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ABSTRACT

This paper studies whether countries with larger foreign exchange and gold reserve buffers exhibit smaller exchange-rate responses to US monetary policy surprises. We test a central-bank reserve balance-sheet channel in which large reserve stocks can deter speculative pressure by signaling credible dollar-liquidity capacity, collateral value, and future intervention capacity, even without contemporaneous reserve sales. For identification, we use high-frequency FOMC monetary surprises, minute-level exchange rates, and predetermined reserve holdings for 18 countries. Countries with larger dollar reserves exhibit smaller exchange-rate depreciations after US monetary tightening, while non-dollar reserves do not display the same pattern. Gold reserves are also associated with smaller depreciations. These buffer effects are concentrated in countries without swap and repo lines and are strongest where dollar exposure, especially external dollar liabilities, is larger. The results show that reserve composition and access to dollar liquidity facilities, not only aggregate reserve size, are empirically relevant for exchange-rate resilience.

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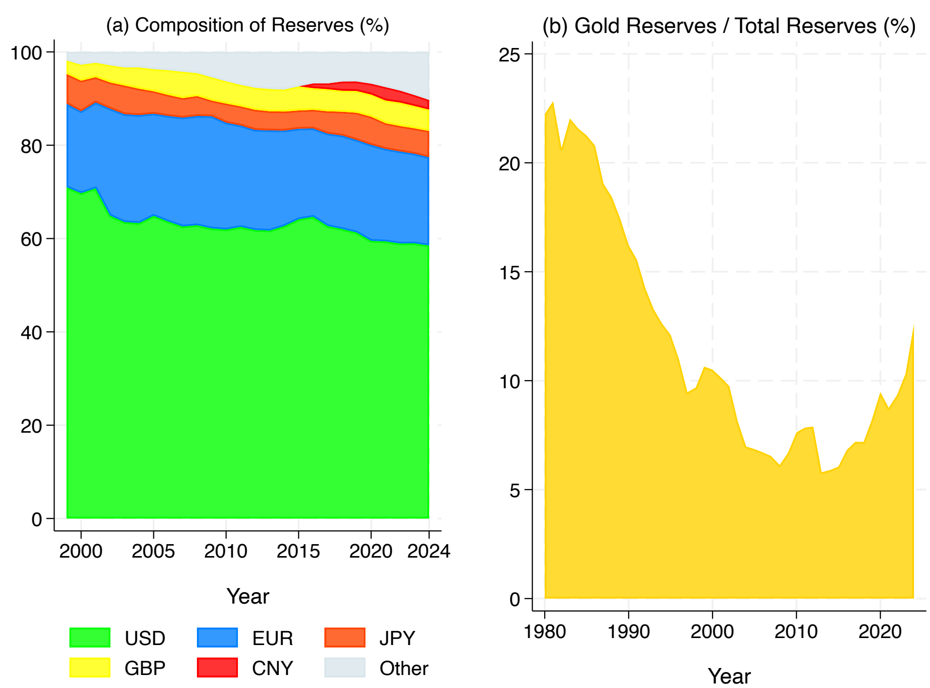
1. Introduction

Reserve managers are confronted with the need to insure against two risks at once. Geopolitical fragmentation has made the legal and political accessibility of reserve assets more salient, while recurrent dollar-funding stress has reinforced the need for assets that can be turned into US dollars immediately. The European Central Bank (ECB) estimates that central banks purchased around 850 tonnes of gold in 2025–below the exceptional pace of 2022-24 but still above historical norms (European Central Bank, 2026). Recent work also documents diversification away from traditional reserve currencies, greater central-bank demand for gold, and increased attention to where gold is held (Arslanalp et al., 2022, 2023, 2026; Arvai et al., 2026; Jiang et al., 2026). However, despite the erosion of the dollar's reserve-currency status, it remains central to international trade and finance (Gopinath et al., 2020; Gopinath and Stein, 2021; Boz et al., 2022). The policy debate is therefore often framed too starkly as "de-dollarisation versus dollar dominance". Fig. 1 illustrates this apparent tension. The dollar remains the largest reserve currency, even as its share of allocated foreign-exchange reserves has trended down, and gold's share of total reserves has recovered from its post-global-financial-crisis trough.[1]

Fig. 1: Dollar and Gold Shares in International Reserves



Note: Panel (a) reports the composition of allocated official FX reserves. Panel (b) reports the market-valued gold share of total official reserves. Data on the Chinese yuan's share is available from 2016 onward. Source: IMF COFER Database, IMF International Financial Statistics, and World Bank.

For central banks, the more practical question is how reserve composition affects resilience when the Federal Reserve surprises markets. US monetary tightening can travel rapidly across borders. Higher dollar returns induce portfolio rebalancing, tighten global financial conditions, and often appreciate the dollar (Rey,

[1] Appendix A reports the volumes of FX and gold reserves, as well as dollar/gold valuation gains in Figs. A.1, A.2, and A.3.

2015; Kalemli-Özcan, 2019; Miranda-Agrippino and Rey, 2020; Akinci and Queralto, 2024). Recent work suggests that foreign exchange (FX) reserves are the canonical self-insurance instrument: central banks accumulate reserves in normal times and can draw them down during periods of external pressure (Fratzscher et al., 2019; Rodnyansky et al., 2026). However, less is known about whether the composition of a central bank's own reserve balance sheet changes the immediate exchange-rate response to US monetary shocks. The key economic distinction is the degree to which reserve assets strengthen the central bank's balance sheet against a dollar-specific monetary shock. Official swap and repo lines provide direct public-sector dollar funding in periods of stress. Dollar reserves are the closest self-insurance substitute because they can be sold, pledged, or used for intervention without currency conversion. Gold is not a perfect substitute for dollar reserves since it is less liquid. However, it can provide collateral value, valuation gains, and convertibility into dollars when direct dollar liquidity is unavailable or politically constrained.[2] In this reserve balance-sheet channel, large liquid reserve stocks can deter speculative pressure by making future dollar-liquidity provision credible even before reserves are sold. Non-dollar FX reserves remain useful reserve assets, but they provide a weaker hedge against a dollar-specific monetary shock.[3]

The first contribution is to provide high-frequency evidence that countries with larger dollar and gold reserve buffers exhibit smaller exchange-rate responses to high-frequency US monetary surprises. The key identification challenge is that reserve holdings and exchange rates are jointly determined by macroeconomic conditions, financial stress, and policy choices. The empirical design addresses this problem by using high-frequency US monetary policy shocks from Bauer and Swanson (2023a,b), measured as changes in Federal funds futures in a narrow 30-minute window around FOMC announcements. These shocks are combined with minute-by-minute exchange rates for 18 countries and lagged annual information on FX, dollar, non-dollar, and gold reserves. The analysis uses the causal variation in US monetary surprises to test whether predetermined reserve composition changes the exchange-rate effect of the same external monetary shock. The channel of interest is the *central-bank reserve balance-sheet channel*: larger reserve stocks can deter speculative pressure by signaling credible dollar-liquidity capacity, collateral capacity, and future intervention capacity even without contemporaneous reserve sales.[4]

This high-frequency design sharpens the reserve-buffer literature. Aizenman et al. (2024) show that international reserves are associated with more resilient real exchange rates in a broad panel of countries, while Ahmed et al. (2023) show that larger ex-ante FX reserves were associated with smaller currency depreciations during the 2021–22 US monetary tightening cycle. Those studies establish an important macroeconomic association between reserves and exchange-rate resilience. The present design is closer to an event-study identification of exogenous global monetary shocks: the shock is measured in a narrow FOMC window, the exchange-rate response is measured at minute frequency, and reserve holdings are predetermined. This reduces concerns that the estimated reserve-response heterogeneity is driven by slow-moving country characteristics, reverse causality from exchange-rate pressure to reserve accumulation, or contemporaneous global shocks that are not monetary in origin.

The baseline estimates show economically meaningful US monetary spillovers and evidence consistent with the central-bank reserve balance-sheet channel. A 10-basis-point surprise increase in the federal funds

[2] Section 7 discusses operational channels through which gold can be converted into dollar liquidity, as well as a recent example of gold reserve drawdowns by three emerging economies to buffer exchange rate depreciations.

[3] This mechanism is closely related to the precautionary self-insurance view of reserves in Aizenman and Lee (2007) and Aizenman and Lee (2008), and to evidence that international reserves cushion real-exchange-rate adjustment to external shocks in Aizenman and Riera-Crichton (2008). Aizenman et al. (2010) further show that central-bank swap lines have only limited scope to substitute for reserves because access to such arrangements is selective and contingent.

[4] The demand for gold may also reflect concerns about the long-run purchasing power of fiat reserve currencies, including the US dollar. In the US case, the Congressional Budget Office projects that federal debt held by the public will rise from 101% of GDP in 2026 to 120% of GDP in 2036, with persistent deficits and rising interest costs contributing to the increase. Such fiscal pressures may reinforce reserve managers' interest in assets that are not another government's liability, including gold.

rate depreciates foreign currencies by about 0.4 percent within 20 minutes. Countries with FX reserves one standard deviation above the mean exhibit an exchange-rate response that is about 0.04 percentage points smaller. The currency composition of reserves is central: countries with larger dollar reserves exhibit smaller responses than countries with comparable non-dollar reserve holdings. Gold reserves are also associated with smaller exchange-rate responses, with an estimated association similar in magnitude to FX reserves for a one-standard-deviation increase, though less precisely estimated. These results indicate that the composition of reserves, rather than only the aggregate stock, is relevant for the high-frequency exchange-rate effect of US monetary shocks.

This finding helps reconcile two developments that can otherwise appear contradictory. Central banks may diversify their reserves towards gold because it is not another country's liability and may be less exposed to sanctions or custodial risk. At the same time, they still need dollar assets because the underlying shock, liabilities, and market-funding needs remain dollar-centred. Gold can improve robustness at the margin, but it does not eliminate the operational value of immediately usable dollar liquidity. Reserve stocks can matter even when no intervention is observed in the event window. A large and liquid portfolio makes future dollar provision more credible. Market participants may therefore price not only actual reserve sales, but also the capacity to intervene, lend dollars domestically, or meet collateral calls. In this sense, reserves operate partly through deterrence and signaling.

The second contribution is to show that access to dollar liquidity shapes the central-bank reserve balance-sheet channel. The Federal Reserve's swap lines and the Foreign and International Monetary Authorities (FIMA) repo facility are designed as backstops during stress, and earlier research shows that access reduces offshore dollar-funding strains (Bahaj and Reis, 2022; Goldberg and Ravazzolo, 2022). Our result shows that in countries where US swap or repo lines are absent, larger dollar and gold reserves are associated with small exchange rate responses to FOMC surprises. By contrast, in countries where swap and repo lines are available, reserve stocks have limited explanatory power for exchange-rate responses. This pattern suggests that official liquidity lines and reserve portfolios are substitute forms of insurance against dollar funding pressure, with gold operating as a complementary collateral and convertibility buffer rather than as a replacement for dollar reserves. When a credible public dollar facility exists, markets need not rely as heavily on the country's own reserve portfolio. Where access is absent or uncertain, the central bank's balance sheet becomes more important. This result also cautions against treating global liquidity facilities as universal: access is selective and contingent.

The third contribution is to document cross-country heterogeneity in the reserve-response gradient. The exchange-rate response to US monetary policy shocks is stronger in countries with larger dollar exposure, especially where external liabilities are denominated in dollars. In these economies, larger dollar and gold reserve holdings are associated with smaller high-frequency exchange-rate responses. This pattern links two balance sheets: the private and public external balance sheets exposed to dollar liabilities, and the central-bank reserve balance sheet that can signal dollar-liquidity capacity. The results connect reserve composition to the dominant-currency paradigm, balance-sheet exposure, and open-economy financial frictions.

This heterogeneity connects the aggregate reserve-response gradient to microeconomic evidence on firms' exchange-rate exposure. Firm-level studies show that depreciations are not neutral: exporters and importers are affected through imported-input costs, pricing margins, and currency invoicing, while firms with foreign-currency liabilities face tighter balance-sheet constraints when the domestic currency depreciates (Amiti et al., 2014; Rodnyansky, 2019; Salomao and Varela, 2022; Fukui et al., 2025). The closest microeconomic evidence is Rodnyansky et al. (2026), who show that FX interventions following US monetary surprises are associated with higher stock prices for firms with US-dollar debt. The results here provide the corresponding country-level exchange-rate channel: dollar and gold reserves are associated with smaller exchange-rate responses precisely in economies where dollar exposure is larger. The paper does not estimate firm-level outcomes. Instead, it tests whether the central-bank reserve balance sheet, through larger dollar and gold reserve stocks, is associated with a smaller causal exchange-rate response to a US monetary surprise, precisely where private-sector currency mismatch is most costly. This micro-macro link is relevant because the real and financial costs of a dollar-liquidity shock depend on the firms and sectors that bear the resulting currency mismatch, not only on the aggregate exchange-rate change.

The final, secondary exercise, reported in Section 7, uses weekly data for Turkey, India, and Thailand to evaluate whether observed FX and gold reserve drawdowns are large enough to be quantitatively relevant during recent depreciation episodes. The exercise is an external-validity and magnitude check rather than a separate source of causal identification, but it links the high-frequency estimates to the operational reserve-management choices of central banks. The case studies also clarify how gold can be mobilized into dollar liquidity through spot sales, swaps, or collateralized transactions, and why gold may become relevant when dollar liquidity is scarce or politically constrained.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the dataset construction. Section 4 presents the empirical methodology. Section 5 discusses the main results. Section 6 studies cross-country heterogeneity. Section 7 presents the weekly reserve case studies. Finally, Section 8 concludes and discusses implications for reserve-composition analysis.

2. Literature Review

This paper contributes to four strands of international macro-finance: US monetary policy spillovers, FX intervention and reserve buffers, reserve composition and dollar dominance, and gold as a reserve asset. The common theme is that the central-bank reserve balance sheet is a policy-relevant state variable shaping the exchange-rate transmission of a common external shock.

US monetary policy spillovers. A substantial literature documents how US monetary shocks propagate across borders through financial channels, exchange rates, and capital flows (Rey, 2015; Kalemli-Özcan, 2019). Empirical work in this tradition relies on high-frequency identification (Eichenbaum and Evans, 1995; Faust et al., 2007; Gürkaynak et al., 2021; Boehm and Kroner, 2025) and structural vector autoregression (VAR) approaches (Miranda-Agrippino and Rey, 2020; Akinci and Queralto, 2024; Cesa-Bianchi et al., 2025) to trace cross-border effects. A defining feature of this literature is that the foreign-country policy response is often treated as part of the transmission environment rather than as the main object of analysis. The empirical setting here keeps the external US monetary shock fixed and studies whether reserve portfolios condition the exchange-rate response across countries.

FX intervention and reserve buffers. On the theoretical side, recent contributions emphasize imperfect asset substitutability and intermediary constraints as central mechanisms through which FX intervention operates (Gabaix and Maggiori, 2015; Cavallino, 2019; Amador et al., 2020; Fanelli and Straub, 2021; Davis et al., 2023; Itskhoki and Mukhin, 2023; Basu et al., 2025; Yago, 2025). The empirical literature evaluates intervention effectiveness through event studies and structural methods (Dominguez and Frankel, 1993; Dominguez, 2003; Dominguez et al., 2013; Fatum and Hutchison, 2010; Kuersteiner et al., 2018; Fratzscher et al., 2019, 2023; Adler et al., 2019; Rodnyansky et al., 2026). Closely related work studies the buffer role of reserves at lower frequency. Aizenman and Riera-Crichton (2008) show that reserves can cushion real-exchange-rate adjustment to external shocks in an era of growing financial and trade integration. Aizenman et al. (2024) document that international reserves are associated with more resilient real exchange rates in a broad panel, and Ahmed et al. (2023) show that higher ex-ante FX reserves were associated with less depreciation during the 2021–22 Federal Reserve tightening cycle. The present setting complements these papers by using high-frequency FOMC surprises and minute-level exchange rates, which gives a sharper source of exogenous variation and reduces the scope for reverse causality from exchange-rate pressure to reserve accumulation. It also decomposes aggregate reserves into dollar, non-dollar, and gold components and tests whether the central-bank reserve balance sheet changes the exchange-rate effect of a common dollar shock.

Reserve accumulation, currency composition, and dollar dominance. The literature on FX reserve accumulation emphasizes precautionary motives, external vulnerability, and exchange-rate management as primary drivers of reserve holdings (Calvo and Reinhart, 2002; Aizenman and Sun, 2012; Aizenman et al., 2020; Das et al., 2026). Work on currency composition—from early contributions by Eichengreen and Frankel (1996); Eichengreen (1998); Chinn and Frankel (2007), through country-level analyses by Dooley et al. (1989) and Eichengreen and Mathieson (2001), to recent work exploiting central-bank disclosures (Ito and McCauley, 2020; Arslanalp et al., 2022; Iancu et al., 2022; Laser et al., 2025)—focuses on currency shares measured at quarterly or annual frequency.

This paper links currency composition to the dominant role of the US dollar in trade invoicing, finance, and external balance sheets. The dollar component of reserves matters because US monetary tightening is a dollar-liquidity shock; non-dollar reserves may be valuable assets, but they need not provide the same immediate hedge against dollar funding pressure. This interpretation builds on the precautionary motive for reserve accumulation. Aizenman and Lee (2007) model reserves as self-insurance against sudden stops and costly liquidation, while Aizenman and Lee (2008) distinguish financial self-insurance from monetary mercantilism in explaining large reserve holdings. In the present setting, large reserve stocks can also affect exchange rates through deterrence: they strengthen the central-bank balance sheet and make future dollar-liquidity provision more credible before actual sales occur.

Gold reserves and dollar/gold complementarity. Historical work traces the role of gold across monetary regimes, from the classical gold standard through Bretton Woods (Bordo and McCauley, 2017; Monnet and Puy, 2020). More recent empirical work finds that gold holdings rise with macroeconomic volatility and global risk (Ghosh, 2016; Gopalakrishnan and Mohapatra, 2018; Rathi et al., 2022), consistent with a broader literature that establishes gold as an inflation hedge (McCown and Zimmerman, 2006), an exchange-rate hedge (Capie et al., 2005), and an equity-market safe haven (Baur and McDermott, 2010; Aizenman and Inoue, 2013). Related work documents gold's sensitivity to geopolitical uncertainty (Baur and Smales, 2018, 2020; Beckmann et al., 2019; Burdekin and Tao, 2021) and central banks' demand for gold as a non-seizable reserve asset under financial-sanctions risk (Arslanalp et al., 2023; Arvai et al., 2026). The contribution here is not primarily the frequency of gold-reserve observations. Instead, the central point is a dollar/gold complementarity: dollar reserves provide direct liquidity against dollar shocks, while gold may provide collateral value, valuation gains, and convertibility into dollars when direct access to dollar liquidity is limited.

Central-bank liquidity arrangements. A growing literature studies the expansion and implications of swap lines and central-bank liquidity facilities, particularly during crises (Bahaj and Reis, 2020, 2022; Ferrara et al., 2025; Goldberg and Ravazzolo, 2022; Kekre and Lenel, 2025; Horn et al., 2023). Related work examines deviations from covered interest parity as signals of dollar funding stress (Du and Schreger, 2016; Cerutti and Zhou, 2024). This paper connects that literature to reserve composition by showing that larger dollar and gold reserve holdings are most strongly associated with smaller exchange-rate responses when official dollar liquidity lines are absent.

Contributions. The paper makes three main contributions. First, it jointly studies US monetary spillovers and recipient-country reserve buffers using high-frequency identification. Second, it shows that the currency and asset composition of reserves matters for the causal exchange-rate effect of US monetary surprises, with dollar reserves acting as the direct self-insurance asset and gold acting as a complementary collateral and convertibility asset. Third, it shows that estimated reserve-response gradients are heterogeneous across access to swap/repo lines and across countries' dollar exposures, linking reserve management to dollar dominance, central-bank reserve balance sheets, and open-economy balance-sheet vulnerabilities.

3. Dataset Construction

We combine multiple data sources. We have 18 sample countries with a flexible exchange rate and where data on both the high-frequency exchange rate and the currency composition of FX reserves are available. The sample countries are as follows: Australia, Brazil, Canada, Chile, the Czech Republic, the Euro Area, India, Israel, New Zealand, Norway, Peru, Poland, Russia, South Africa, Sweden, Switzerland, Turkey, and the United Kingdom. Our sample countries are geographically diverse and include both advanced and emerging economies with different degrees of dollar exposures. (We will study cross-country heterogeneity in Section 6.) The sample period is between 2009 and 2023 since high-frequency data on exchange rates start in 2009 and the data on US monetary policy shocks end in 2023.[5]

We obtain intraday minute-by-minute exchange rate data from First Rate Data. We obtain the volume of FX and gold reserves from the IMF International Financial Statistics. We combine data on the currency composition of FX reserves in Ito and McCauley (2020); Iancu et al. (2022), and Laser et al. (2025). The country-level GDP data is downloaded from the World Bank. We use high-frequency US monetary surprises constructed by Bauer and Swanson (2023a,b).[6] The shock is measured by changes in the Federal funds futures rate in a 30-minute window around (from 10 minutes before to 20 minutes after) FOMC announcements. We use historical data on swap and repo lines collected by Bahaj et al. (2026). Finally, we use data on invoicing currencies for exports and imports from Boz et al. (2022) and for external assets and liabilities from Bénétrix et al. (2020).

Table 1, row 1, shows the summary statistics for the US monetary policy shock. The shock is in terms of basis points, and a positive value corresponds to an increase in the policy rate (monetary tightening). Rows 2-4 show the summary statistics for FX, dollar, and gold reserves, measured as percentage ratios over GDP. FX reserve holdings are larger than gold reserve holdings on average, and some countries, including Canada, Israel, New Zealand, and Norway, had either zero or close to zero gold reserve holdings. Rows 5-8 show the ratio of external assets denominated in US dollars to total external assets, as well as the corresponding ratios for external liabilities, exports, and imports.

Table 2, columns 1-3, shows the percentage ratios of FX reserves to GDP, dollar reserves to GDP, and gold reserves to GDP, respectively. The table shows that emerging economies, including Brazil, Chile, India, Israel, and Peru, are large holders of FX and dollar reserves, as they face volatile capital flows and exchange rates. In contrast, advanced economies, including Australia, Canada, the Euro Area, and the United Kingdom, have low FX reserves-to-GDP ratio. The exception is Switzerland, which accumulates FX reserves to prevent the appreciation of the franc during crisis times due to its safe-haven currency status. Columns 4-7 show the percentage ratios of external dollar assets to total assets, external dollar liabilities to total liabilities, dollar exports to total exports, and dollar imports to total imports. Peru has the largest dollar asset, export, and

[5] The COVID-19 period (March to December 2020) is not included in our sample, as Bauer and Swanson (2023a,b) treat orthogonalized monetary shocks as missing values during this period. An important limitation is that since the data on monetary policy shocks is not available after 2024, we cannot conduct a subsample analysis including the second Trump administration period. In Section 7, we provide case studies for three countries, Turkey, India, and Thailand, using weekly FX and gold reserves data after 2025.

[6] To construct monetary policy surprises, Bauer and Swanson (2023a) take 30-minute changes in the current-month, next-quarter, two-quarter-ahead, and three-quarter-ahead Eurodollar futures contracts (and the corresponding SOFR futures contract after 2023). They take the first principal component of the change in Eurodollar futures, scaled so that the impact on the three-quarter-ahead Eurodollar futures contract is unity, and define it as the monetary policy surprise. Using this measure, Bauer and Swanson (2023b) compute the residual from regressing the monetary policy surprise on six macro and financial variables, including the surprise component of the nonfarm payrolls, 12-month employment growth, the log change in the S&P500 from 3 months before to the day before the FOMC announcement, the change in the yield curve slope over the same period, the log change in a commodity price index over the same period, and the option-implied skewness of the 10-year Treasury yield (Bauer and Chernov, 2024). They interpret the residual as the component of monetary policy surprises orthogonal to publicly available information and thus unlikely to be driven by the "Fed response to news" channel. Our paper uses this orthogonalized measure of monetary policy shocks.

import ratios, and Russia has the largest dollar liability ratio. Other emerging economies, including Brazil, Chile, India, and Israel, also tend to have high dollar exposures. In Section 6, we study this heterogeneity in detail and show that both dollar and gold reserves are associated with a stronger exchange-rate buffer in emerging economies with large dollar exposures.

Table 1: Summary Statistics

	Obs	Mean	Median	SD	Min	p10	p25	p75	p90	Max
US Monetary Shock (bp)	108	0.66	0.23	3.58	-8.49	-4.03	-1.07	2.14	6.30	11.84
FX Reserves / GDP (%)	1944	18.2	13.7	20.4	0.4	2.6	7.0	21.5	33.1	136.5
$ Reserves / GDP (%)	1758	8.7	6.2	8.7	0.1	0.4	2.3	10.5	21.0	47.9
Gold Reserves / GDP (%)	1919	1.1	0.4	1.9	0.0	0.0	0.0	1.2	2.7	9.3
External $ Asset (%)	1122	43.2	42.1	10.8	15.5	25.8	31.5	54.9	61.2	84.5
External $ Liability (%)	1122	22.9	24.5	9.4	1.4	7.4	17.6	29.5	33.0	44.7
$ Export (%)	1424	55.5	53.5	29.1	7.9	17.3	27.0	84.8	94.1	97.4
$ Import (%)	1466	53.1	50.7	24.0	16.2	23.9	30.7	80.7	88.7	94.2

Note: Row 1 shows the summary statistics for US monetary shocks, in terms of basis points. Positive and negative values correspond to unexpected increases and decreases in the federal funds rate, respectively. Rows 2-4 show the summary statistics for the ratios of FX reserves to GDP, dollar reserves to GDP, and gold reserves to GDP, expressed as percentages. Rows 5-8 show the summary statistics for the ratios of external dollar assets to total external assets, external dollar liabilities to total external liabilities, dollar exports to total exports, and dollar imports to total imports, expressed as percentages.

Table 2: Reserve Holdings and Dollar Exposures in Each Country

	FX Reserves	$ Reserves	Gold Reserves	$ Asset	$ Liability	$ Export	$ Import
Australia	3.0	1.5	0.2	41.1	27.4	84.4	55.4
Brazil	16.6	14.1	0.2	57.5	31.9	94.0	82.3
Canada	3.7	2.5	0.0	58.9	25.3	-	-
Chile	14.2	8.9	0.0	55.2	32.0	94.7	86.0
Czech Republic	37.7	7.3	0.2	13.2	2.4	13.1	21.3
Euro Area	0.4	0.3	0.2	-	-	-	-
India	15.8	8.6	1.1	50.1	18.5	86.6	86.6
Israel	31.0	20.7	0.0	59.4	26.5	83.3	70.2
New Zealand	7.9	1.7	0.0	36.3	27.8	59.4	50.0
Norway	13.0	6.6	0.0	34.4	26.8	48.7	24.9
Peru	29.6	24.4	0.8	76.2	23.7	97.3	92.8
Poland	19.4	7.9	1.1	29.6	7.4	17.4	28.7
Russia	23.5	9.9	4.1	43.7	33.3	71.1	39.4
South Africa	10.6	6.5	1.5	32.1	13.9	42.1	-
Sweden	8.5	4.4	1.0	25.5	16.4	26.5	29.9
Switzerland	79.7	26.0	6.7	32.0	18.8	20.5	35.6
Turkey	9.7	6.2	2.6	49.8	29.4	45.8	62.0
United Kingdom	3.3	0.4	0.5	39.4	27.6	29.5	39.3
All Countries	18.2	8.7	1.1	43.2	22.9	55.5	53.1

Note: The table reports the percentage ratios of FX reserves to GDP, dollar reserves to GDP, gold reserves to GDP, external dollar assets to total assets, external dollar liabilities to total liabilities, dollar exports to total exports, and dollar imports to total imports for each country, averaged over the sample period.

4. Empirical Strategy

This section shows the empirical strategy and discusses the identification assumption. We employ the local projections framework, developed by Jordà (2005), to estimate the dynamic responses of the exchange rate to US monetary shocks. First, we estimate the following equation:

$$e_{i,t+h} - e_{i,t-1} = \alpha + \beta_h FFR_t + D_i + \epsilon_{i,t}, \quad h \in [-10, 20]. \tag{1}$$

e denotes the logarithm of the spot exchange rate, defined as the value of currency i per US dollar. An increase in e corresponds to a depreciation of currency i or an appreciation of the US dollar. t denotes the minute of the FOMC announcement. The left-hand side, $e_{i,t+h} - e_{i,t-1}$, denotes a percentage change in the exchange rate from minute $t-1$ to $t+h$. FFR_t denotes the federal funds rate shock at minute t. A one-unit increase in FFR_t corresponds to an unexpected 10-basis-point increase in the federal funds rate. $\beta_h > 0$ implies that a surprise tightening of the US monetary policy leads to a depreciation of currency i. We follow the literature on high-frequency monetary policy (Nakamura and Steinsson, 2018; Jarociński and Karadi, 2020; Bauer and Swanson, 2023a,b) and take a 30-minute change in the exchange rate from 10 minutes before to 20 minutes after FOMC announcements. D_i denotes the country fixed effect.

Next, we estimate the following equation to measure how countries with different degrees of FX and gold reserves respond differently to Federal funds rate shocks.

$$\begin{gathered} e_{i,t+h} - e_{i,t-1} = \alpha + \beta_h FFR_t + \gamma_h reserves_{i,y-1} + \delta_h \left(FFR_t \times reserves_{i,y-1}\right) + D_i + \epsilon_{i,t}, \\ h \in [-10, 20]. \end{gathered} \tag{2}$$

$reserves_{i,y-1}$ denotes the ratio of FX or gold reserves to GDP in the previous year. We take a one-year lag for reserves to reduce simultaneity concerns. The reserve variables are standardized, so that a one-unit increase corresponds to a one-standard-deviation larger reserve position. The interaction coefficient δ_h captures how the marginal effect of reserves varies with the federal funds rate surprise. To simplify the interpretation, we consider a 10-basis-point surprise increase in the federal funds rate, corresponding to $FFR_t = 1$, and report the marginal effect of a one-standard-deviation larger FX or gold reserve position:

$$\left.\frac{\partial E[e_{i,t+h} - e_{i,t-1}]}{\partial reserves_{i,y-1}}\right|_{FFR_t=1} = \gamma_h + \delta_h.$$

Under the maintained identification assumptions, this object identifies the causal reserve balance-sheet effect of a larger pre-existing reserve position on the event-window exchange-rate change following the same exogenous US monetary tightening. A negative estimate indicates that a larger reserve position reduces exchange-rate depreciation following the shock.

Our identification assumption is that the exchange rate is orthogonal to other macroeconomic news shocks in a narrow time window around FOMC announcements (Bauer and Swanson, 2023a,b). The shock is robust to the "Fed response to news" channel; that is, it is not explained by differences between the Federal Reserve's response to publicly available macroeconomic news and the market's expectation of that response. We exploit this cleanly identified monetary shock as an exogenous driver of the exchange rate and compare exchange rate movements in countries with different degrees of FX reserve holdings and dollar exposures.

This design is particularly useful for revisiting the reserve-buffer effect. Lower-frequency estimates are informative about medium-run resilience, but they can confound reserve adequacy with country fundamentals, endogenous policy responses, and other global shocks. By measuring both the US monetary surprise and the exchange-rate response within the FOMC window, the empirical strategy isolates the immediate exchange-rate sensitivity to an external monetary shock and then tests whether predetermined reserve composition explains cross-country differences in that sensitivity.

The causal variation in the design comes from the high-frequency US monetary surprise. The interaction with predetermined reserve stocks tests the central-bank reserve balance-sheet channel: whether the same exogenous dollar shock has a smaller exchange-rate effect when the central bank holds larger liquid reserve assets. This channel does not require observing reserve sales in the event window. It operates through the stock of assets on the central-bank balance sheet, which can deter speculative pressure by signaling credible dollar-liquidity provision, intervention capacity, or collateral capacity.

The robustness interpretation follows the logic of the design. Pre-announcement coefficients in the event window assess whether exchange rates move before the monetary surprise. The decomposition into total FX, dollar, non-dollar, and gold reserves tests whether the estimated buffer is specific to dollar liquidity rather than aggregate reserve adequacy. The swap/repo-line and dollar-exposure splits test whether the estimates are concentrated in the environments where dollar-liquidity constraints should bind most strongly. We further provide additional robustness checks that condition the dollar-reserve response gradient on dollar-exposure controls and on macroeconomic fundamentals summarized by a principal-component index.

The high-frequency empirical strategy is complementary to other approaches in the literature. Policymakers may be interested in exchange rate movements at business-cycle frequencies, such as monthly or quarterly. The seminal work by Miranda-Agrippino and Rey (2020) uses vector autoregression to identify monetary shocks and study their effects on the macroeconomy and asset prices over 24 months. In contrast, we follow the literature on high-frequency monetary policy and study 30-minute exchange rate changes in the exchange rate around FOMC announcements. As shown in Table 1, the magnitude of the high-frequency monetary shock is small, with a standard deviation of 3.58 basis points. As discussed by Nakamura and Steinsson (2018), this "power problem" can cause bias if we aggregate monetary shocks to a lower frequency. To minimize this issue, we focus on high-frequency exchange rate changes rather than monthly or quarterly changes.

One limitation of our approach is that we rely on annual data on dollar and gold reserves, since high-frequency data is difficult to obtain. The literature on foreign exchange intervention has advanced by using intraday data (Kuersteiner et al., 2018; Menkhoff et al., 2021; Ferreira et al., 2025) or daily data (Fratzscher et al., 2019; Rodnyansky et al., 2026). However, to the best of our knowledge, it is difficult to have global coverage for high-frequency data on central banks' gold reserve holdings. (In Section 7, we provide case studies using weekly data on FX and gold reserves in three countries, including Thailand, Turkey, and India. We call weekly data 'high-frequency' since existing literature on gold reserve uses annual data.) Due to this data limitation, we use annual data on FX and gold reserves, which are available for a larger set of countries and allow us to exploit rich cross-country heterogeneity. We expect that improvements in data availability in the future would enable more rigorous econometric analysis regarding gold reserves and exchange rates.

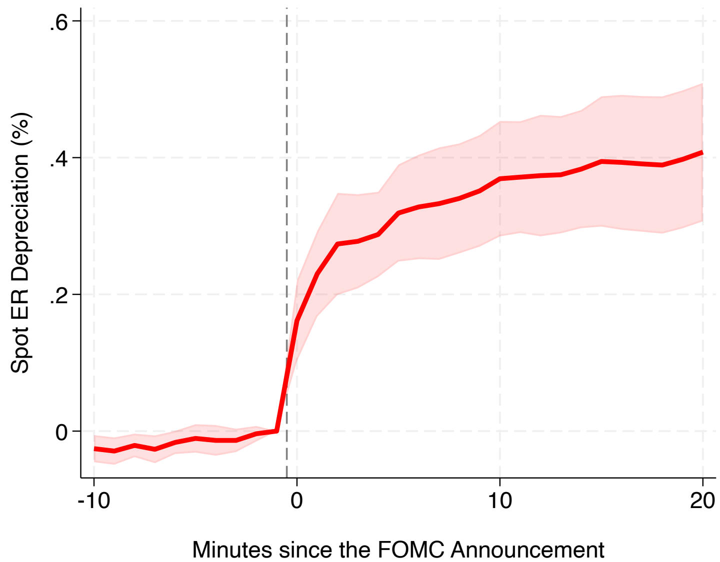
5. Results

5.1. Baseline Findings

We turn to the baseline empirical results. The estimates are organized to distinguish three channels that are central in international economics: the aggregate reserve-response gradient, the currency composition of that gradient, and the interaction between central-bank self-insurance and official dollar liquidity facilities. The coefficients test whether the central-bank reserve balance sheet changes the causal exchange-rate effect of US monetary surprises. The key results are as follows. First, a surprise increase in the US monetary policy rate leads to a depreciation of foreign exchange rates, but countries with larger FX reserves exhibit smaller high-frequency depreciations. Second, the currency decomposition shows that this pattern is concentrated in US dollar reserves, while reserves denominated in currencies other than the US dollar have a limited estimated association. Finally, both FX and gold reserves are associated with smaller exchange-rate responses to US monetary shocks. The estimated association for FX reserves is more precise, consistent with the greater liquidity of FX reserves relative to gold reserves.

We begin by estimating Equation 1 for all sample countries to study the effect of US monetary shocks on the exchange rate. Fig. 2 plots the estimated β_h coefficient in a 30-minute window around FOMC announcements. The result shows that a 10 bp surprise increase in the federal funds rate leads to around 0.4 pp depreciation of the spot exchange rate in 20 minutes, while there is little pre-trend prior to the announcement.

Fig. 2: Effect of Monetary Policy on the Exchange Rate

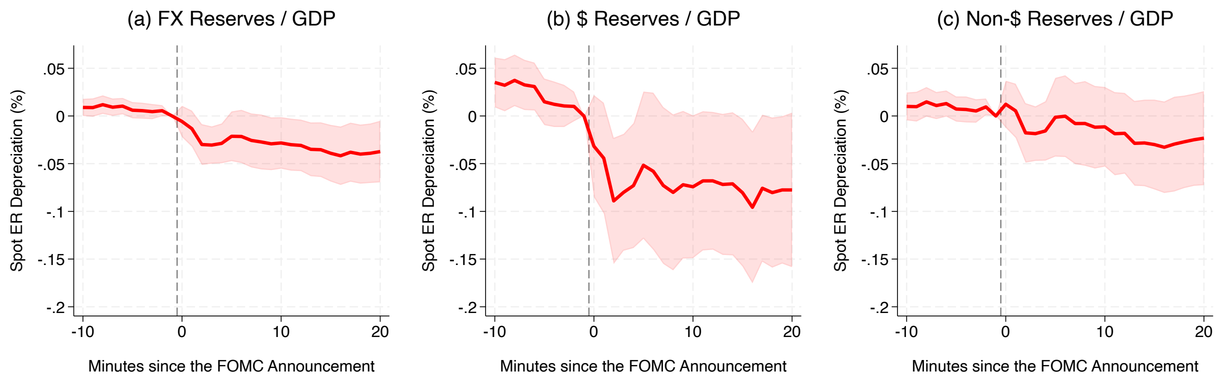


Note: The figure plots the estimated effect of a 10 bp increase in the federal funds rate on the exchange rate. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

Next, we study whether countries with larger FX reserves exhibit smaller exchange-rate responses to US monetary spillovers. We estimate Equation 2, where $reserves_{i,y-1}$ is the FX reserves-to-GDP ratio. Fig. 3, panel (a), plots the estimated marginal response associated with FX reserves, measured as $\gamma_h + \delta_h FFR_t$, in a 30-minute window around FOMC announcements. The negative interaction pattern indicates that, following a 10 bp surprise increase in the federal funds rate, countries with FX reserves one standard deviation higher (20.4 pp) exhibit about 0.04 percentage points less exchange-rate depreciation. Comparing this result with Fig. 2, this response difference is around 10% of the average response to the federal funds rate shock. The estimate is consistent with the central-bank reserve balance-sheet channel: larger FX reserve holdings signal a credible capacity to supply dollar liquidity or intervene, which can deter speculative pressure and dampen the exchange-rate effect of the US shock.

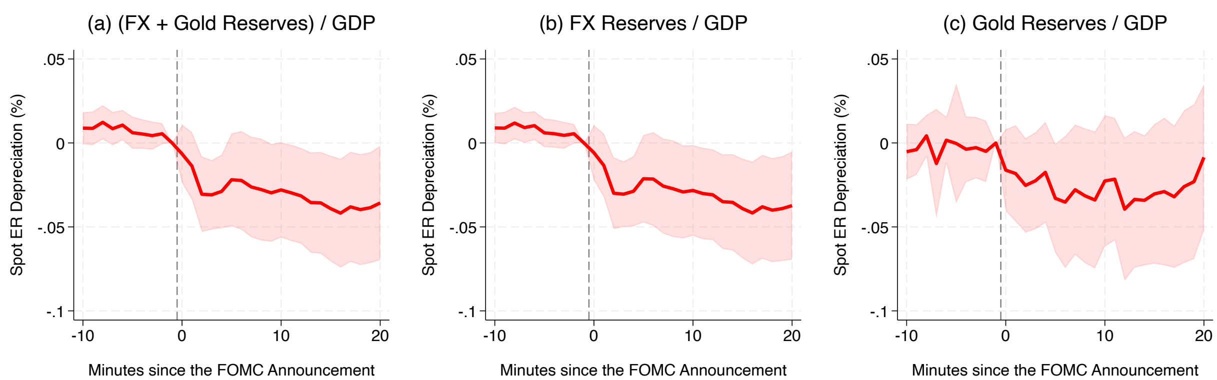
Furthermore, we decompose FX reserves into those denominated in US dollars (panel b) and other currencies (panel c). Panel (b) shows that countries with dollar reserves 20.4 pp higher, corresponding to one standard deviation of total FX reserves, exhibit depreciation responses that are smaller by up to 0.1 percentage points, or about 25% of the average response to the federal funds rate shock. Panel (c) shows that the corresponding association for non-dollar reserves is smaller and statistically insignificant. These results suggest that not only the total volume of FX reserves but also their currency composition is empirically relevant for exchange-rate responses to US monetary spillovers.

Fig. 3: Effect of FX Reserves on the Exchange Rate



Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a 20.4 pp difference in reserves (one standard deviation of total FX reserves). Panels (a), (b), and (c) show the responses by total FX reserves, dollar reserves, and non-dollar reserves, respectively. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

Fig. 4: Complementarity between FX and Gold Reserves



Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a one-standard-deviation difference in reserves. Panel (a) shows the result for combined FX and gold reserves, and panels (b) and (c) show the results for FX and gold reserves, respectively. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

Finally, we compare the estimated response gradients associated with FX and gold reserves. Fig. 4, panel (a), shows the combined association for FX and gold reserves. We take the ratio of the sum of FX and gold reserves to GDP and plot its interaction with the federal funds rate. Panels (b) and (c) decompose this association into FX and gold reserves. The results show that countries with larger FX reserves and countries with larger gold reserves exhibit smaller exchange-rate responses to US monetary spillovers. Quantitatively, following a 10 bp increase in the federal funds rate, a one-standard-deviation higher FX reserves-to-GDP ratio (20.4 pp) is associated with about 0.04 percentage points less exchange-rate depreciation, and a one-standard-deviation higher gold reserves-to-GDP ratio (1.9 pp) is associated with about 0.04 percentage points less depreciation. The association is more precisely estimated for FX reserves than for gold reserves. A cautious interpretation is that FX reserves are more liquid than gold reserves and may therefore be perceived as the more immediate source of intervention capacity.

5.2. *Swap and Repo Lines*

Official dollar liquidity facilities are central to the interpretation of reserve-buffer effects. In October 2008, Federal Reserve swap lines were extended to several emerging markets, including Brazil, Mexico, South Korea, and Singapore, to ease severe dollar funding shortages and stabilize financial conditions. In March 2020, the Federal Reserve established the Foreign and International Monetary Authorities (FIMA) Repo Facility, which allowed foreign central banks to temporarily exchange US Treasury securities for US dollars. These arrangements imply that the exchange-rate relevance of self-insurance through dollar and gold reserves may depend on access to official dollar liquidity.

The previous section shows that larger liquid dollar reserves are associated with smaller exchange-rate depreciations following US monetary shocks, consistent with a signaling channel for future FX intervention capacity. This result raises an important question about the role of central banks' liquidity provision programs, including swap and repo lines, in conditioning exchange-rate responses. Swap and repo lines are widely recognized as tools to improve financial stability, especially after the global financial crisis and the COVID-19 pandemic (Bahaj and Reis, 2022). Improved access to dollar liquidity via swap and repo lines may reduce the exchange-rate relevance of reserve stocks when the US tightens monetary policy. To check this possibility, we estimate whether the dollar-reserve response gradient differs between countries with and without swap and repo lines.

We use a comprehensive dataset of a global network of liquidity lines constructed by Bahaj et al. (2026). In the baseline analysis, we focus on liquidity lines signed with the United States and denominated in US dollars. Swap and repo lines cover 10 out of our 18 sample countries: swap lines are signed by Australia, Brazil, Canada, the Euro Area, New Zealand, Norway, the United Kingdom, and Switzerland, while repo lines through the FIMA facility cover Chile and Sweden.[7] Appendix B reports the corresponding country-list figures and additional figures on swap/repo-line coverage and dollar-exposure heterogeneity in Figs. B.1–B.4.

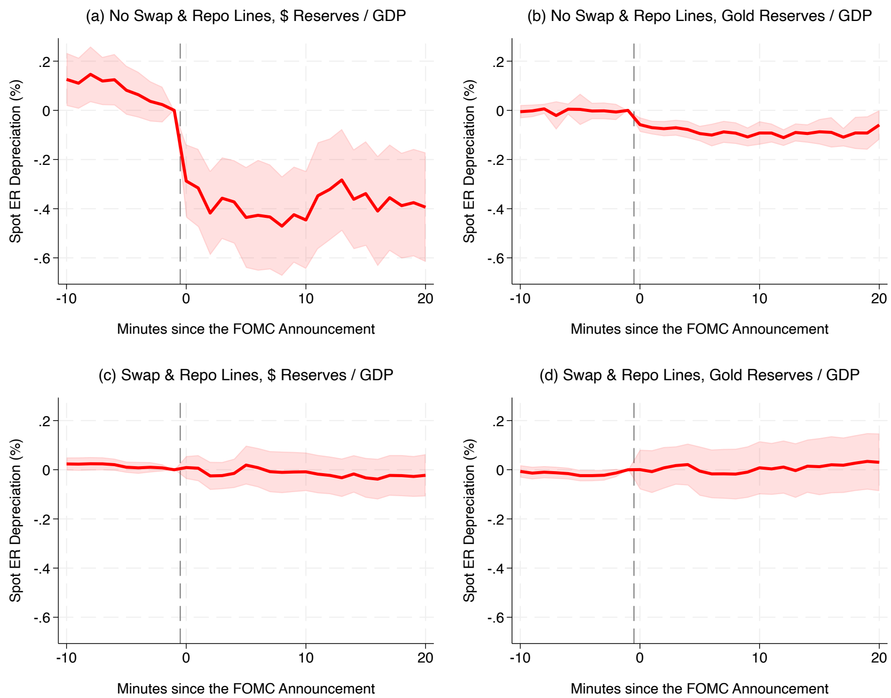
In the first exercise, we estimate Equation 2, where $reserves_{i,y-1}$ is the dollar reserves-to-GDP ratio, in countries with and without swap and repo lines. Fig. 5, panel (a), shows that, among countries without swap and repo lines, larger dollar reserves are associated with substantially smaller exchange-rate depreciation after US monetary surprises. Quantitatively, following a 10 bp unexpected increase in the federal funds rate, a 20.4 pp higher dollar reserve ratio (one standard deviation of total FX reserves) is associated with about 0.4 percentage points less exchange-rate depreciation. Compared with Fig. 2, the point estimate is similar in magnitude to the average exchange-rate response to a US monetary surprise. Panel (b) shows that a 1.9 pp higher gold reserve ratio (one standard deviation of gold reserves) is associated with about 0.1 percentage point less depreciation, or about 25% of the average response to the federal funds rate shock. In contrast, panels (c) and (d) show that, in countries with swap and repo lines, dollar and gold reserve stocks have limited explanatory power for high-frequency exchange-rate responses.

This pattern suggests that dollar and gold reserves are complementary reserve assets, while official swap and repo lines reduce the marginal exchange-rate relevance of own reserve buffers by providing an external dollar-liquidity backstop. US monetary tightening increases the demand for US dollars and is associated with capital outflows and foreign-currency depreciation. Without swap and repo lines, countries with larger dollar and gold reserve buffers exhibit smaller exchange-rate responses to the same US monetary surprises. This is a central-bank balance-sheet channel: reserve availability, expected intervention capacity, and collateral

[7] Fig. B.1 shows the list of all countries that have signed swap and repo lines with the United States and whose currency is denominated in US dollars, including countries not in our sample. Similarly, Fig. B.2 shows the list of all countries that have signed swap and repo lines with any other country and whose currency is denominated in US dollars. The limitation of our analysis is that the within-country variation on swap lines from 2009 to 2023 is limited. As shown in Figs. B.1 and B.2. Hence, our sample countries with swap or repo arrangements include those with arrangements for the entire sample period, including Canada, the Euro Area, Switzerland, and the United Kingdom, or only in periods following the global financial crisis (2009–10) and the pandemic (2021–23), including Australia, Brazil, Chile, New Zealand, Norway, and Sweden.

value can be priced by foreign-exchange markets even when contemporaneous reserve sales are not observed. In contrast, where swap and repo lines are available, improved access to dollar liquidity may accommodate the demand for dollars and reduce the exchange-rate relevance of reserve stocks.

Fig. 5: Dollar and Gold Reserve Buffers by Swap and Repo-Line Access



Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a 20.4 pp difference in dollar reserves (the standard deviation of total FX reserves) and a 1.9 pp difference in gold reserves (the standard deviation of gold reserves). Panels (a) and (b) show the results for countries without swap and repo lines, and panels (c) and (d) show the results for countries with swap and repo lines, respectively. For panels (c) and (d), the swap and repo lines are denominated in US dollars, and the source country is the United States. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

The main result focuses on swap and repo lines signed with the United States. As a robustness check, in Fig. B.3, we consider swap and repo lines signed with any other country and denominated in the US dollar. The results show that, in countries without swap and repo lines, larger dollar reserves are associated with smaller depreciation responses as in the baseline. Gold reserves are also associated with smaller depreciation responses, although the association is smaller than for dollar reserves. This pattern is consistent with gold serving as a complementary reserve asset when US dollar liquidity facilities are unavailable or perceived as politically constrained.

6. Cross-Country Heterogeneity

The average reserve-response gradient can mask substantial differences across countries. A natural prediction of open-economy models with dominant-currency pricing and dollar balance-sheet exposure is that US monetary policy shocks should matter more when private or public balance sheets are more dollarized, and that the central-bank reserve balance sheet should be more relevant when dollar exposure is large. Our sample countries are geographically diverse and have different economic structures, as discussed in Section 3.

In this section, we study three dimensions of cross-country heterogeneity, including exposure to the dollar exchange rate risks, commodity exporters and manufacturers, and advanced and emerging economies.

6.1. *Dollar Exposure*

The dollar-exposure analysis links two balance-sheet channels. External dollar liabilities proxy for private and public currency mismatch: depreciation raises the local-currency value of dollar debt and weakens borrower net worth. Dollar and gold reserves capture the central-bank reserve balance sheet: the capacity to provide dollar liquidity, pledge collateral, or signal future intervention. Dollar invoicing of exports and imports proxies for dominant-currency pricing and imported-input exposure. If reserve stocks deter speculative pressure by making exchange-rate defense more credible, the reserve-response gradient should be strongest where dollar liabilities make depreciation most costly. The exercise remains at the country level. It uses dollar exposure as a state variable to test whether reserve portfolios are most relevant in the economies where firm-level studies predict that depreciations are most costly.

There is a growing empirical observation that a small number of currencies, especially the US dollar, play a central role in international trade (Gopinath et al., 2020; Gopinath and Stein, 2021) and finance (Rey, 2015; Miranda-Agrippino and Rey, 2020; Di Giovanni et al., 2022). Theories show that exposure to the dollar exchange rate risk plays a central role in the international transmission of US monetary policy. In this section, we study the effects of US monetary policy and dollar and gold reserves on the exchange rate in countries with different degrees of dollar exposures. We focus on the following four dimensions of heterogeneity, including external assets, external liabilities, exports, and imports.

According to a classical theory (Mundell, 1960; Fleming, 1962), an exchange rate depreciation increases countries' export competitiveness. Recent empirical and theoretical studies revisit these insights. On the trade side, under the dominant currency paradigm, the effect of an exchange rate depreciation on exports is limited due to incomplete pass-through of exchange rates into import prices (Gopinath et al., 2020). Furthermore, since large exporters are simultaneously large importers, a depreciation may negatively affect them by raising the cost of imported intermediate inputs (Amiti et al., 2014; Rodnyansky, 2019).

On the finance side, during a US monetary contraction, investors may become risk-averse (Miranda-Agrippino and Rey, 2020) and withdraw their portfolios from dollar-exposed economies (Converse and Mallucci, 2023; Converse et al., 2023), further accelerating the exchange rate depreciation. Moreover, if countries have debt denominated in US dollars, an exchange rate depreciation increases repayment in terms of the local currency. This harms firms or banks with large dollar debt due to currency mismatches on balance sheets (Aoki et al., 2021; Salomao and Varela, 2022; Jiang et al., 2024; Akinci and Queralto, 2024; Cesa-Bianchi et al., 2025; Fukui et al., 2025; Rodnyansky et al., 2026). Hence, exchange rates in countries with large external liabilities in dollars can be significantly affected by US monetary shocks.

We conduct two exercises. First, we test whether exchange rates in countries with different dollar exposures are affected more by US monetary shocks. Second, we test whether dollar and gold reserves are associated with smaller exchange-rate responses in economies with large dollar exposure.[8] For external assets and liabilities, we use the international investment position database constructed by Bénétrix et al. (2020). For exports and imports, we exploit the currency invoicing data constructed by Boz et al. (2022).

[8] This result is complementary to Rodnyansky et al. (2026), who show that FX interventions stabilize stock prices of firms with US dollar debt when there is an unexpected US monetary shock. We show that both FX reserves and gold reserves are associated with smaller exchange-rate responses, suggesting a complementarity between FX and gold reserves.

In the first exercise, we estimate the following equation to study the transmission of US monetary policy in countries with different degrees of dollar exposure:

$$e_{i,t+h} - e_{i,t-1} = \alpha + \beta_h FFR_t + \gamma_h exposure_{i,y-1} + \delta_h \left(FFR_t \times exposure_{i,y-1}\right) + D_i + \epsilon_{i,t},$$
$$h \in [-10, 20].$$

Here, $exposure_{i,y-1}$ denotes country i's dollar exposure in the previous year. We measure financial exposure using the percentage shares of external assets and liabilities denominated in US dollars, and trade exposure using the percentage shares of exports and imports invoiced in US dollars. We consider a 10-basis-point surprise increase in the federal funds rate, corresponding to $FFR_t = 1$. The marginal effect of dollar exposure conditional on this monetary tightening is

$$\left.\frac{\partial E[e_{i,t+h} - e_{i,t-1}]}{\partial exposure_{i,y-1}}\right|_{FFR_t=1} = \gamma_h + \delta_h.$$

Because dollar exposure is measured in percentage points, the effect of a 10-percentage-point increase in dollar exposure is

$$10\,(\gamma_h + \delta_h)\,.$$

Under the maintained identification assumptions, this object identifies how a 10-percentage-point larger pre-existing dollar exposure changes the event-window exchange-rate response to the same exogenous US monetary tightening. A positive estimate indicates that greater dollar exposure amplifies depreciation following the shock.

Fig. 6, plots the estimated marginal effect of a 10 pp increase in external dollar assets (panel a), external dollar liabilities (panel b), dollar exports (panel c), and dollar imports (panel d) in a 30-minute window around FOMC announcements. The effect is the strongest for external dollar liabilities. Quantitatively, when there is a surprise increase in the federal funds rate by 10 bp, a 10 pp increase in external dollar liabilities amplifies depreciations by up to 0.2%. This result is consistent with our hypothesis that countries with large external dollar liabilities are vulnerable to exchange rate fluctuations driven by portfolio rebalancing. Similar increases in external dollar assets and dollar imports amplify depreciations by 0.1%, while dollar exports have little effect.[9]

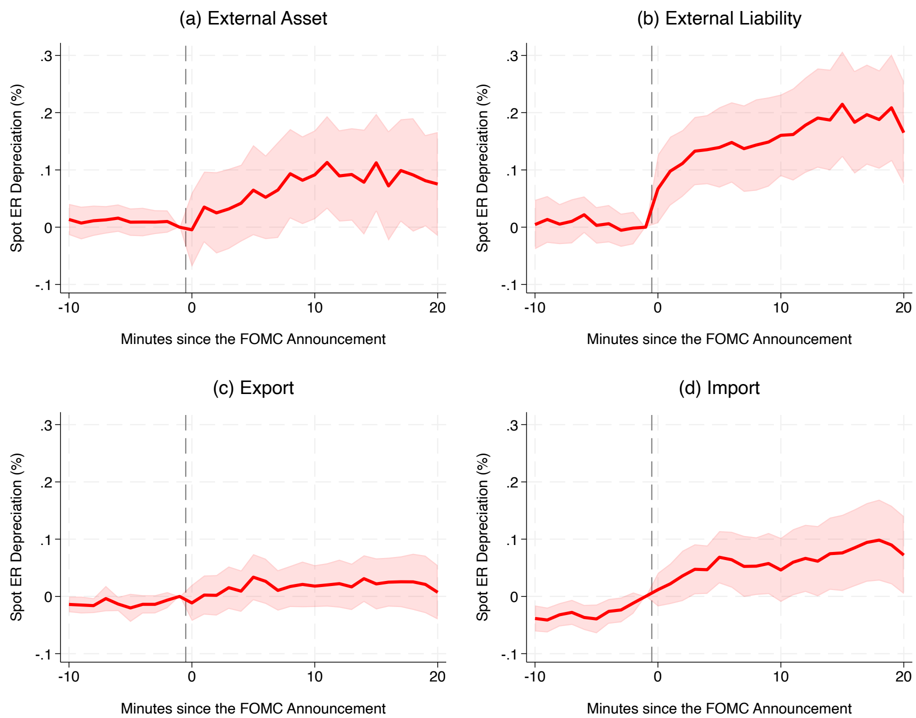
In the second exercise, we test whether the association between dollar and gold reserves and exchange-rate responses is stronger in economies with large dollar exposure. To simplify the interpretation, we define countries with large external dollar assets as those whose external assets are greater than the median. Countries with large external liabilities, exports, and imports are defined similarly. We estimate Equation 2 for FX and gold reserves after limiting the sample to countries with large external assets, external liabilities, exports, and imports. Appendix C reports the corresponding continuous-dollar-exposure triple-interaction specification and the associated estimates in Figs. C.1–C.2.

Fig. 7, panels (a)–(b), plots the estimated marginal responses associated with one-standard-deviation higher dollar and gold reserves in countries whose external assets are greater than the median, following a 10 bp increase in the federal funds rate. Panels (c)–(d), (e)–(f), and (g)–(h) show the corresponding results for external liabilities, exports, and imports, respectively. The left column shows that, in countries with large dollar exposure, a 20.4 pp higher dollar reserve ratio (one standard deviation of total FX reserves) is associated with exchange-rate depreciation that is smaller by up to around 0.4–0.9 percentage points. The association is strongest for countries with large dollar liabilities (panel c).

[9] As an alternative exercise, Fig. B.4 plots the estimated marginal effect of a 10 bp increase in the federal funds rate for different levels of dollar exposure. The estimates indicate that countries with higher dollar exposures experience a larger depreciation following US monetary tightening.

The right column shows that a 1.9 pp higher gold reserve ratio (one standard deviation of gold reserves) is associated with a depreciation that is smaller by up to around 0.1–0.2 percentage points. In contrast, when all countries are pooled, similar increases in dollar and gold reserves are associated with depreciation responses that are smaller by 0.1% (Fig. 3, panel b) and 0.04% (Fig. 4, panel c), respectively. These results are consistent with the prediction that larger dollar and gold reserve holdings are associated with smaller depreciations in countries with large dollar exposures, especially external dollar liabilities.

Fig. 6: Dollar Exposure (Effects of US Monetary Policy)



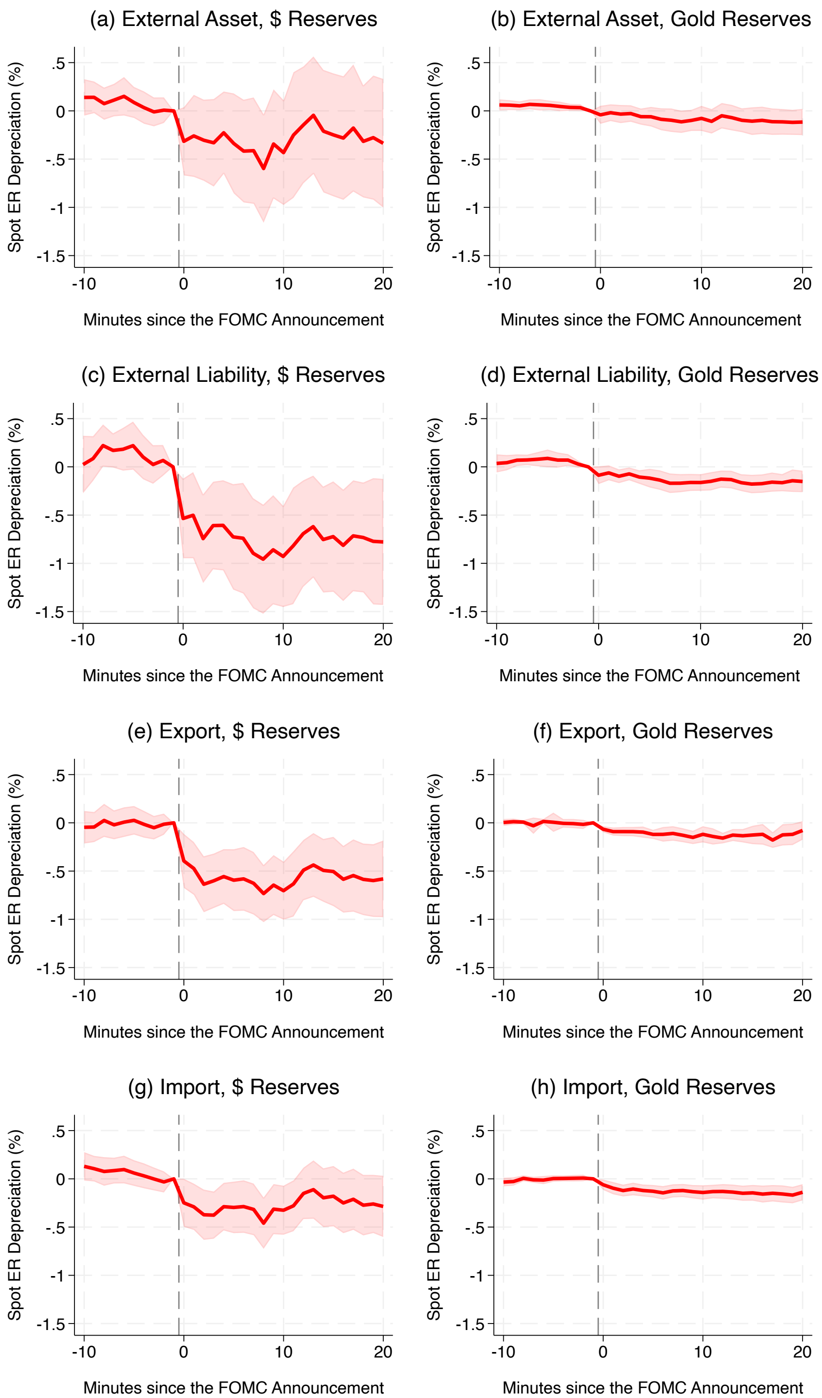
Note: Panel (a) plots the estimated marginal effect of a 10 pp increase in external assets on the spot exchange rate, following a 10 bp increase in the federal funds rate. Panels (b), (c), and (d) show the corresponding results for external liabilities, exports, and imports, respectively. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

The result for dollar liabilities provides evidence for the balance-sheet channel: markets appear to price the stock of reserve assets because it supports credible dollar-liquidity provision when external dollar liabilities make depreciation costly. Countries with dollar assets are less vulnerable than those with dollar liabilities since dollar assets can act as a hedge against exchange rate risks if domestic firms or banks have dollar assets. In addition, the result for dollar imports supports the intermediate input channel since dollar liquidity provides a buffer against depreciations that can increase the cost of imports. Dollar liquidity can also mitigate terms-of-trade fluctuation faced by exporters, as discussed in Section 6.3, while dollar exports can also provide an exchange rate hedge at the same time.

6.2. Advanced and Emerging Economies

The previous section shows that larger dollar and gold reserve holdings are associated with smaller exchange-rate responses in countries with large dollar exposure. Table 2 shows that emerging economies

Fig. 7: Dollar Exposure (Effect of Dollar and Gold Reserves)

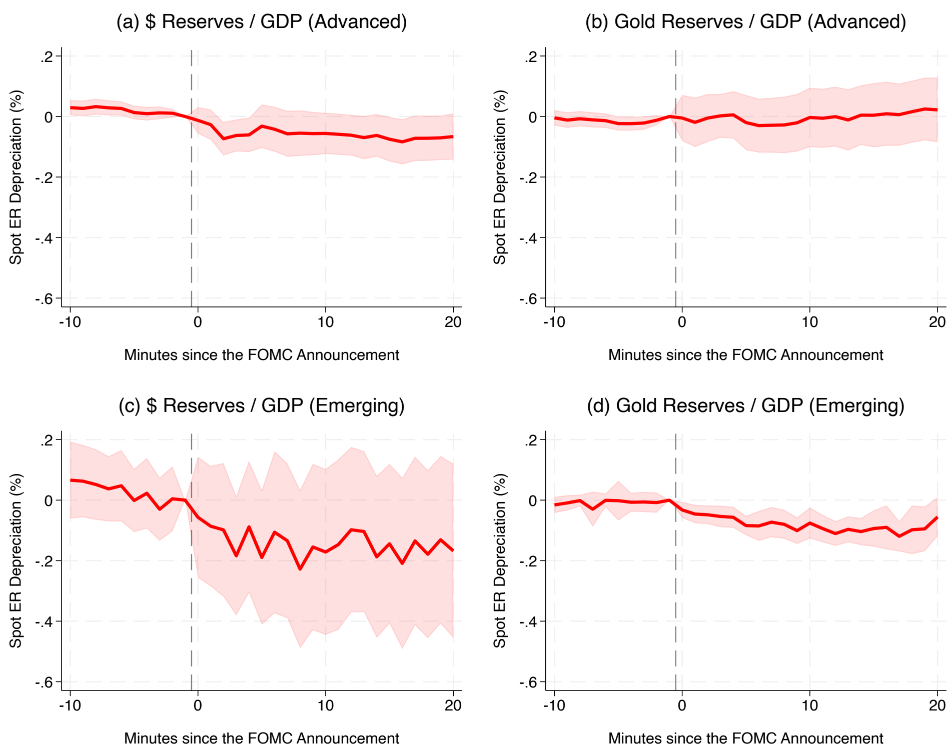


Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a 20.4 pp difference in dollar reserves (the standard deviation of total FX reserves) and a 1.9 pp difference in gold reserves (the standard deviation of gold reserves). Panels (a)–(b) show in countries whose external assets are greater than the median. Panels (c)–(d), (e)–(f), and (g)–(h) show the corresponding results for external liabilities, exports, and imports, respectively. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

are more exposed to dollar risks than advanced economies. We therefore examine whether the reserve-response gradient is stronger in economies with larger dollar and gold reserve holdings, especially where reserve drawdowns are observed during crisis times, as in the case studies for Turkey, India, and Thailand in Section 7. Among the sample countries, the advanced economies are Australia, Canada, the Czech Republic, the Euro Area, New Zealand, Norway, Poland, Sweden, Switzerland, and the United Kingdom, and the emerging economies are Brazil, Chile, India, Israel, Peru, Russia, South Africa, and Turkey.

In Fig. 8, we estimate Equation 2 after splitting the sample countries into advanced and emerging economies. Panels (a) and (b) show the results for advanced economies, and panels (c) and (d) show the results for emerging economies, respectively. The estimates are consistent with the prediction that larger dollar and gold reserve holdings are more strongly associated with smaller exchange-rate responses in emerging economies after an unexpected increase in the federal funds rate. A limitation is that we have a large standard error for emerging economies' results due to limited availability of data on currency composition for emerging economies. We expect that improved data availability on currency composition of reserves would improve our estimates.

Fig. 8: Advanced vs Emerging Economies



Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a 20.4 pp difference in dollar reserves (the standard deviation of total FX reserves) and a 1.9 pp difference in gold reserves (the standard deviation of gold reserves). Panels (a) and (b) show the results for advanced economies, and panels (c) and (d) show the results for emerging economies, respectively. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

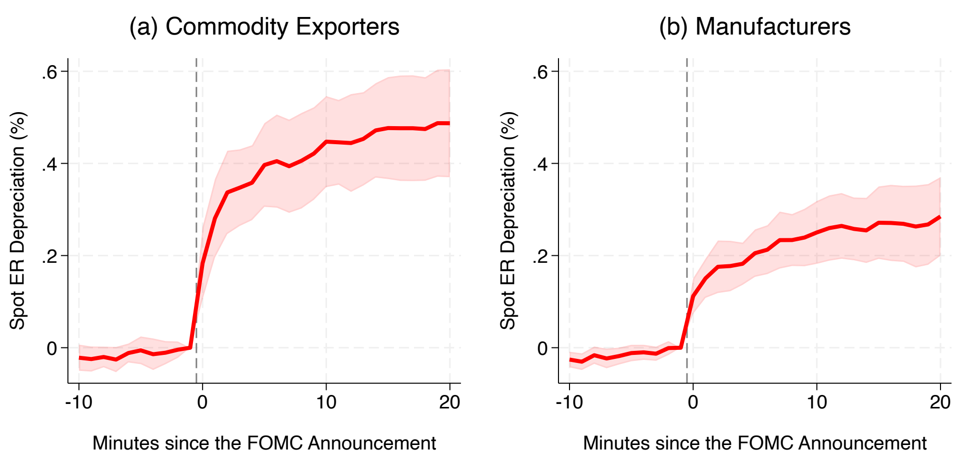
6.3. *Commodity Exporters and Manufacturers*

We further consider additional cross-country heterogeneity: commodity exporters and manufacturers, since commodity exporters face larger terms-of-trade volatility than manufacturers. This suggests that commodity exporters may be more affected by exchange-rate shocks driven by US monetary shocks, and that the association between FX and gold reserves and smaller exchange-rate responses may be stronger for commodity exporters than for manufacturers. To check this hypothesis, we use the UNCTAD State of Commodity Dependence Statistics 2025 (United Nations, 2025) and define commodity exporters (manufacturers) as countries whose share of commodity exports over total exports is above (below) the median. Among the sample countries, commodity exporters are Australia, Brazil, Canada, Chile, New Zealand, Norway, Peru, Russia, and South Africa, and manufacturers are the Czech Republic, India, Israel, Poland, Sweden, Switzerland, Turkey, and the United Kingdom.

First, in Fig. 9, we estimate Equation 1 after splitting our sample into commodity exporters and manufacturers. Panel (a) shows that in commodity-exporting countries, a 10 bp increase in the federal funds rate leads to around a 0.5 pp depreciation in exchange rates. In contrast, panel (b) shows that in manufacturing countries, the same shock leads to around a 0.3 pp depreciation. Hence, US monetary tightening leads to a larger depreciation for commodity exporters.

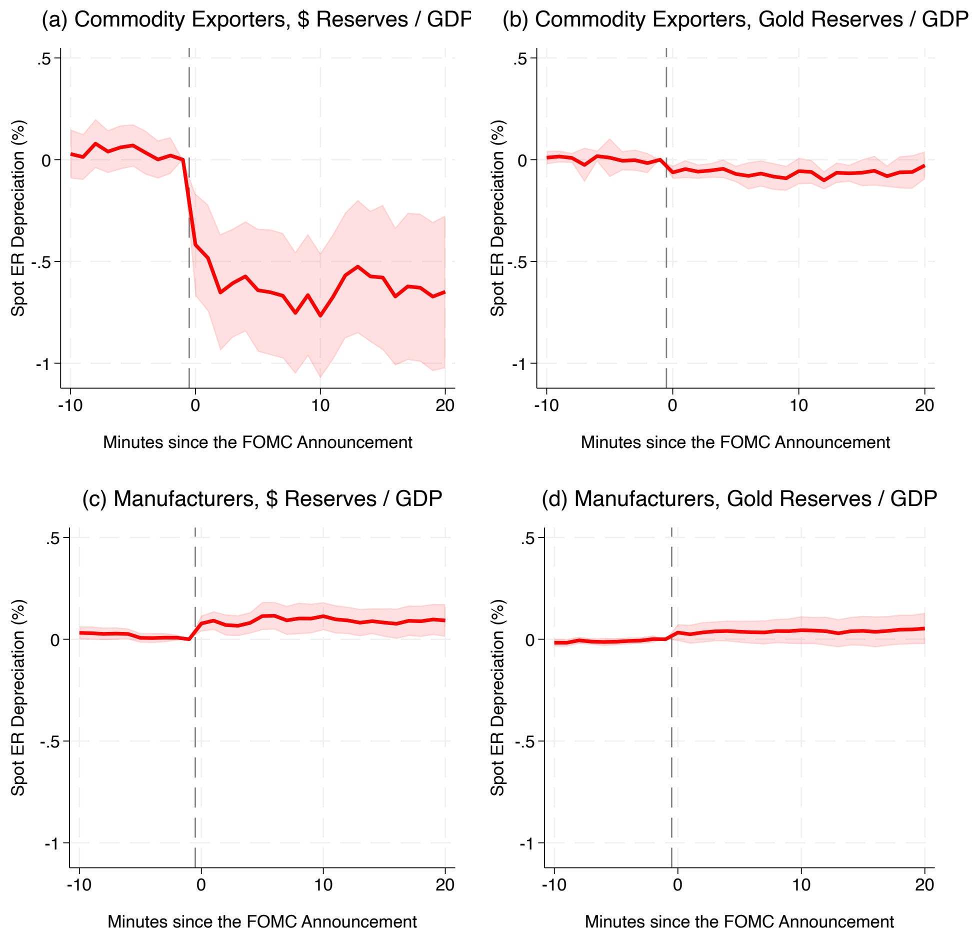
Next, in Fig. 10, we estimate Equation 2 separately for commodity exporters and manufacturers. Panels (a) and (b) show the results for commodity-exporting countries. Dollar reserves 20.4 pp higher (one standard deviation of total FX reserves) are associated with depreciation that is smaller by up to around 0.7 percentage points, with a point estimate larger than the average estimated response to US monetary policy shocks. Gold reserves that are 1.9 pp higher (one standard deviation) are associated with depreciation that is smaller by around 0.1 percentage points, or around 20% of the average response to US monetary shocks. In contrast, panels (c) and (d) show the results for manufacturing countries, in which neither dollar nor gold reserves are strongly associated with exchange-rate responses. These results are consistent with the prediction that dollar and gold reserves are associated with larger exchange-rate response differences for commodity exporters than for manufacturers.

Fig. 9: Commodity Exporters vs Manufacturers (Effect of Monetary Policy)



Note: The figure plots the estimated effect of a 10 bp increase in the federal funds rate on the exchange rate. Panels (a) and (b) show the results for commodity exporters and manufacturers, respectively. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

Fig. 10: Commodity Exporters vs Manufacturers (Effects of Dollar and Gold Reserves)



Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a 20.4 pp difference in dollar reserves (the standard deviation of total FX reserves) and a 1.9 pp difference in gold reserves (the standard deviation of gold reserves). Panels (a) and (b) show the results for commodity exporters, and panels (c) and (d) show the results for manufacturers, respectively. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

6.4. Additional Robustness Checks

To minimize the endogeneity concern, we combine high-frequency monetary shocks with minute-by-minute exchange rates and predetermined reserves. However, one potential concern is that even though the reserve holdings are predetermined, they may still be correlated with dollar exposure or slow-moving macroeconomic fundamentals. While we acknowledge this limitation, we provide additional robustness checks in the appendix to minimize this omitted-variable-bias concern. First, in Appendix D, we directly control for dollar exposure related to balance-sheet and imported-input channels. Next, in Appendix E, we control for nine macroeconomic fundamentals summarized by a principal-component approach. We find that the results on the dollar-reserve gradient remain robust even if we control for dollar exposures or macroeconomic fundamentals.

7. Weekly Reserve Dynamics and Case Studies

This section is secondary to the high-frequency estimates and the cross-country heterogeneity analysis. Its purpose is to provide the magnitude of reserve drawdowns observed in the data and an external validity check of our empirical estimates, not an additional source of causal identification. Sections 5.1 and 5.2 show that larger FX and gold reserve holdings are associated with smaller exchange-rate responses to US monetary policy shocks. The baseline analysis uses annual reserve data, which is useful for cross-country coverage but does not show whether observed reserve movements are large enough to matter at higher frequency. This subsection therefore uses weekly data on FX and gold reserves published by the central banks of three emerging economies, Turkey, India, and Thailand, and combines this information with data on exchange rates and gold prices. The exercise calculates the implied buffer associated with observed reserve drawdowns, using the estimates in Sections 5.1 and 5.2 as calibration. It focuses on recent exchange-rate depreciation episodes that occurred amid heightened geopolitical risks and were accompanied by drawdowns of FX and gold reserves by central banks. The case-study calibration is therefore interpreted as a magnitude check rather than evidence that selling reserves caused the realized exchange-rate path.

Gold can be converted into dollar liquidity through several operational channels. A central bank can sell gold in the spot market, enter a gold-for-currency swap, pledge gold as collateral in a secured transaction, or conduct transactions through domestic commercial banks and international bullion banks. The main private counterparties include bullion banks, refiners, institutional investors, exchange-traded funds, jewelry-sector intermediaries, and other official-sector reserve managers. The relevant market is therefore not only a physical market for bullion but also a dollar-liquidity market in which gold can be transformed into cash or collateralized borrowing capacity. This mechanism is important for the interpretation of the case studies: observed gold drawdowns may reflect outright sales, temporary swaps that are scheduled to reverse, valuation changes, or portfolio operations designed to obtain foreign currency liquidity without permanently reducing long-run gold holdings.

The exercise is descriptive. It does not estimate a causal weekly intervention effect, since weekly reserve changes may reflect intervention, valuation effects, accounting changes, reserve-income flows, or other balance-sheet operations.[10] Moreover, the exchange rate is observed after any central-bank response, so the counterfactual depreciation that would have occurred without reserve deployment is not observed. The exercise therefore asks a narrower question: whether observed weekly reserve drawdowns are large enough, when mapped through the estimated reserve-response gradients in Sections 5.1 and 5.2, to account for a quantitatively meaningful share of observed weekly depreciation pressure.

Let $FX_{i,w}$ denote FX reserves, $G_{i,w}$ the US-dollar value of gold reserves, and $s_{i,w}$ the bilateral exchange rate against the US dollar for country i in week w. The exchange rate is defined as local currency units per US dollar, so that an increase in $s_{i,w}$ corresponds to a depreciation of the domestic currency. Let P_w^G denote the observed gold price in millions of US dollars. We infer the quantity of gold reserves in terms of millions of troy ounces as:

$$Q_{i,w}^G = \frac{G_{i,w}}{P_w^G},$$

where $G_{i,w}$ is measured in millions of US dollars and $Q_{i,w}^G$ is measured in millions of troy ounces.

[10] With the available data, we do not observe or control for possible coordination between the fiscal authority and the central bank. Such coordination may affect the central bank's effective room for maneuver by altering the timing, scale, and instruments of reserve deployment, including the use of foreign-exchange reserves, gold reserves, or other public-sector balance-sheet operations. The weekly calculations should therefore be interpreted as observed-data magnitude checks rather than as estimates of central-bank intervention capacity in isolation.

The weekly exchange-rate change in percentage terms is:

$$\Delta e_{i,w} = 100 \times \log\left(\frac{s_{i,w}}{s_{i,w-1}}\right).$$

We focus on reserve drawdowns that occur in weeks of currency depreciation. This avoids attributing reserve movements in appreciation weeks to exchange-rate smoothing. Observed FX reserve deployment over an event window E is:

$$D^{FX}_{i,E} = \sum_{w\in E} \mathbf{1}\{\Delta e_{i,w} > 0\} \max\left\{-(FX_{i,w} - FX_{i,w-1}), 0\right\}.$$

For gold, we use an implied quantity-adjusted measure to remove valuation effects coming from movements in the gold price:

$$D^{G}_{i,E} = \sum_{w\in E} \mathbf{1}\{\Delta e_{i,w} > 0\} \max\left\{-P^G_w\left(Q^G_{i,w} - Q^G_{i,w-1}\right), 0\right\}.$$

This measure counts reductions in the implied quantity of gold reserves, valued at the observed weekly gold price. It therefore differs from changes in the US-dollar value of gold reserves, which can increase when the gold price rises even if the physical quantity of gold does not increase. We normalize reserve deployment by nominal GDP:

$$d^{FX}_{i,E} = 100 \times \frac{D^{FX}_{i,E}}{GDP_i}, \qquad d^{G}_{i,E} = 100 \times \frac{D^{G}_{i,E}}{GDP_i}.$$

The calibration uses the response gradients reported in Sections 5.1 and 5.2. In the baseline specification, countries with FX reserves one standard deviation higher, equal to 20.4 percentage points of GDP, exhibit depreciation responses that are about 0.04 percentage points smaller following a 10-basis-point US monetary tightening. Countries with gold reserves one standard deviation higher, equal to 1.9 percentage points of GDP, exhibit a similar response difference of about 0.04 percentage points.

To construct an observed-data magnitude check, we calculate the response difference associated with a one-percentage-point difference in FX or gold reserves following a 10-basis-point increase in the federal funds rate. We define these response gradients as conversion factors: (λ^B_{FX}) and gold reserves (λ^B_G). The baseline conversion factors are:

$$\lambda^B_{FX} = \frac{0.04}{20.4} = 0.002, \qquad \lambda^B_G = \frac{0.04}{1.9} = 0.021.$$

For countries without US swap and repo lines, the estimated response gradients are larger. Countries with dollar reserves one standard deviation higher exhibit depreciation responses that are about 0.40 percentage points smaller, while countries with gold reserves one standard deviation higher exhibit depreciation responses that are about 0.10 percentage points smaller. The no-swap/repo-line conversion factors are:

$$\lambda^N_{FX} = \frac{0.40}{20.4} = 0.020, \qquad \lambda^N_G = \frac{0.10}{1.9} = 0.053.$$

For each country and event window, the implied exchange-rate buffer is defined as the sum of conversion factors weighted by the FX and gold reserves-to-GDP ratios:

$$\widehat{A}^b_{i,E} = \lambda^b_{FX} d^{FX}_{i,E} + \lambda^b_G d^G_{i,E}, \qquad b \in \{B, N\}.$$

The calibrated response difference $\widehat{A}^b_{i,E}$ is measured in percentage points of exchange-rate depreciation. We compare it with observed cumulative gross weekly depreciation pressure $\Pi_{i,E}$, defined as the sum of exchange rate depreciation only over depreciation weeks:

$$\Pi_{i,E} = \sum_{w \in E} \max\{\Delta e_{i,w}, 0\}.$$

For calibration purposes, implied pre-buffer depreciation is defined as the sum of cumulative gross depreciation $\Pi_{i,E}$ and the buffer term $\widehat{A}^b_{i,E}$. This object is not an observed counterfactual; it is a mechanical mapping from the cross-country high-frequency estimates to weekly reserve drawdowns.

We define the stabilization ratio as:

$$\widehat{\theta}^b_{i,E} = 100 \times \frac{\widehat{A}^b_{i,E}}{\Pi_{i,E} + \widehat{A}^b_{i,E}}, \qquad b \in \{B, N\}.$$

This statistic measures the percentage share of calibrated pre-buffer depreciation pressure associated with the reserve-buffer estimate. Since realized exchange rates are post-response outcomes, this ratio should be interpreted as a conservative observed-data magnitude check rather than as a causal intervention-effect.

The weekly evidence shows substantial heterogeneity across the three case studies. Table 3 shows the observed weekly deployment during 2025Q1–2026Q1. "Dep. weeks" is the number of weeks in which the domestic currency depreciates against the US dollar. Columns "Net Dep." and "Gross Dep. (Π_E)" are the net and gross depreciations over the window. The table also reports the observed FX and gold reserve deployment, D^{FX} and D^G, and their GDP shares, d^{FX} and d^G, the implied buffer, $\widehat{A}^B$ and $\widehat{A}^N$, and the stabilization ratios, $\widehat{\theta}^B$ and $\widehat{\theta}^N$.

Table 3: Observed Weekly Reserve Deployment and Implied Exchange-Rate Buffer

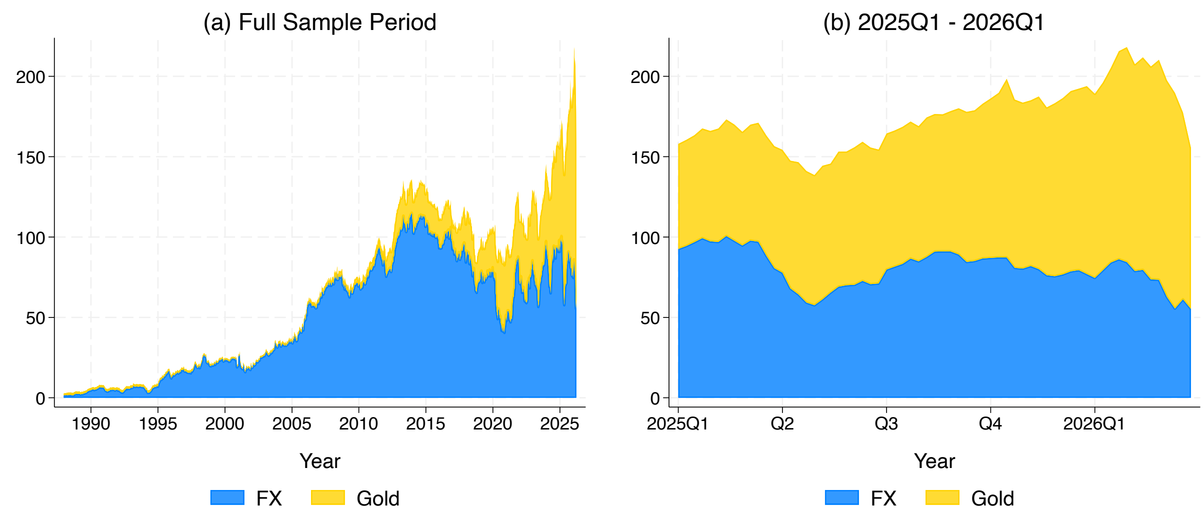
Country	Dep. weeks	Net Dep. (%)	Gross Dep. (Π_E) (%)	D^{FX} (USD bn)	D^G (USD bn)	d^{FX} (% GDP)	d^G (% GDP)	$\widehat{A}^B$ (pp)	$\widehat{A}^N$ (pp)	$\widehat{\theta}^B$ (%)	$\widehat{\theta}^N$ (%)
Turkey	55	22.80	23.75	103.15	20.46	7.80	1.55	0.048	0.234	0.201	0.977
India	39	10.06	21.91	72.02	23.76	1.84	0.61	0.016	0.068	0.075	0.310
Thailand	28	-4.66	21.42	26.84	5.78	5.10	1.10	0.033	0.158	0.154	0.731

Note: The table reports observed weekly reserve deployment during 2025Q1–2026Q1. "Dep. weeks" is the number of weeks in which the domestic currency depreciates against the US dollar. "Net Dep." and "Gross Dep. (Π_E)" are the net and gross depreciation over the 2025Q1-2026Q1 window, respectively. D^{FX} is the sum of FX reserve drawdowns in depreciation weeks. D^G is the sum of implied quantity-adjusted gold reserve drawdowns in depreciation weeks, valued at the observed weekly gold price. d^{FX} and d^G express these quantities as percentages of 2024 nominal GDP. $\widehat{A}^B$ is the implied buffer under the baseline calibration. $\widehat{A}^N$ is the implied buffer under the no-swap/repo-line calibration. $\widehat{\theta}^B$ and $\widehat{\theta}^N$ report the implied buffer as a share of estimated pre-buffer depreciation pressure, defined as observed gross depreciation pressure plus implied buffer.

Turkey. Turkey is the clearest case for studying the conversion of gold reserves into dollar liquidity. The lira is sensitive to dollar funding conditions and to imported energy costs, and the central bank has used both FX reserves and gold-related operations during periods of exchange-rate pressure. Turkey's high dependence on imported energy makes adverse regional shocks particularly relevant for foreign-currency demand (Siccardi, 2024).

Turkey is the case in which weekly reserve deployment is quantitatively largest (Fig. 11). The lira depreciates by 22.80 percent on a cumulative log basis between 2025Q1 and 2026Q1, and gross weekly depreciation pressure is 23.75 percent. During depreciation weeks, observed FX reserve drawdowns amount to USD 103.15 billion, or 7.80 percent of 2024 GDP. Implied quantity-adjusted gold drawdowns amount to USD 20.46 billion, or 1.55 percent of GDP. The implied buffer is 0.048 percentage points under the baseline calibration and 0.234 percentage points under the no-swap/repo-line calibration. These correspond to stabilization ratios of 0.201 percent and 0.977 percent, respectively. The quantity channel is also visible in physical units: inferred gold holdings decline from 24.62 million troy ounces to 22.59 million troy ounces over the window, a net decline of 2.03 million troy ounces, or 63.25 metric tons. Cumulative implied gold-quantity drawdowns during depreciation weeks are larger, at 4.59 million troy ounces, or 142.88 metric tons, because purchases and drawdowns can occur in different weeks.

Fig. 11: FX and Gold Reserves in Turkey (Billions USD)



Note: The figure plots weekly FX and gold reserves in Turkey, in billions of US dollars. Panel (a) shows the full sample period, and panel (b) shows the period between 2025Q1 and 2026Q1.

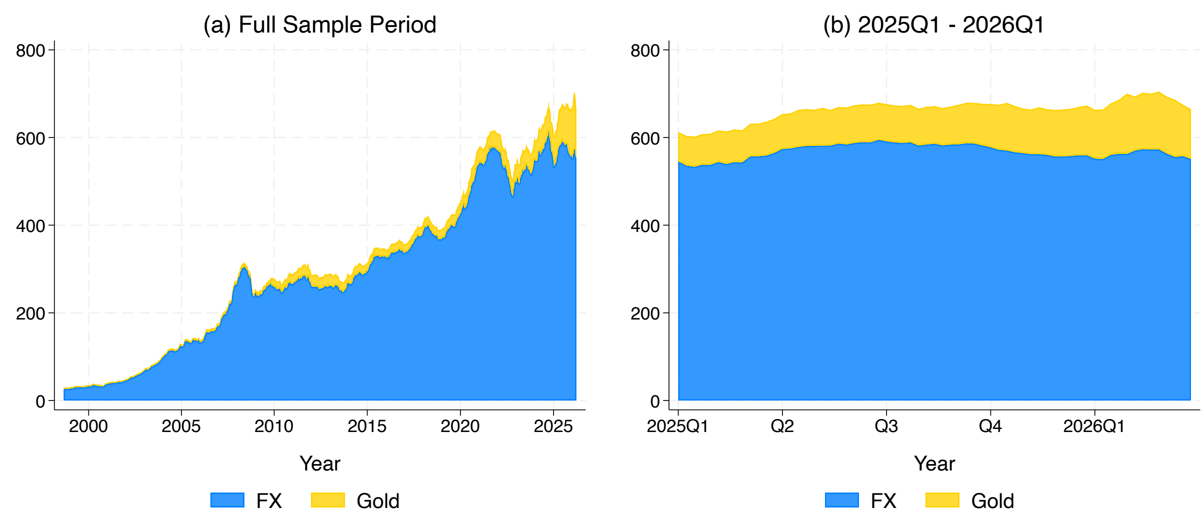
India. India provides a complementary case because the Reserve Bank of India holds a large diversified reserve portfolio and often emphasizes exchange-rate smoothing rather than a fixed exchange-rate target. In routine operations, dollar liquidity is likely to be supplied primarily through FX reserves, while gold can serve as a secondary liquidity and collateral buffer. Gold transactions may be attractive when exchange-rate pressure coincides with a desire to preserve highly liquid dollar assets or to diversify the composition of reserve use across assets.

India records USD 72.02 billion of FX reserve drawdowns and USD 23.76 billion of implied quantity-adjusted gold drawdowns during depreciation weeks (Fig. 12). These magnitudes correspond to 1.84 percent and 0.61 percent of 2024 GDP, respectively. The implied buffer is 0.016 percentage points under the baseline calibration and 0.068 percentage points under the no-swap/repo-line calibration. These values correspond to stabilization ratios of 0.075 percent and 0.310 percent, respectively.

Thailand. Thailand is informative because the baht is exposed to trade, tourism, and portfolio-flow shocks, while the central bank maintains substantial reserves relative to GDP. Reserve drawdowns during depreciation weeks can therefore reflect efforts to smooth disorderly market conditions rather than to defend a mechanical exchange-rate level. Gold can complement FX reserves as a balance-sheet asset whose value may rise during global stress, even though dollar reserves remain the most direct instrument for short-run foreign-exchange liquidity.

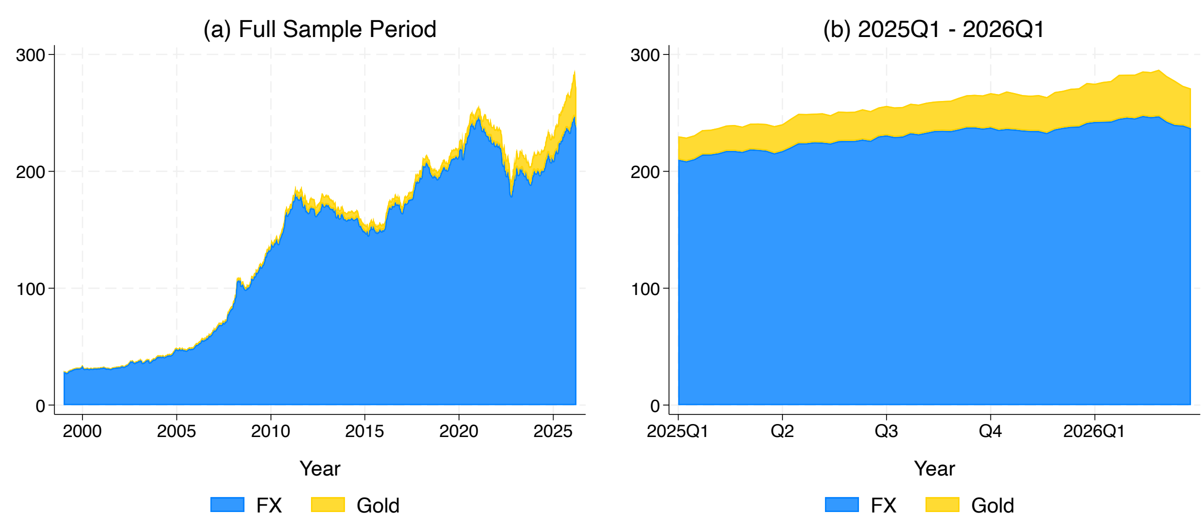
Thailand displays larger reserve deployment relative to GDP, with FX drawdowns of USD 26.84 billion and implied quantity-adjusted gold drawdowns of USD 5.78 billion during depreciation weeks (Fig. 13). These represent 5.10 percent and 1.10 percent of GDP, respectively. The implied buffer is 0.033 percentage points under the baseline calibration and 0.158 percentage points under the no-swap/repo-line calibration, corresponding to stabilization ratios of 0.154 percent and 0.731 percent, respectively. The baht appreciates on net over the window, so the table should be read as capturing gross weekly depreciation episodes within a broader period of baht appreciation.

Fig. 12: FX and Gold Reserves in India (Billions USD)



Note: The figure plots weekly FX and gold reserves in India, in billions of US dollars. Panel (a) shows the full sample period, and panel (b) shows the period between 2025Q1 and 2026Q1.

Fig. 13: FX and Gold Reserves in Thailand (Billions USD)



Note: The figure plots weekly FX and gold reserves in Thailand, in billions of US dollars. Panel (a) shows the full sample period, and panel (b) shows the period between 2025Q1 and 2026Q1.

Overall, the weekly evidence is consistent with a cautious interpretation of the reserve-buffer mechanism. Observed FX and gold reserve movements are large in dollar terms and are particularly pronounced in Turkey. However, when these weekly drawdowns are mapped through the estimated reserve-response gradients, the implied buffer remains modest relative to observed gross weekly depreciation pressure. This does not imply that reserve deployment has no smoothing role, because the counterfactual exchange rate without reserve use is unobserved. Rather, the weekly data are consistent with the buffer mechanism while also indicating that observed reserve drawdowns alone do not explain most exchange-rate stabilization in these case studies.

8. Conclusion

The central message is that the central-bank reserve balance sheet is a state variable associated with the exchange-rate transmission of US monetary shocks. The relevant policy channel is not simply the choice between dollar and gold reserves, but rather the set of reserve assets that can provide dollar liquidity, collateral value, and credible intervention capacity under stress. Official liquidity lines provide direct public backstops, dollar reserves provide self-insurance in the shock currency, and gold provides a complementary asset that can be converted into dollar liquidity or pledged as collateral when direct dollar access is limited.

This paper shows that US monetary policy surprises exert significant spillover effects on exchange rates through dollar liquidity and capital-flow channels. Using high-frequency exchange-rate data and detailed currency composition of reserves for 18 countries, the analysis shows that estimated reserve-response gradients depend on reserve composition. Countries with larger dollar-denominated reserves exhibit smaller depreciation responses, while non-dollar reserves have smaller estimated associations. Gold reserves are also associated with smaller exchange-rate responses, though less strongly than liquid FX holdings because of differences in immediacy and usability.

The findings refine the interpretation of international reserves as an exchange-rate buffer. The relevant margin is not only the aggregate reserve stock but also whether reserve assets provide dollar liquidity, collateral value, and credibility under stress. This distinction is especially important when US monetary tightening raises the demand for dollars and when geopolitical fragmentation affects the perceived accessibility of reserve assets.

The results highlight that access to international liquidity facilities, such as central-bank swap and repo lines, changes the marginal role of own reserve stocks. These arrangements are associated with a smaller role for reserve stocks in explaining high-frequency exchange-rate responses during periods of dollar-funding stress, suggesting that official liquidity lines partly substitute for own dollar and gold reserve buffers. Taken together, the findings indicate that aggregate reserve size alone does not capture all dimensions associated with external resilience; currency composition and access to dollar liquidity facilities are empirically relevant for exchange-rate responses to US monetary shocks.

The analysis reveals substantial cross-country heterogeneity linked to dollar exposure, economic structure, and development levels. Estimated response differences are largest where dollar exposure is high and where official dollar liquidity lines are absent. These patterns connect reserve management to the broader international monetary architecture: dollar dominance remains central to the transmission of US monetary shocks, while gold appears to provide a complementary buffer when dollar liquidity is scarce or politically constrained. In an era of potential global financial fragmentation, the results document the persistent asymmetry of the US dollar in the international monetary system and highlight the empirical relevance of reserve composition and liquidity arrangements for exchange-rate responses to US monetary shocks.

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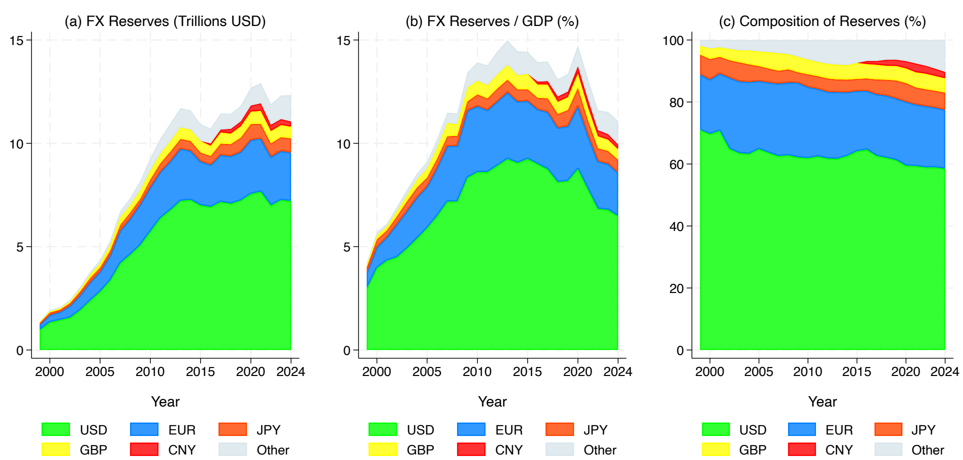
Appendix: Supplementary Materials

A. FX and Gold Reserve Composition

In this appendix, we report the volumes of FX and gold reserves, as well as valuation gains of the dollar and gold. Fig. A.1 shows the currency composition of central banks' FX reserve holdings, measured in trillions of US dollars (panel a), the ratio to GDP (panel b), and the ratio to total reserves (panel c). The volume of central banks' FX reserve holdings has increased from USD 1.3 trillion in 1999 to 12.3 trillion in 2024. However, the ratio of FX reserves to GDP has shown a declining trend, with the decline most pronounced for US dollar reserves. The ratio of dollar reserves to total reserves has also declined from 71.0% in 1999 to 58.5% in 2024.

Fig. A.2 shows central banks' gold reserve holdings, measured in trillions of US dollars (panel a), the ratio to GDP (panel b), and the ratio to total reserves (panel c). The figure shows that central banks have rapidly increased their gold reserve holdings and have shifted their composition of reserves toward gold, especially during the late 2010s to 2020s.[11]

Fig. A.1: Central Banks' FX Reserve Holdings in Different Currencies

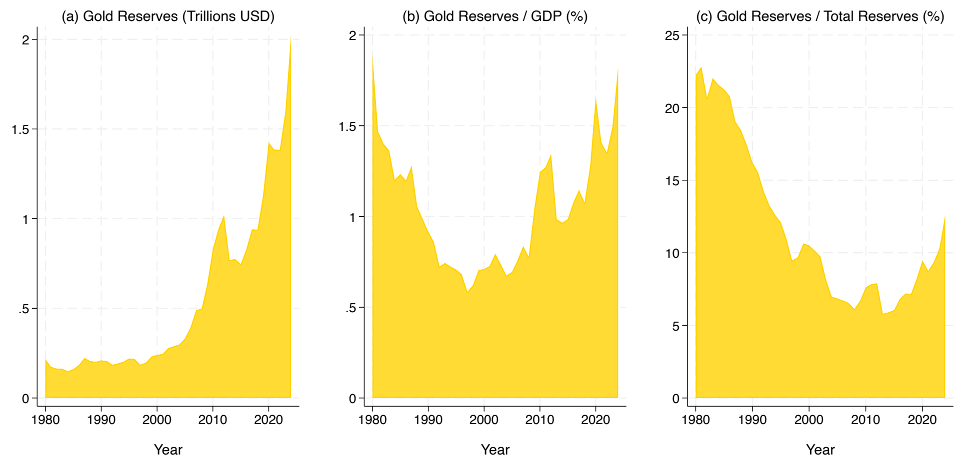


Note: Panel (a) reports the composition of allocated official FX reserves. Panel (b) reports the percentage ratio of FX reserves to GDP. Panel (c) reports the percentage ratio of FX reserves to total reserves. Data on the Chinese yuan's share is available from 2016 onward. We use aggregate data across all countries. Source: IMF COFER Database, World Bank.

Fig. A.3 shows the decline in capital gains from dollars and the increase in capital gains from gold. Panel (a) illustrates the negative correlation between the US real interest rate, measured by the real 10-year Treasury yield (red line), and the gold price in US dollars per troy ounce (yellow line). During the global financial crisis, the 10-year Treasury real yield was negative, while gold holdings experienced large positive valuation gains. In contrast, after 2022, the traditional negative correlation between gold prices and the US interest rate became more volatile, as market uncertainty and geopolitical risks increased and the return gap between US dollar bonds and gold widened. This return gap between gold and the dollar can also be observed in panel (b), which plots the real broad dollar index (blue line), defined as the trade-weighted value of the US dollar against foreign currencies, against the gold price (yellow line). The figure shows that the gold price has increased substantially faster than the appreciation of the dollar, especially since the mid-2010s.

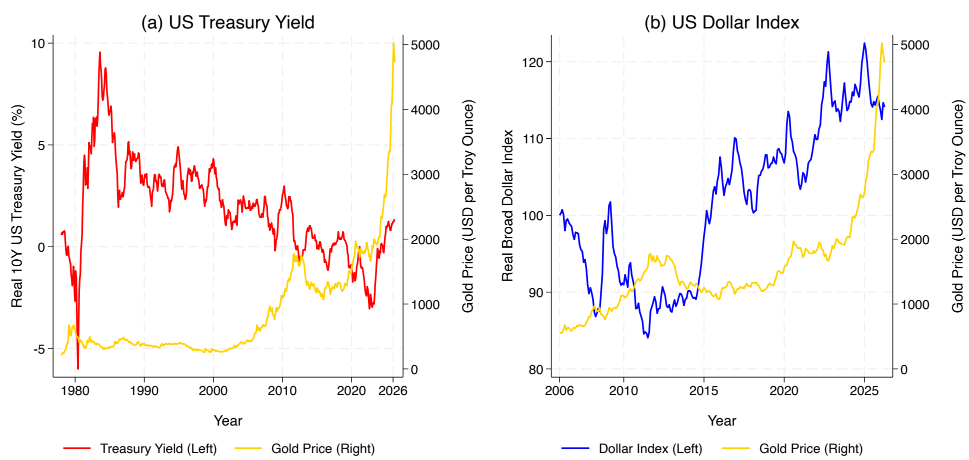
[11] Fig. A.1, panel (c) presents the same data as Fig. 1, panel (a). Fig. A.2, panel (c) presents the same data as Fig. 1, panel (b).

Fig. A.2: Central Banks' Gold Reserve Holdings



Note: Panel (a) shows central banks' gold reserves in millions of US dollars. Panel (b) shows the percentage ratio of gold reserves to GDP. Panel (c) shows the percentage ratio of gold reserves to total reserves. We use aggregate data across all countries. Source: IMF International Financial Statistics, World Bank.

Fig. A.3: Capital Gains from the Dollar and Gold

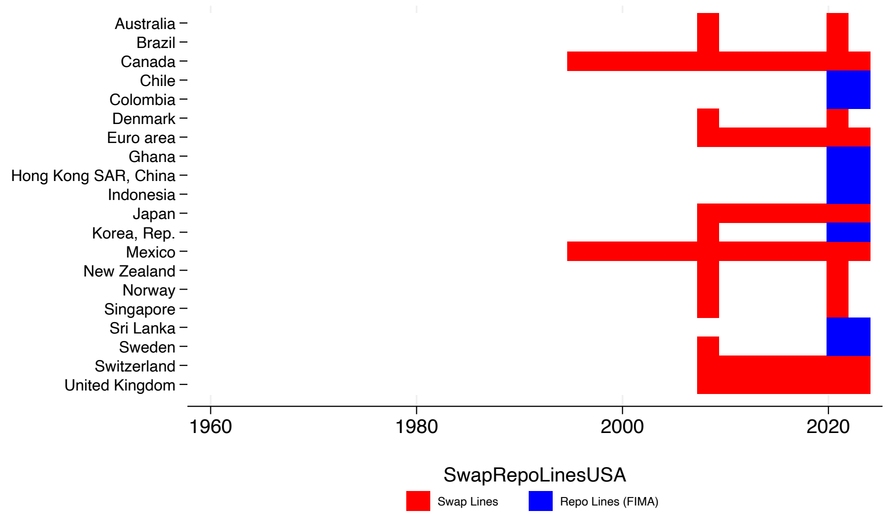


Note: The red line (panel a) shows the real 10-year US Treasury yield, the blue line (panel b) shows the real broad dollar index, and the yellow line (panels a and b) shows the gold price, respectively. Source: Federal Reserve Bank of St. Louis, World Gold Council.

Based on these figures, the peak of FX reserve accumulation (Fig. A.1, panel b) can be explained by gold reserve accumulation over the last decade (Fig. A.2). Gold has become more attractive to investors as capital gains on gold reserves have increased (Fig. A.3). Hence, part of the previous decade's FX reserve accumulation has been replaced by gold reserve accumulation.

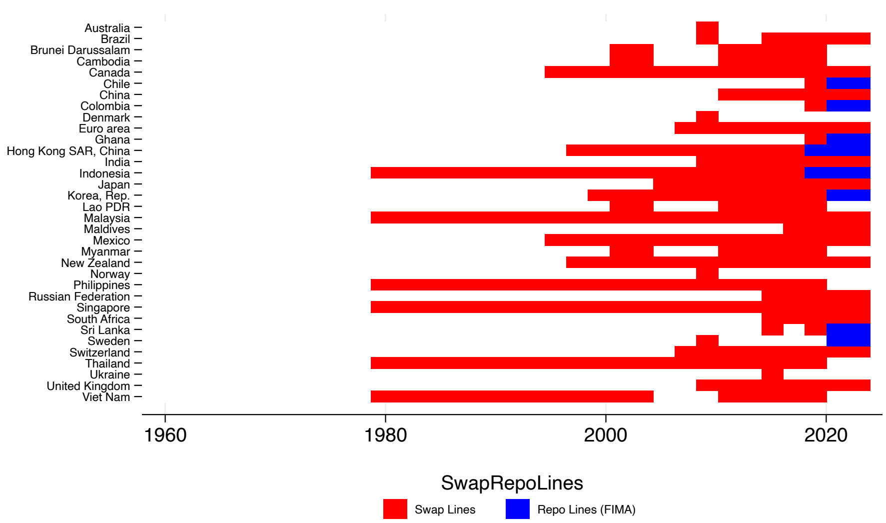
B. Additional Figures

Fig. B.1: List of Countries with Swap and Repo Lines (Signed with the United States)



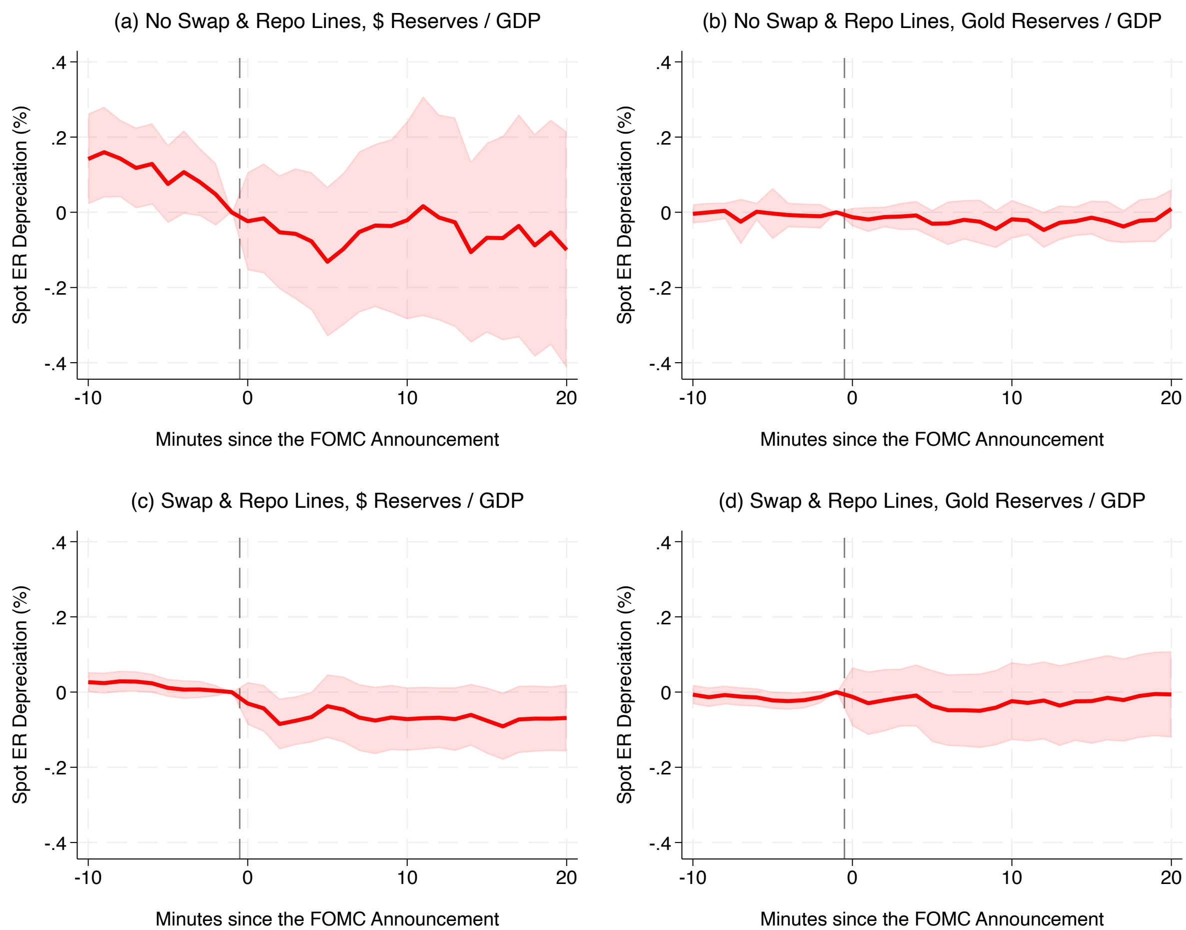
Note: The figure reports the list of countries that have signed swap lines (red) and repo lines (blue) with the United States and whose currency is denominated in US dollars. For illustrative purposes, the figure includes countries not included in our sample of 18 countries. Source: Bahaj et al. (2026)

Fig. B.2: List of Countries with Swap and Repo Lines (Signed with Any Other Country)



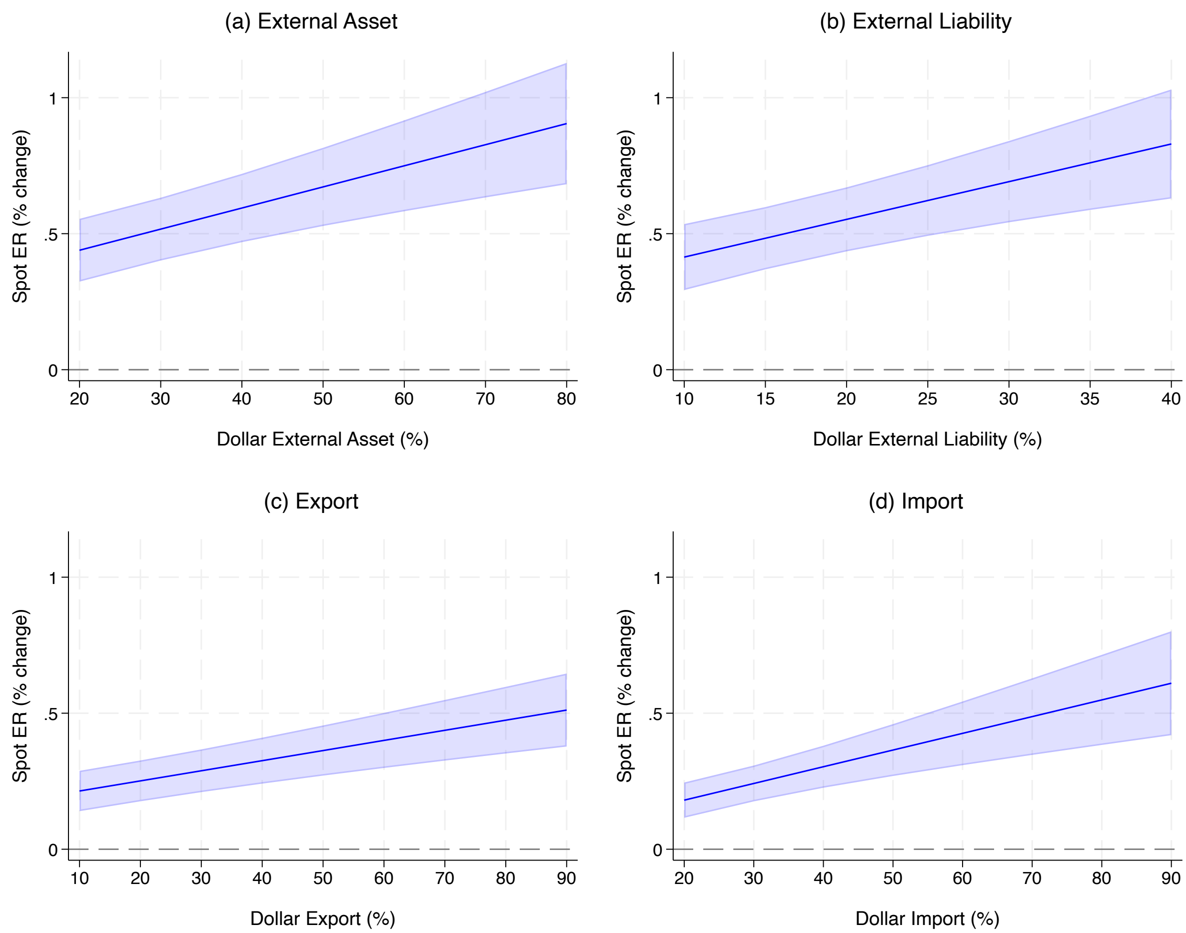
Note: The figure reports the list of countries that have signed swap lines (red) and repo lines (blue) with any other country and whose currency is denominated in US dollars. For illustrative purposes, the figure includes countries not included in our sample of 18 countries. Source: Bahaj et al. (2026)

Fig. B.3: Swap and Repo Lines (Signed with Any Other Country)



Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a 20.4 pp difference in dollar reserves (the standard deviation of total FX reserves) and a 1.9 pp difference in gold reserves (the standard deviation of gold reserves). Panel (a-b) shows the results for countries without swap and repo lines, and panel (c-d) shows the results for countries with swap and repo lines, respectively. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

Fig. B.4: Effect of Monetary Policy (Different Levels of Dollar Exposure)



Note: The figure plots the estimated exchange-rate response to a 10 bp increase in the federal funds rate for different levels of dollar exposure. Panels (a), (b), (c), and (d) show the results for external assets, external liabilities, exports, and imports, respectively. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

C. Triple Interaction for Dollar Exposure

In Section 6.1, we study the relationship between FX and gold reserves and exchange-rate responses in economies with high dollar exposure, defined as countries whose external dollar assets, external dollar liabilities, dollar-invoiced exports, or dollar-invoiced imports exceed the corresponding sample median. To examine this relationship using a continuous measure of dollar exposure, we estimate a specification with a triple interaction among the US monetary policy shock, reserve holdings, and dollar exposure:

$$\begin{aligned} e_{i,t+h} - e_{i,t-1} = \alpha &+ \beta_h^1 FFR_t + \beta_h^2 reserve_{i,y-1} + \beta_h^3 exposure_{i,y-1} \\ &+ \beta_h^4 \left(FFR_t \times reserve_{i,y-1}\right) + \beta_h^5 \left(FFR_t \times exposure_{i,y-1}\right) \\ &+ \beta_h^6 \left(reserve_{i,y-1} \times exposure_{i,y-1}\right) \\ &+ \beta_h^7 \left(FFR_t \times reserve_{i,y-1} \times exposure_{i,y-1}\right) \\ &+ D_i + \epsilon_{i,t}, \qquad h \in [-10, 20]. \end{aligned}$$

The coefficient β_h^7 on the triple interaction captures how the shock-contingent reserve gradient varies with dollar exposure. More generally, the marginal effect of reserves implied by this specification is:

$$\frac{\partial E\left[e_{i,t+h} - e_{i,t-1}\right]}{\partial reserve_{i,y-1}} = \beta_h^2 + \beta_h^4 FFR_t + \beta_h^6 exposure_{i,y-1} + \beta_h^7 \left(FFR_t \times exposure_{i,y-1}\right).$$

We evaluate this marginal effect for a 10-basis-point surprise increase in the federal funds rate, corresponding to $FFR_t = 1$, and at a given level of dollar exposure x. The resulting conditional reserve effect is:

$$\begin{aligned} \left.\frac{\partial E\left[e_{i,t+h} - e_{i,t-1}\right]}{\partial reserve_{i,y-1}}\right|_{FFR_t=1,\ exposure_{i,y-1}=x} &= \beta_h^2 + \beta_h^4 + \beta_h^6 x + \beta_h^7 x \\ &= \beta_h^2 + \beta_h^4 + \left(\beta_h^6 + \beta_h^7\right) x. \end{aligned}$$

To simplify the interpretation, we evaluate this conditional reserve effect at the 90th-percentile value of dollar exposure. From Table 2, the 90th percentile corresponds to 61.2% for external dollar assets, 33.0% for external dollar liabilities, 94.1% for dollar-invoiced exports, and 88.7% for dollar-invoiced imports. Denoting the relevant 90th-percentile exposure value by x^{90}, the estimated object reported in Fig. C.1 is:

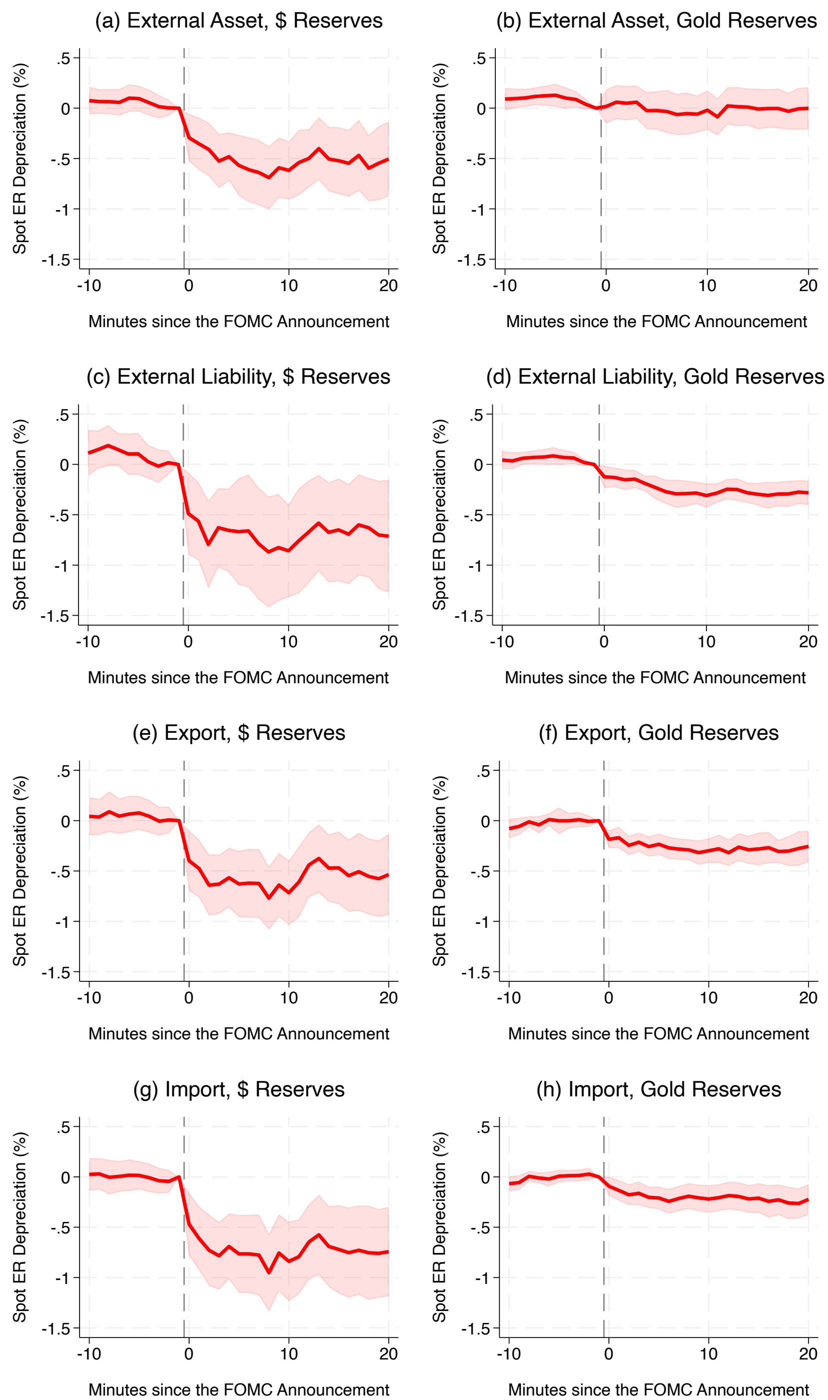
$$\beta_h^2 + \beta_h^4 + \left(\beta_h^6 + \beta_h^7\right) x^{90}.$$

Because the reserve variables are standardized, this object measures the event-window exchange-rate difference associated with a one-standard-deviation larger dollar or gold reserve position in the previous year, conditional on the same exogenous 10-basis-point FOMC tightening and a high level of dollar exposure. Under the maintained identification assumptions, it identifies the causal reserve balance-sheet effect at that exposure level. A negative estimate indicates that a larger reserve position reduces exchange-rate depreciation following the monetary-policy shock.

Fig. C.1 shows the estimated marginal response. The first column shows that, in countries with large dollar exposure, dollar reserves 20.4 pp higher (one standard deviation of total FX reserves) are associated with exchange-rate depreciation that is smaller by 0.7–0.8 percentage points. Similarly, the second column of Fig. C.1 shows that gold reserves one standard deviation higher (1.9 pp) are associated with exchange-rate depreciation that is smaller by around 0.2–0.3 percentage points in countries with large dollar exposure. In contrast, if we do not condition on large dollar exposure, the corresponding associations are 0.1% (Fig. 3, panel b) and 0.03% (Fig. 4, panel c). These results suggest that both FX and gold reserves are associated with smaller exchange-rate responses, particularly in countries with large dollar exposure.

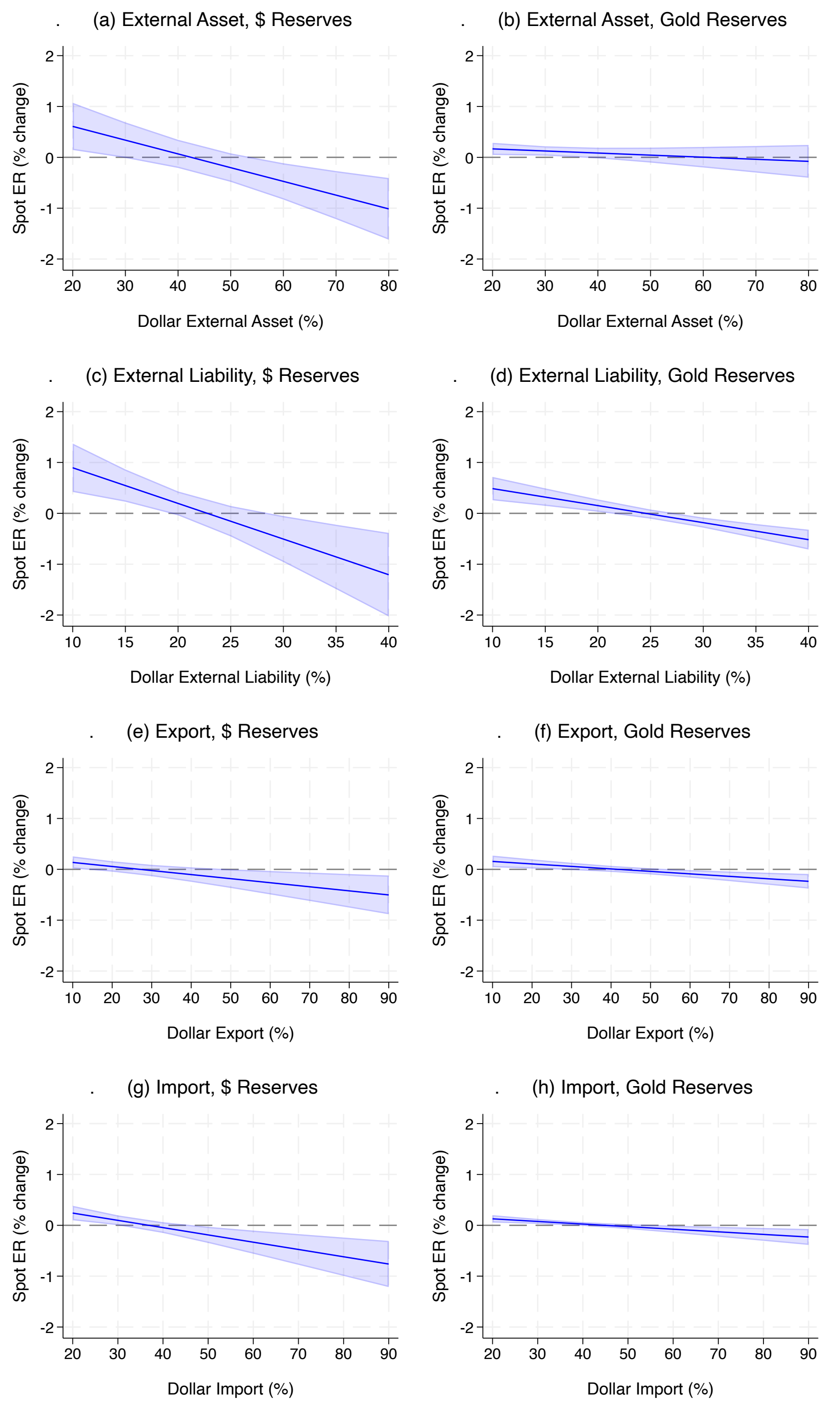
Fig. C.2 complements this exercise by tracing the conditional reserve effect over different levels of dollar exposure. The estimates indicate that the reserve-response gradient is stronger in countries with higher dollar exposure than in those with lower dollar exposure.

Fig. C.1: Dollar Exposure (Effect of Dollar and Gold Reserves)



Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a 20.4 pp difference in dollar reserves (the standard deviation of total FX reserves) and a 1.9 pp difference in gold reserves (the standard deviation of gold reserves). Panels (a)–(b) show the results for countries with external assets at the 90th percentile. Panels (c)–(d), (e)–(f), and (g)–(h) show the corresponding results for external liabilities, exports, and imports, respectively. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

Fig. C.2: Effects of Dollar and Gold Reserves (Different Levels of Dollar Exposure)



Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a 20.4 pp difference in dollar reserves (the standard deviation of total FX reserves) and a 1.9 pp difference in gold reserves (the standard deviation of gold reserves). Panels (a)–(b) plot the results for countries with different levels of external assets. Panels (c)–(d), (e)–(f), and (g)–(h) show the results for external liabilities, exports, and imports, respectively. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%.

D. Robustness to Dollar Exposure

This appendix examines whether the dollar-reserve response gradient is robust to controlling directly for dollar exposure. The concern is that the baseline reserve coefficient may partly reflect the fact that countries with larger dollar exposures also hold larger dollar reserves. We therefore re-estimate the dollar-reserve specification while adding lagged dollar-exposure controls. The exercise focuses on the two exposure margins most closely related to the balance-sheet and imported-input channels discussed in Section 6.1: external dollar liabilities and dollar-invoiced imports.

Let $R^{\$}_{i,y-1}$ denote the standardized lagged dollar-reserves-to-GDP ratio, $L^{\$}_{i,y-1}$ the standardized external-dollar-liability share, and $M^{\$}_{i,y-1}$ the standardized dollar-invoiced import share. We first estimate specifications in which these exposure variables enter as additional predetermined controls. The first specification controls jointly for finance and trade exposure:

$$\begin{aligned} e_{i,t+h} - e_{i,t-1} = \alpha + \beta_h FFR_t + \gamma_h R^{\$}_{i,y-1} + \delta_h \left(FFR_t \times R^{\$}_{i,y-1} \right) \\ + \phi^L_h L^{\$}_{i,y-1} + \phi^M_h M^{\$}_{i,y-1} + D_i + \epsilon_{i,t}, \qquad h \in [-10, 20]. \end{aligned} \tag{D.1}$$

The second specification controls for trade exposure only:

$$\begin{aligned} e_{i,t+h} - e_{i,t-1} = \alpha + \beta_h FFR_t + \gamma_h R^{\$}_{i,y-1} + \delta_h \left(FFR_t \times R^{\$}_{i,y-1} \right) \\ + \phi^M_h M^{\$}_{i,y-1} + D_i + \epsilon_{i,t}, \qquad h \in [-10, 20]. \end{aligned} \tag{D.2}$$

These regressions control for the level of dollar exposure. We also estimate a more demanding interacted-control specification that allows the exchange-rate response to the US monetary surprise itself to vary with dollar exposure. For finance and trade exposure, the specification is:

$$\begin{aligned} e_{i,t+h} - e_{i,t-1} = \alpha + \beta_h FFR_t + \gamma_h R^{\$}_{i,y-1} + \delta_h \left(FFR_t \times R^{\$}_{i,y-1} \right) \\ + \phi^L_h L^{\$}_{i,y-1} + \theta^L_h \left(FFR_t \times L^{\$}_{i,y-1} \right) + \phi^M_h M^{\$}_{i,y-1} + \theta^M_h \left(FFR_t \times M^{\$}_{i,y-1} \right) \\ + D_i + \epsilon_{i,t}, \qquad h \in [-10, 20]. \end{aligned} \tag{D.3}$$

The corresponding interacted-control specification for trade exposure only is:

$$\begin{aligned} e_{i,t+h} - e_{i,t-1} = \alpha + \beta_h FFR_t + \gamma_h R^{\$}_{i,y-1} + \delta_h \left(FFR_t \times R^{\$}_{i,y-1} \right) \\ + \phi^M_h M^{\$}_{i,y-1} + \theta^M_h \left(FFR_t \times M^{\$}_{i,y-1} \right) + D_i + \epsilon_{i,t}, \qquad h \in [-10, 20]. \end{aligned} \tag{D.4}$$

As in the baseline analysis, the reported object is the marginal effect of a one-standard-deviation larger dollar-reserve position after a 10-basis-point surprise increase in the federal funds rate,

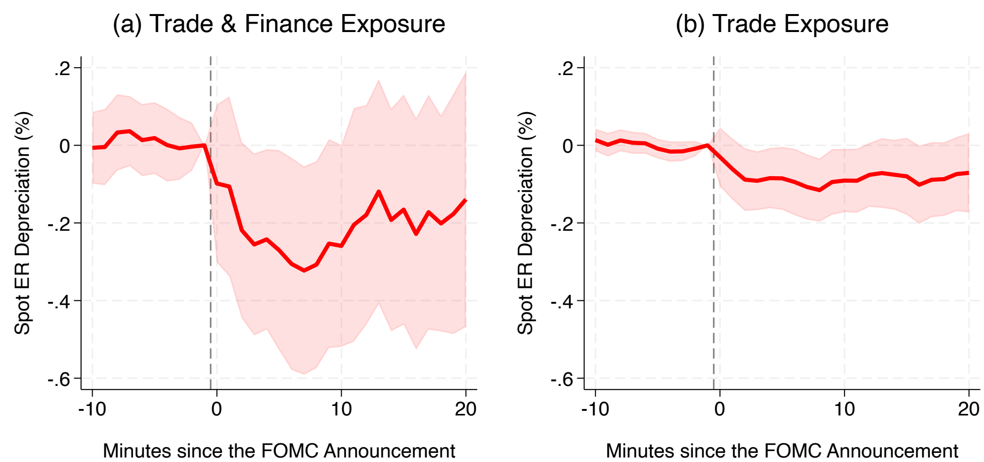
$$\left. \frac{\partial E[e_{i,t+h} - e_{i,t-1}]}{\partial R^{\$}_{i,y-1}} \right|_{FFR_t = 1} = \gamma_h + \delta_h.$$

Following Jorda and Taylor (2025), we complement pointwise confidence intervals with a joint Wald test over the post-announcement response path. This joint inference evaluates whether the reserve-response gradient is jointly different from zero over the event-window path, rather than at a single horizon. The joint post-announcement null is

$$H_0: \quad \gamma_h + \delta_h = 0 \quad \text{for all } h = 0, 1, \ldots, 20.$$

Fig. D.1 reports the specifications that control for dollar-exposure levels. The dollar-reserve gradient remains negative after the FOMC announcement when both external dollar liabilities and dollar-invoiced imports are included as controls. The pattern is smaller but still negative when the specification controls only for dollar-invoiced imports. The joint post-announcement tests reject the hypothesis that the reserve gradient is zero across all horizons in both specifications. These findings indicate that the baseline dollar-reserve buffer is not driven only by the correlation between reserve holdings and dollar exposure.

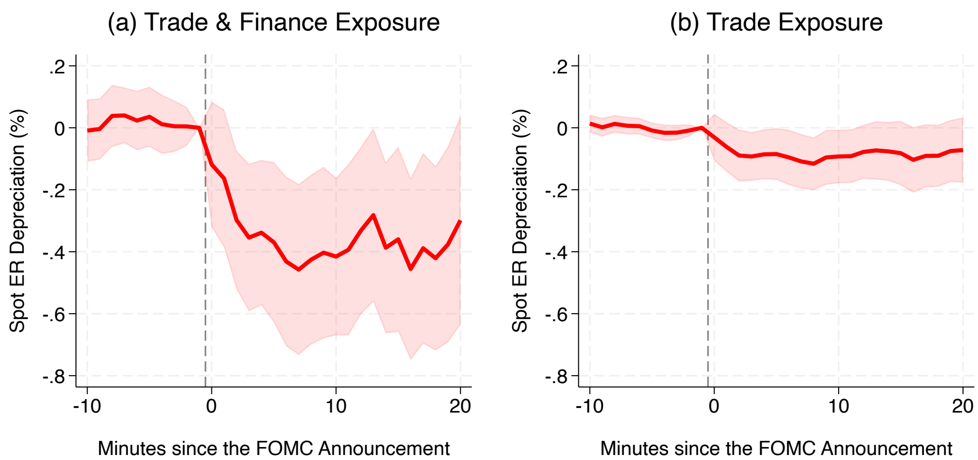
Fig. D.1: Robustness to Dollar Exposure: Exposure Controls



Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a one-standard-deviation difference in dollar reserves. Panel (a) reports the specification that controls for external dollar liabilities and dollar-invoiced imports, as in Equation D.1. Panel (b) reports the specification that controls for dollar-invoiced imports, as in Equation D.2. All reserve and exposure controls are lagged and standardized. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%. Joint Wald tests of $H_0 : \gamma_h + \delta_h = 0$ for all post-announcement horizons $h = 0, 1, \ldots, 20$ give $\chi^2(21) = 46.18$ and $p = 0.0012$ for panel (a), and $\chi^2(21) = 35.71$ and $p = 0.0235$ for panel (b).

Fig. D.2 reports the interacted-control specifications. These estimates allow US monetary spillovers to vary directly with external dollar liabilities and dollar-invoiced imports, and therefore absorb the direct exposure-specific sensitivity to the FOMC surprise. The dollar-reserve gradient remains negative in the finance-and-trade specification and in the trade-only specification, and the joint post-announcement tests reject the zero-gradient restriction in both panels. The implication is that larger dollar reserves retain independent explanatory power for smaller high-frequency depreciations even after controlling for both the level of dollar exposure and the differential transmission of US monetary shocks through these exposure margins.

Fig. D.2: Robustness to Dollar Exposure: Interacted Exposure Controls



Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a one-standard-deviation difference in dollar reserves. Panel (a) reports the specification that controls for external dollar liabilities, dollar-invoiced imports, and their interactions with the federal funds rate shock, as in Equation D.3. Panel (b) reports the specification that controls for dollar-invoiced imports and its interaction with the federal funds rate shock, as in Equation D.4. All reserve and exposure controls are lagged and standardized. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%. Joint Wald tests of $H_0 : \gamma_h + \delta_h = 0$ for all post-announcement horizons $h = 0, 1, \ldots, 20$ give $\chi^2(21) = 61.00$ and $p < 0.0001$ for panel (a), and $\chi^2(21) = 33.13$ and $p = 0.0448$ for panel (b).

E. Robustness to Macro Fundamentals

This appendix examines whether the dollar-reserve response gradient is robust to controlling for macroeconomic fundamentals. Because macroeconomic fundamentals are correlated with each other and with reserve holdings, we summarize them using a principal-component approach. Let $PCA^{M}_{i,y-1}$ denote the standardized first principal component of the lagged macro-fundamental controls. The PCA approach provides a parsimonious way to absorb common variation in macro fundamentals without overfitting the high-frequency panel.

The PCA factor is constructed from nine lagged and standardized macroeconomic controls, based on Ahmed et al. (2023). These controls cover relative income, relative prices, the current-account position, financial development, trade openness, fuel-export and fuel-import dependence, capital-account openness, and exchange-rate-regime stability. The real GDP per capita, current-account, trade-openness, and fuel-trade variables are obtained from the World Development Indicators; the CPI variable is obtained from the IMF International Financial Statistics; the financial-institutions index is obtained from the IMF Financial Development Index; capital-account openness is obtained from the Chinn–Ito database; and exchange-rate stability is obtained from the Aizenman–Chinn–Ito trilemma database. Each variable is lagged by one year and standardized before applying the PCA transformation, so that the factor summarizes predetermined macro fundamentals rather than contemporaneous exchange-rate movements. Table E.1 reports the variables, definitions, and sources.

Table E.1: Macro Variables Used to Construct the PCA Factor

Empirical variable	Definition	Source	Identifier / website
Ypc^{rel}	Real GDP per capita relative to the United States	World Development Indicators, World Bank	`NY.GDP.PCAP.KD`
CPI^{rel}	Consumer price index relative to the United States	International Financial Statistics, IMF	`PCPI_IX`
CA	Current-account balance as a share of GDP	World Development Indicators, World Bank	`BN.CAB.XOKA.GD.ZS`
FIN	Financial institutions index	Financial Development Index, IMF	`FD_FI_IX`
TRD	Trade openness, measured as exports plus imports as a share of GDP	World Development Indicators, World Bank	`NE.TRD.GNFS.ZS`
FEX	Fuel exports as a share of total exports	World Development Indicators, World Bank	`TX.VAL.FUEL.ZS.UN`
FEM	Fuel imports as a share of total imports	World Development Indicators, World Bank	`TM.VAL.FUEL.ZS.UN`
KA	Capital-account openness	Chinn–Ito database	https://web.pdx.edu/~ito/Chinn-Ito_website.htm
ERS	Exchange-rate-regime stability	Aizenman–Chinn–Ito trilemma database	https://web.pdx.edu/~ito/trilemma_indexes.htm

Note: The variables are lagged and standardized before the PCA transformation.

The first principal component is best interpreted as a broad macro-financial resilience, openness, and development factor. Let tildes denote the lagged standardized controls listed in Table E.1. The estimated first component is approximately:

$$PCA^{M}_{i,y-1} \approx 0.4525\,\widetilde{Ypc}^{rel}_{i,y-1} - 0.3397\,\widetilde{CPI}^{rel}_{i,y-1} + 0.3198\,\widetilde{CA}_{i,y-1} + 0.3214\,\widetilde{FIN}_{i,y-1} + 0.3224\,\widetilde{TRD}_{i,y-1} + 0.0585\,\widetilde{FEX}_{i,y-1} - 0.2989\,\widetilde{FIM}_{i,y-1} + 0.4549\,\widetilde{KA}_{i,y-1} + 0.2656\,\widetilde{ERS}_{i,y-1}.$$

Higher values of $PCA^{M}_{i,y-1}$ therefore correspond to countries with higher relative real GDP per capita, lower relative CPI, stronger current-account positions, stronger financial institutions, greater trade openness, lower fuel-import dependence, greater capital-account openness, and more stable exchange-rate regimes. The loading on fuel exports is small, indicating that the factor is not primarily a commodity-export factor. Instead, it summarizes the macro-financial fundamentals that could otherwise confound the reserve coefficient: development, price stability, external balance, financial institutions, openness, capital-account integration, fuel-import vulnerability, and exchange-rate-regime stability. This makes the PCA factor a useful control for omitted-variable concerns while preserving degrees of freedom in the high-frequency panel.

We consider two specifications. The first includes the PCA factor as a control:

$$e_{i,t+h} - e_{i,t-1} = \alpha + \beta_h FFR_t + \gamma_h R^{\$}_{i,y-1} + \delta_h \left(FFR_t \times R^{\$}_{i,y-1}\right) + \theta_h PCA^{M}_{i,y-1} + D_i + \epsilon_{i,t}, \quad h \in [-10, 20]. \tag{E.1}$$

The second specification also allows the exchange-rate response to the US monetary surprise to vary with macro fundamentals:

$$e_{i,t+h} - e_{i,t-1} = \alpha + \beta_h FFR_t + \gamma_h R^{\$}_{i,y-1} + \delta_h \left(FFR_t \times R^{\$}_{i,y-1}\right) + \theta_h PCA^{M}_{i,y-1} + \kappa_h \left(FFR_t \times PCA^{M}_{i,y-1}\right) + D_i + \epsilon_{i,t}, \qquad h \in [-10, 20]. \tag{E.2}$$

In both specifications, the reserve-response object remains

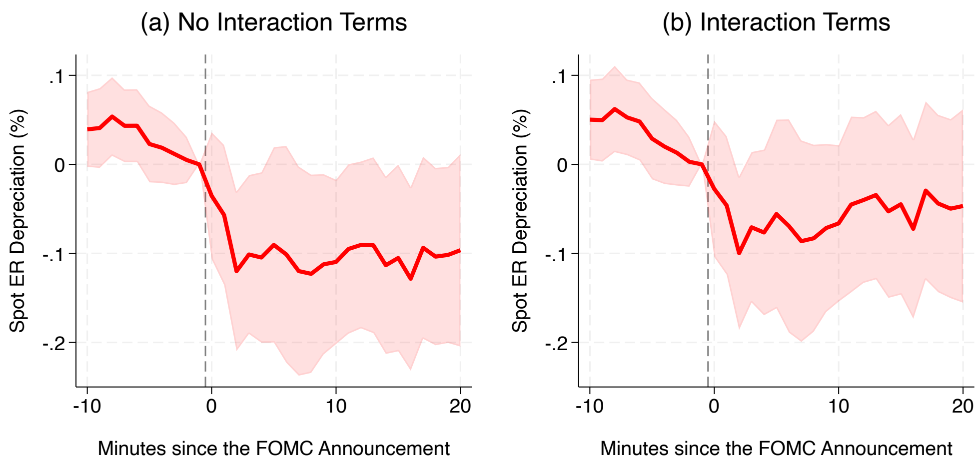
$$\left.\frac{\partial E[e_{i,t+h} - e_{i,t-1}]}{\partial R^{\$}_{i,y-1}}\right|_{FFR_t=1} = \gamma_h + \delta_h.$$

Following Jorda and Taylor (2025), we again complement pointwise confidence intervals with a joint Wald test over the post-announcement response path. This test summarizes whether the dollar-reserve gradient remains jointly different from zero after conditioning on macro-fundamental controls. The corresponding joint post-announcement null is

$$H_0: \quad \gamma_h + \delta_h = 0 \quad \text{for all } h = 0, 1, \ldots, 20.$$

Fig. E.1 shows that the dollar-reserve gradient remains negative after controlling for the PCA factor of macro fundamentals. The estimated pattern is similar when the PCA factor is included only as a level control and when it is also interacted with the US monetary shock. The interacted specification is useful because it allows macro fundamentals to affect the sensitivity of exchange rates to the monetary surprise itself. The persistence of the negative dollar-reserve gradient in both panels supports the interpretation that the baseline result is not simply a proxy for broader macroeconomic strength or vulnerability. Rather, dollar reserves continue to capture a distinct balance-sheet buffer against US monetary spillovers.

Fig. E.1: Robustness to Macro Fundamentals: PCA Approach



Note: The figure plots estimated exchange-rate responses following a 10 bp increase in the federal funds rate, evaluated at a one-standard-deviation difference in dollar reserves. Panel (a) reports the specification that controls for the standardized first principal component of lagged macro fundamentals, as in Equation E.1. Panel (b) additionally interacts the monetary-policy shock with the PCA factor, as in Equation E.2. The exchange rate is defined as the value of the US dollar in terms of foreign currencies. The standard error is clustered at the date level. The confidence interval is 95%. For the interacted-PCA specification in panel (b), the joint Wald test of $H_0 : \gamma_h + \delta_h = 0$ for all post-announcement horizons $h = 0, 1, \ldots, 20$ gives $\chi^2(21) = 43.79$ and $p = 0.0025$.