

Online Annex 2.1. Glossary of Key Foreign Exchange (FX) Market Terms

Bid-ask spread	The bid-ask spread is the difference between the highest price (exchange rate) that a dealer is willing to pay (bid) to buy foreign currency and the lowest price which the dealer is willing to accept (ask) to sell the foreign currency. The (average) bid-ask spread in the market reflects liquidity conditions and transaction costs.
Cross-currency basis	Cross-currency basis is the difference between the interest rates implied by foreign exchange swap markets and those observed in domestic money markets, often reflecting funding imbalances or market frictions between two currencies.
Currency exposure (mismatch)	Difference between an entity's assets and liabilities denominated in different currencies. This creates exposure to exchange rate fluctuations, as changes in currency values can affect the value of liabilities relative to assets.
Currency options	Contracts that give the right, but not the obligation, to exchange currency at a set rate before a specified date.
Currency swaps	Exchange of principal and interest payments in different currencies over a period.
Dealers	Market-making institutions that purchase and sell foreign currency from their own inventory for a profit
FX derivatives	Financial contracts whose value is based on the exchange rate between two currencies, such as forwards, futures, options, and swaps.
FX spot transactions	Immediate exchange of currencies at the current market rate.
FX hedging	The use of financial instruments—such as forwards, swaps, and options—to reduce or eliminate exposure to currency risk from currency mismatch on entity's balance sheets.
FX swaps	Simultaneous purchase (on spot rate) and sale (at a predetermined forward rate) on a future date of a currency.
Long position	In an FX swap, a long position in a currency involves selling that currency in the spot leg and buying it back in the forward leg at a pre-agreed forward rate.
Net settlement system	A payment arrangement where, instead of settling each transaction individually in real time, all transactions between participants over a given period are aggregated, and only the net amount owed or receivable is transferred at settlement.
Over-the-counter derivatives	Over-the-counter (OTC) derivatives are financial contracts—such as swaps, forwards, and options—negotiated privately between two parties rather than traded on an exchange.
Outright forwards	Agreements to exchange currencies at a future date at a predetermined rate.
Payment-vs-payment	Payment-versus-payment (PvP) is a settlement mechanism that ensures the simultaneous exchange of two currencies in a foreign exchange transaction, eliminating the risk that one party delivers its currency while the other does not.
Settlement risk	Settlement risk is the risk that one party in a financial transaction fails to deliver the promised asset or payment after the other party has already fulfilled their obligation.
Short position	In an FX swap, a short position in a currency involves buying that currency in the spot leg and selling it back in the forward leg at a pre-agreed forward rate.

Online Annex 2.2. Data Description and Sources**A. Foreign Exchange Market Data****Continuous Linked Settlement (CLS)**

Measuring global foreign exchange (FX) trading activity is inherently challenging due to the market's fragmented and decentralized nature, with trading dispersed across numerous platforms, institutions, and jurisdictions. CLS, a specialized market infrastructure that facilitates payment-versus-payment (PvP) settlement for FX transactions, plays a critical role in bridging this gap by providing centralized, high-quality data on settled trades. The primary source of FX data for this chapter is CLSMarketData, which offers high-frequency information—including hourly spot and forward prices, as well as daily spot flows—for 40 exchange rates covering 18 currencies and over 70 major financial institutions. This dataset enables a granular and timely view of global FX market dynamics, supporting robust analysis of trading patterns, liquidity conditions, and market responses to macroeconomic developments.

CLS records hourly buy and sell trading volumes in the base currency, as well as transaction counts, covering the entire FX trading week from Sunday 9 PM to Friday 9 PM (London time, GMT). It classifies FX market participants into four groups: banks, corporates, funds, and other nonbank financial institutions. “Banks” include large commercial banks, custodian banks, investment banks, and central banks that maintain accounts directly with CLS Bank. “Funds” include mutual funds, pension funds, hedge funds, and sovereign wealth funds. “Nonbank financial institutions” cover insurance companies, brokers, and clearing houses; and “corporates” comprise all nonfinancial firms. Corporates, funds, and other nonbank financial firms are considered price takers (the buy side), whereas banks act as market makers (the sell side). Thus, hourly “buy volume” represents how much base currency price takers purchase from banks, and “sell volume” refers to how much they sell back to banks. For FX swap transactions, this generally corresponds to purchasing the far leg of the swap.

The bespoke data developed for this chapter corresponds to the aggregate values of transactions from a sector in a country to banks in another country, aggregated at (country-sector) x (counterparty country)-level. The data on prices are volume-weighted and segmented for respective flows from a sector in a country and the counterparty in another country. The list of countries—both for parties and counterparties—includes 20 countries representing 16 advanced and 4 emerging market economies, with the Euro area divided into Germany, Spain, France, Italy, Netherlands, and a group of other euro area countries.¹ It also includes monthly data on FX swap prices and flows disaggregated by trading partners at the country-sector level and by maturity bucket (1-3 days, 4-95 days, 96-360 days, or more).

CLS transactions cover over 50 percent of the volumes traded in the global FX market for the 18 currencies settled in CLS Settlement. The average daily traded volume is about USD2 trillion from over 70 settlement members and over 35,000 third-party participants, of which over 28,000 are funds (including 81 percent of the top-tier asset managers) and the remainder are non-financial corporates (multinationals) and NBFIs.

Of the CLS Settlement eligible transactions (which comprise approximately 80 percent of the total global FX market according to a 2022 Bank for International Settlements survey), 51 percent of the traded notional is settled through CLS Settlement on average. In terms of specific FX instruments, CLS captures about 45 percent of spot, 55 percent of FX swap, and 15 percent of outright forward transactions.

While CLS settles only a portion of global FX transactions, it is important to note that CLS data closely mirrors broader market trends, including relative trading activity across different instruments and currencies, as documented by the BIS Triennial Survey (2022).² Several studies—such as Hasbrouck and Levich (2021), Kloks et al. (2023), and Rinaldo and Somogyi (2021)—note that CLS-based metrics broadly track aggregate FX market dynamics, making them a useful proxy for overall market behavior despite its partial coverage.

Other FX data sources

Additional information on the FX market and exchange rates for an expanded group of economies is obtained from the Bank for International Settlement’s (BIS) Triennial Central Bank Survey of Foreign Exchange and Over-the-Counter (OTC) Derivatives Markets, BIS OTC derivatives statistics, Bloomberg, LSEG EIKON and DataStream (see Online Annex Table 2.2.1). The BIS Triennial Survey is a comprehensive and authoritative source of information on the structure and trends in the global FX market. It provides a snapshot of daily FX trading activity every third year in the month of April based on data collected by central banks from bank-dealers in their jurisdictions.

¹ Exact country coverage may vary across exercises because of differences in data availability.

² For instance, the majority of CLS trades involve the U.S. dollar. EUR/USD and USD/JPY together account for nearly half of all CLS positions, reflecting their status as the two most-traded currency pairs globally (BIS, 2022). The top five CLS currency pairs—all against the U.S. dollar—represent almost 70 percent of the total, while FX swaps account for roughly 80 percent of all CLS transactions, broadly matching the shares reported in the BIS Triennial Central Bank Survey (2022).

Online Annex Table 2.2.1. Foreign Exchange Market Data Sources

A. Foreign Exchange Market Data

Sample Period: January 1, 2015–May 31, 2025						
Settlement type		PvP Currencies			Non-PvP Currencies	
		CLS		Non-CLS PvP Platform		
Data Source		CLS Market Data	Trading partners		Bloomberg, LSEG EIKON, DataStream	Bloomberg, LSEG EIKON, DataStream
			Sectors (n=4)	Jurisdictions (n=20)		
Advanced Economies (AE)	Currencies (n=17)	AUD, CAD, CHF, DKK, EUR, GBP, HKD, ILS, JPY, KRW, NOK, NZD, SEK, SGD, USD	Bank, investment fund, other NBFIs, nonfinancial corporate,	AUS, CAN, CHE, DEU, DNK, ESP, FRA, HKG, ITA, JPN, KOR, NLD, SGP, GBR, USA, Other EA		CZK, TWD
	Pairs (n=38)	AUD/CAD, AUD/CHF, AUD/JPY, AUD/NZD, AUD/USD, CAD/JPY, CHF/JPY, EUR/AUD, EUR/CAD, EUR/CHF, EUR/DKK, EUR/GBP, EUR/JPY, EUR/NOK, EUR/NZD, EUR/SEK, EUR/SGD, EUR/USD, GBP/AUD, GBP/CAD, GBP/CHF, GBP/JPY, GBP/USD, NOK/SEK, NZD/JPY, NZD/USD, USD/CAD, USD/CHF, USD/DKK, USD/HKD, USD/ILS, USD/JPY, USD/KRW, USD/NOK, USD/SEK, USD/SGD				USD/CZK, USD/TWD
Emerging Markets (EM)	Currencies (n=11)	HUF, MXN, ZAR		CHN, MEX, RUS, ZAR	MYR, THB, BRL, INR	PLN, RUB, TRY, CLP
	Pairs (n=11)	USD/HUF, USD/MXN, USD/ZAR			USD/MYR, USD/THB, USD/BRL, USD/INR	USD/PLN, USD/RUB, USD/TRY, USD/CLP

B. Summary of Main Data Sources

Type of Data	Data Frequency	Geographic Coverage	Period Coverage	Source
Macro-financial uncertainty				
Economic Policy Uncertainty index	Daily	US	2005:M1-2025:M5	Baker, Bloom, and Davis (2016)
VIX	Daily	US	2005:M1-2025:M5	LSEG DataStream
MOVE	Daily	US	2005:M1-2025:M5	LSEG DataStream
Macro-financial data				
Macroeconomic data (GDP, inflation, etc.)	Monthly, Quarterly	19 AE, 19 EM	2005:M1-2025:M5	Haver; IMF database
Stock price	Daily	19 AE, 19 EM	2000:M1-2025:M5	Bloomberg; Haver; LSEG DataStream; LSEG EIKON
Commodity price index	Daily	Global	2005:M1-2025:M5	Bloomberg
Chicago Financial Condition Index	Daily	US	2005:M1-2025:M5	Federal Reserve Bank of Chicago
Goldman Sachs Financial Condition Index	Daily	17 AE, 13 EM	2005:M1-2025:M5	Goldman Sachs
Sovereign bond yield	Daily	19 AE, 19 EM	2005:M1-2025:M5	Bloomberg; Haver; LSEG DataStream; LSEG EIKON

Policy rates	Daily	19 AE, 19 EM	2005:M1-2025:M5	Bloomberg; Haver; LSEG DataStream; LSEG EIKON; Bank for International Settlements
Overnight Index Swap, T-Bill and Reference Rate	Daily	19 AE, 19 EM	2000:M1-2025:M5	Bloomberg; Haver; LSEG DataStream; LSEG EIKON; IMF database
Foreign Exchange (FX) and Capital Flow				
CLS spot FX rate	Hourly	16 AE, 2 EM (40 pairs)	2015:M1-2025:M5	CLS MarketData
CLS forward FX rate	Hourly	16 AE, 2 EM (40 pairs)	2005:M1-2025:M5	CLS MarketData
CLS spot FX flows	Daily	16 AE, 2 EM (40 pairs)	2005:M1-2025:M5	CLS MarketData
CLS swap FX flows	Weekly	16 AE, 2 EM (40 pairs)	2015:M1-2025:M5	CLS MarketData
Exchange rates (bid, ask)	30-minute intervals, daily	19 AE, 19 EM (60 pairs)	2000:M1-2025:M5	Bloomberg; LSEG DataStream; LSEG EIKON
FX UIP and CIP premium, bid-ask spread	Monthly	19 AE, 19 EM (60 pairs)	2005:M1-2025:M5	IMF Staff Calculations
FX market turnover	Triannual	52 AEs and EMDEs	1986-2022	Bank for International Settlement
FX net speculative positions (related to carry trade)	Weekly	AUD, BRL, CAD, EUR, JPY, MXN, NZD, GBP, RUB, ZAR, CHF	2005:M1-2025:M5	Haver; CFTC “Reportable noncommercial long positions” and “Reportable noncommercial short positions”
Bilateral banking claims and liabilities	Quarterly	19 AE, 19 EM	2005:Q1-2025:Q2	BIS consolidated/location banking statistics
Sovereign debt				
EM sovereign debt holding by sector	Quarterly	19 EMDEs	2005:Q1-2025:Q2	Haver
AE sovereign debt holding by sector	Quarterly	19 AEs	2005:Q1-2025:Q2	Haver
Financial system				
Financial sector balance sheet, and financial ratios	Quarterly	19 AEs, 19 EMDEs	2005:Q1-2025:Q2	Haver; IMF “Financial Soundness Indicators”
Asset-weighted banking sector CDS spread	Daily	USA	2005:M1-2025:M5	Bloomberg
Asset-weighted banking sector EDF score	Daily	USA	2005:M1-2025:M5	Moody’s KMV

Online Annex 2.3. How has the global FX market evolved over time?

To analyze the key structural developments in the global FX market over the past decade, this chapter constructs a set of variables that seek to capture trends in FX market conditions, transaction volumes, participation shares of countries, institutional sectors, and currency pairs, as well as compositional shifts in trading dynamics.

FX market conditions

FX market conditions are examined using the following three price-based indicators:

- (i) Excess exchange rate return volatility, proxied by 30-day excess return realized volatility ($ERV_{c,cr,t}$).³

³ Excess Realized Volatility (ERV) is defined as the realized volatility of excess returns, where excess returns are defined as $\log(\text{exchange rate at time } t / \text{exchange rate at time } t-1) - \log(\text{forward rate at time } t-1 / \text{exchange rate at time } t-1)$ with overnight forward rate proxied by overnight interest rate differential. Conceptually, this is correlated with the exchange rate deviation from uncovered interest rate parity (UIP) with one day maturity..

- (ii) Market liquidity proxied by the bid-ask spread ($Bid_Ask_{c,c',t}$), normalized by the mid rate.
- (iii) Funding liquidity and hedging cost proxied by the US dollar covered interest parity (CIP) premium ($CIP_PRM_{c,usd,t}$).

Following Du, Tepper, and Verdelhan (2018), the CIP premium is computed as the difference between the direct cost of borrowing a foreign currency and the implied cost of obtaining it via FX swaps or forwards. Formally:

$$(1 + i_{t,\tau}^{FC})^{\frac{\tau}{360}} = (1 + i_{t,\tau}^{LC} + CIP_Premium_{t,\tau})^{\frac{\tau}{360}} \left(\frac{SpotFX_{t,\tau}}{ForwardFX_{t,\tau}^{Market}} \right) \quad (2.3.1)$$

In log terms, the CIP deviation is equal to the difference between the direct foreign currency rate from the cash market and the synthetic dollar interest from the FX swap market:

$$CIP_Premium_{t,\tau} = i_{t,\tau}^{FC} - (i_{t,\tau}^{LC} - \rho_{t,\tau}) \quad (2.3.2)$$

where $\rho_{t,\tau}$ is the annualized forward premium of selling currency i in exchange for the foreign currency. Following Du et al. (2018), the CIP premium (in log form) relative to the US dollar is computed as follows:

$$CIP_Premium_{t,\tau}^{OIS} \equiv i_{t,t+n}^{USD,OIS} - (i_{t,\tau}^{LC,OIS} - \rho_{t,\tau}) \quad (2.3.3)$$

where $i_{t,\tau}^{USD,Libor}$ and $i_{t,\tau}^{USD,OIS}$ are the direct costs of funding in foreign currency at time t for duration τ -days (the τ -maturity interest rate in foreign currency), $i_{t,\tau}^{LC,OIS}$. For robustness, and to extend the analysis to a broader set of EMs, we construct an alternative measure of CIP deviation based on the yield differentials of government bonds, following Du, Im, and Schreger (2020), as follows:

$$CIP_{t,\tau}^{Treasury} \equiv i_{t,\tau}^{Govt} - \rho_{i,\tau} - i_{USD,\tau}^{Govt} \quad (2.3.4)$$

where $i_{t,\tau}^{Govt}$ is the n -year local-currency government bond yield in country i , $\rho_{i,\tau}$ is the τ -days market-implied forward premium for hedging currency i against the US dollar, and $i_{USD,\tau}^{Govt}$ is the τ -days US treasury bond yield.⁴ The 5-years government bond yield is used for the computation of the measure following (Du et al. 2018). The Treasury CIP deviation measures the deviation between the yield on a U.S. Treasury security and the synthetic yield implied by converting a foreign bond's returns into USD using a FX swap.

A larger CIP deviation indicates a greater premium or discount for holding US Treasuries relative to CIP-implied levels, often reflecting shifts in hedging demand or funding conditions. Market frictions, including limited arbitrage capacity, regulatory constraints, or liquidity shortages, create CIP premiums by preventing arbitrageurs from correcting pricing discrepancies (Du et al. 2018; Du and Huber 2024).

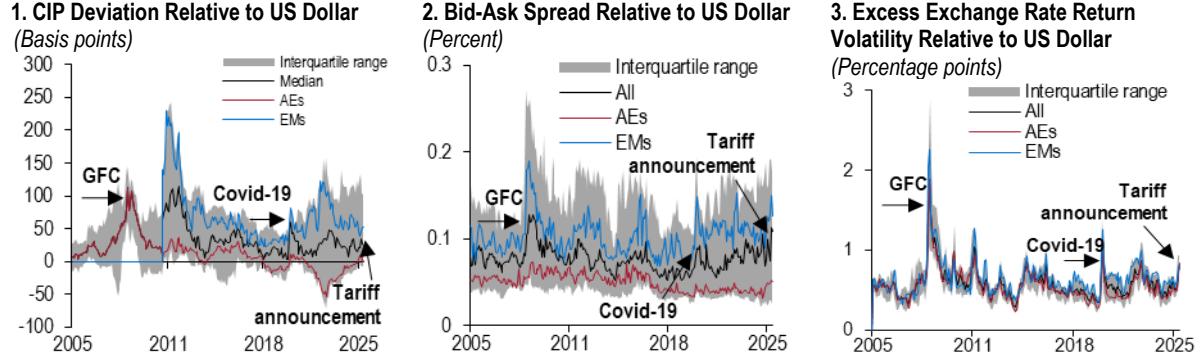
Empirical Results.

Figure 2.3.1 shows the evolution of the key FX market condition metrics discussed above. FX funding and market liquidity conditions deteriorated significantly during the global financial crisis and the COVID-19 market turmoil. in both advanced and emerging market economies.

⁴ A negative OIS cross-currency basis indicates that the direct dollar interest rate is lower than the synthetic dollar interest in the FX swap market, and a positive cross-currency basis means that the direct dollar rate is higher than the synthetic rate. Conversely, a positive treasury premium implies that the convenience yield of U.S. Treasuries is higher than the convenience yield of that country's government bonds.

Online Annex Figure 2.3.1. Macrofinancial Uncertainty and Foreign Exchange Market Conditions by Country Group

FX funding and market liquidity conditions deteriorated significantly during the global financial crisis and the COVID-19 market turmoil.



Sources: Bloomberg Finance L.P.; Refinitiv; and IMF staff calculations.

Note: In panel 1, CIP deviation is calculated using 5-year government rates for 10 emerging market economies and 12 advanced economies against the US dollar. A negative widening basis signals stress in dollar funding markets. Panel 2 shows bid-ask spread calculated as (ask rate-bid rate)/mid rate (in percent). Wider spreads suggest reduced market liquidity. The sample includes 19 emerging market economies and 18 advanced economies. In panel 3, excess exchange rate return is defined as $\log(\text{exchange rate at time } t / \text{exchange rate at time } t-1) - \log(\text{forward rate at time } t-1 / \text{exchange rate at time } t-1)$. Tariff announcement refers to the April 2, 2025, declaration of new import tariff rates by the United States. AEs=advanced economies; CIP = covered interest parity; EMs=emerging markets; GFC = global financial crisis; OIS = Overnight index swaps.

Transaction volumes

The empirical analysis is performed using sector-level data from CLS bank—covering FX spot and swap market transactions among banks, investment funds, other financial institutions, and non-financial corporates across major economies. Unless otherwise indicated, the sample period is January 1, 2015, to May 31, 2025. Details on the main data sources and countries included in the sample are provided in Annex 2.2.

Spot market. Let $FX_Flows_{c,c',i,j,s,t}$ denote the value of a FX spot transaction between sector s in country i and the banking sector in country j during period t , as observed directly from the CLS dataset.⁵ The flow is assumed as positive if sector s in country i receives currency c against a payment made in currency c' , and negative otherwise. Based on this, the gross inflows and outflows of currency c for country-sector i, s in period t , from and to the rest of the world, can be calculated as follows:

$$InFlows_{c,i,s,t} = \sum_{c'} \sum_{j \neq i} \max (FX_Flows_{c,c',i,j,s,t}, 0) \quad (2.3.5)$$

$$OutFlows_{c,i,s,t} = \sum_{c'} \sum_{j \neq i} \min (FX_Flows_{c,c',i,j,s,t}, 0) \quad (2.3.6)$$

Swap market. Let $SWAP_Flows_{c,c',i,j,s,t}$ denote the FX flows associated with a swap transaction between sector s in country i and the banking sector in country j during period t . The flow value is recorded as positive if sector s in country i receives currency c in exchange for a payment made in currency c' , and negative otherwise.

Gross inflows and outflows of foreign currency c related to swap contracts are calculated as follows:

$$SwapInFlows_{c,i,s,t} = \sum_{c'} \sum_{j \neq i} \max (Swap_Flows_{c,c',i,j,s,t}, 0) \quad (2.3.7)$$

⁵ CLS membership mainly consists of large banks, and every transaction flow from an institutional sector in the dataset is recorded predominantly with banks.

$$SwapOutFlows_{c,i,s,t} = \sum_{c'} \sum_{j \neq i} \min(SwapFlows_{c,c',i,j,s,t}, 0). \quad (2.3.8)$$

The net flows of currency c into country-sector i, s in period t via swap contracts can be obtained by subtracting the sector-specific outflows from the corresponding inflows: $NetSwapFlows_{c,i,s,t} = SwapInFlows_{c,i,s,t} - SwapOutFlows_{c,i,s,t}$. Country-level gross inflows, gross outflows, and net flows can be calculated through aggregation of the corresponding flows across all sectors s .

The accumulation of gross flows from swap contracts that have not yet matured as of time t provides a proxy for the *outstanding* open long and short positions of country-sector i, s in foreign currency c :

$$LongSwapPositions_{c,c',i,s,t} = \sum_{\substack{\tau \leq t \\ Maturity(\tau) > t}} SwapInFlows_{c,c',i,s,\tau} \quad (2.3.9)$$

$$ShortSwapPositions_{c,c',i,s,t} = \sum_{\substack{\tau \leq t \\ Maturity(\tau) > t}} SwapInFlows_{c,c',i,s,\tau}. \quad (2.3.10)$$

Similarly, the long and short swap positions of country i can be approximated by aggregating the corresponding exposures across all sectors, as follows:

$$LongSwapPositions_{c,c',i,t} = \sum_s \sum_{\substack{\tau \leq t \\ Maturity(\tau) > t}} SwapInFlows_{c,c',i,s,\tau} \quad (2.3.11)$$

$$ShortSwapPositions_{c,c',i,t} = \sum_s \sum_{\substack{\tau \leq t \\ Maturity(\tau) > t}} SwapInFlows_{c,c',i,s,\tau}. \quad (2.3.12)$$

Additional Stylized Facts

Online Annex Figure 2.3.2 presents the shares of FX spot and swap transactions by currency pair over the period 2015M1–2025M5. The discussion below provides more details on sectoral flows for spot and swap US dollar transactions.

USD spot market. US and non-US dealer banks are at the core of the global FX market, as they perform market making intermediation services that facilitate transactions among clients, including non-dealer banks (Online Annex Figure 2.3.3). The stylized facts that emerge from the dataset reveal that most of the time (under normal conditions), US banks exhibit negative net USD flows as they act as providers of USD funding to other market participants; in contrast, non-US banks tend to exhibit positive net USD flows.

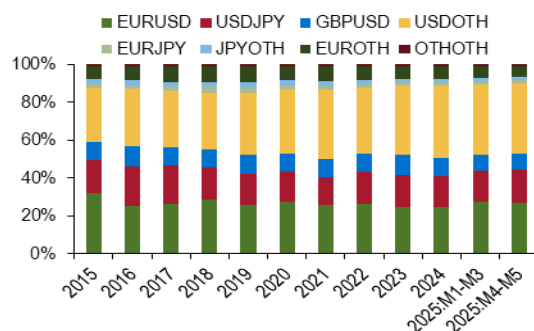
Non-banks domiciled outside the US are most often net buyers of USD, but their trading patterns exhibit high sensitivity to changes in global macro-financial conditions. Non-banks, in the US exhibit less distinctive trading patterns and could be at times either net buyers or net sellers of USD.

USD swap market. In the swap market with tenors longer than 35 days, net demand for USD funding and hedging is driven mostly by non-banks (Online Annex Figure 2.3.4). For this reason, net trading flows for non-banks are mostly negative (i.e. they receive USD in the spot leg and sell USD in the forward leg of the swap contracts)—this is clearly the case for non-banks domiciled outside the US. US banks perform a maturity transformation role in USD FX swaps by borrowing dollars short term from other banks and lending them to non-banks seeking longer-term hedges.

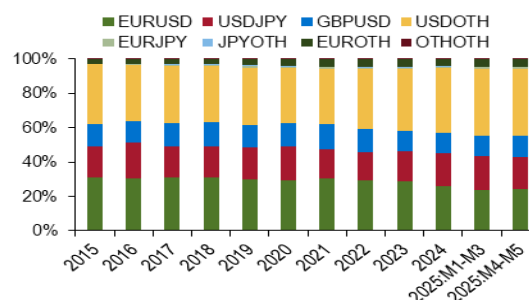
Although US banks are the largest providers of USD on a gross basis, aggregated flow data show them to be net dollar borrowers in the FX swap market, due to their role in intermediating between short-term funding sources and longer-term hedging demand. Non-banks in the US can either buy or sell opportunistically. Note that these trends could somewhat differ if measured using outstanding positions, which capture institutions' full balance sheet exposures and reduce the potential overrepresentation of positions that are frequently rolled over at short maturities. Similar dynamics are reported in Klok and others. (2023), which show that, in aggregate, US banks often maintain matched books when measured on an outstanding basis.

Online Annex Figure 2.3.2 Global FX Market: Structure and Trends

1. FX Spot by Currency Pair, 2015–2025:M5
(Percent of the total)



2. FX Swap by Currency Pair, 2015–2025:M5
(Percent of the total)

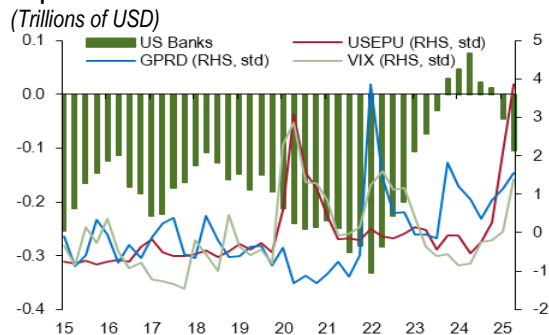


Sources: CLS; and IMF staff calculations.

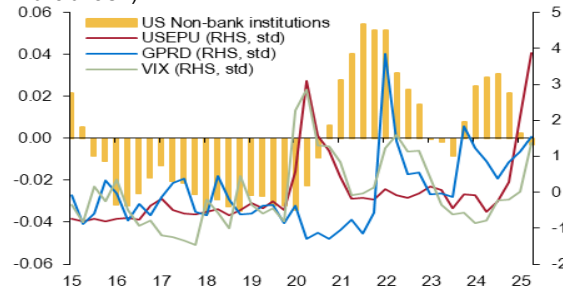
Notes: The panels show the composition of FX spot (left panel) and swap transactions (right panel) aggregated by currency pairs and across time. EUR = euro; GBP = British pound; JPY = Japanese yen; OTH = other currencies; USD = US dollar.

Online Annex Figure 2.3.3. Spot Market USD Net Flows for Different Types of Institutions

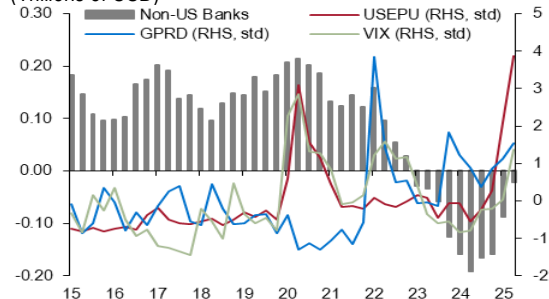
1. Spot Market Net Flows for US Banks
(Trillions of USD)



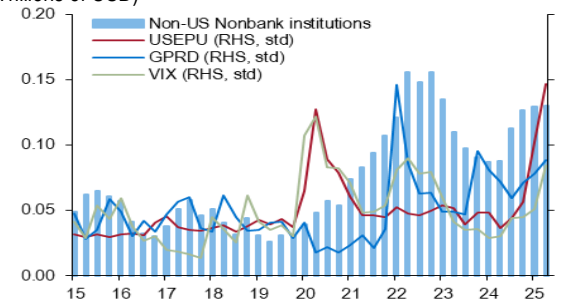
2. Spot Market Net Flows for US Nonbank Institutions
(Trillions of USD)



3. Spot Market Net Flows for Non-US Banks
(Trillions of USD)



4. Spot Market Net Flows for Non-US Nonbank institutions
(Trillions of USD)

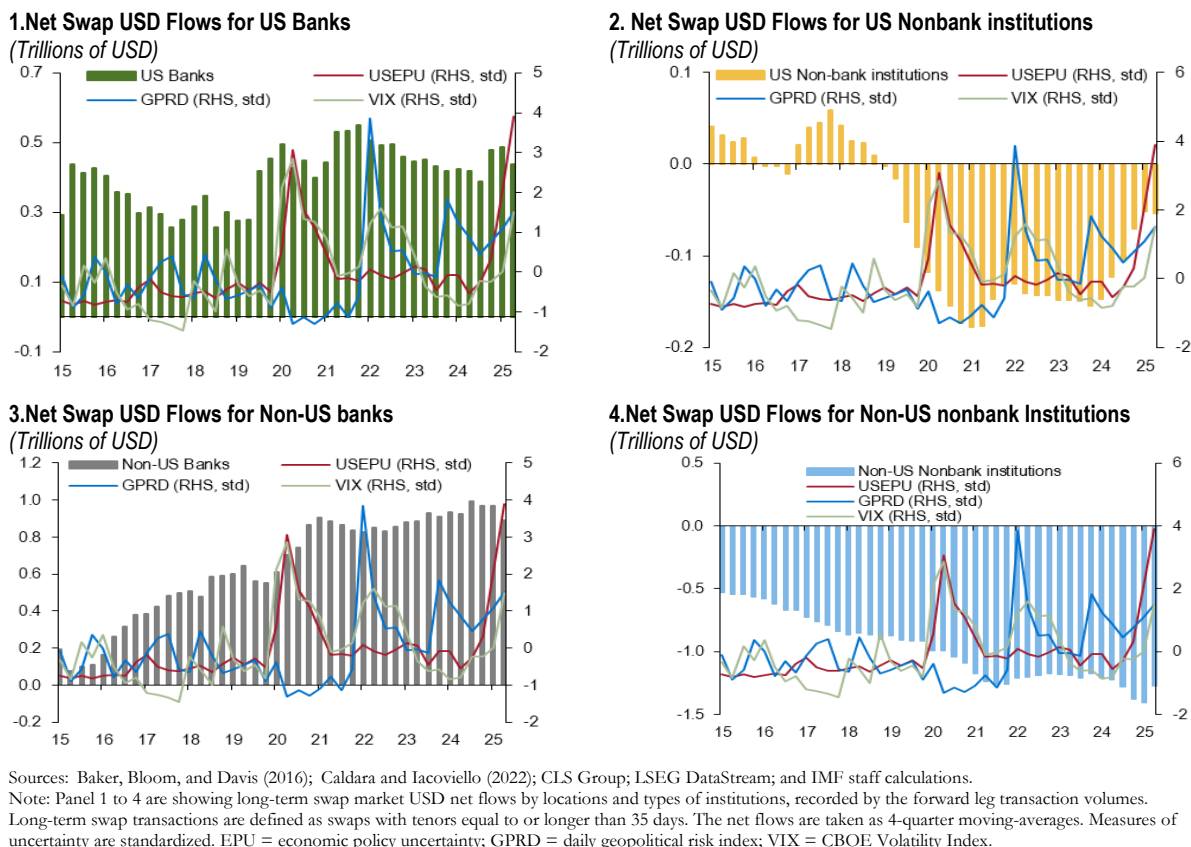


Sources: Baker, Bloom, and Davis (2016); Caldara and Iacoviello (2022); CLS Group; LSEG DataStream; and IMF staff calculations.

Note: Panel 1 to 4 are showing spot market 4-quarter moving-average USD net flows by locations and types of institutions. Measures of uncertainty are standardized. EPU = economic policy uncertainty; GPRD = daily geopolitical risk index; VIX = CBOE Volatility Index.

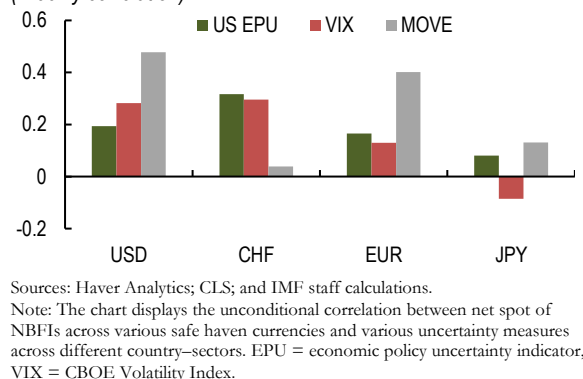
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Online Annex Figure 2.3.4. Long-term Net Swap USD Flows by Sector



Online Annex Figure 2.3.5 shows the unconditional relationship between net spot flows of nonresident NBFIs and different types of uncertainty shocks over the period 2015M1–2025M5. The evidence indicates that, when macrofinancial uncertainty rises, nonresident NBFIs tend to increase their demand for safe-haven assets. This behavior is evident not only in U.S. dollar assets but also in other traditional safe-haven currencies. In particular, net spot purchases of the euro and Swiss franc rise markedly during these episodes, suggesting that NBFIs actively diversify across safe haven assets amid higher macro-financial uncertainty.

Online Annex Figure 2.3.5. NBFIs: Net Spot Flows of Safe-Heaven Currencies vs VIX, EPU and MOVE, 2015M1–2025M5 (Weekly correlation)



Structural changes and vulnerabilities

Measures of concentration, currency imbalances (mismatches), and participation shares of NBFIs are constructed to identify structural shifts and vulnerabilities that could act as amplifiers of external shocks:

a. Dealer Concentration. The dealer concentration measure is computed as a Herfindahl-Hirschman Index ($HHI_{c,c',t}$) for each currency-pair c, c' , and period t by summing the squared market shares of dealer flows over total FX flows:

$$HHI_{c,c',t} = \sum_{\bar{i}} \sum_s \sum_j \left(\frac{|FX_Flows_{c,c',\bar{i},j,s,t}|}{\sum_{\bar{i}} \sum_s \sum_j |FX_Flows_{c,c',\bar{i},j,s,t}|} \right)^2. \quad (2.3.13)$$

Where $FX_Flows_{c,c',\bar{i},j,s,t}$ is the flow from/to country-sectors with dealer banks ($\bar{i}$) as identified by the list of primary dealers published by the Federal Bank of New York (namely Canada, France, Germany, Japan, Switzerland, the UK, and the US). A higher HHI indicates greater concentration and fewer dominant dealers.

b. Share of NBFi Flows (of investment funds and other NBFIs). An increase in the share of NBFIs relative to other market participants—measured by transacted volumes in the FX market—may have destabilizing effects on the market. This is because investment funds and other NBFIs typically seek higher investment yields and tend to adjust cross-border investment positions more rapidly in response to shocks and changes in risk perceptions. The participation share of NBFIs for each currency pair c, c' , and period t is defined as follows:

$$ShareNBFi_{c,c',t} = \frac{\sum_i \sum_j (|FX_Flows_{c,c',i,j,Fund,t}| + |FX_Flows_{c,c',i,j,OtherNBFi,t}|)}{\sum_i \sum_s \sum_j |FX_Flows_{c,c',i,j,s,t}|}, \quad (2.3.14)$$

where flows corresponding to the sectors $s \in \{\text{Funds, Other NBFi}\}$ are shown separately and total FX flows in the denominator exclude bank-to-bank flows, to allow for a more direct comparison across end-customer flows.

c. Currency mismatch (“hedging pressure”). To capture the net hedging behavior across sectors with respect to currency c , we follow the literature for commodity future markets (e.g., Kang et al. 2020), and define “hedging pressure” as the difference between all short and long FX swap (forward) positions for a given sector s scaled by the global *outstanding* contracts in currency c .⁶ Formally, this measure reflects the directional imbalance in hedging demand, providing insight into sector specific currency exposures:

$$Hedging\ Pressure_{USD,c',t} = \left(\frac{\sum_i ShortSwapPositions_{USD,c',i,s,t} - \sum_i LongSwapPositions_{USD,c',i,s,t}}{\frac{1}{52} \sum_{k=0}^{52} \sum_i \sum_s OI_{USD,c',i,s,t-k}} \right), \quad (2.3.15)$$

where the denominator is the *outstanding interest* in USD computed as the sum of short and long FX swap *outstanding* positions across all sectors trading currency *USD* against currency c' .⁷ One-year moving average of the outstanding interest is used in the denominator to smooth large fluctuations. This measure is particularly relevant for NBFIs, especially investment funds, which often account for the largest share of volume in the forward rate market and may therefore exhibit more pronounced hedging behavior.⁸

⁶ Forward contracts are categorized as short positions for market participants who sell forward contracts in currency c , and as long positions for those who buy forward contracts in currency c . Outstanding positions is extracted from a CLS bespoke dataset.

⁷ Namely, outstanding interest is defined as $OI_{c,c',i,t} = \sum_{s \in \text{Sector}} (Long\ Positions_{c,c',i,s,t} + Short\ Positions_{c,c',i,s,t})$.

⁸ For example, funds are a counterparty in 63 percent of all outstanding interest in forwards for the EURUSD rate

The chapter also examines other measures of currency mismatch, such as the cross-currency funding (gap) ratio (CCFR) and the net foreign investment position (NIP). The CCFR captures the actual balance sheet mismatch on the banking sector of country i . Formally, this is defined as:

$$USD\ FX_Mismatch_{i,t} = \frac{USD_Assets_{i,t} - USD_Liabilities_{i,t}}{USD_Assets_{i,t}} \quad (2.3.16)$$

where $USD_Assets_{i=c,t}$ and $USD_Liabilities_{i=c,t}$ represents financial assets and liabilities denominated in USD, derived from BIS Locational Banking Statistics at quarterly frequency. The measure is computed at both the country and currency-area levels, with the latter based on a weighted average across constituent countries. It serves as a proxy for reliance on “synthetic” funding via FX swaps, under the assumption—partly shaped by regulatory requirements—that banks typically avoid holding unhedged FX positions.⁹

NIP is defined as the difference between foreign residents’ holdings of US bonds and US residents of foreign bonds, scale by the sum of the positions:

$$NIP_{i,t} = \frac{Foreign\ Positions\ in\ US\ bonds_{i,t} - US\ Positions\ in\ Foreign\ bonds_{i,t}}{Foreign\ Positions\ in\ US\ bonds_{i,t} + US\ Positions\ in\ Foreign\ Bonds_{i,t}} \quad (2.3.17)$$

A positive NIP indicates that foreign holdings of US bonds excess US holdings of foreign bonds of country i , implying greater potential hedging demand from foreign investors into US dollars. Foreign and US positions to construct the measure draw on the monthly long-term bond holdings (TIC) dataset compiled by the US Treasury. CCFR and NIP are used in the empirical analysis at the currency level, aggregating countries within the same currency area using GDP-weighted averages.

Empirical results. Additional analysis studies the main drivers of fund hedging pressure measure.

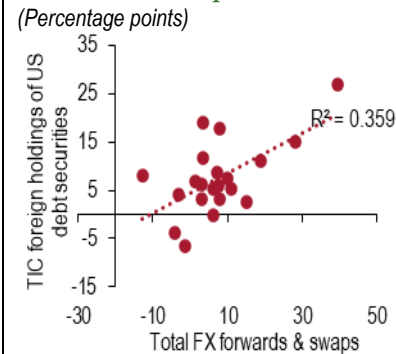
Beyond term spread differentials, the measure is, as expected, closely linked to the USD net investment position. Quantitatively, a one–percentage point change in NIP corresponds to a 1.2 percentage point change in hedging pressure.¹⁰

Intuitively, if foreign investors hold significantly more U.S. bonds than U.S. investors hold foreign bonds (positive NIP), foreign investors are long USD assets and exposed to USD currency risk. To reduce this risk, they typically sell USD forward (or equivalently, buy their home currency forward), increasing measured hedging pressure in the market. These results are consistent with the hedging channel documented by Liao and Zhang (2025). Consistent with this evidence, changes in FX swap or forward positions of NBFIs tend to be positively correlated with changes in U.S. Treasury holdings by foreign institutions (Online Annex Figure 2.3.6).

Online Annex 2.4. How do macrofinancial uncertainty shocks affect trading activity?

To address this question, the chapter uses the following measures to capture macroeconomic and financial uncertainty:

Online Annex Figure 2.3.6.
Changes in Foreign Holding of US Long-Term Debt vs Changes in FX Forward and Swaps



Source: BIS OTC Derivatives Statistics; and Treasury International Capital (TIC) System; and IMF staff calculations.

⁹ The measure can take positive or negative values. A negative value may indicate that a bank secures substantial FX through deposits or money markets but does not channel these funds into lending. A similar approach is employed in Barajas et al. (2020) and Eguren-Martin et al. (2023).

¹⁰ The estimated model controls for currency-specific fixed effects, the USD broad index, and the term spread differential. Similar results are obtained when employing a richer set of time fixed effects.

- Economic Policy Uncertainty (EPU) is the index for the US developed by Baker et al. (2016). The index for the US is considered because of its availability at a higher frequency than for the global index. In general, movements in US policy uncertainty are highly correlated with global uncertainty due to its dominant role in the global economy. A shock to the index (D_UNCRT_t) is defined as an event in which the AR(1) residual for the EPU exceeds two standard deviations above its mean.¹¹
- Financial uncertainty is proxied by the VIX index of the Chicago Board of Options Exchange. Shocks to this measure ($D_FINUNCRT_t$) are defined as an event in which the AR(1) residual of the VIX exceeds two standard deviations above its mean.
- Monetary policy uncertainty is captured by the Merrill Option Volatility Estimate (MOVE) index. A shock to the index (D_MOVE_t) is defined as an event in which the AR(1) residual of the exceeds two standard deviations above its mean. For robustness, shocks to monetary policy-related uncertainty are also considered by constructing another variable, D_MPU_t , derived from the US EPU index.¹²

Next, the effect of these shocks on FX trading activity is estimated, while differentiating between the various types of institutional sectors, as follows:

$$\Delta \log(InFlow_{c,i,s,t+h}) = \alpha_{c,i,s}^h + \lambda_{c,i,t}^h + \beta_c^h GShock_t + \gamma_c^h \cdot Control_{c,i,s,t} + \delta_c^h \cdot Global_t^h + v_{c,i,s,t}^h \quad (2.4.1)$$

where $InFlow_{c,i,s,t+h}$ is the inflow of currency c corresponding to sector s in country i and Δ indicates the change between time t and $t+h$; $GShock_t$ refers to the uncertainty measures indicated above (level and shock) at time t ; and $Control_{c,i,s,t}$ includes the domestic country term spread defined as the difference between the country i 's 10-year and 3-month government bond yield, and the exchange rate for currency c . The model for FX swap inflows also controls for the 3-month CIP deviation. $Global_t$ controls for common factors such as a commodity price index, the Chicago Financial Condition Index, US term spread defined as the difference between US 10-year and 3-month government bond yield, end-of-quarter dummy to control for seasonality. Finally, the model includes $\alpha_{c,i,s}$ as the country-sector fixed effect, as well as country-month-year effects ($\lambda_{c,i,t}^h$) to control for potential macroeconomic developments that could impact FX flows in specific currencies to country i .

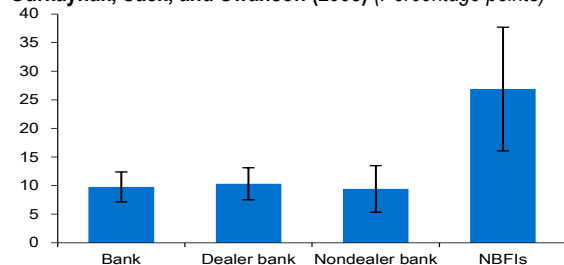
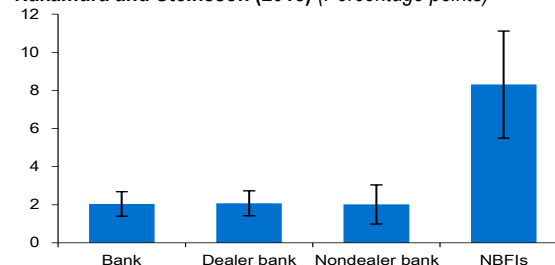
Equation (2.4.1) is estimated with weekly frequency trading flows for both spot and swap transactions, using data from CLS over the period January 1, 2015–May 31, 2025.¹³ Additionally, the specification is estimated across different sectors to evaluate the cross-sectoral impact of shocks, as well as differentiating countries by USD FX mismatch (CCFR) or net foreign investment position in USD (NIP). The analysis focuses mainly on the USD, but the analysis for other safe-haven currencies, such as CHF and JPY, are also included. Standard errors are clustered at the country level.

Empirical results. Online Annex Figure 2.4.1 presents the baseline model estimates using proxies for monetary policy uncertainty (D_MPU_t). The patterns closely mirror those in the main text (Figure 2.7), reinforcing the robustness of the results.

¹¹ Specifically, an AR(1) model is estimated as follows: $UNCRT_t = \alpha + \beta \cdot UNCRT_{t-1} + e_t^{UNCRT}$. Using the estimated residual e_t^{UNCRT} , the economic policy uncertainty shock is defined as $D_UNCRT = Dummy(\hat{e}_t^{UNCRT} > 2 \cdot Stdev(\hat{e}_t^{UNCRT}))$, where $Dummy(x)$ is a dummy variable equal to one when x is true, and $Stdev(x)$ is the historical standard deviation of x .

¹² Because the monetary policy uncertainty sub-component of the US EPU index is not directly available at weekly frequency, a proxy is constructed by regressing the EPU index on US monetary policy surprises, as identified by Nakamura and Steinsson (2018) or Gürkaynak, Sack, and Swanson (2005), and using the fitted values as a high-frequency measure of monetary policy-driven economic policy uncertainty. This approach isolates the component of EPU attributable to unexpected changes in US monetary policy. Shocks to this series are defined as an event in which its AR(1) residual exceeds the mean by two standard deviations.

¹³ The inflow of currencies in the FX swap market corresponds to the outflow of foreign currency in the forward leg of the transaction.

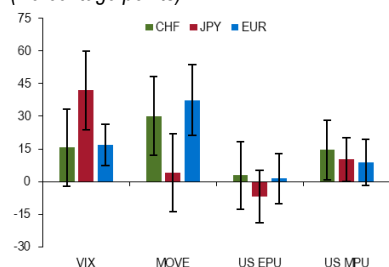
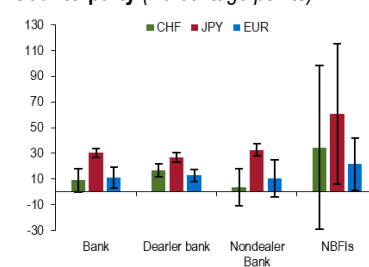
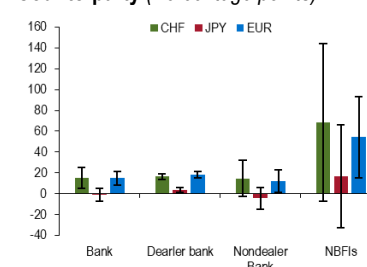
Online Annex Figure 2.4.1 Effect of Monetary Policy Uncertainty on FX Spot Activity**1. Change in USD Spot Flows following an Increase in Monetary Policy Uncertainty due to Monetary Policy Shocks Based on Gürkaynak, Sack, and Swanson (2005) (Percentage points)****2. Change in USD Spot Flows following an Increase in Monetary Policy Uncertainty due to Monetary Policy Shocks Based on Nakamura and Steinsson (2018) (Percentage points)**

Sources: Baker, Bloom, and Davis (2016); CLS Group; LSEG Datastream; and IMF staff calculations.

Notes: USD flows refer to spot transactions by non-US financial and nonfinancial institutions in 15 jurisdictions. The panels show the impact of monetary policy uncertainty shock proxies on weekly changes in USD inflows in the spot market, estimated using a panel model. These shocks are constructed by regressing the U.S. EPU index on two alternative measures of monetary policy surprises, following Gürkaynak, Sack, and Swanson (2005) and Nakamura and Steinsson (2018). The model controls for a range of global and domestic macro-financial factors, including the Chicago Financial Conditions Index, a commodity price index, the US term spread, domestic term spreads, and the spot exchange rate. The specification also includes country-sector fixed effects and country-time fixed effects. Uncertainty shocks are defined as dummy variables equal to 1 when the AR(1) residual of the respective indicator exceeds two standard deviations. NBFIs = nonbank financial institutions.

In addition to USD flows, the demand for other safe-haven currencies such as the CHF, the JPY, and the EUR is also analyzed. The results show that heightened global uncertainty results in increased demand for these currencies by nonresidents (Online Annex Figure 2.4.2). For instance, a shock to VIX is estimated to increase the volume of transactions in the spot market for JPY by about 40 percent, suggesting that investors reallocate their asset portfolios toward safe-haven currencies when uncertainty increases.¹⁴

Across sectors, the increase in demand for safe-haven currencies is the most pronounced for NBFIs following global uncertainty shocks. Specifically, following VIX shocks, the volume transacted by NBFIs in the JPY spot market increases by 55 percent, twice as much as the volume transacted by banks. Similarly, a shock to the MOVE index, increases the volume transacted by NBFIs in the CHF spot market by 47 percent, while the effect for banks is below 20.

Online Annex Figure 2.4.2 Effect of External Shocks on FX Spot Activity in CHF, JPY and EUR**1. Change in CHF, JPY, and EUR Spot Flows following Uncertainty Shocks (Percentage points)****2. Change in CHF, JPY, and EUR Spot Flows following a VIX Shock by Counterparty (Percentage points)****3. Change in CHF, JPY, and EUR Spot Flows following a MOVE Shock by Counterparty (Percentage points)**

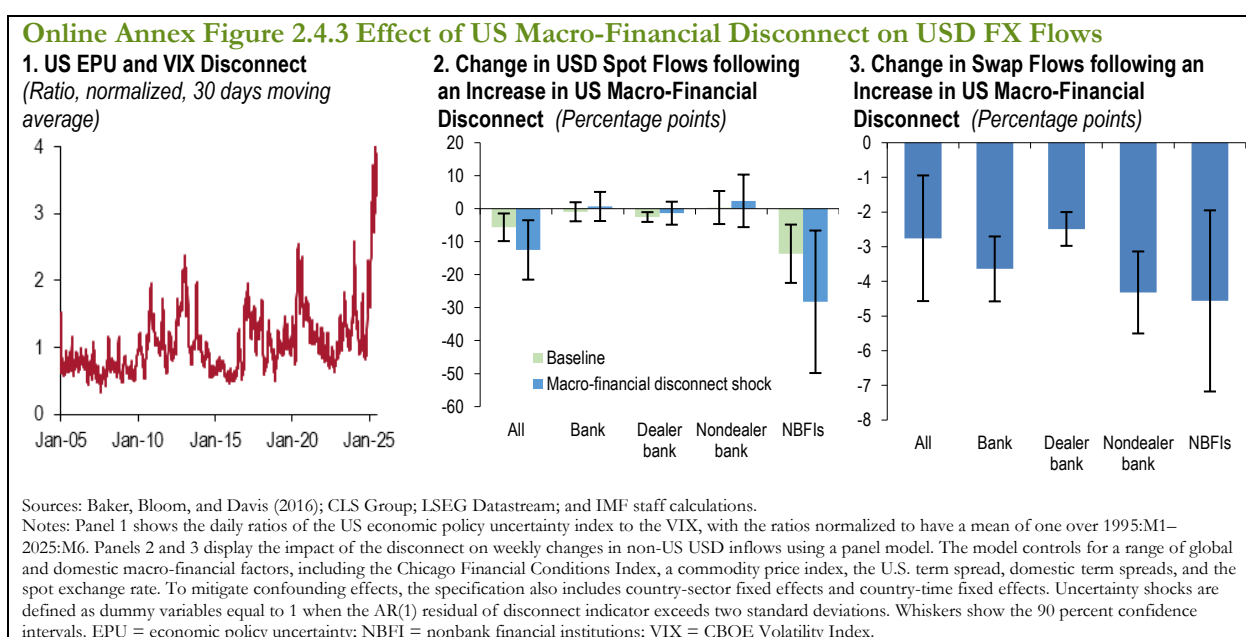
Sources: Baker, Bloom, and Davis (2016); CLS Group; LSEG Datastream; and IMF staff calculations.

Notes: The panels display the impact of different uncertainty shocks on weekly changes in CHF, JPY, and EUR inflows using a panel model. Flows refer to non-US non-residents inflows in the spot market. Specifically, CHF FX flows refer to spot transactions by non-Switzerland, non-US financial and nonfinancial institutions, JPY FX flows refer to spot transactions by non-Japan, non-US financial and nonfinancial institutions, and EUR FX flows refer to spot transactions by non-Eurozone, non-US financial and nonfinancial institutions. In the main text, USD purchases refer to transactions by the euro area, Japan, and Switzerland. The results shown in this panel remain consistent when transactions by US institutions are included. The model controls for a range of global and domestic macro-financial factors, including the Chicago Financial Conditions Index, a commodity price index, the U.S. term spread, domestic term spreads, and the spot exchange rate. To mitigate confounding effects, the specification also includes country-sector fixed effects and country-time fixed effects. Uncertainty shocks are defined as dummy variables equal to 1 when the AR(1) residual of the respective indicator exceeds two standard deviations. Whiskers show the 90 percent confidence intervals. EPU = economic policy uncertainty; NBFIs = nonbank financial institutions; VIX = CBOE Volatility Index.

¹⁴ While the response of JPY turnover to uncertainty shocks appears larger than that of the USD, this disparity is largely due to the difference in market size. For context, in the weeks immediately preceding the COVID-19 outbreak, the average weekly USD spot transactions were roughly USD 2.2 trillion; a 21 percent rise during the crisis therefore corresponded to an additional USD 0.46 trillion in trading volume. By comparison, average weekly JPY spot transactions were only about USD 0.6 trillion, so a 42 percent increase amounted to USD 0.25 trillion. Therefore, despite the larger percentage change, the increase in USD inflows remained more significant in absolute terms.

The nature of the shocks is also important. Localized episodes—such as increases in U.S.-specific policy uncertainty—can have different effects from broad-based surges in global financial uncertainty. To capture this distinction, we construct a measure of the disconnect between U.S. policy uncertainty (EPU) and global financial uncertainty (VIX) and use it as an alternative variable in equation (2.4.1) to the global uncertainty shock measure employed in the main analysis.

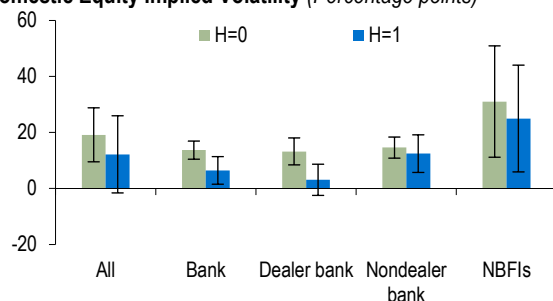
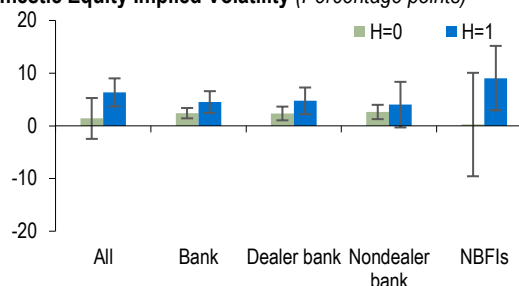
As shown in panel 1 of Online Annex Figure 2.4.3, the “macro-financial” disconnect has shown considerable movement over time. Consistent with earlier empirical evidence (October 2024 GFSR, Chapter 2), the analysis shows that when US EPU is high, while global financial uncertainty may be contained (i.e., EPU–VIX disconnect is wider), nonresident investors may reduce USD purchases (Online Annex Figure 2.4.3, panels 2 and 3).¹⁵ The effect is nonlinear, increasing in the magnitude of the disconnect. Furthermore, institutions also react to the disconnect in the swap market by decreasing hedging activity to some extent.



To assess the response of nonresident USD FX flows to large domestic shocks across countries, equation (2.4.1) is re-estimated by replacing the global shock variable with a domestic analogue. This variable is constructed in the same way as the VIX shock but based on the implied volatility of 10 percent out-of-the-money put options specific to the domestic currency area.

The results, presented in Online Annex Figure 2.4.4, confirm the main findings: large domestic financial uncertainty shocks also trigger increased purchases of U.S. dollars in both spot and swap markets. Consistent with earlier results, NBFIs appear also more sensitive to such shocks, with their response in the swap market occurring with a one-period lag relative to the spot market.

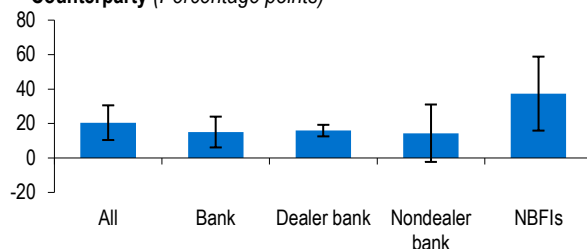
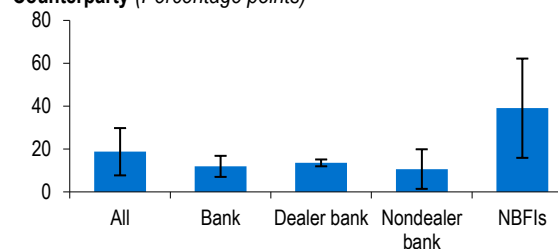
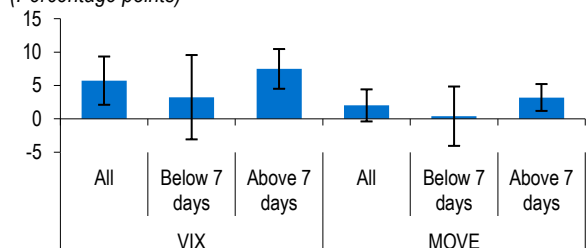
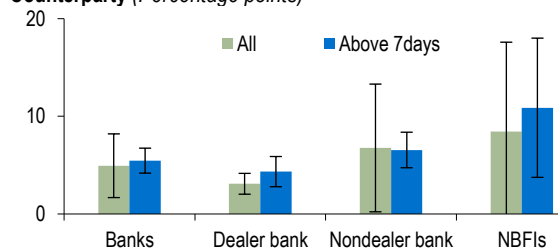
¹⁵ As discussed in October 2024 GFSR, Chapter 2, several factors can drive macro–market disconnects, often linked to the perception that policy actions will step in to limit downside risks. Such disconnects can arise when political signals are weak, when investor views diverge more sharply, or when equity markets remain strong despite rising uncertainty. They can also be influenced by technical market dynamics, such as the widespread use of option strategies like covered-call hedging, which can dampen volatility indicators and keep measures like the VIX unusually low.

Online Annex Figure 2.4.4 Effect of Domestic Equity Implied Volatility**1. Change in USD Spot Flows following an Increase in Domestic Equity Implied Volatility (Percentage points)****2. Change in USD Swap Flows following an increase in Domestic Equity Implied Volatility (Percentage points)**

Sources: CLS Group; LSEG Datastream; and IMF staff calculations.

Notes: The panels show the impact of shocks to domestic equity implied volatility on weekly changes in USD inflows (spot and swap), estimated using a panel model. The model controls for a range of global and domestic macro-financial factors, including the Chicago Financial Conditions Index, a commodity price index, the U.S. term spread, domestic term spreads, the spot exchange rate and 3-months CIP deviation. To mitigate confounding effects, the specification also includes country-sector fixed effects and country-time fixed effects. Uncertainty shocks are defined as dummy variables equal to 1 when the AR(1) residual of the respective indicator exceeds two standard deviations. Green bars indicate the effect of contemporaneous shocks while the blue bars indicate the effect of shocks over the next week. Whiskers show the 90 percent confidence intervals. NBFIs = nonbank financial institutions;

Robustness analysis. The model is tested under various fixed-effect specifications, including country-sector–time fixed effects, country-sector and time fixed effects. Additional robustness exercises check for end-of-month, as well as the presence of FX swap lines. An extended specification also incorporates FX implied volatility, the LIBOR–OIS spread as well as additional global factors such as USD broad index. Alternative clustering of standard errors is also conducted at the country-sector level. Finally, Online Annex Figure 2.4.5 presents the results for equation (2.4.1) for the period 2015:M1–2024:M12 to exclude the period around April 2 tariff announcements, with unusually high levels of economic policy uncertainty. The results remain robust to the baseline results reported in the main text.

Online Annex Figure 2.4.5 Robustness Pre-tariff Period: Effect of Macrofinancial Uncertainty on Foreign Exchange Swap Flows**1. Change in Spot US Dollar Inflows After a VIX Shock, by Counterparty (Percentage points)****2. Change in Spot US Dollar Inflows After a MOVE Shock, by Counterparty (Percentage points)****3. Change in US Dollar Swap Inflows Following Uncertainty Shocks (Percentage points)****4. Change in US Dollar Swap Inflows Following VIX Shocks by Counterparty (Percentage points)**

Sources: CLS Group; LSEG Datastream; and IMF staff calculations.

Notes: The panels display the impact of different uncertainty shocks on weekly changes in dollar inflows using a panel model excluding the 2025 period. The model controls for a range of global and domestic macrofinancial factors, including the Chicago Financial Conditions Index, a commodity price index, the US term spread, domestic term spreads, the spot exchange rate and the 3-months CIP deviation (for swap flow regressions only). The specification also includes country-sector fixed effects and country-time fixed effects. Uncertainty shocks are defined as dummy variables equal to 1 when the AR(1) residual of the respective indicator exceeds two standard deviations. Whiskers show the 90 percent confidence intervals. MOVE = Merrill Lynch Option Volatility Estimate; NBFIs = nonbank financial institutions; VIX = CBOE Volatility Index.

Online Annex 2.5. How do macro-financial uncertainty shocks affect FX market conditions? Do structural vulnerabilities in FX markets amplify the effects of these shocks?

To examine the effect of macro-financial uncertainty shocks on FX market conditions, the following regression is estimated:

$$Y_{c,c',t+h} = \alpha_{c,c'}^h + \beta_{c,c'}^h \cdot GShock_t + \gamma_{c,c'}^h \cdot Control_{c,c',t} + \delta_{c,c'}^h \cdot Global_t + v_{c,c',t}^h \quad (2.5.1)$$

where $Y_{c,c',t+h}$ reflects the different measures of FX market conditions ($ERV_{c,c',t}$, $Bid_Ask_{c,c',t}$, $CIP_PRM_{c,c',t}$) for a currency-pair c, c' . $Control_{c,c',t}$ includes home economy default probability, forward bid-ask spread, the term spread differential (i.e. 10-years bond yields minus 3-years bond yield), and US dollar index to control for global factors ($Global_t^h$). Currency-fixed effects $\alpha_{c,c'}^h$ are included to control for unobserved time-invariant characteristics. Equation (2.5.1) is estimated at weekly frequency across different time horizons ($h=0, \dots, 16$ weeks). The analysis covers 11 currency pairs over the period January 1, 2006–May 31, 2025.¹⁶ The results in the main text of the chapter correspond to $h=0$, while the findings for longer horizons are discussed below.

To evaluate whether structural vulnerabilities in the FX market—such as concentration of dealers, currency mismatches of financial institutions, and increased involvement of NBFIs—amplify the impact effects of uncertainty shocks on excess return volatility and liquidity of specific currency pairs, equation (2.5.1) is extended to include interaction terms between shocks and these vulnerabilities, as follows:

$$Y_{c,c',t+h} = \alpha_{c,c'}^h + \beta_{c,c'}^h \cdot GShock_t * Vulnerability_{c,c',t-1} + \gamma_{c,c'}^h \cdot Control_{c,c',t} + \delta_{c,c'}^h + \delta_{c,c'}^h \cdot GShock_t + \eta_{c,c'}^h \cdot Vulnerability_{c,c',t-1} + \eta_{c,c'}^h \cdot Global_t + v_{c,c',t}^h \quad (2.5.2)$$

where the dependent variable, $GShock$, $Control$, and $Global$ are defined as in equation (2.5.1). $Vulnerability_{c,c',t-1}$ reflects the measures for dealer concentration, currency mismatch, and the participation share of NBFIs defined above in Online Annex 2.3. The analysis is conducted at weekly frequencies. Standard errors are calculated using the Newey–West heteroskedasticity- and autocorrelation-consistent (HAC) estimator, which corrects for potential heteroskedasticity and serial correlation in the regression residuals.

Finally, extensions of the analysis also explore how policy-related factors could influence FX market conditions. Formally:

$$Y_{c,c',t+h} = \alpha_{c,c'}^h + \beta_{c,c'}^h \cdot GShock_t * Policy Measure_{c,c',t-1} + \gamma_{c,c'}^h \cdot Control_{c,c',t} + \delta_{c,c'}^h + \delta_{c,c'}^h \cdot GShock_t + \eta_{c,c'}^h \cdot Policy Measure_{c,c',t-1} + \eta_{c,c'}^h \cdot Global_t + v_{c,c',t}^h \quad (2.5.3)$$

where the policy factor corresponds to a dummy variable equal to one for the currencies for which the Federal Reserve announced a new swap line during the COVID-19 pandemic, or the level of international reserves held by central banks (normalized by GDP).¹⁷

Additional stylized facts. Online Annex Figure 2.5.1 compares US Treasuries and dealer balance sheets with the international capital ratio, the latter based on He et al. (2017) and defined as intermediaries' equity divided by total assets—the inverse of leverage and a proxy for financial capacity. The charts below show that the US Treasury supply has surged in recent years, driven by large government borrowing, while dealer balance sheets have remained flat, limiting their ability to absorb inventory and intermediate. Over the same

¹⁶ Models including vulnerability measures based on CLS data will have a coverage restricted to the period 2015–2025.

¹⁷ In 2020, the Federal Reserve introduced temporary U.S. dollar swap lines with the Reserve Bank of Australia, Banco Central do Brasil, Danmarks Nationalbank, Bank of Korea, Banco de México, Reserve Bank of New Zealand Monetary Authority of Singapore, Sveriges Riksbank, and Norges Bank. Currencies in the sample with new swap lines include the Danish krone, the Norwegian krone, the Singapore dollar, and the Swedish krona. The dummy variable takes the value of one for these currencies starting in the week the new swap lines were announced (week 12 of 2020). The results remain consistent when currencies with outstanding swap lines are excluded or over the sample period with active use of the swap lines.

period, the international capital ratio fluctuated but has not kept pace with the growth in marketable debt, suggesting potential constraints on market-making capacity.

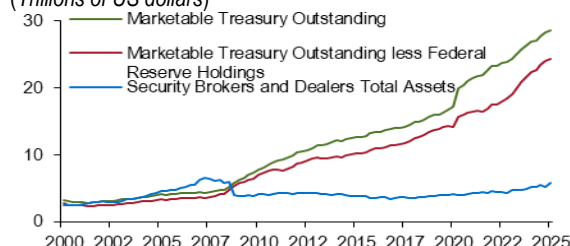
Online Annex Figure 2.5.1 US Treasury Supply and Dealers' Balance sheet Capacity

While the supply of U.S. Treasuries has surged in recent years...

... dealer balance sheets have not expanded in tandem, limiting their capacity to absorb inventory and intermediate in key markets.

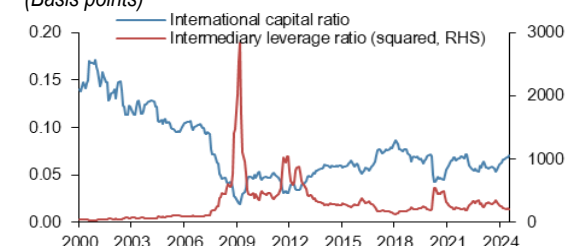
1. US Treasuries and Dealers Balance Sheet

(Trillions of US dollars)



2. International Capital Ratio

(Basis points)



Source: FRED; He et al. (2017); and IMF staff calculations.

Note: The international capital ratio is based on He, Kelly, and Manela (2017) and is measured as intermediaries' equity divided by total assets, serving as the inverse of leverage and a proxy for their financial capacity.

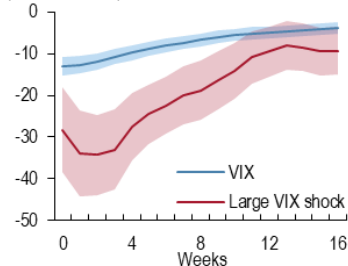
Empirical results. Online Annex Figure 2.5.2 presents additional results from the model in equation (2.5.1), examining the persistence of external shocks across various FX market conditions over time. The findings show that the impact of VIX shocks peaks at around four weeks and persists for up to 16 weeks, with similar patterns observed for the US EPU shocks. While these results are specific to advanced economy currencies included in CLS, equation (2.5.1) is also estimated for a broader sample including major emerging market (EM) economies. As OIS rates are unavailable for many EM currencies, the OIS-based CIP deviation is replaced with the government yield-based measure described in Online Annex 2.3. In this case, a larger government CIP deviation signals dollar funding stress, i.e., tighter dollar liquidity.

Results are reported in Online Annex Figure 2.5.3. The analysis shows that EMs generally face stronger and more persistent impacts from uncertainty shocks across all indicators of FX market functioning. On average, the Treasury CIP deviation widens by 16 basis points and bid-ask spreads by 0.04 basis points—both more than double the increase observed for advanced economies—while excess exchange rate return volatility rises by 0.2 percentage points. As much of the variation in Treasury CIP deviations could reflect credit risk (e.g., Du and Schreger 2016; Du and Schreger 2022; Dao and Gourinchas 2025), the regression analysis controls for expected default frequency of the banking sector, with results robust to the use of sovereign CDS spreads.

Online Annex Figure 2.5.2. Effect of External Shocks on FX Conditions across Time

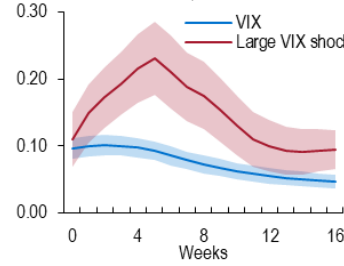
1. Effect of an increase in VIX on CIP deviation vis-à-vis the USD over time

(Basis points)



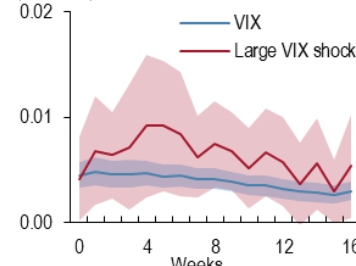
2. Effect of an increase in VIX on excess exchange rate return volatility vis-à-vis the USD over time

(Percentage points)



3. Effect of an increase in VIX on bid-ask spreads vis-à-vis the USD over time

(Percent)

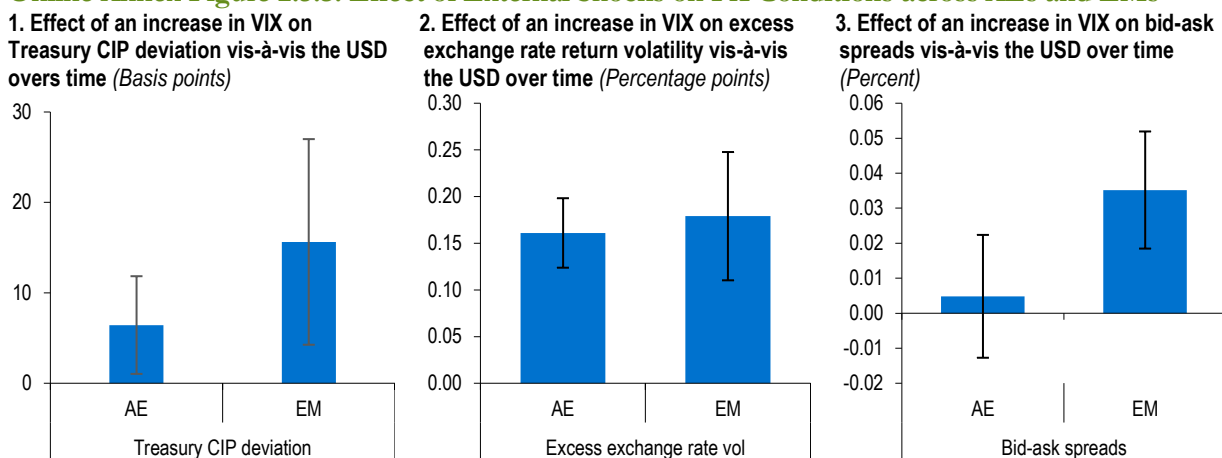


Sources: Baker, Bloom, and Davis (2016); CLS Group; LSEG Datastream; and IMF staff calculations.

Note: The panel shows the effect of one standard deviation of each uncertainty indicator and corresponding shocks across time on weekly 3-months OIS CIP deviation, excess rate return volatility, and bid-ask spreads (respectively). High uncertainty shocks are defined as dummy variables equal to 1 when the AR(1) residual of the respective indicator exceeds two standard deviations. VIX = CBOE Volatility Index.

Finally, in addition to the effect of the Fed’s swap line announcements documented in the chapter (Figure 2.12), the analysis evaluates the impact of international reserves on FX market conditions. Online Annex Figure 2.5.4 shows that international reserves serve as a key stabilizer in stress episodes by enabling central banks to provide dollar liquidity to domestic institutions and possibly by also bolstering sovereign creditworthiness, and limiting depreciation pressures on the currency. Economies with reserve buffers about one standard deviation above the average show markedly smaller CIP deviations and lower excess exchange rate return volatility after macro-financial uncertainty shocks.

Online Annex Figure 2.5.3. Effect of External Shocks on FX Conditions across AEs and EMs



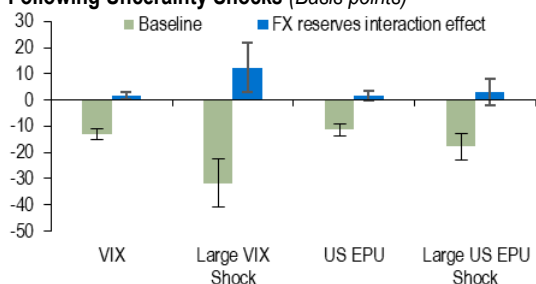
Sources: Baker, Bloom, and Davis (2016); CLS Group; LSEG Datastream; and IMF staff calculations.

Note: The panel shows the effect of one standard deviation of each uncertainty indicator and corresponding shocks across time on weekly 5-years CIP deviation based on the government bond yields to extend data coverage among EMs, excess rate return volatility, and bid-ask spreads (respectively). The EM sample comprises 16 emerging market economies, with coverage varying by the availability of the target variable. Large uncertainty shocks are defined as dummy variables equal to 1 when the AR(1) residual of the respective indicator exceeds two standard deviations. Whiskers show the 90 percent confidence intervals. AE = advanced economies; EM = emerging market economies; VIX = CBOE Volatility Index.

Online Annex Figure 2.5.4. International Reserves and FX Market Stress

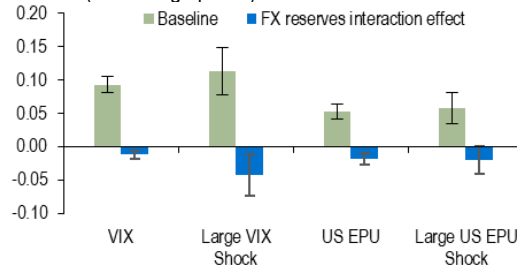
International reserves help to temper dollar-funding stress ...

1. Mitigating Effect of International Reserves on CIP Deviations Following Uncertainty Shocks (Basis points)



... and help stabilize FX market volatility.

2. Mitigating Effect of International Reserves on Excess Exchange Rate Return Volatility Following Uncertainty Shocks (Percentage points)



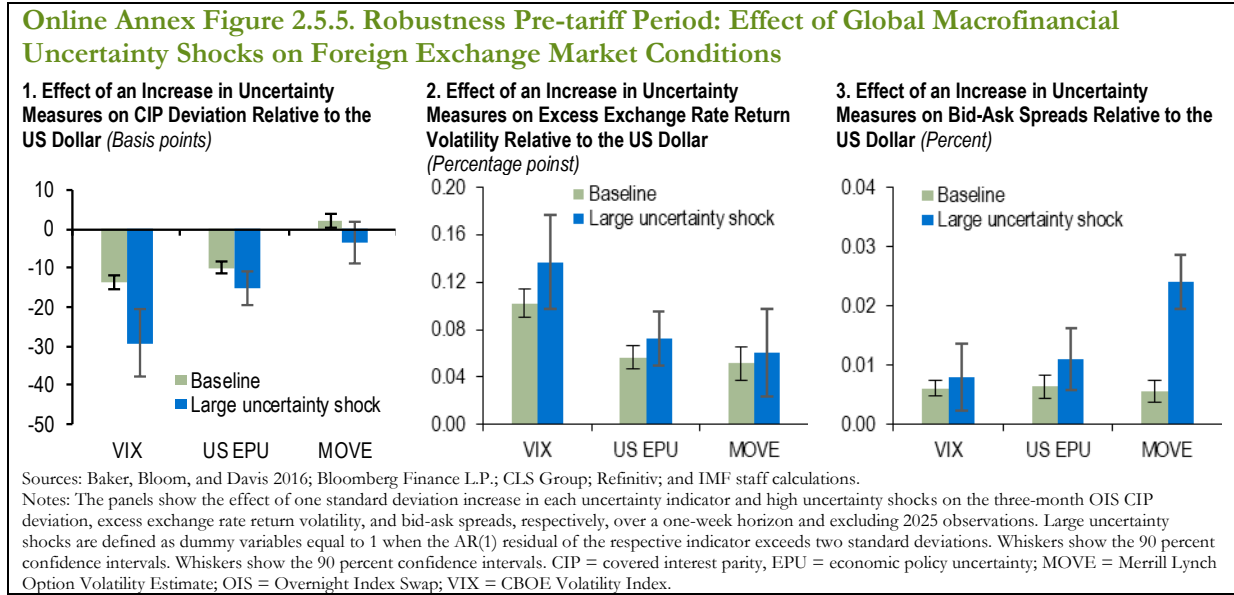
Sources: Bloomberg; Refinitiv; and IMF staff calculations.

Note: The panels show the effect of one-standard deviation increase in VIX and US EPU and their uncertainty shocks on FX market conditions, along with the mitigating effects of international reserve holdings (normalized by GDP). The FX reserves interaction term captures the incremental impact of an uncertainty shock associated with a one-standard deviation increase in FX reserves. Whiskers show the 90 percent confidence intervals. EPU = economic policy uncertainty; VIX = CBOE Volatility Index.

Robustness analysis. To assess the sensitivity of the results to alternative model specifications, the model is evaluated under various fixed-effects, including currency, time, and currency–time fixed effects. Additional robustness checks control for end-of-month and end-of-quarter effects. An extended specification also incorporates 3-months FX option-implied volatility and the LIBOR–OIS spread. In addition, to address potential endogeneity concerns of the hedging pressure measure to FX market

conditions, an identification strategy using the granular instrumental variables (GIV) methodology proposed by Gabaix and Koijen (2023) is deployed. The GIV methodology extracts idiosyncratic shocks from two granular instruments based on cross-sectional differences in capital ratios of (i) primary dealer and non-dealer banks and (ii) bank asset size-weighted and equal-weighted aggregates.¹⁸ Results remain broadly consistent across all robustness tests.

For robustness, the analysis in Figure 2.9 of the main text is also repeated using data only up to 2024M12. The results are broadly consistent with the baseline.



Online Annex 2.6. Does stress in FX markets spillover to other financial markets?

To evaluate the potential spillovers from FX market stress to other financial markets, the following panel regression specification is estimated:

$$y_{c,t+h} = a_c + \tau_t + \beta v_{c,t} + e_{c,t}, \quad (2.6.1)$$

where c indexes countries, t denotes the time, sampled at a weekly frequency, and h the horizon, in weeks, at which the effects are estimated. The dependent variable $y_{c,t}$ captures the financial market outcomes of interest, including 2-year and 5-year government bond yields, stock prices and a financial conditions index. Country fixed effects a_c and time fixed effects τ_t control for unobserved heterogeneity across countries and time capturing global shocks that are common across countries; the regressor $v_{c,t}$ measures FX market stress and is defined as the country-specific three-month cross-currency basis against the U.S. dollar; and $e_{c,t}$ is an error term.

Ordinary least squares estimation of this regression is subject to endogeneity bias due to the interconnected nature of financial markets. To address this concern, granular instrumental variables (Gabaix and Koijen

¹⁸ The instruments build on the idea that dealer banks' capacity to supply liquidity in derivatives markets is constrained by their capital ratios, allowing shocks to these ratios to serve as exogenous drivers of the hedging pressure measure. While the average capital ratio of dealer banks can influence investment funds' hedging demand, other financial variables may also jointly affect both capital ratios and hedging demand. To address this, the GIV methodology removes common valuation effects related to the overall stock market and the banking sector, isolating only the idiosyncratic component of changes in dealer bank valuations. The analysis defines dealer banks following the New York Fed's classification and includes the top 500 commercial banks by total assets, with data sourced from Bloomberg.

2023) are constructed using transaction-level data from CLS.¹⁹ Specifically, flows from sectors that are, on average, net lenders of US dollars in the swap market are excluded, and net buying pressure by sector, country, time, and tenor is defined as follows:

$$\text{net buy}_{c,s,t,\tau} \equiv \text{buy volume}_{c,s,t,\tau} - \text{sell volume}_{c,s,t,\tau}, \quad (2.6.2)$$

where s denotes sector and $\tau \in \{< 7\text{days}, 7 - 35\text{days}, > 35\text{days}\}$ corresponds to tenor buckets. The time-series average $\overline{\text{net buy}}_{c,s,\tau}$ is computed and only those series with positive average net buying are retained. The $\text{net buy}_{c,s,t,\tau}$ time series is then standardized as follows:

$$\widehat{\text{net buy}}_{c,s,t,\tau} \equiv \frac{\text{net buy}_{c,s,t,\tau} - \overline{\text{net buy}}_{c,s,\tau}}{\sigma(\text{net buy}_{c,s,t,\tau})}. \quad (2.6.3)$$

To construct a market-level instrument, individual sector-level pressures are weighted by their transaction volume shares, as follows:

$$w_{c,t,s,\tau} = w_{c,s,\tau} \equiv \frac{\sum_{\tau,t} \text{buy volume}_{c,s,t,\tau} + \text{sell volume}_{c,s,t,\tau}}{\sum_{\tau,t,s} \text{buy volume}_{c,s,t,\tau} + \text{sell volume}_{c,s,t,\tau}}, \text{ for all } t. \quad (2.6.4)$$

The resulting, simple granular instrumental variable is given by:

$$\tilde{Z}_{c,t,\tau} = \sum_s w_{c,t,s,\tau} \cdot \left(\widehat{\text{net buy}}_{c,s,t,\tau} - \overline{\widehat{\text{net buy}}_{c,t,\tau}} \right). \quad (2.6.5)$$

Since three tenor buckets are used, the approach yields three separate instruments that are used to obtain the baseline estimates. The instruments capture idiosyncratic shifts in sectoral activity in the FX swap market, and for this reason can be expected to be exogenous.

The main threat to identification is failing to fully isolate idiosyncratic shocks, allowing aggregate shocks to bias the estimates. Aggregate factors—such as shifts in global risk sentiment or broad asset price co-movements—may still simultaneously affect hedging flows and market outcomes, generating reverse causality.

To further address this concern, the analysis residualizes sector-level net buying series using principal component analysis (PCA), thereby purging common variation attributable to aggregate shocks. This approach mitigates bias arising from simultaneous feedback effects across asset classes and strengthens the plausibility that the remaining variation reflects idiosyncratic shocks (Gabaix and Koijen 2023). Specifically, for each $\widehat{\text{net buy}}_{c,s,t,\tau}$, the first three principal components (computed separately for each currency) are removed and a residualized series, denoted $\widehat{\text{net buy residual}}_{c,s,t,\tau}$, is computed. The first three principal component generally explains less than 40 percent of the total variation, indicating limited common factor structure. The baseline results are obtained by using the residualized instrument, given by:

$$Z_{c,t,\tau} = \sum_s w_{c,t,s,\tau} \cdot \left(\widehat{\text{net buy residual}}_{c,s,t,\tau} - \overline{\widehat{\text{net buy residual}}_{c,t,\tau}} \right). \quad (2.6.6)$$

The specifications are estimated for the following countries: Germany, France, Italy, Spain, the Netherlands, Japan, the United Kingdom, Canada, Switzerland, Australia, New Zealand, Sweden and Norway.

Empirical results. Online Annex Figure 2.6.1 displays the panel regression results obtained using the granular instrumental variables approach outlined above. The analysis shows that a widening of cross-currency bases prompts a flight to quality, lowering local currency sovereign bond yields while weighing on equity prices. The effects are economically significant: a one-standard-deviation widening (about 25 basis

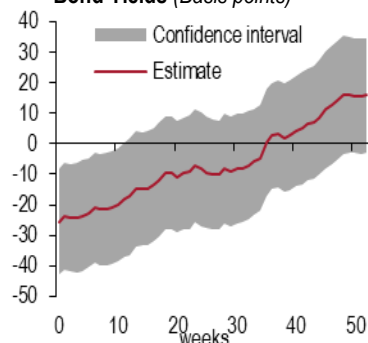
¹⁹ The intuition is that idiosyncratic shocks to sufficiently large market participants can generate price movements (relevance condition). By construction, these shocks are orthogonal to aggregate price drivers and macroeconomic variables (exclusion restriction).

points) reduces longer-term sovereign bond yields by roughly 25 basis points, with the impact lasting for up to three months. Shorter-term yields fall even more sharply, reflecting stronger demand for assets less exposed to interest rate risk.

Online Annex Figure 2.6.1. Financial Spillovers of FX Market Stress

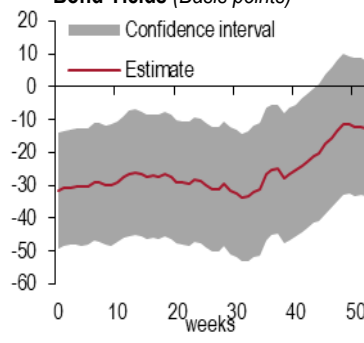
An increase in the cross-currency basis against the USD reduces sovereign bond yields, suggesting de-risking by investors

1. Effect of a Widening of the Cross Currency Basis on 5-year Sovereign Bond Yields (Basis points)



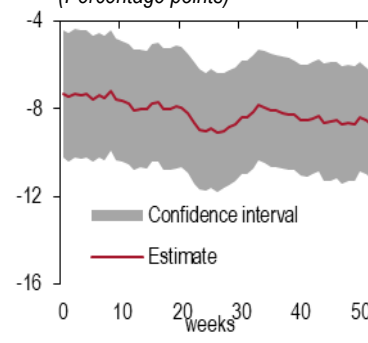
The yield curve steepens, as 2-yr. sovereign bond yields decline more than 5-yr. yields, reflecting demand for liquidity.

2. Effect of a Widening of the Cross Currency Basis on 2-year Sovereign Bond Yields (Basis points)



The price of riskier assets, such as stocks, decline.

3. Effect of a Widening of the Cross Currency Basis on Stock Prices (Percentage points)



Sources: Bloomberg; CLS Group; LSEG DataStream; and IMF staff calculations.

Notes: Panels 1-3 show the estimates from panel regressions of the outcome variable on the cross-currency basis of the local currency against the USD. In all the regressions, a granular instrumental variables (GIV) approach is used, whereby the cross-currency basis is instrumented with variables that capture idiosyncratic shocks to demand for US dollar funding in the FX swap market, for three different tenors (less than 7 days, between 7 and 35 days, and greater than 35 days). The cross-currency basis and the idiosyncratic demand shocks are standardized for each currency and tenor. The shaded areas represent 90 percent confidence intervals, obtained using Driscoll-Kraay standard errors, with the number of lags equal to $\sqrt{T}$, where T denotes the number of time periods in the sample. The specifications include time and currency effects. The currencies in the sample include the euro, the Japanese yen, the British pound, the Swiss franc, the Canadian dollar, the Australian dollar, the New Zealand dollar, the Swedish krona, and the Norwegian krona against the USD. The stock prices are detrended by removing a linear trend from the logarithm of the stock price, separately for each country.

Online Annex 2.7. Foreign Exchange Market Dynamics around the US Liberation Day Tariff Announcement

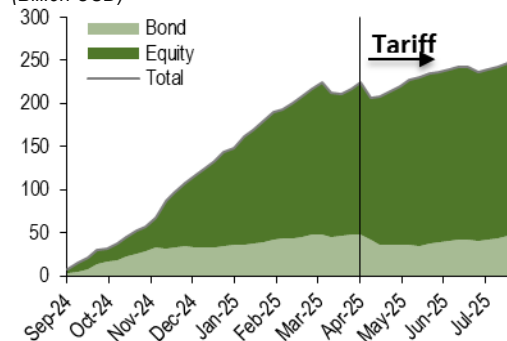
Box 2.1 presents the dynamics of USD flows surrounding the April 2, 2025, tariff announcement by the US. To provide a more comprehensive view of global FX market behavior during this period, this section observes (i) investment flows by non-US investment funds and (ii) FX flows to major non-US currencies – euro and Japanese yen, to support these findings.

Investment fund flows. Portfolio flow data of foreign-domiciled investment funds obtained from the EPFR shows that following the April 2 tariff announcement by the US, flows into the US have risen on a cumulative basis, but at a slower pace than before the announcement. Bond fund flows, dropped in April but have recovered since then (Online Annex Figure 2.7.1).

FX flows of major non-US currencies. The flow decomposition of CLS market data for the euro indicates that, prior to the tariff announcement around the end of February 2025, US institutions collectively shifted to become major net buyers of the euro, while institutions in the UK moved into a selling position (Online Annex Figure 2.7.2, panel 1). While there is no clear evidence of a major shift in flow positions following April 2, euro-bound flows from Canada appear to have increased. When considered alongside

Online Annex Figure 2.7.1. Investment fund flows to United States

Net cumulative flows to U.S. by asset class
(Billion USD)



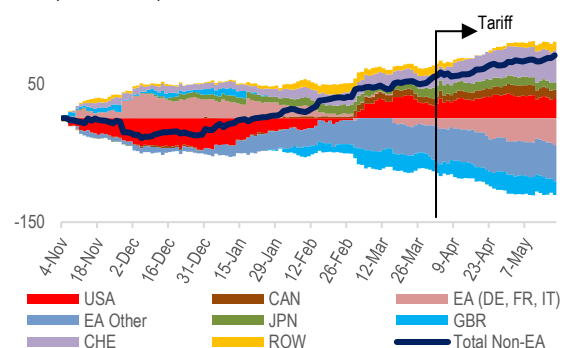
Sources: EPFR; and IMF staff calculations.

Canadian institutions' net sales of the USD, as documented in Box 2.1 in the main text, this suggests a possible reallocation away from the USD in favor of the euro.

Online Annex Figure 2.7.2. Cumulative FX flows of Euro and Yen around Tariff Announcement

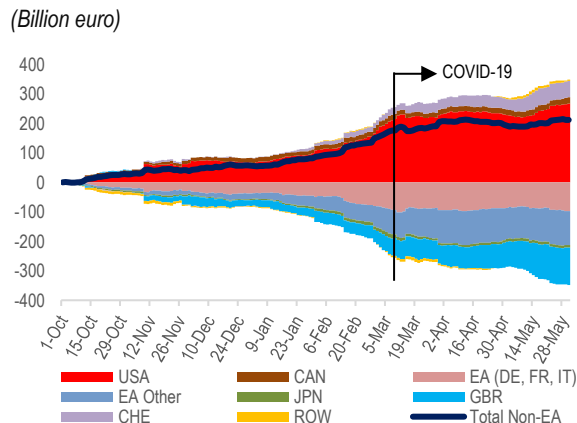
Flows into the euro exhibited some compositional shift after April 2, 2025...

1. Net euro cumulative spot flows by sector and nationality (Billion euro)



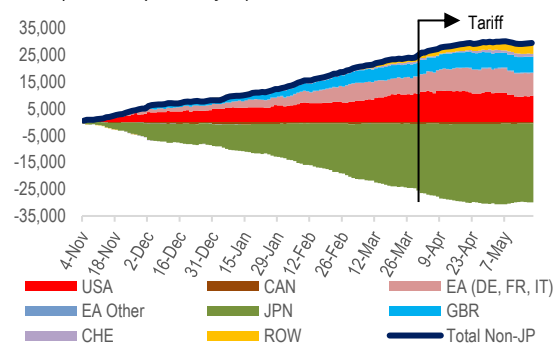
Flows into the euro were larger following the COVID-19 turmoil compared to the recent tariff episode...

3. Net euro cumulative spot flows by sector and nationality around the COVID-19 market turmoil (Billion euro)



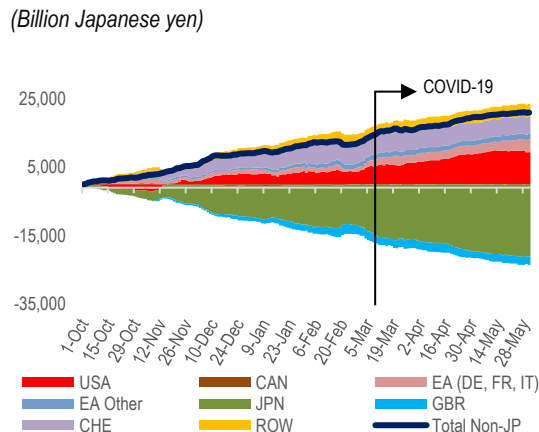
...while for the JPY, the composition of foreign purchasers remained broadly the same.

2. Net yen cumulative spot flows by sector and nationality (Billion Japanese yen)



...but for JPY, the increase in flows during the COVID-19 pandemic was relatively smaller to the recent tariff episode.

4. Net yen cumulative spot flows by sector and nationality around the COVID-19 market turmoil (Billion Japanese yen)



Sources: CLS Group; IMF staff calculations.

Notes: Panels 1 and 2 display cumulative flows beginning on November 1, 2024, while Panels 3 and 4 show cumulative flows starting from October 2019. The arrows indicating tariff-related events correspond to April 3, 2025, for Panels 1 and 2, and March 9, 2020, for the COVID-19 market turmoil. These statistics are purely descriptive and do not account for other potential drivers of FX market dynamics beyond the tariff and COVID-19 shocks—such as interest rate differentials or other macroeconomic factors. Country names are represented by ISO 3-digits code except EA (DE, FR, IT)=Germany, France, and Italy; EA Other=euro area except Germany, France, and Italy; ROW=Rest of the World.

For the Japanese yen, net purchases by foreign institutions have been steadily increasing, a trend that has continued following the tariff announcement. This rise has occurred without any notable shifts in the composition of buyers (Online Annex Figure 2.7.2, panel 2). Compared to the market turmoil during the COVID-19 episode in March 2020, the cumulative volume of flows from non-euro countries into the euro appears notably smaller during the recent tariff-related episode. However, the composition of foreign buyers has been more diversified. In contrast, net flows into the yen since April 2 have significantly exceeded those observed during the COVID-19 period, with substantial inflows originating from the United Kingdom and major euro area economies.

Online Annex 2.8. The Relevance of Settlement Risk in Foreign Exchange Markets

This section provides the methodological details and results of the analysis presented in Box 2.2 on the effect of settlement risk on excess foreign exchange rate returns and volatility. Two empirical approaches are followed: (i) a difference-in-differences (DID) analysis to estimate the impact of CLS accession on the Hungarian Forint (HUF) in 2015, and (ii) a panel regression using an extended set of currencies with and without payment-versus-payment (PvP) arrangements over a longer time period (2000-2025).

i) Case study: Hungarian Forint

Hungary joined the CLS system on November 16, 2015, enabling HUF transactions to be settled under PvP arrangements, thereby reducing FX settlement risk originating from counterparty exposure. This case study analyzes the impact of lower settlement risk on HUF exchange rate dynamics, focusing on two indicators: excess exchange rate returns and volatility.²⁰ The DID approach is implemented within a panel framework, considering daily data from one month before and after the event date (October 16-December 15, 2015).

To apply the DID methodology, the analysis considers the Czech koruna (CZK) and the Polish zloty (PLN) as control currencies. All three countries, Hungary, the Czech Republic, and Poland, are central European economies and share several similar macroeconomic and structural characteristics. The CZK and PLN exhibited exchange rate return patterns against the USD that closely mirrored those of the HUF during the pre-treatment period. Specifically, their exchange rate returns show strong correlations with the HUF's exchange rate returns against the USD—0.8 for CZK/USD and 0.9 for PLN/USD—during the one-year period before the event date. A formal parallel trends test confirms no statistically significant differences in pre-event trajectories.²¹

To estimate the impact of CLS entry on the HUF, the following model is estimated:

$$Y_{c,t} = \alpha + \beta_1 \cdot Treated_i + \beta_2 \cdot Post_t + \delta \cdot (Treated_i \cdot Post_t) + \gamma_t + \mu_c + \lambda_{i,m} + \epsilon_{i,t} \quad (2.8.1)$$

where $Y_{c,t}$ is the excess exchange rate returns of the currency pair (c, USD) or its volatility at time t. $Treated_i$ is a binary variable equal to 1 for the treated currency pair, i.e. Hungarian Forint and the USD (HUF/USD), and 0 for the control currency pairs (e.g. PLN/USD, CZK/USD). $Post_t$ is a dummy variable equal to 1 for observations on and after the event date (i.e., after November 16, 2015, when HUF joined CLS), and 0 otherwise. $Treated_i \cdot Post_t$ is the interaction term capturing the DID effect of CLS accession on the treated currency pair relative to the control pairs. γ_t denotes time fixed effects to control for common global shocks and μ_c are country fixed effects that control for time-invariant unobserved heterogeneity across countries. $\lambda_{i,m}$ is country-month-year fixed effects. In addition, the model includes daily stock market returns for Hungary, Czech Republic and Poland, to control for possible cross-asset correlations. $\epsilon_{i,t}$ is the clustered error term at the country level.

Equation (2.8.1) is estimated over the time period covering one month before and after the event date (October 16 to December 15, 2015). For robustness, the impact is also estimated over a broader window of

²⁰ The analysis focuses on these two indicators as settlement risk is most likely to affect a currency's risk premia. An analysis of the bid-ask spread, which captures market liquidity of a currency, shows that the effect of CLS entry on the bid-ask spread of HUF against the USD was not statistically significant. The effect on cross-currency basis could not be examined due to the limited availability of data on the 3-month CIP premium for the currencies considered in the analysis.

²¹ The validity of the parallel trends assumption is supported by a pre-event regression of exchange rate returns on a linear time trend, a treatment group dummy (HUF), and their interaction. Specifically, the following model is estimated.

$$Y_{i,t} = \beta_0 + \beta_1 \cdot date_t + \beta_2 \cdot HUF_i + \beta_3 \cdot (date_t \times HUF_i) + \epsilon_{i,t},$$

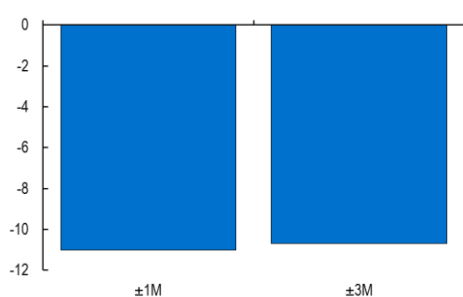
where $Y_{i,t}$ is exchange rate returns from t-1 to t. $i \in \{HUF, PLN, CZK\}$. The interaction term, $date_t \times HUF_i$, captures the differential pre-trend for the Hungarian forint (HUF) relative to the control group currencies (PLN, CZK). The estimated coefficient on this interaction is not statistically significant ($\beta_3 = 8.3 \times 10^{-8}$, p -value = 0.99), suggesting no systematic difference in pre-trend behavior across groups. This provides quantitative evidence that the parallel trends assumption holds during the one-year period prior to CLS accession.

three months, from August 16, 2015 to February 15, 2016. The estimated coefficient, δ , in equation (2.8.1), thus, reflects the average daily impact on excess HUF/USD returns and volatility of joining the CLS.²²

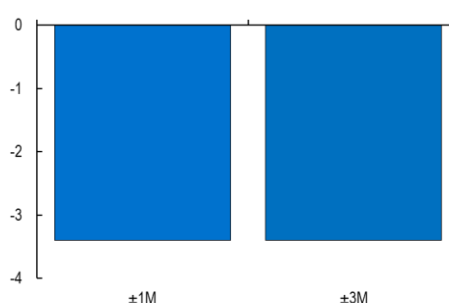
The results, presented in Online Annex Figure 2.8.1, show that joining the CLS system reduced both the excess FX returns and volatility of the HUF vis-à-vis the USD. On average, the daily excess return declined by 11 basis points one month after the entry date and 10.7 basis points three months after. Similarly, excess HUF/USD return volatility decreased by about 3.4 basis points in both the one-month and the three-month periods following CLS participation, relative to the corresponding pre-CLS periods representing a 4 percent reduction relative to the average volatility observed during the one-year period prior to Hungary's accession to CLS.²³

Online Annex Figure 2.8.1. Effects of Hungarian Forint's Participation in the CLS System

1. HUF's Excess Exchange Rate Return
(Daily, Basis points)



2. HUF's Excess Exchange Rate Return Volatility
(Daily, Basis points)



Sources: Bloomberg; Haver; LSEG DataStream; LSEG EIKON; IMF staff calculations.

Notes: The two panels show the average daily DID impact on excess HUF/USD returns and its volatility from participation in the CLS system (November 16, 2015). The DID analysis accounts for country- and time- fixed effects and controls for stock price returns. Standard errors are clustered at country level. The horizon axis indicates the event windows around the event date. In all cases, the effects are statistically significant at the 10 percent significance level or below. HUF=Hungarian Forint, USD=US Dollar.

ii) Panel analysis

Besides Hungary, several other currencies are part of the CLS system, while some emerging markets have their own PvP arrangements. A panel regression analysis is conducted over a longer time period—from January 1, 2000, to May 31, 2025—and with an expanded currency sample that includes 20 currencies currently settled through PvP arrangements (the CLS system, CHATS, CCIL and B3) as well as 6 currencies not settled through PvP arrangements, totaling 26 currencies. The analysis examines the effects of settlement risk on the excess exchange rate returns and volatility of these currencies.

To account for the fact that the timing of PvP arrangement entry varies across currencies, a dummy variable is used, taking the value of 1 from the date a currency joined a PvP arrangements onward. For example, CLS commenced operations on September 9, 2002, with seven founding currencies: USD, CAD, GBP, EUR, CHF, JPY, and AUD. On September 11, 2003, DKK, NOK, SEK, and SGD joined the system. This was followed by the inclusion of HKD, NZD, KRW, and ZAR on December 6, 2004. ILS and MXN became CLS-settled currencies on May 26, 2008, and HUF joined on November 16, 2015. INR, MYR, and THB were added to CHATS on April 6, 2015; November 13, 2006; and July 28, 2014, respectively. Finally, BRL began settlement in B3 on April 22, 2002.

²² Given that Hungary's accession to CLS involved substantial preparation and close coordination between the Magyar Nemzeti Bank (MNB) and CLS Group—including technical testing and operational readiness assessments—the timing of the event can be considered exogenous for the purposes of this analysis. Accordingly, the estimated effect may be interpreted as causal.

²³ The results should be interpreted with the following caveat: while the small number of clusters (three countries) limits the reliability of standard errors and p-values, clustering at the country level remains the most appropriate approach given the nature of the DID design. Treatment is assigned at the country level, and expanding the cluster base is not feasible without compromising comparability. Despite this limitation, the control group was carefully selected based on macroeconomic similarity, and robustness checks complement the analysis.

The following panel regression is estimated over the 2000–2025 period to assess the impact of PvP system participation on FX market conditions:²⁴

$$Y_{c,t} = \alpha + \beta_1 \cdot PvP_{i,t} + \beta_2 \cdot Controls_{i,t} + \mu_i + \gamma_t + \lambda_{i,m} + \epsilon_{i,t} \quad (2.8.2)$$

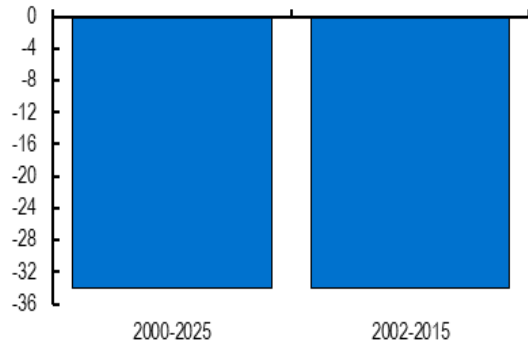
where $Y_{c,t}$ is the excess FX return of the currency pair (c, USD) or its volatility at time t. $PvP_{i,t}$ is a dummy variable equal to 1 from the date a country joined a PvP system and thereafter. $Controls_{i,t}$ include stock price return and 3-month interest rate differential with the US. μ_i and γ_t are country and time fixed effects, respectively. $\lambda_{i,m}$ is country-week-year fixed effects, and $\epsilon_{i,t}$ is the error term, clustered at the country level.

Online Annex Figure 2.8.2. illustrates the average effect of PvP participation on the risk premia of the selected currencies. The findings suggest a significant reduction of 34.1 basis points on excess returns associated with PvP system participation both over the full sample period, 2000–2025, and during a shorter sample period of 2002–2015. Excess FX return volatility also declines by about 3.1 basis points. These findings provide evidence that PvP arrangements help reduce uncertainty and risk premiums in FX settlement.

Online Annex Figure 2.8.2. Effects of Participation in the PvP System

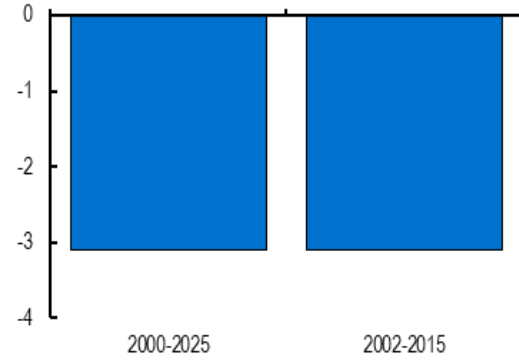
1. Excess FX Returns

(Daily, Basis points)



2. Excess FX Return Volatility

(Daily, Basis points)



Source: Bloomberg; Haver; LSEG DataStream; LSEG EIKON; IMF staff calculations.

Note: The charts present the average impact of CLS participation on excess FX returns and volatility, based on panel regression analysis. The regressions account for country-week-year, country, and time fixed effects, and controls for country-level stock price returns and interest rate differentials. The regression for excess FX returns in panel 1 additionally controls for lagged excess FX returns. Standard errors are clustered at the country level. In all cases, the effects that are statistically significant at the 10 percent level or below.

Online Annex 2.9. Implications of Operational Disruptions in Foreign Exchange Markets

Box 2.3 analyzes the effects of two outages of primary market venues, where currencies are traded in the interdealer market, on FX market conditions: the FX Matching outage on June 30, 2015, and the EBS outage on July 25, 2023.²⁵ The effects are quantified for the euro, the Japanese yen, the British pound, the Swiss franc, the Canadian dollar, the Australian dollar, the New Zealand dollar, the Swedish krona, and the Norwegian krona against the US dollar.

In the first part of the analysis, the differential effects of the outages are quantified, comparing the currencies whose primary trading venue was down to the other currencies in the sample. Specifically, the following specification is estimated:

$$\tilde{m}_{c,t} = \gamma_t + \delta_{c,u,y} + \beta d_{c,t} + \epsilon_{c,t} \quad (2.9.1)$$

²⁴ For robustness, the model is also estimated over a narrower window from 2002 to 2015—the period during which all PvP-settled currencies joined the systems at different times between 2002 and 2015.

²⁵ FX Matching is the primary market venue for the Commonwealth and Scandinavian currencies, whereas EBS is the primary market venue for the Euro, the British pound and the Swiss franc.

where c denotes a currency against the US dollar, t date-time, u time of the day, y year, and $\tilde{m}$ the standardized market condition of interest. γ_t and $\delta_{c,u,y}$ represent date and currency-time-year effects, respectively. The indicator variable is such that:

$$d_{c,t} = \begin{cases} 1 & \text{if FX Matching down at time } t \text{ and } c \in \{\text{GBP, CAD, AUD, NZD, SEK, NOK}\} \\ 1 & \text{if EBS down at time } t \text{ and } c \in \{\text{EUR, JPY, CHF}\} \\ 0 & \text{otherwise.} \end{cases} \quad (2.9.2)$$

The market condition analyzed is the bid-ask spread in the spot market, sampled at 30-minute intervals.²⁶ The sample period comprises the day of each outage, along with the 90 days preceding and following it. For each currency and each time of day, the bid-ask spread is standardized to have a mean of 0 and a standard deviation of 1 within each of the two 181-day windows comprising the sample:

$$\tilde{m}_{c,t} = \frac{m_{c,t} - \bar{m}_{c,u,y}}{\sigma_{c,u,y}^m}. \quad (2.9.3)$$

The effects of the outages are also estimated on two other indicators of market liquidity: the realized illiquidity measure of Ranaldo and Santucci de Magistris (2022) and a price dispersion measure. The realized illiquidity measure is given by:

$$\text{realized illiquidity}_{c,t} = \frac{\sum_u |\log s_{t,u} - \log s_{t,u-1}|}{v_{c,t}}, \quad (2.9.4)$$

where $s_{t,u}$ denotes the spot exchange rate between currency c and the US dollar on date t at time u and $v_{c,t}$ denotes the total volume of transactions in the currency pair on date t . The numerator of the measure is the realized absolute variation of the returns of the currency c against the US dollar on date t . The returns are sampled at 30-minute intervals. The volume is computed using the data on flows in the spot market from CLS. Price dispersion is measured by the coefficient of variation of the transaction prices for each currency pair on each date:

$$\text{price dispersion}_{c,t} = \frac{\sigma_{c,t}^s}{\bar{s}_{c,t}} \quad (2.9.5)$$

where the numerator is the sample standard deviation of the volume-weighted spot exchange rates at which transactions are conducted across sectors, and the denominator is their sample mean.

The effects of the outages on realized illiquidity and price dispersion are quantified at a daily frequency by estimating the following specification:

$$\tilde{m}_{c,t} = \gamma_t + \delta_{c,y} + \beta d_{c,t} + \varepsilon_{c,t}, \quad (2.9.6)$$

where t denotes a date, γ_t and $\delta_{c,y}$ represent date and currency-year effects, respectively, and $d_{c,t}$ is defined as above, taking a value of 1 for the currencies whose primary trading venue experienced an outage on date t . The sample period again comprises two 181-day windows centered on the days when outages occurred, and the liquidity measure is standardized separately for each currency, in each window, as follows:

$$\tilde{m}_{c,t} = \frac{m_{c,t} - \bar{m}_{c,y}}{\sigma_{c,y}^m}. \quad (2.9.7)$$

In the second part of the analysis, the effects of the outages are quantified for all currencies in the sample, comparing market conditions during the outages to those prevailing before and after the events. Specifically, the following specification is estimated:

²⁶ The forward bid-ask spreads are computed from the bid-ask spreads in the swap and spot market.

$$\tilde{m}_{c,t} = \delta_{c,u,y} + \beta d_t + \varepsilon_{c,t}, \quad (2.9.8)$$

where the indicator variable is such that:

$$d_t = \begin{cases} 1 & \text{if FX Matching down at time } t \\ 1 & \text{if EBS down at time } t \\ 0 & \text{otherwise.} \end{cases} \quad (2.9.9)$$

The market conditions analyzed are the bid-ask spreads in the spot and forward markets, sampled at 30-minute intervals. These spreads are standardized following the same procedure as in the first part of the analysis.²⁷ The sample period is also identical, encompassing the day of each outage along with the 90 days before and after.

Implications for non-CLS currencies

The relatively small effects of the disruptions on the market liquidity of the currencies in the sample raises the question whether larger effects could be expected for currencies that are not currently settled on CLS. Disruptions in interdealer platforms could have such larger effects, for example, due to trading in non-CLS currencies being more concentrated among fewer counterparties. The following analysis sheds light on this question by investigating how the magnitude of the effects of the disruptions varies along an important dimension along which CLS and non-CLS currencies differ from each other: interbank transactions as a percentage of the total volume of transactions in the spot market.

According to the BIS 2022 Triennial Central Bank Survey, interbank transactions accounted for 61% of the total for the CLS currencies and for 66% for the non-CLS currencies in the survey.²⁸ The implications of this difference for the effects of disruptions in the interbank market are quantified by estimating the following specification:

$$\tilde{m}_{c,t} = \gamma_t + \delta_{c,u,y} + \beta d_{c,t} + \theta d_{c,t}(s_c - \bar{s}) + \varepsilon_{c,t} \quad (2.9.10)$$

where s_c denotes the volume of interbank transactions as a percentage of the total volume of transactions, $\bar{s}$ its sample mean, and the other variables are defined as in (2.9.1).²⁹ The coefficient θ measures how the effect of the disruption on the market condition of interest varies as the share of interbank transactions increases. After having obtained an estimate of θ , the effect of the disruption can be obtained by setting $s_c - \bar{s}$ equal to the difference in the interbank share between CLS and non-CLS currencies. The estimates obtained in this way are illustrated in Online Annex Figure 2.9.1.³⁰

The results indicate that the effect of interdealer market disruptions on bid-ask spreads and market illiquidity are substantially larger for currencies for which the interbank transactions account for a larger share of the total volume of transactions. More specifically, the estimates suggest that for currencies with an interbank share of transactions equal to that for the non-CLS currencies in the BIS 2022 Triennial Central Bank Survey, the increase in bid-ask spreads in the spot (forward) market due to an interdealer platform disruption is four (three) times larger than for the CLS currencies. Similarly, the increase in price impact of trading volume is estimated to be four times larger for the non-CLS than for the CLS currencies.

²⁷ The forward bid-ask spreads are computed from the bid-ask spreads in the swap and spot market.

²⁸ The non-CLS currencies in the BIS 2022 Triennial Central Bank Survey for which the volume of interbank transactions is available are: the Brazilian real, the Chinese yuan, Indian rupee, Polish zloty, Russian ruble, and Turkish lira.

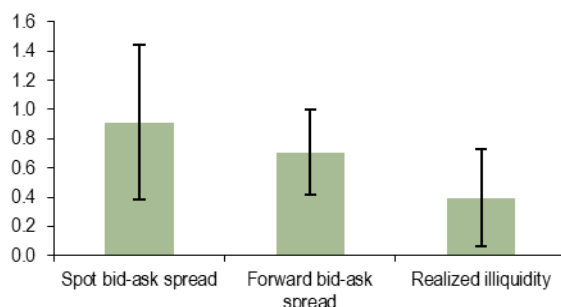
²⁹ When the market condition is sampled at a daily frequency, $\delta_{c,u,y}$ becomes $\delta_{c,y}$ as in (2.9.6).

³⁰ The sample used to estimate (2.9.10) excludes the Swedish krona and the Norwegian krona as their inclusion renders the estimates substantially less imprecise, due to the bid-ask spreads and trading volumes of these two currencies against the US dollar being more volatile as they are more traded against the euro than the US dollar.

Online Annex Figure 2.9.1. Effect of Interdealer Platform Disruptions on Market Liquidity

Bid-ask spreads increase, and market liquidity deteriorates during the outages more strongly for currencies with higher interbank share of transactions

Effect of FX Interdealer Platform Disruption for Currencies Primarily Traded on the Platform with Higher Share of Interbank Transactions (Standard deviations)



Sources: Bloomberg; CLS Group; and IMF staff calculations.

Notes: The bars represent the effect of the platform outage on the outcome variable, estimated using the specification in (2.9.10), evaluated at $s_c - \bar{s}$ equal to 4.3 percent, the difference in the interbank shares of transaction volumes between CLS and non-CLS currencies, according to the BIS 2022 Triennial Central Bank Survey. Realized illiquidity, defined as in Rinaldo and Santucci de Magistris (2022), refers to the ratio between the realized absolute variation of intraday returns and the volume of transactions in billions of USD, and measures the price impact of trading volume. The bid-ask spreads are sampled at 30-minute intervals while realized illiquidity is constructed at a daily frequency. The sample period comprises the day of each outage, and 90 days before and after it. All the measures are standardized separately in each of the two 181-day windows and for each currency. The currencies in the sample include the euro, the Japanese yen, the British pound, the Swiss franc, the Canadian dollar, the Australian dollar, and the New Zealand dollar against the USD. The specifications include time and currency-year effects. The specifications for the bid-ask spreads additionally include currency-time of the day-year effects. The error bars represent 90 percent confidence interval, obtained using Driscoll-Kraay standard errors, with the number of lags equal to $\sqrt[4]{T}$, where T denotes the number of time periods in the sample.

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