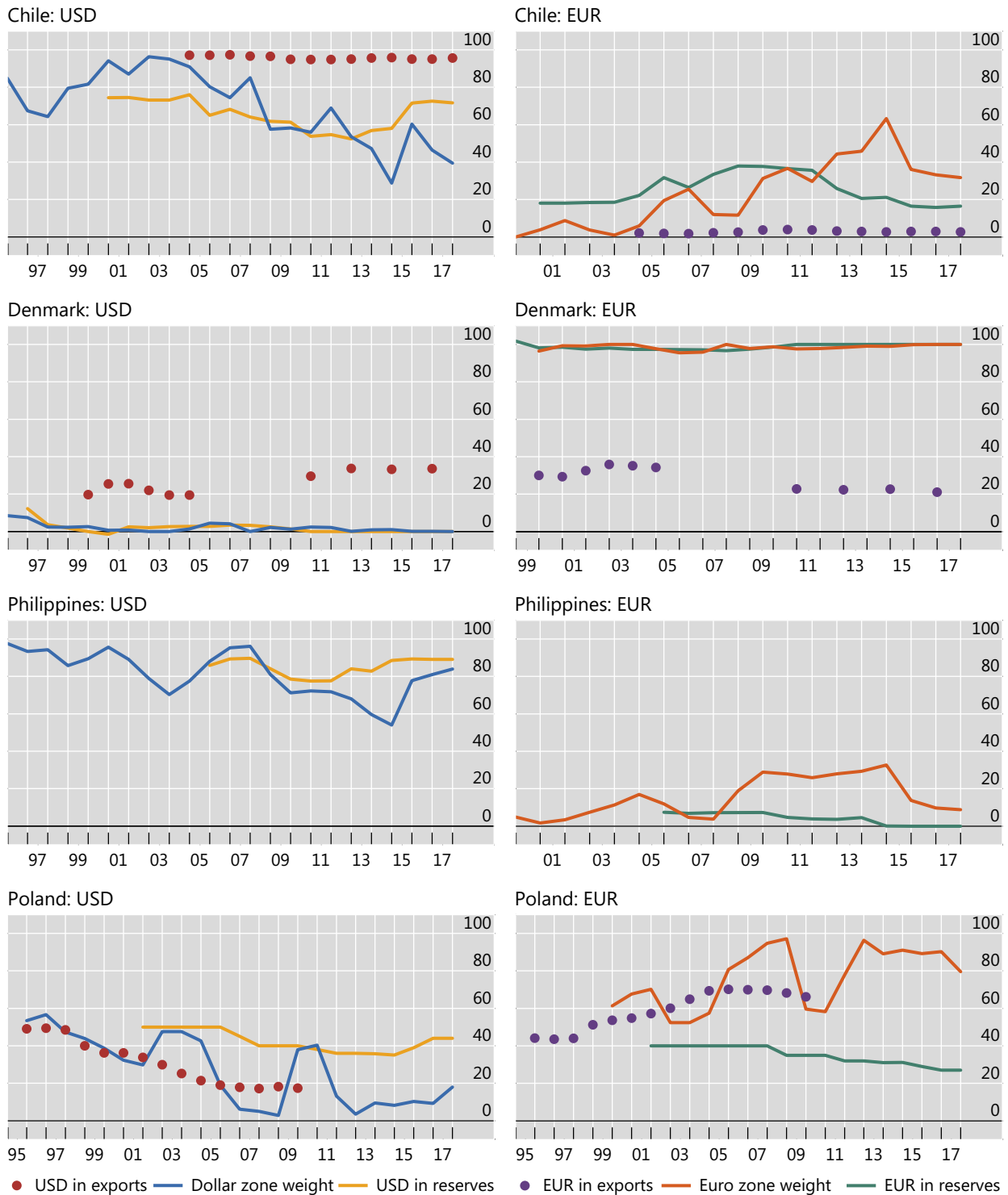
Fourth, currencies of the larger Latin American economies such as Argentina, Brazil, and Chile (Graph 8) have come in recent years to share some of the euro's movement against the dollar. This appears to be part of a broader recent move on

the part of both commodity prices and commodity currencies to share the movements of the euro against the dollar (Borio (2019), Ito and McCauley (2019)).

USD and EUR shares in export invoicing, currency weights and FX reserves

In per cent

Graph 8



Source: Authors' calculations.

Fifth, while several countries shifted towards the euro in terms of either currency weights or FX reserves, or both in the early 2000s, some (but not Denmark) then shifted back toward the dollar in the aftermath of the GFC or the European debt crisis. These bouts of financial instability may have contributed to the comeback of the USD at the expense of the euro (see below).¹⁵

Thus, the currency composition of FX reserves has remained stable for some countries while it changed hugely for others. How do these observations relate to the interrelated variation in the trade denomination and currency co-movements?

4.2 Panel regression analysis

Now, using our panel data, we regress the USD share in FX reserves on the following variables or groups of variables:

- the share of USD invoicing of exports or the US share in total international trade as a proxy;
- the estimated co-movement of the domestic currency with the USD; and
- the USD share of the external debt stock, though we mostly keep this variable offstage.

We estimate this model, by including the above variables both individually and jointly, on the panel of 58 countries between 2000 and 2017. For the estimation, we use 6 non-overlapping three-year averages of both the dependent and the independent variables in recognition of the variability of our measure of currency co-movements and the spottiness of invoicing data.

We report the results for two samples. The small sample contains economies for which the USD share in export invoicing is available. The large sample is constrained only by the availability of the FX reserve composition and uses the US share in total international trade as a proxy for the USD share in export invoicing.

Panel analysis of the dollar share of reserves, 2000-2017					
Dependent variable: share of USD in reserves, 6 unbalanced 3-year averages					Table 3
	Small (1)	Large (2)	Large (3)	Small (4)	Large (5)
USD share in export invoicing	0.79 (0.06)***			0.49 (0.08)***	
US share in trade		1.01 (0.17)***			0.61 (0.12)***
USD currency weight			0.54 (0.03)***	0.37 (0.07)***	0.49 (0.03)***
<i>N</i>	92	272	259	92	259
Adjusted R ²	0.63	0.19	0.50	0.72	0.57
# countries	27	58	55	27	55
Notes: Table reports ordinary least squares regressions. * p<0.1; ** p<0.05; *** p<0.01. Robust standard errors are in brackets. A constant term is used in estimation but its estimate is not presented.					
Source: authors' estimates.					

¹⁵ Ito and Rodriguez (2015) show this trend for international debt securities.

As shown in Graph 6, left-hand panel, a higher dollar share in export invoicing leads to a higher dollar share in FX reserves holding (Table 3, column (1)). In column (4), the estimate retains its statistical significance even when the co-movement with the USD is included. A one percentage point increase in the dollar invoicing share leads to a 0.50 percentage points increase in the dollar reserve share. The share of trade with the United States exerts about the same effect in the large sample.

Similarly, co-movement with the dollar exerts a significantly positive effect on dollar FX reserves in columns (4) and (5), with the magnitude ranging from 0.37 to 0.49. The small sample goodness of fit is quite high, with an adjusted R^2 of 0.72.

The analysis of the euro share produces results (Table 4) that are consistent with the analysis focused on the dollar. More use of the euro in export invoicing and more currency co-movement with the euro both lead to higher levels of euro FX reserves (columns (1, 5)). The euro area's share in trade works as well as EUR trade invoicing.

Panel analysis of the euro share of reserves, 2000-2017

Dependent variable: share of the EUR in reserves, 6 unbalanced 3-year panels

Table 4

	Small (1)	Large (2)	Large (3)	Small (5)	Large (6)
EUR share in export invoicing	0.67 (0.07)***			0.30 (0.10)***	
EUR share in trade		1.12 (0.07)***			0.57 (0.07)***
EUR currency weights			0.54 (0.04)***	0.47 (0.08)***	0.34 (0.04)***
<i>N</i>	101	263	250	99	250
Adj. R^2	0.41	0.51	0.56	0.59	0.65
# of countries	26	54	51	25	51

Notes: Table reports ordinary least squares regressions. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Robust standard errors are in brackets. A constant term is used in estimation but its estimate is not presented.

Source: authors' estimates.

As pointed out in the conference, we need to pay special attention to the variables for the currency co-movement because they are generated as estimates from another regression (ie, equation (1)). Not taking into account that they have their own sampling variances leaves the standard errors estimated in our main regressions too small. This in turn could lead to spurious ease in rejecting the null hypothesis (ie, finding the estimated coefficients statistically significant too readily).

One solution is to bootstrap the regression model. When we bootstrap models (4) and (5) in Tables 3 and 4 1,000 times each, the standard errors of the estimated coefficients rise only slightly, and do not lower their statistical significance below the indicated thresholds. Thus, although we generate the currency weights, their use does not lend our results spurious significance.

Table 5 transforms the findings in Tables 3 and 4 into standardised beta coefficients. These show how many standard deviations the dependent variable, ie, the dollar or the euro shares in FX reserves, moves if one of the explanatory variable

moves by one standard deviation *ceteris paribus*. The beta coefficients thus measure the relative importance of the explanatory variables.¹⁶

Beta coefficients for estimations for dollar and euro shares in FX reserves

Unbalanced 3-year panels, 2000-2017

Table 5

	USD share			EUR share	
	Small sample (1)	Large sample (2)		Small sample (3)	Large sample (4)
USD share in export invoicing	0.15 (0.02)***		EUR share in export invoicing	0.09 (0.03)***	
US share in trade		0.08 (0.01)***	EUR share in trade		0.10 (0.01)***
USD currency weights	0.13 (0.02)***	0.18 (0.01)***	EUR currency weights	0.17 (0.03)***	0.12 (0.02)***
<i>N</i>	92	259	<i>N</i>	99	250
Adj. R2	0.72	0.57	Adj. R2	0.59	0.65
# of countries	27	55	# of countries	25	51

Notes: Table reports ordinary least squares regressions. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Robust standard errors are in brackets. The estimates in this table should be interpreted as showing by how many standard deviations the dollar or the euro shares in FX reserves, move if one of the explanatory variables moves by one standard deviation *ceteris paribus*. The constant term is included in the estimation but its estimate is omitted from presentation.

Source: authors' estimates.

We find that the USD share in export invoicing and the USD currency weights exert equal force. In particular, a one standard deviation increase in the USD share in export invoicing and the USD currency weights lead 0.15 and 0.13 standard deviation increases in the USD share in FX reserves, respectively. For the EUR share in FX reserves, the EUR weights pack more punch than the EUR share in export invoicing.

Let us illustrate our findings by juxtaposing the estimates of Table 3, column 4 with observations for a small, an intermediate, and a large economy. For Israel, Graph 9, left-hand panel, shows the contributions of the explanatory variables, and the predicted and observed USD shares in FX reserves for 2012-14 and 2015-17. The observed dollar share (Benita et al (2019)) is just 3.4% points short of the predicted share.

Graph 9, centre panel, does the same for South Africa for 2012-14 and 2015-17. For both three-year periods, the model under-predicts the observed USD share in FX reserves. The extent of under-prediction is as large as 26 percentage points. Neither the dollar share in South Africa's trade invoicing¹⁷ nor in the co-movement of the rand is particularly high.

Graph 9, right panel, illustrates the same exercise for China for 2012-14 using the Mainland's single 2014 observation on its USD share. Data on the USD share in the

¹⁶ Recall that the variation across economies or time differs across our currency share variables.

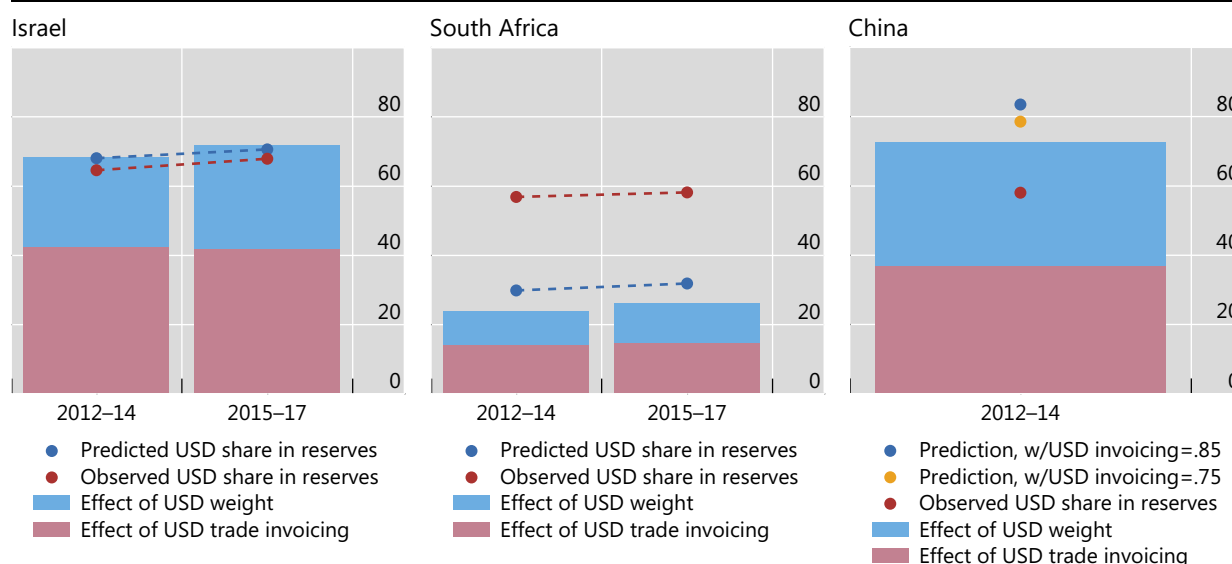
¹⁷ Because the USD share in export invoicing for South Africa in 2015-2017 is unavailable, we used the average of the USD share, namely 30%, in export invoicing in 2009-2011 and 2012-2014. See South African Reserve Bank (2019, p 254) for the influence of trade invoicing.

Mainland's export invoicing are unavailable, but partner data support our considering it in the range of 75-85%.¹⁸ Depending on whether 75% or 85% of China's exports are dollar-invoiced, our estimates suggest USD shares in China's FX reserves of 78.6% or 83.5%. In either case, we over-predict the USD share in FX reserves of 58% in 2014.

The contributions of currency weights and trade invoicing, and predicted and observed USD share in FX reserves

In per cent

Graph 9



Source: Authors' calculations.

Policy toward the co-movement of the RMB and the dollar could figure in the 20-25% difference. For 2014, our estimated dollar weight of the RMB is high at 95.3%. The Chinese authorities have set out a policy of keeping the RMB stable against a basket of currencies (McCauley and Shu (2019)). An RMB that moves enough against the dollar to trade with stability against a basket of trading partners' currencies would have a dollar weight something like one-half (Ito and McCauley (2019)). The product of the difference between 95.3% and one-half (45.3%) and Table 3, column 4's coefficient of .37 on the dollar weight is 17%, most of the 20-25% gap between the observed and predicted dollar share.

In sum, using our novel and rich dataset, we find that trade invoicing and currency co-movements shape with about equal force the choice of the currency composition of FX reserves. If an economy denominates a larger share of trade in the USD, then it tends to hold more dollar-denominated FX reserve. This confirms Ito et al (2015) with a much larger data set and shows that the Gopinath and Stein (2018a,b) finding survives the competition of currency co-movement, whether measured as in Ito and McCauley (2019) or, as below, Ilzetzi et al (2019). If an economy's currency

¹⁸ In 2014, 73.3% of Japan's imports from Asia were invoiced in USD whereas only 1.2% were invoiced in the RMB; these shares cannot be too different for Sino-Japanese trade since China accounts for 42% of Japan's trade with Asia. Japan's Ministry of Finance reports in its bi-annual report on the currency composition of trade invoicing currency shares in its exports and imports only for the world, United States, EU, and Asia. Similarly, in 2014, 83.8% of Korea's imports were invoiced in USD, whereas only 0.2% were in the RMB; these shares cannot be too different for Sino-Korean trade since China is Korea's largest trading partner.

trades with greater relative stability against the dollar, then it tends to hold more dollar-denominated FX (McCauley and Chan (2014), and Ito et al (2015)). Both findings take big steps beyond analyses that examined only US trade shares and dummies for dollar pegs (Heller and Knight (1978), Dooley et al (1989), Eichengreen and Mathieson (2000)).

5. Robustness checks

The conference discussion suggested several robustness tests, which we undertook. In general, the results of these do not change our main messages. Eight follow: alternative estimation method, the stability of the results across global or national financial strains, alternative measures of currency zones, and the impact of additional variables from FX trading to size of reserves to interest differentials/exchange rate trends and financial market openness.

5.1 Alternative estimation methods and inertia

Chinn and Frankel (2007) emphasise the hysteresis or inertia in the choice of reserve currencies. That is, the choice of currency composition in FX reserves can be path dependent. To better reflect such persistence, one may include a lagged dependent variable in the estimation. This requires an estimation of a dynamic specification. Thus, we adopt the system generalised method of moments (GMM) estimation and present the estimation results in Online Appendix to conserve space.

The GMM estimation shows high degrees of persistence for both USD and EUR shares, reflecting relatively stable shares for both USD and EUR in FX reserves. However, the high persistence in USD and EUR shares robs almost all of the other variables of their statistical significance. Thus, the GMM leaves us with little more than the finding that FX reserve composition is what it was. These unsatisfactory results may be because the sample is small (especially, in the number of economies) and highly unbalanced. Hence, while this exercise suggests a high degree of inertia in the currency composition of FX reserves, it does not rule out the importance of trade or currency co-movement.

5.2 Coefficient stability over the Great Financial Crisis

An economy gripped by financial instability may shift to USD-denominated FX reserves ("flight to safety"). Most central banks outside of Europe have little choice but to use the dollar to intervene in the domestic currency FX market, and many national banking systems have extensive dollar assets to be funded with dollar liabilities. Moreover, the GFC of 2008 led central banks to de-risk the instruments held in reserves, retreating from bank deposits to Treasury bills (McCauley and Rigaudo (2011)). Did central banks respond to the GFC or the subsequent euro debt crisis by retreating into the US dollar in their FX reserve management?

We test whether the determinants of the currency composition in FX reserves changed around the GFC by running the regressions separately for three subsamples: 2000–02, 2003–05, and 2006–08; 2009–11; and 2012–14 and 2015–17. The 2009–11 panel serves as the crisis period, either the GFC or euro debt crisis. These regressions

do not yield any evidence for coefficient instability (not reported). Therefore, we conclude that the GFC did not cause any structural changes in the choice of the USD share in FX reserves.¹⁹

5.3 Impact of national financial crises and financial instability

While the GFC did not change the global determinants of the USD share in FX reserves, national crises may affect the composition of national FX reserves. Financial crises may involve dollar sales or dollar liquidity shortages so the USD share might rise for crisis-hit economies. Thus, we examine the impact of financial crisis by including dummy variables for currency, debt, and banking crisis in the USD share estimation, expecting the estimation to attach positive coefficients to the dummies for all three.²⁰

As expected, the dummies for currency and debt crisis enter the estimation with significantly positive signs, but do not affect the main explanatory variables (Table 6). Conversely, the dummies attract negative coefficients for the euro share. Thus, crisis-hit economies tend to increase the dollar share of their reserves by 6–14% at the expense of the euro. However, the estimate of the banking crisis dummy is significantly negative, contrary to our prior.²¹

The impact of financial crises			Table 6	
Dependent variables:	USD share		EUR share	
	Small sample	Large sample	Small sample	Large sample
	(1)	(2)	(3)	(4)
USD/EUR share in export invoicing	0.49 (0.08)***		0.29 (0.10)***	
US/Euro area share in trade		0.61 (0.12)***		0.56 (0.07)***
USD/EUR currency weights	0.36 (0.07)***	0.47 (0.03)***	0.46 (0.08)***	0.33 (0.04)***
Currency crisis	0.06 (0.03)**	0.11 (0.03)**	−0.06 (0.03)**	−0.05 (0.02)**
Debt crisis	0.07 (0.03)**	0.14 (0.03)***	−0.04 (0.03)	−0.07 (0.02)***
Banking crisis	−0.19 (0.05)***	−0.08 (0.03)***	0.15 (0.05)***	0.04 (0.04)
<i>N</i>	92	259	99	250
Adj. <i>R</i> ²	0.73	0.59	0.58	0.65
# of countries	27	55	25	51

Notes: Table reports ordinary least squares regressions. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Robust standard errors are in brackets.
Source: authors' calculations.

¹⁹ Graph 2 shows that the EUR share declines after 2010, suggesting a structural break. However, this decline can be explained in part by the effect of slow growth in the euro area on the EUR share's in export invoicing, which has declined (Lu and Wang (2019, Figure 2, p 11). Furthermore, high growth economies such as China and other EMEs tend to hold more USD FX reserves, which lowers the EUR share in FX reserves even without any behavioural change in the currency composition choice.

²⁰ The identification of the three types of crises is based upon Laeven and Valencia (2018).

²¹ However, the countries for which the banking crisis dummy takes the value of one are mostly European: Iceland (in 2006–08) and Russia (2006–08) in the small sample and the U.K., Denmark, Sweden, Iceland, Kazakhstan, Russia, and Ukraine (all in 2006–08), Nigeria (2009–11), and Ukraine (2012–14) in the large sample.

5.4 Alternative measure of currency zones

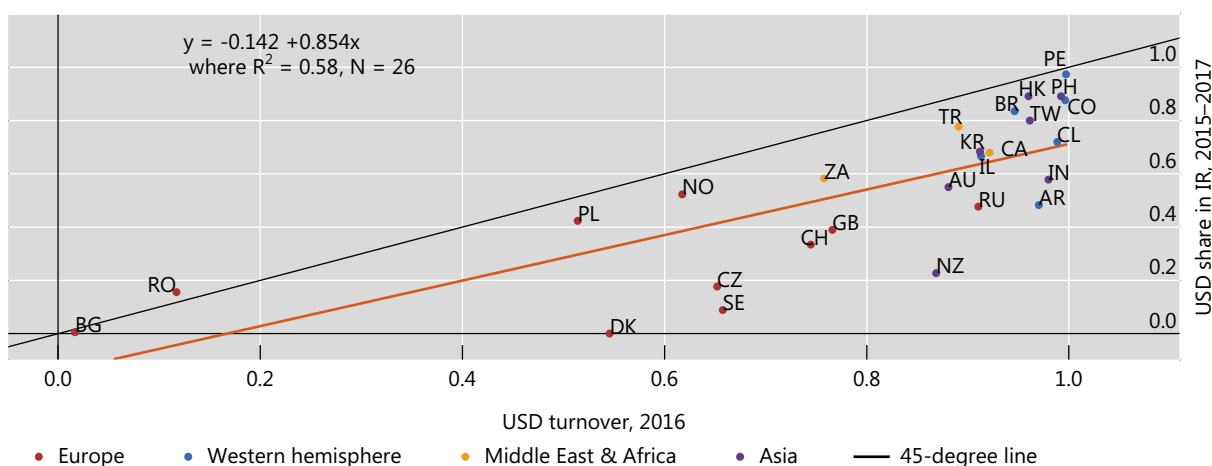
While past studies estimated the impact of currency pegs on the currency composition in FX reserves, our study takes a more nuanced approach by estimating time-varying co-movement of currencies. What if we use, not our Frankel-Wei estimates, but the “winner take all” assignment of currencies to zones of Ilzetzi et al (2017, henceforward, IRR)? Although IRR share with us the goal of identifying currency zones, their approach differs substantially. Most importantly, IRR assign each currency a single, dominant anchor currency for each country-year. We generate continuous weights between one and zero for each candidate anchor currency.²² Using the binary dummy for the dollar zone instead of using the continuous currency weights does not alter the estimation results (not reported).²³

5.5 Foreign exchange trading turnover

On a bivariate basis, the share of USD trading in the spot market lines up well with the share of dollar reserves, as in Ito et al (2015) (Graph 10). This relationship remains in a multivariate setting that **controls** for the USD share in trade invoicing and currency co-movement with the USD (Table 7). In particular, a one percent increase in the dollar share of spot trading is associated with a 0.42-0.43 percentage point increase in the share of dollar FX reserves. Similarly, a larger share of euro spot trading makes for more euro FX reserves. The estimates of USD share in export invoicing and USD currency weights are left intact.

USD share in FX turnover and FX reserves, 2015–17

Graph 10



Note: USD turnover is the ratio of spot local currency trading against USD to all spot local currency trading.

Source: BIS, *Triennial Survey*; authors' calculations.

²² Also, IRR exclude the country-years when the rate of inflation exceeds 40%, dubbing the currency “freely falling,” and assigning it no anchor currency. We exclude months of dollar depreciations in excess of 10% but still assign **high** inflation currencies an anchor.

²³ There is a tendency for the magnitude of the estimate on the exchange rate regime dummy to be smaller than that of the estimate on the dollar zone weights, possibly because the variance of the indicator variable is larger than that of our continuous variable while both range between zero and one. The euro share estimations also yield significantly positive estimates on the euro peg dummy, and they tend to be smaller in magnitude. The estimation results are available upon request.

Foreign exchange trading turnover as a candidate determinant				Table 7
Dependent variables:	USD share		EUR share	
	Small sample (1)	Large sample (2)	Small sample (3)	Large sample (4)
USD/EUR share in export invoicing	0.31 (0.08)***		−0.08 (0.11)	
US/Euro area share in trade		0.14 (0.13)		0.32 (0.11)***
USD/EUR currency weights	0.25 (0.09)***	0.40 (0.06)***	0.33 (0.11)***	0.21 (0.07)***
Ratio of USD/EUR turnover to total local currency turnover	0.43 (0.09)***	0.42 (0.08)***	0.55 (0.10)***	0.43 (0.08)***
<i>N</i>	66	125	71	114
Adj. R ²	0.68	0.68	0.58	0.59
# of countries	19	27	18	23

Notes: Table reports ordinary least squares regressions. * p<0.1; ** p<0.05; *** p<0.01. Robust standard errors are in brackets.
Source: authors' calculations

5.6 Size of foreign exchange reserve holdings

One can hypothesise that a country tends to become more able to hold non-USD assets when it holds FX reserves in larger size. Institutionally, many central banks separate (“tranche”) a liquidity portfolio from an investment portfolio and invest the latter in a wider range of instruments and currencies (Borio et al (2008)). For instance, the Hong Kong Monetary Authority holds a so-called backing portfolio that in accord with the currency board rationale is 100% invested in dollars, while the rest of the FX reserves (including some fiscal reserves) are invested in a variety of currencies. Lu and Wang (2019) argue that the liquidity portfolio should be invested in accord with the numeraire²⁴ (ie minimum variance portfolio) while the investment portfolio should be allocated using a means-variance optimisation.

Like those of Beck and Weber (2011),²⁵ our estimates do not strongly support this hypothesis. The estimated coefficient on the size of FX reserves (as a share of GDP) is negative but statistically insignificant (Columns (1) and (2) of Table 8). The estimates on the USD share in export invoicing and on the USD weight are robust to the inclusion of this variable. However, in the EUR share estimation, the estimated coefficient on the aggregate amount of FX reserves is significantly *positive*, indicating larger foreign reserve holders may tend to diversify their reserve portfolio more toward including euro-denominated reserve assets (not reported).²⁶

²⁴ If the numeraire is the domestic currency, then emerging European economies would hold their liquidity portfolio in the euro.

²⁵ Beck and Weber (2011) argue that larger reserves would lead to more reserve diversification only if the motive to hold FX reserves is not precautionary. Aizenman et al (2019) find emerging markets as well as developing economies diversify their holdings of FX reserves away from the SDR currencies (ie, USD, EUR, British sterling, and the Japanese yen) when their holdings increase.

²⁶ The results are available from authors upon request.

Panel analysis of the dollar share of reserves, additional control variables							Table 8	
Unbalanced 3-year panels, 2000-2017								
	Size of FX reserves		Interest rate differentials		Rate of depreciation		Interest rate diff's & deprec	
	Small (1)	Large (2)	Small (3)	Large (4)	Small (5)	Large (6)	Small (7)	Large (8)
USD share invoicing	0.47 (.08)***		0.51 (.08)***		0.49 (.08)***		0.51 (.08)***	
US share in trade		0.59 (.12)***		0.62 (.12)***		0.59 (.12)***		0.60 (.12)***
USD curr weights	0.37 (.07)***	0.48 (.03)***	0.34 (.07)***	0.46 (.03)***	0.37 (.07)***	0.48 (.03)***	0.32 (.08)***	0.46 (.03)***
FX reserve (% GDP)	-0.19 (0.14)	-0.09 (0.09)						
Int rate diffs.			0.27 (0.34)	0.36 (0.23)			0.29 (0.34)	0.32 (0.23)
Deprec vs USD					0.01 (.01)	0.01 (.00)***	0.01 (.01)	0.01 (.00)***
N	91	251	91	245	92	256	91	242
Adj. R ²	0.72	0.56	0.72	0.58	0.72	0.57	0.72	0.58
# counts	27	53	27	55	27	55	27	55
	Financial development		Financial openness		Fin'l dev and openness		Fin'l openness & FX reserves size	
	Small (9)	Large (10)	Small (11)	Large (12)	Small (13)	Large (14)	Small (15)	Large (16)
USD share invoicing	0.50 (.07)***		0.50 (.07)***		0.50 (.07)***		0.48 (.07)***	
US share in trade		0.63 (.12)***		0.66 (.12)***		0.67 (.12)***		0.67 (.12)***
USD curr weights	0.34 (.08)***	0.47 (.04)***	0.31 (.07)***	0.45 (.04)***	0.31 (.09)***	0.45 (.04)***	0.31 (.07)***	0.43 (.04)***
Financial develop	-0.08 (0.08)	-0.05 (0.06)			-0.01 (0.09)	-0.02 (0.06)		
Financial openness			-0.13 (.06)**	-0.09 (.04)**	-0.13 (.07)*	-0.09 (.04)**	-0.12 (.06)*	-0.11 (.04)***
FX reserve (% GDP)							-0.15 (0.15)	-0.06 (0.09)
N	92	258	92	258	92	258	91	251
Adj. R ²	0.72	0.57	0.74	0.58	0.74	0.58	0.73	0.57
# counts	27	54	27	54	27	54	27	53

Notes: Ordinary least squares regressions. * p<0.1; ** p<0.05; *** p<0.01. Robust standard errors are in brackets. "Rate of depreciation against the USD" refers to three-year average of the rates of depreciation against the USD.

Source: authors' estimates.

5.7 The impacts of the interest rate and the exchange rates

It has been suggested that the composition of FX reserves could **respond** to the level of domestic interest rates, depreciation of the domestic currency or the level of

domestic inflation. Central banks with high domestic interest rates might find it very costly to hold reserves “financed” in some sense by domestic liabilities (Genberg et al (2005), Borio et al (2008); McCauley (2008); Jeanne and Rancière (2011)). They might reach for yield or at least try to avoid negative yields on offer in the euro or the yen.

However, the interest rate differentials between the domestic country and the US do not enter the estimation significantly (Columns (3) and (4) of Table 9), while leaving the other estimates intact. This result also holds for the euro share estimation (not reported).

It has also been suggested that an economy suffering a depreciating currency might hold more dollars. This might occur owing to the risk of encountering macroeconomic or financial instability (especially when it is indebted largely in the USD), against which holding USD liquid reserves might seem advisable. In the event, the rate of depreciation against the USD (ie, positive values indicate domestic currency depreciation) contributes positively to the dollar share in the large sample (Columns (5) and (6)).²⁷ This exchange rate impact survives even when both interest rate differentials and the USD exchange rate change are included in the estimation (Column (8)).

When a measure for the inflation differential with respect to the United States is included in the estimation in place of the interest rate differential or the rate of depreciation, its estimated coefficient is consistently significantly positive across different estimation models (not reported). When the same exercise is done for the euro share, the estimate is negative, mostly significantly so. Again, a country with macroeconomic or financial instability tends to have a higher USD share in its FX reserves.

5.8 The impacts of financial development and openness

Countries with less sophisticated financial markets may tend to hold more dollar-denominated FX reserves if these are “introductory” or default assets for reserve managers. Likewise, economies with capital controls tend to have less sophisticated financial markets (Chinn and Ito (2006)) and may hold a larger share of dollars. Thus, as a country develops and liberalises its financial markets, it may diversify its FX reserves into non-dollar currencies. Hence, greater financial development or openness may line up with a lower dollar share in FX reserves.

Greater financial development, which we measure with the IMF index on financial development (Sahay et al (2015)),²⁸ does not have any impact on the USD share in FX reserves, however (columns (9) and (10) of Table 9).²⁹ Greater financial openness, based on the Chinn and Ito (2006, 2008, updates) index, does lead to a smaller USD

²⁷ In the euro share estimation, the rate of depreciation is found to be a significantly negative factor in the estimation with the large sample.

²⁸ This index is based on measures of depth, access and efficiency of financial institutions and markets. Higher values of this index indicate more developed financial markets.

²⁹ The impact of financial development on the EUR share is found to be positive, often significantly so when the euro currency weight is not included in the estimation.

share. The negative impact remains even when we control for financial development.³⁰

This result is different from Eichengreen and Mathieson's (2000) who find the positive relationship between capital account openness and the USD and GBP shares in FX reserves. They argue that capital account openness "works to the advantage of the countries with particularly active international financial markets". Considering that financial globalisation after the millennium yielded many active financial centres (as shown in Lane and Milesi-Ferretti (2017)), such a positive impact of financial openness does not confine itself to New York or London. Rather, financial globalisation may have led to more portfolio diversification in reserve management and consequently to a lower USD share in FX reserves.

Previously, we found that reserve managers of a country with ample FX reserves do not decrease the USD share, but might increase the EUR share. We now find the negative contribution of financial openness to the USD share in FX reserves. An economy with more open financial markets may hold more foreign reserves for precautionary reasons (Aizenman and Lee (2007)), which may lead the impact of financial openness to spuriously reflect the size of foreign reserves, or vice versa. Including both financial openness and foreign reserves in the estimation model still retains the significantly negative effect of financial openness (Columns (15) and (16)).

6. Conclusions

As researchers and commentators have revived interest in issues related to international currencies in recent years, they usually find that the dollar dominance continues as if the post-WWII international monetary system remains intact. When they embark on research on the predominance of the dollar in FX reserves, they quickly encounter severe data limitations that impede empirical analysis. We attempt to remove this impediment by compiling a dataset from annual reports, financial statements, and other relevant documents of the central banks across the world. We arrive at dataset on the currency composition of FX reserves for 58 economies in the last two decades. Using this, we are able to construct some sturdy results.

The share of the dollar in FX reserves is higher where the domestic currency varies less against the dollar than against other key currencies. Why? If a currency varies less against the dollar than against other key currencies, then a reserve portfolio with a substantial dollar share poses less risk when returns are measured in domestic currency. If a larger share of trade is denominated in the USD, the USD share in FX reserves tends to be higher as well.

A remaining question for research is whether dollarisation or euroisation of the domestic banking system tilts to the holding of FX reserves toward the dollar or the euro. A central bank that may be called upon to serve as lender of last resort in one or the other key currency may hold more of it than might be indicated by the co-movement of its currency or its trade invoicing.

³⁰ The impact of financial openness on the EUR share is significantly positive in most of the estimation models.

Although long-shrouded in secrecy, the currency composition of FX reserves has emerged into the light in a fair fraction of economies. Now, the spottiness of data on currency invoicing of trade constrains the analysis of the interaction of various uses of international currencies. We understand that the ECB and the IMF are working together to improve the data on currency invoicing of trade. Reserve managers around the world can only cheer such efforts.

Annex 1: The variance minimising reserve portfolio³¹

This annex shows that if the domestic currency serves as the numeraire for the FX reserve portfolio, then a portfolio composition that matches the Frankel-Wei weights for the domestic currency minimises the portfolio variance.³² We abstract from the returns on FX reserve assets so that only exchange rates determine the value of the FX reserve portfolio. Thus, we abstract from the allocation of FX reserves across instruments of varying duration, credit and liquidity risk, an important topic in its own right (Genberg et al (2005), Borio et al (2008); McCauley (2019)). We also neglect any tranching of the FX reserve portfolio into eg liquidity and investment portfolios and the influence it may exert on the currency composition choice (Lu and Wang (2019)).

Survey evidence points to the increasing importance of the domestic currency as the numeraire for central bank reserve management (Borio et al (2008); McCauley (2008)). This allows valuation gains and losses on the FX reserves to be systematically included in the central bank's profit and losses. Often these results in turn feed into the government's budget—eg, in Switzerland, into even cantonal budgets. The numeraire strongly influences optimal currency shares (Papaioannou et al (2006)).

Consider the simplest case of domestic currency X, which moves shares the euro's movement against the dollar according to equation A1:

$$(A1) \quad \% \Delta \left(\frac{X}{USD} \right) = B \cdot \% \Delta \left(\frac{EUR}{USD} \right)$$

The FX reserve manager chooses weights for the portfolio P, A for the USD share and (1-A) for the euro share. Given equation A1, the return, r_P , on the portfolio is in currency X is given by equation A2:

$$(A2) \quad r_P = A \cdot \% \Delta \left(\frac{USD}{X} \right) + (1 - A) \cdot \% \Delta \left(\frac{EUR}{X} \right)$$

Note the following:

$$(A3) \quad \% \Delta \left(\frac{USD}{X} \right) = -\% \Delta \left(\frac{X}{USD} \right) \text{ and}$$

$$(A4) \quad \% \Delta \left(\frac{EUR}{X} \right) = \% \Delta \left(\frac{EUR}{USD} \right) + \% \Delta \left(\frac{USD}{X} \right) = \% \Delta \left(\frac{EUR}{USD} \right) - \% \Delta \left(\frac{X}{USD} \right)$$

Substituting (A1), (A3) and (A4) into (A2):

$$\begin{aligned} r_P &= A \cdot \% \Delta \left(\frac{USD}{X} \right) + (1 - A) \cdot \% \Delta \left(\frac{EUR}{X} \right) \\ &= A \cdot \left\{ -B \cdot \% \Delta \left(\frac{EUR}{USD} \right) \right\} + (1 - A) \cdot \left\{ \% \Delta \left(\frac{EUR}{USD} \right) - B \cdot \% \Delta \left(\frac{EUR}{USD} \right) \right\} \\ (A5) \quad r_P &= (1 - A - B) \cdot \% \Delta \left(\frac{EUR}{USD} \right) \end{aligned}$$

Taking the variance:

$$(A6) \quad var(r_P) = (1 - A - B)^2 \times var \left(\% \Delta \left(\frac{EUR}{USD} \right) \right)$$

This is minimised (abstracting from A1's error term, is zero) when $A = 1 - B$. In words, matching the reserve shares to the Frankel-Wei weights of the domestic currency with respect to the key currencies minimises the variance of the returns on the FX reserve portfolio.

³¹ We thank Larry Kreicher for help with this Annex.

³² See William White in Genberg et al (2015), pp 91-92.

Annex 2: Country list (58 economies)

Asia & Pacific (11): Australia^{AE}, Bangladesh^{EME}, China^{EME}, Hong Kong SAR, China^{AE}, India^{EME}, Korea, Rep.^{AE}, New Zealand^{AE}, Papua New Guinea, Philippines^{EME}, Sri Lanka, Taiwan, China^{AE}

Western Europe (6): Denmark^{AE}, Iceland^{AE}, Norway^{AE}, Sweden^{AE}, Switzerland^{AE}, United Kingdom^{AE}

Eastern Europe and Central Asia (17): Azerbaijan, Bosnia and Herzegovina, Bulgaria^{EME}, Croatia, Czech Republic^{AE}, Georgia, Kazakhstan, Kyrgyz Republic, Macedonia, Moldova, Poland^{EME}, Romania^{EME}, Russian Federation^{EME}, Serbia, Tajikistan, Turkey^{EME}, Ukraine^{EME}

West Hemisphere (12): Argentina^{EME}, Bolivia, Brazil^{EME}, Canada^{AE}, Chile^{EME}, Colombia^{EME}, Costa Rica, Ecuador, Paraguay, Peru^{EME}, Uruguay, Venezuela, RB^{EME}

Africa and Middle East (12): Ghana, Israel^{AE}, Kenya, Malawi, Mozambique, Namibia, Nigeria, South Africa^{EME}, Tanzania, Tunisia, Uganda, Zambia

Notes: "AE" stands for "advanced economies" whereas "EME" stands for emerging market economies. The definitions are based on the IMF categorisation.

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