Do central banks rebalance their currency shares?

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Abstract

Do central banks rebalance their currency shares? We explore this question by using different types of datasets from the global aggregated level, the country-level, and a panel context. At the disaggregate level, we find a mixed bag; some economies do rebalance while others do not. However, our casual analysis show that the US does not rebalance. Switzerland, a no-G3 advanced economy, does seem to rebalance FX reserves. Its currency composition is independent of the dollar exchange rate movements. We also explore the question of rebalancing with a panel data analysis and find that our sample economies on average do not rebalance. Emerging market economies (EMEs) do not rebalance and advanced economies do rebalance. Larger economies maintain stable currency composition while smaller economies have their reserves more vulnerable to exchange rate shocks.

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1. Introduction

Do central banks rebalance their currency shares? Or, should they? Does the size of reserves, the transparency of the reserve portfolio, or the existence of a currency board matter for the answers? Do or should central banks rebalance less when strains hit financial markets?

Reserve managers must answer such questions given movements in the dollar (USD) against the euro, the yen, the pound sterling, the Swiss franc, the Canadian and Australian dollars, and most recently the renminbi. Yet economists have paid little attention to these questions even ifas reserve holdings grew rapidly in the 2000s, Blanchard et al, (2005) resurrected portfolio balance theory to analyze the effects on the euro/dollar rate of a change in China's reserve allocation. What is the baseline behavior from which some momentous re-allocation should be measured?

Instability of private portfolio behavior was of course the subject of Kindleberger's (1937) thesis, the theme of Nurkse (1944), and the elephant in the room ignored by proponents of floating exchange rates (Friedman,1953, 1968; Johnson, 1969). Between the Wars, Młynarski (1929) warned of instability in *official* currency allocations; Eichengreen and Flandreau (2007) demonstrated such instability in the 1930s. Triffin (1960) updated Młynarski's warning for Bretton Woods (Bordo and McCauley, 2019) and sterling's decline demonstrated such instability in the 1960s and 1970s (Schenk, 2003). Proponents of a substitution account in 1979-80 sought to pre-empt such instability by replacing officially held dollars with International Monetary Fund (IMF) Special Drawing Rights (SDRs) (McCauley and Schenk, 2011).

We follow Williams (1934, 1937, 1944) and Kindleberger (Mehrling, forthcoming) in distinguishing the behavior of the central banks that manage key currencies from their 100+ counterparts. The Fed, the Euro-system, and the Bank of Japan hold official foreign exchange reserves to manage the system, both exchange rates and wholesale funding liquidity.

For the rest, liquidity considerations may motivate holding disproportionate amounts of

dollars matching the vehicle currency in the largely private spot FX market (BIS (2019)). In all but Japan, the United Kingdom, Switzerland, Sweden, Poland, and a handful of other European countries, the authorities have little choice but to intervene using the dollar.

But as reserves grow, central banks tend to come to the view that they represent a portfolio to be managed as such. Reserves are often split into liquidity and investment tranches (Borio et al., 2008). Means-variance optimization and eclectic methods guide the latter's allocation (Frankel, 1985; Ramaswamy, 2008). Depending on central bank transparency, reserve managers report and defend their allocations to senior management, the central bank board, the legislature or the public.

FX moves typically do not change whatever reasoning produced an allocation deemed optimal. Chinn and Frankel (2005) argue that rebalancing should be taken as the norm. The exception would be elastic expectations, which conclude that a strengthening dollar is more likely to continue to do so. Given long dollar swings (Engel and Hamilton, 1990; Kreicher and McCauley, 2021), such expectations cannot be dismissed put of hand. A reserve manager judged on annual results might not safely assume a random walk.

Central bank rebalancing matters because it can stabilise key FX rates. When the dollar rises, do central banks sell it? When the dollar falls, do central banks buy it? If so, they counter the widespread momentum-following FX strategy of leveraged commodity ("CTA") funds and others (Neely et al. 2009; Menkhoff et al., 2012: Moskowitz et al., 2012; Ivanova, et al. 2021).

We connect with research on the relationship of private equity portfolio rebalancing and exchange rates. Hau and Rey (2006), Cappiello and De Santis (2005, 2007) and Camanho et al. (2020) posit that global investors rebalance symmetrically in response to own-currency equity movements and currency movements, but Curcuru, et al. (2014) find that US investors do not stabilise FX rates by rebalancing after FX movements. Recognising widespread currency hedging of international equity holdings (Borio et al., 2017), Melvin and Prins (2015) show that equity

gains lead index-tracking investors simultaneously to sell the currency forward, depreciating it.

We examine several factors that may shape reserve managers' response to FX changes:

- **Regime:** A currency board like Hong Kong may feature a backing portfolio in the currency of the link (ie $) that is not subject to rebalancing, so rebalancing is at most partial.
- **Scale of FX reserves**: Larger reserves are likely to be managed as an endowment rather than as a liquid pool (even if there are matching interest-bearing liabilities). Optimisation and rebalancing become more likely with greater size (Beck and Weber, 2011).
- **Scale of the change of FX reserves**: On the upside, there may be lags in the reinvestment from the intervention currency (usually the dollar) into other key currencies.[1] So very rapid growth in the reserves may see partial rebalancing quarter by quarter. On the downside, a reserve drawdown requires purchase of the intervention currency with other key currencies, and this rebalancing too may lag, particularly if the drawdown is rapid.
- **Market volatility:** If reserve managers seek to rebalance without the order flow's disturbing key FX rates (eg dollar/euro), then strained markets may inhibit or at least slow the rebalancing (Fischer et al., 2021).[2] Think 2008Q4 or 2020Q1.
- **Dollar trend**: A long dollar upswing (Engle and Hamilton, 1990; Kreicher and McCauley, 2021) may lead to a larger dollar weight in the strategic asset allocation. This was reported to have been the case at Governor Rajan's Reserve Bank of India in 2015 (Sarin and Singh, 2015). Such a choice may be more likely when euro yields are negative, given the reserve manager's capital-preservation mandate (Borio et al., 2008; Schanz, 2019). By the same token, in a long dollar downswing, a big reserve holder whose diversification could move

[1] See Gerlach-Kristen et al. (2016) on the similar lag between the Japanese Ministry of Finance (MoF) buying dollars and its investing them in US Treasury securities.

[2] Or central banks may follow the advice of Harvey et al. (2021) and not rebalance in volatile markets if exchange rate changes are perceived to have momentum, so that delaying rebalancing is profitable.

dollar/euro (Blanchard et al., 2005) may do so opportunistically by not rebalancing.

The main findings of this paper are four. First, the key currency perspective does not mislead: at least one of the G3 central banks[3] does not rebalance, consistent with its role as manager rather than participant in the international monetary and financial system.

Second, we find a mixed bag at the aggregate level. While an appreciating dollar does significantly raise the USD share in FX reserves, the rise is also significantly less than what would find if no central bank were rebalancing. In other words, some central banks reporting in the IMF currency composition of official FX reserves (COFER) database rebalance and some don't.

Third, major non-G3 reserve holders tend to rebalance FX reserves. This behaviour stabilizes key FX rates as the appreciating currency is sold in favor of the depreciating one.

Fourth, many emerging market economies (EMEs) do not rebalance but the big holders do.

The rest of this paper is in four parts. In Section 2, we analyse aggregate rebalancing, using the COFER database. In Section 3, we focus on the reserve management of two well-reported reserve holders, the United States and the Swiss National Bank (SNB; Streit and Muhl, 2020). Section 4 widens the scope to panel analysis of more than 50 countries using the dataset of Ito and McCauley (2020) to shed light on reserve managers' rebalancing. In Section 5, we conclude.

2. The big picture of reserve management –rebalancing or not?

We start our analysis with an overview of the use of major international currencies as reserve currencies. For that, the COFER database is useful.

Figure 1 illustrates the USD is clearly the dominant reserve currency, followed only by EUR but with a large margin. From 1999 through 2014, the USD share was on a moderately declining

[3] For ease of exposition, we shall write as if FX reserves are held in central banks. In fact, the Japanese MoF holds almost all of Japan's $1 trillion in FX reserves and the US Treasury and the Fed split US FX reserves more evenly. We do not analyse how various institutional arrangements affect rebalancing behaviour.

trend, falling from 72% to 60%. The share rises in 2015 and falls again afterwards.[4] The development of the EUR share is a mirror image of that of the USD share. The EUR share is in a moderately rising trend from the beginning of the sample period up to 2010, rising from less than 20% to 28%, after which the EUR share slowly declines to 2015. Since then, the share has been constant at 20%.

The JPY and GBP come in a distant third, with shares hovering around at less than 5%.

Figure 2 displays the development of the shares of USD and EUR, and the respective currencies' shares without the valuation effects – the USD and EUR shares are recalculated using only the exchange rates of all the reported currencies as of 1999Q1. Once the valuation effects are removed, the two shares are more stable than the observed currency shares from the COFER database that incorporate the exchange rate movements. That indicates that the decline in the USD share (especially since 2003) is mainly driven by the exchange rate movements, i.e., dollar depreciation.[5] As far as these data are concerned, central banks in the world, as an aggregate, do not rebalance their currency shares.

Figure 3(a) zooms into the USD shares – with and without the valuation effects – and compare them with the US nominal effective exchange rates (US-NEER). Both USD shares with and without the valuation effects have been slowly declining, but Table 1, which shows the estimation results of regressing the USD shares with or without the valuation effects on a time trend, indicates that the trend decline is statistically steeper in the USD share with the valuation effects than those without (columns (1) and (2)). From the US-NEER shown in Figure 3(b), the whole sample period contains three structural break points: 2002Q1, 2011Q3, and 2020Q2. In

[4] The rise may be a statistical artifact due to the entry of China's renminbi for the reporting in the COFER database. However, the RMB series start in 2016, which does not seem to coincide with the rise in the USD share in 2015.
[5] Conversely, the moderate rising trend in the EUR share is mainly due to the appreciation of the EUR in that period. Once the valuation effect is removed, the EUR share becomes trendless (Figure 6).

2002Q1 – 2011Q3, while the USD share with the valuation effect is in a declining trend, once the valuation effects are removed, the USD share is constant (columns (3) and (4)). In Table 2, we regress the USD share with or without valuation effects on US-NEER, and see that in the full sample period and the 2002Q1 – 2011Q3 subsample period, the USD share with valuation effects is positively correlated with US-NEER whereas the USD share without valuation effects is negatively correlated with US-NEER, though with much smaller magnitudes. All these findings suggest that that, especially in the 2002Q1 – 2011Q3 subsample, the declining trend of the USD share (blue solid line in Figure 2) is mainly due to dollar depreciation. Once the impact of the change in the dollar value is removed (dotted blue line), the declining trend of USD essentially disappears. The fact that the USD share (with valuation effects) was in a declining trend when the dollar was in a depreciation trend indicates that, in the aggregate, reserve managers, when observing dollar depreciation, were *not* rebalancing their portfolio, but letting the USD share fall instead.

During the period 2011Q3 – 2020Q2, the dollar is on a rising trend. However, even with the rising dollar value, the dollar share remains statistically constant (column (5) of Table 1), and interestingly, the USD share without evaluation effects was on a declining trend. That the USD share with valuation effects remains constant while the dollar is in an appreciating trend suggest that reserve managers were rebalancing to maintain the constant USD share. The correlation between US-NEER and the USD share without valuation effects is found to be significantly negative. That means, there are some forces that led the USD share (net of the exchange rate impacts) to decline.

Now, let us conduct a more formal analysis by estimating the valuation effect of the dollar on the USD share in the foreign exchange (FX) reserves using the aggregate COFER data.

We are interested in examining the impacts of the exchange rate movements on the share of

the USD, in the cases of portfolios for FX reserves. Considering that exchange rate movements reflect changes in the economic conditions as well as policy changes, this investigation is essentially about whether reserve managers respond to changes in economic conditions and policy. Despite a change in the foreign exchange rate, reserve fund managers might try to maintain a certain currency composition by rebalancing the reserve portfolio or let the currency composition change by not rebalancing the currency composition.

For that, we construct a variable called Val_Eff_{USD}, which represents the valuation effect of the dollar. The USD share in FX reserves changes depends on both the movements of the exchange rates of the dollar against the other currencies and the change in the quantity of reserves in different currencies. The valuation effect of the dollar using the COFER data can be expressed as follows:

$$Val\_Eff_{USD}^{COFER} = \frac{\mathrm{R}_{USD}(\mathrm{t}-1)}{\sum_C^C \frac{\mathrm{R}_C(\mathrm{t}-1)}{FX_C(t)}} - \frac{\mathrm{R}_{USD}(\mathrm{t}-1)}{\sum_C^C \frac{\mathrm{R}_C(\mathrm{t}-1)}{FX_C(t-1)}} \qquad (1).^{6}$$

R_c is foreign exchange reserves in major currency *c,* which we obtain from the COFER database. That is, R_{USD} is FX reserves in USD, R_{JPY} is FX reserves in the Japanese yen, and so forth. Non-USD reserves, $R_{c,c\neq USD}$, needs to be converted to USD by using the exchange rate of currency *c* per dollar. Hence, $\frac{\mathrm{R}_c(t)}{FX_c(t)}$ is the FX reserves that were originally denominated in *c*, but now converted to USD. In equation (1), while the first term succeeds the second term by one time period (i.e., the exchange rate $(FX_c(t))$ is updated from the previous period's exchange rate $(FX_c(t-1))$, R_{USD} and R_c are not. We are only interested in the valuation effect that happens when

[6] More generally, the valuation effect of major currency *c* is: $Val\_Eff_c^{COFER} = \frac{\frac{R_C(\mathrm{t}-1)}{FX_C(t)}}{\sum_C^C \frac{\mathrm{R}_C(\mathrm{t}-1)}{FX_C(t)}} - \frac{\frac{\mathrm{R}_C(\mathrm{t}-1)}{FX_C(t-1)}}{\sum_C^C \frac{\mathrm{R}_C(\mathrm{t}-1)}{FX_C(t-1)}}$.

the exchange rate move, but keeps the "quantity" of reserves in each major currency c in its local currency constant. By subtracting the observed USD share (the second term in equation (1)) from the USD share that only incorporates the exchange rate change (not the quantum of the reserve currencies), we obtain $Val\_Eff_{USD}^{COFER}$.

We are interested in examining whether and how the valuation effect, $Val\_Eff_{USD}^{COFER}$, affects the USD share from the COFER database by regressing the latter on the former. If the estimated coefficient on $Val\_Eff_{USD}^{COFER}$ is found to be one, that would mean that reserve managers let the USD reserve share change following the exchange rate movements with a 1:1 ratio, which therefore does not involve rebalancing. In contrast, if the estimated coefficient is found to be zero, that implies reserve managers maintain the USD reserve share constant by rebalancing the reserve portfolio.

The estimation results reported in Table 3 show that the estimated coefficient of $Val\_Eff_{USD}^{COFER}$ across different models is significantly positive, but less than one across different models. When the null hypothesis of $\beta(VE)$=1 is tested, , it is rejected at statistically significant levels in all cases but Model 3, indicating that the estimate of the valuation effect variable is less than one.[7] That means that overall, countries conduct partial rebalancing. This finding is not surprising that the aggregate data reflects the average characteristics of countries, some of which may rebalance and others of which may not.

We also test the growth rates of total reserve assets net of the exchange rate effects.[8] Its estimate is found to be significantly positive. That suggests that when the entire portfolio grows, the USD share rises, indicating that the USD is an intervention currency. When the portfolio grows

[7] The p-value is reported at the bottom row of the table.

[8] "Total reserve assets" are "allocated reserves in dollars" in the COFER database. The way of removing the valuation effects is analogous to equation (1). Here, instead of maintaining the volumes of local currency reserves constant, we hold the exchange rate constant over the consecutive quarters and let the local currency reserves vary.

larger, there must be a disproportionally larger increase in USD-denominated reserves, because much of FX interventions are done using the USD. This is another piece of evidence that the USD is the dominant international currency. It also reflects that the markets for converting from a third, non-major currency to another third currency are not sufficiently thick, so cross-currency transactions almost inevitably involve USD.

In model 3, we test whether there is any interactive effect between the value effect variable and the growth rate of the reserve portfolio, and find the estimate is significantly negative. That indicates that the valuation effect positively affects the USD share in FX reserves, but its impact is smaller when the reserve portfolio is expanding rapidly.

When the economy of concern faces economic uncertainty, the respective central banks' reserve managers may decide to hold more USD-denominated assets as a buffer to a possibly forthcoming adverse event. If that is the case, an occurrence of financial instability can lead to a higher USD share in their reserve portfolio. The correlation between the USD and the VIX index which we treat as a proxy to financial instability, is then predicted to be positive.

Or, when the level of economic uncertainty rises, reserve managers may try to convert USD-denominated assets into nonfinancial assets, in which case the USD share is predicted to be negatively correlated with the VIX index.

In model 4, we include the natural log of VIX in the estimation. Its estimate is found to be positive, but not statistically significant while the estimate on $Val\_Eff_{USD}^{COFER}$ is still significantly positive. In model 5, we test if there is any interactive effect between the VIX and the value effect variable, and find the interactive effect is significantly positive. The valuation effect is stronger when there is global financial instability.

In Figure 3, we saw that when the dollar was in a depreciating trend from 2002 to 2011, the USD shares were more reflective of the depreciation trend. From 2012 to 2020, however, the dollar

appreciation did not involve higher USD shares. Model 6 includes the dummy for the subsample periods of 1997Q1-2002q1 and 2011Q3-2020Q1, in both of which the dollar appreciated against main trading partners. We test this more formally and find that when the dollar appreciates, the USD reserve share tends to be higher, but the impact is not statistically significant (column (6)). In column (7), we interact the dummy variable with $Val\_Eff_{USD}^{COFER}$; that does not yield a significant estimate for the interaction term.

3. Case studies with rich data – US and Swiss reserve management

Now, we take a closer look at reserve management by focusing on two country case studies. Both the US and Swiss central banks disclose detailed information regarding the reserve portfolio on a quarterly basis. This section treats the US data in summary fashion to establish that its value moves with the dollar. For Switzerland, we essentially repeat the same exercise as we did in the last subsection to determine whether SNB's reserve management differs from the aggregate.

Figure 4 shows how US foreign exchange reserves evaluated in dollar mirrors the dollar's effective exchange rate. FRBNY (2021, p 15) ascribes the changes in euro holdings of $1.1 billion and yen holdings of $0.4 billion, as usual, to FX rate changes: "These changes are largely driven by foreign exchange translation effects" in the context of a depreciating dollar. The inverse relationship is striking even though the reserves are invested only in euro and yen (59%-41% at end-2020 FX rates), while even the narrow BIS effective dollar puts considerable weight on the Canadian dollar and pound sterling. The graph begins in October 2000, the month following the US intervention in support of the euro. There is only one intervention in the 20+ years shown, in March 2011 after the Tohuku earthquake in Japan, when the US joined with the Japanese Ministry of Finance, the ECB, the Bank of Canada and the Bank of England in selling yen (Sack and McNeil, 2011; Neely, 2011). The strong inverse relationship between the dollar's value against major

currencies and the dollar value of US reserves suggests a static portfolio of X euros and Y yen subject to valuation effects.

In the period shown, there were big swings in then euro/yen rate that manifest themselves as big swings in the currency allocation of US reserves, consistent with **no rebalancing.** The euro peaked against the yen at 168 yen per euro in June 2008, and troughed at 99 yen per euro in June 2012, in the wake of the European sovereign debt crisis. In June 2008 the US reserve portfolio consisted of 63.8% euro and 36.2% yen. In June 2012, it consisted of 53.9% euro and 46.1% yen. The US authorities do not rebalance in the face of big swings in the euro/yen.

Turning now to Switzerland, Figure 5 illustrates the development of the major currency shares in SNB's FX reserves since 2005Q1 through 2020Q4.[9]

Interestingly, the share of the USD appears to be roughly stable from 2005Q1 through 2015Q1, hovering 26-28%, though there are two spikes down, one in 2010Q1-Q2 when the Greek debt crisis broke out and the other in 2012Q2 when President of the European Central Bank Mario Draghi made the "whatever it takes" comment in July 2012. In the beginning of 2015, after ending the exchange rate peg policy against the euro, the USD share gradually rises, getting closer to 40%. For the last five years, it is stabilized around 35-37%.[10]

SNB reports the shares of JPY, GBP, and CAD, but as was in the case of the aggregate picture based on the COFER dataset, none of these currencies appear to be a third dominant

[9] From the SNB's website, we use the data "Foreign currency investments, including derivatives, excluding foreign exchange swaps for monetary policy purposes." There is another data series called "Foreign currency investments, excluding foreign exchange derivatives" and its time series starts in 1997Q1. However, the latter include spot positions in the dollar and euro that result from swaps done for monetary policy purposes. In particular, faced with a small domestic money market but a large FX market, the SNB often swaps CHF against USD to provide domestic bank reserves. This increases its holdings of USD, but not its USD exposure. Thus, of more interest from a reserve management perspective are the SNB's FX holdings excluding swaps.

[10] The EUR share has a mirror image. It peaks at 70% in 2010Q1 and again at 60% in 2012Q1, after which, however, the EUR share consistently falls. For the last few years of the sample, it marks around 40%.

currency.

How do the SNB reserve managers respond to movements in the key currency exchange rates? As in Table 3, we first construct $Val\_Eff_{USD}^{SNB}$ by using the SNB's data for the currency shares and reserve assets. We regress the USD share on $Val\_Eff_{USD}^{SNB}$ and report the results in Table 4.[11]

The estimation results suggest that rebalancing is very much the norm at the SNB. The coefficient on the constructed valuation change is consistently insignificant. Rapid growth of the SNB's reserves is associated with a lower dollar share (second row).[12] This finding is consistent with the SNB's interveningin the spot FX market to buy euro and then rebalancing by buying dollars only with a lag. In particular, if the SNB sought to minimise the effect on the euro/dollar rate of such rebalancing, it could have used algorithmic trading to dribble orders into EBS. But this would introduce lags, especially if euro-buying were heavy at end-quarter.

Stepping back, the contrast between the US and Swiss reserve management in the face of exchange rate changes could hardly be more stark. The US Treasury and Fed hold a certain number of euros and yen and, scant interest earnings aside, hold them from quarter to quarter. This means that the share of euro and yen in the US reserve portfolio drifts with the euro/yen exchange rate. By contrast, the SNB has (varying) targets for the dollar and euro portions of its reserves. Exceptional growth in those reserves apart, it serves as a source of stability in the FX market by selling a rising dollar and buying a falling dollar.

4. Testing the valuation effects on the USD share in the panel context

[11] It must be noted that because there have been apparent policy changes that can affect currency composition, we include the dummies for 2010Q1, 2010Q3, 2015Q1, and 2017Q1. For more details, refer to the Foreign Exchange Investments" section of the relevant years' SNB Annual Reports.

[12] The negative effect of the growth rate of the SNB's reserves is greater when the valuation effect is greater (third row).

We have seen the behavior of partial rebalancing for the global aggregate and that of fuller rebalancing for Switzerland. Naturally, not only does the motivation for holding foreign exchange reserves differ across central banks, but the preferences for reserve currencies should vary across countries. We now attempt to explain the variations in the currency composition of FX reserves both over time and across countries.

Ito and McCauley (2020) investigated the determinants of the shares of major currencies in foreign exchange reserves, but their work is one of the few because of data limitations. The COFER data are reported for either the entire world, the group of industrialized economies, or that of emerging and developing economies, but not for individual countries.[13]

Here, we test the impacts of exchange rate fluctuations on the currency composition in a panel data setting. For that, we first construct the valuation effect variable, $Val\_Eff_{USD}^{IM}$, by using the Ito-McCauley dataset and estimate the impact of $Val\_Eff_{USD}^{IM}$ on the first-difference of the USD shares in FX reserves for 56 countries over the period of 2001 through 2018.

Our sample does not include the US, Japan, or the euro member countries. To control for time invariant factors that may affect the currency composition, we include the country fixed effects in the estimation model.

First of all, the estimate on the valuation effect is significantly positive except for models (7) and (8) (Table 5), with its coefficient ranging around 0.76 to 0.96 and statistically no different from the value of one in most models. That is, *on average,* the impact of the exchange rate movements fully passes through to the USD share in FX reserves with a 1:1 ratio.

The growth rate of the portfolio (net of the valuation effect) positively affects the USD share,

[13] 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.

again suggesting that when the portfolio expands, the volume of USD reserves disproportionally increases, making the USD share rise. This happens because for most of the sample economies, the dollar is the vehicle currency in the spot market. It is evidence that the US dollar is a dominant intervention currency.

We also test other variables such as the percentage point change in VIX, its interaction with the valuation effect, FX reserves minus gold (as % of GDP), and interaction term with the valuation effect. However, none of these variables enter the model significantly.

The US does not actively intervene the FX markets and allows the exchange rate movements to affect the currency composition. In other words, the US does not balance its currency share. Whatever happens to the exchange rate, a large economy like the US may be able to absorb the shocks. We also saw that SNB rebalances and shun the impact of exchange rate movements from affecting the currency composition. However, smaller economies may have access to foreign exchange markets to stabilize the currency composition of the reserve portfolio. Thus, the size of the economy of concern may affect the behavior of rebalancing.

With the prior that the size of the economy may affect the behavior of rebalancing, we conduct the weighted regression methodology while we use the weight based on the the PPP-based income shares of world total.

In model (8), while the growth rate of foreign reserves remains to be a significantly positive contributor to the USD share, the estimate on the valuation effect now becomes insignificant. This finding suggests that larger economies tend to have an insignificant estimate on the valuation effect. That is, larger economies tend to rebalance their portfolio and maintain its currency composition stable, whereas smaller economies do not rebalance.

To test possible heterogeneity across countries, we divide the full sample into the

subsamples of advanced economies (AEs) and emerging market economies (EMEs).[14]

In columns (1) and (2) of Table 6, we see that among AEs, the exchange rate movement does not pass through to the currency composition. These central banks would intervene foreign exchange markets and stabilize their portfolios. In contrast, the estimate on the valuation effect for the EMEs is significantly positive. Also, the estimate is not statistically different than the value of one. This finding indicates EMEs' reserve portfolios are vulnerable to exchange rate shocks.

Interestingly, the estimate coefficient on the growth rate of reserve portfolio is significantly positive for EMEs, but significantly negative for AEs. As has been already discussed, the positive estimate indicates that the US dollar is the vehicle currency for the economies in the sample. The country composition of the subsample in Appendix 2 include many Latin American countries and Asian economies that are highly dollar-oriented economies. In contrast, the AE group is comprised of many large European economies that use the euro as the vehicle currency, such as Denmark, Norway, Poland, Sweden, Switzerland, and the UK. The negative estimate on the portfolio growth reflects that as the size of the portfolio gets larger, there would be a disproportional increase in euro reserves and a disproportional decrease in dollar reserves.

Lastly, we divide the full sample between commodity exports and non-commodity exporters and examine whether there is any difference between the two subsamples in the way how exchange rate movements affect the currency composition.

We find that the estimate of the valuation effect of the commodity exporters is greater in magnitude than that of the non-commodity exporters, though we find the difference is not statistically significant. The greater estimate for the commodity exporters can be explained by the fact that the US dollar is the most dominantly used currency among commodity exporters. Among

[14] Country grouping is based on the definition by the IMF.

the commodity exporters in our sample, Norway is the only country that does not use the US dollar as the vehicle currency. Commodity exporters' reserve portfolio is more subject to the valuation effects than those of non-commodity exporters (though the difference is not statistically significant).

5. Concluding remarks

How do reserve managers respond to exchange rate movements? It sounds like a simple question, but there has not been much academic, empirical research on this issue. This is mainly due to the lack of data.

By using different types of data, we explore the question of how central banks' reserve managers respond to exchange rate movements. Plainly, we focus on the question of whether central banks' reserve managers rebalance their currency shares or not.

The main findings of this paper are four.

First, the US, one of the G3 economies, does not rebalance, consistent with its role as manager rather than participant in the international monetary and financial system. It lets its foreign exchange portfolio fluctuate and reflect exchange rate (e.g., the euro-yen exchange rate) movements.

Second, we find a mixed bag at the aggregate level. Our regression analysis with the COFER data suggests that countries conduct partial rebalancing on average. While an appreciating dollar does significantly raise the USD share in FX reserves, the rise is also significantly less than what would find if no central bank were rebalancing. In other words, some central banks reporting in the IMF COFER database rebalance and some don't.

Third, major non-G3 reserve holders tend to rebalance FX reserves. We examine the case of Switzerland's reserve management and find SNB's reserves do not react to the dollar exchange

rate movements. SNB tries to nullify the impact of economic shocks on its reserve portfolio by rebalancing the currency shares in its reserves. Thus, this behaviour stabilizes key FX rates as the appreciating currency is sold in favor of the depreciating one.

Fourth, many emerging market economies (EMEs) do not rebalance, that means the impact of the exchange rate movements fully passes through to the USD share in FX reserves with 1:1 ratio. Larger economies tend to rebalance. In other words, large economies are capable to maintaining stable currency composition while smaller economies are more vulnerable to exchange rate shocks. Smaller EMEs cannot lean against the fluctuations of exchange rates.

Appendix 1: Data definitions and sources

$Val\_Eff_{USD}^{COFER}$: The valuation effect of the USD, defined as:

$$\frac{\mathrm{R}_{USD}(\mathrm{t}-1)}{\sum_c^C \frac{\mathrm{R}_c(\mathrm{t}-1)}{FX_c(t)}} - \frac{\mathrm{R}_{USD}(\mathrm{t}-1)}{\sum_c^C \frac{\mathrm{R}_c(\mathrm{t}-1)}{FX_c(t-1)}}$$

where R_C is reserves, claimed in major currency c. FX_C is the value of major currency c per dollar. The reserve data are extracted from the IMF's COFER database. The exchange rate data is from the IMF *International Financial Statistics (IFS)*.

$Val\_Eff_{USD}^{SNB}$ is computed in the same way, but uses the data from SNB's database https://data.snb.ch/en/topics/snb#!/cube/snbcurrp.

$Val\_Eff_{USD}^{SNB}$ is analogous to $Val\_Eff_{USD}^{IM}$, but uses the data from Ito and McCauley (2020). Unlike the previous two valuation effects variables, this variable is not only time-variant but also variant across countries.

Total reserve assets net of the exchange rate effects are calculated using the following formula:

$$\frac{\mathrm{R}_{USD}(\mathrm{t})}{\sum_c^C \frac{\mathrm{R}_c(\mathrm{t})}{FX_c(t-1)}} - \frac{\mathrm{R}_{USD}(\mathrm{t}-1)}{\sum_c^C \frac{\mathrm{R}_c(\mathrm{t}-1)}{FX_c(t-1)}}$$

VIX is the Chicago Board Options Exchange's (CBOE) Volatility Index, which is used as the measure of global financial instability. The index is available at: https://www.cboe.com/indices/ .

NEER is the narrow nominal effective exchange rate, published by the Bank for International Settlements (BIS).

IR_G is the variable for FX reserves minus gold as a share of GDP. The data is extracted from the World Bank's *World Development Indicators*.

Appendix 2: Country list (56 economies) for the panel analysis

Asia & Pacific (9): Australia[AE], Bangladesh, Hong Kong SAR, China[AE], India, Korea, Rep.[AE], New Zealand[AE], Papua New Guinea, Philippines, Sri Lanka

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, Croatia, Czech Republic[AE], Georgia, Kazakhstan, Kyrgyz Republic, Macedonia, Moldova, Poland, Romania, Russian Federation, Serbia, Tajikistan, Turkey, Ukraine

West Hemisphere (12): Argentina, Bolivia, Brazil, Canada[AE], Chile, Colombia, Costa Rica, Ecuador, Paraguay, Peru, Uruguay, Venezuela, RB

Africa and Middle East (12): Ghana, Israel[AE], Kenya, Malawi, Mozambique, Namibia, Nigeria, South Africa, Tanzania, Tunisia, Uganda, Zambia

Notes: "AE" stands for "advanced economies" whereas the rest of the countries are "emerging market and developing economies." The definitions are based on the IMF categorisation.

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Table 1: Testing trends in the USD shares

	Full sample		2002Q1 – 2011Q3		2011Q3 – 2020Q1	
	USD share w/ VE (1)	USD share w/out VE (2)	USD share w/ VE (3)	USD share w/out VE (4)	USD share w/ VE (5)	USD share w/out VE (6)
Quarter	-0.106 (0.009)***	-0.063 (0.006)***	-0.185 (0.014)***	0.021 (0.016)	-0.003 (0.028)	-0.155 (0.013)***
N =	88	88	38	39	35	35
Adj R2	0.62	0.60	0.81	0.02	-0.03	0.81

Table 2: Correlation between the USD share w/ or w/out valuation effects and US NEER

	Full sample		2002Q1 – 2011Q3		2011Q3 – 2020Q1	
	USD share w/ VE (1)	USD share w/out VE (2)	USD share w/ VE (3)	USD share w/out VE (4)	USD share w/ VE (5)	USD share w/out VE (6)
US-NEER	0.229 (0.031)***	-0.055 (0.023)**	0.231 (0.017)***	-0.055 (0.018)***	0.050 (0.031)	-0.162 (0.021)***
N =	88	88	38	39	35	35
Adj R2	0.39	0.05	0.84	0.18	0.05	0.64

Table 3: Regression of USD shares on valuation effects, using COFER data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
USD valuation effect (VE)	0.710 (0.062)***	0.724 (0.061)***	0.791 (0.096)***	0.724 (0.061)***	-0.438 (0.575)	0.716 (0.063)***	0.751 (0.080)***
Growth rate of FX assets		0.048 (0.020)**		0.048 (0.021)**	0.051 (0.020)**	0.050 (0.021)**	0.048 (0.021)**
VE x asset growth			-0.034 (0.030)				
VIX in log				0.011 (0.170)			
VE x VIX					0.387 (0.191)**		
NEER apprec. period						0.059 (0.120)	
VE x NEER app							-0.067 (0.129)
N	87	87	87	87	87	87	87
Adj R2	0.60	0.62	0.60	0.62	0.63	0.62	0.62
H0: beta (VE) =1 (p-value)	0.00	0.00	0.03	0.00	0.01	0.00	0.00

Notes: * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 4: Regression of USD shares on valuation effects, using SNB data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
USD valuation effect (VE)	-0.147	-0.099	0.016	-0.111	0.901	-0.106	-0.003
	(0.238)	(0.233)	(0.248)	(0.234)	(1.873)	(0.240)	(0.332)
Growth rate of FX assets		-0.024		-0.027	-0.023	-0.023	-0.023
		(0.012)**		(0.012)**	(0.012)*	(0.012)*	(0.012)*
VE x asset growth			-0.019				
			(0.010)*				
VIX in log				0.474			
				(0.518)			
VE x VIX					-0.338		
					(0.628)		
NEER apprec. period						0.053	
						(0.366)	
VE x NEER app							-0.196
							(0.476)
N	63	63	63	63	63	63	63
Adj R2	0.42	0.45	0.44	0.45	0.44	0.44	0.44
H0: beta (VE) =1 (p-value)	0.00	0.00	0.00	0.00	0.96	0.00	0.00

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$.

Table 5: Determinants of Change in the USD Share in FX Reserves: 2001-2018, using the Ito-McCauley data

	F.E.	F.E.	F.E.	F.E.	F.E.	F.E.	F.E.	WEIGHTED
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
USD Valuation Effect (VE)	0.522	0.788	0.955	0.771	0.763	0.783	0.637	0.153
	(0.258)**	(0.262)***	(0.294)***	(0.263)***	(0.263)***	(0.265)***	(0.435)	(0.203)
Growth rate of FX assets		0.044	0.044	0.044	0.044	0.044	0.044	0.028
		(0.008)***	(0.008)***	(0.008)***	(0.008)***	(0.008)***	(0.008)***	(0.012)**
Growth rate of FX assets x VE			-1.102					
			(0.883)					
Change in VIX				-0.000				0.000
				(0.001)				(0.001)
dVIX x VE					-0.049			
					(0.052)			
FX reserves minus gold						0.005		
(% of GDP)						(0.038)		
FX reserves x VE							0.949	
							(2.185)	
N	733	721	721	721	721	718	718	721
# of countries	56	56	56	56	56	56	56	56
Overall R2	0.01	0.06	0.06	0.06	0.06	0.06	0.06	0.04
W/in R2	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.01
B/w R2	0.10	0.21	0.22	0.21	0.22	0.21	0.22	0.16
H0: beta (VE) =1 (p-value)	0.06	0.42	0.88	0.39	0.37	0.41	0.40	0.00

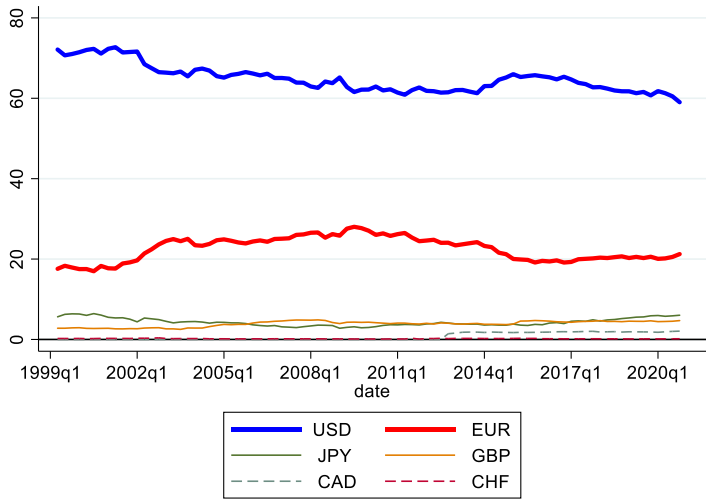
Table 6: Determinants of Change in the USD Share in FX Reserves: 2001-2018

Using the Ito-McCauley dataset, AEs and EMEs

	AEs	EME	COMM	Non-COMM
	(1)	(2)	(3)	(4)
USD Valuation Effect (VE)	-0.135	1.426	1.062	0.655
	(0.294)	(0.353)***	(0.543)*	(0.300)**
Growth rate of FX assets	-0.041	0.057	0.045	0.043
	(0.017)**	(0.010)***	(0.012)***	(0.013)***
Change in VIX	-0.000	-0.000	-0.001	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)
N	178	543	211	510
# of countries	13	43	15	41
Overall R2	0.04	0.10	0.08	0.04
W/in R2	0.04	0.09	0.08	0.03
B/w R2	0.04	0.25	0.14	0.37
H0: beta (VE) =1 (p-value)	0.00	0.23	0.91	510

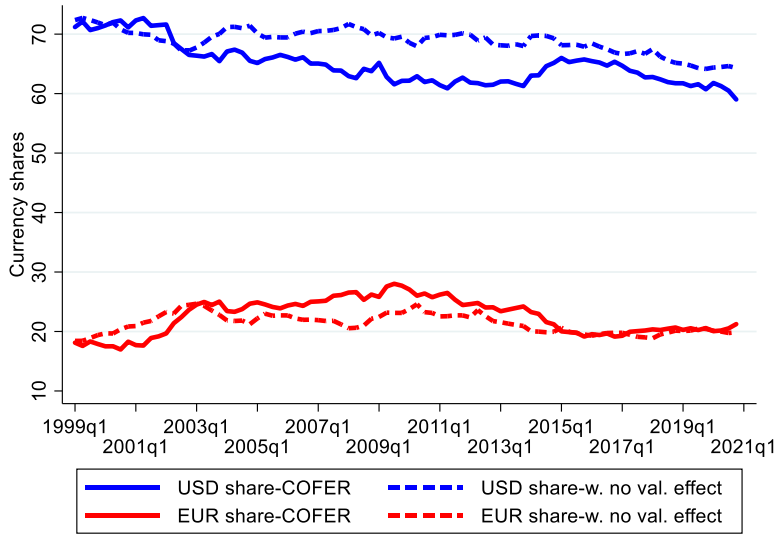
Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Figure 1: Shares of major currencies – COFER dataset



Source: International Monetary Fund (IMF) COFER database

Figure 2: Share of USD and EUR in FX reserves with and without valuation effects



Sources: IMF COFER database and authors' calculations.

Figure 3

(a): Share of USD in FX reserves (COFER) with and without valuation effects

(b): US NEER

Sources: IMF COFER database, BIS, and authors' calculations.

Note: The dotted lines correspond to 2002m2, 2011m7, and 2020m4.

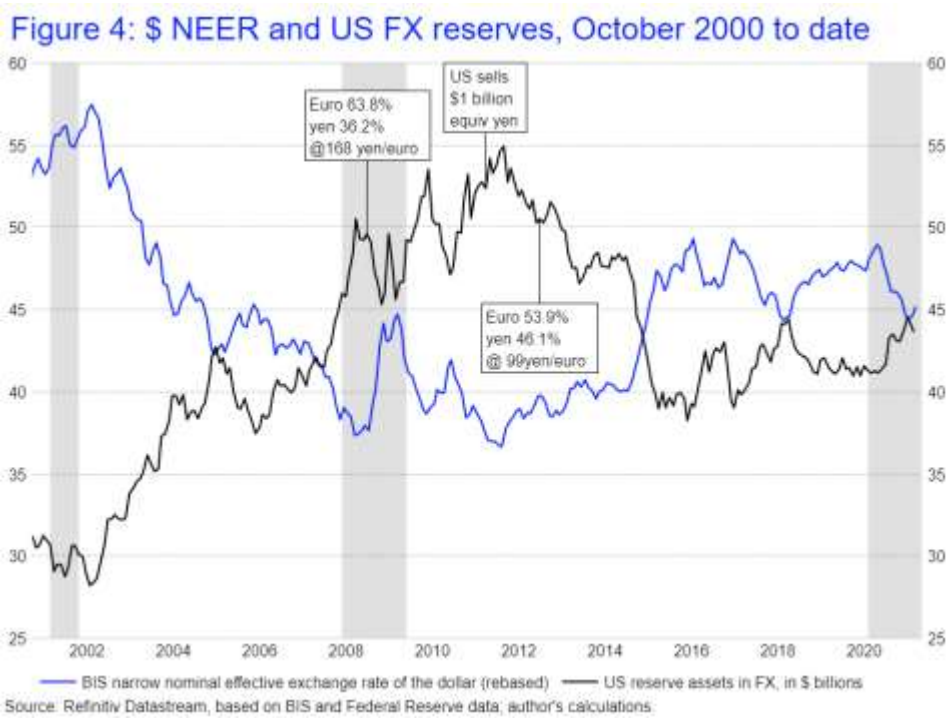
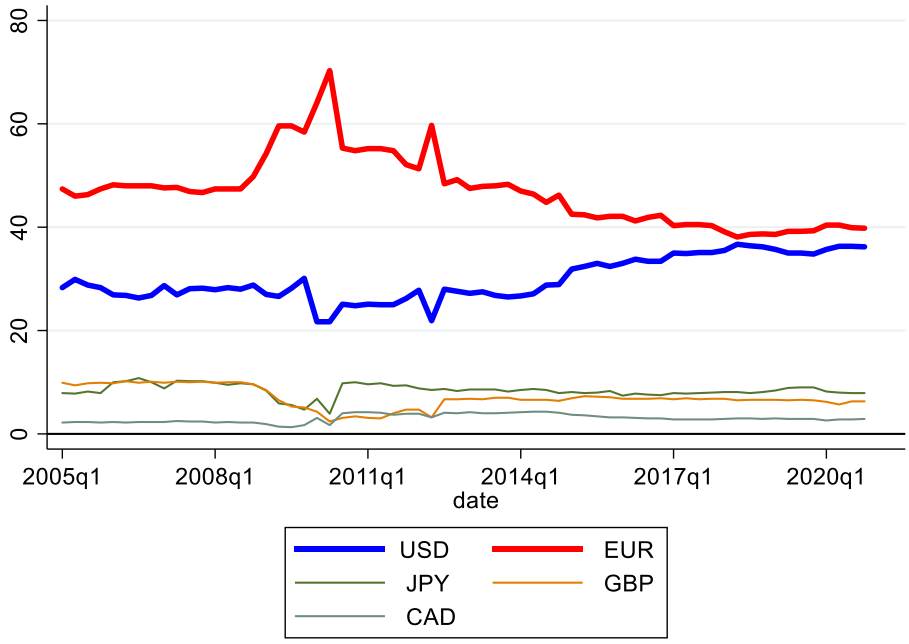


Figure 5: Currency composition of SNB's reserve assets, 1997Q4 – 2020Q4



Source: Swiss National Bank. https://data.snb.ch/en/topics/snb#!/cube/snbcurrp