Can Time-Varying Currency Risk Hedging Explain Exchange Rates?

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Abstract

The rise in net international bond positions of non-US investors over the last decade can account for the long-run surge in net dollar hedging positions in FX derivatives. The latter influence spot exchange rates through CIP arbitrage. Using intermediaries' capital ratio as a supply shifter, we identify a price inelastic derivative demand by institutional investors and document that changes in their net hedging positions can explain approximately 30% of all monthly variation in the seven most important dollar exchange rates from 2012 to 2022.

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1 Introduction

Foreign portfolio positions in US bond markets have strongly increased in the past ten years, and often exceed more modest reciprocal holdings of US investors in foreign bonds.[1] Increasing gross and net investment positions turns foreign bond investors not only into important players in the US bond market, but also create a large and time-varying demand for foreign exchange (FX) hedging.[2]

Such currency hedging by international investors appears to depend on the perceived exchange rate risk and varies over time. Liao and Zhang (2021) document that the share of currency risk hedged by nine large Japanese insurance companies fluctuates greatly between 40% and 80%. Similarly, new evidence by Sialm and Zhu (2023) shows that the hedge ratio of US bond funds can vary between close to zero and up to 90%, with an average rate at 18%. The supply conditions of derivative contracts may also vary as banks face fluctuating balance sheet capacities to accommodate the derivative demand. As a consequence, net dollar short positions in USD forward contracts of (buy side) investors — referred to as hedging pressure — can greatly alter and potentially become a major determinant of the exchange rate.

Figure 2 provides suggestive evidence of an economically significant linkage between aggregate net hedging pressure from investment funds in the seven most important dollar rates, and the corresponding basket of dollar rates: More net short selling of dollar forwards (i.e. an increase shown by the green line) coincides with a decline in the dollar rate (i.e. a decrease shown by the blue line) relative to the other currencies. The negative correlation of yearly changes features an astonishing -66%, indicating a strong economic relationship.

In this paper, we address four research questions related to such FX risk hedging. First,

[1] Figure 1 shows that the gross bilateral bond holding of seven countries vis-à-vis the US, namely Euro Area, Switzerland, Japan, the United Kingdom, Canada, Australia, and New Zealand. Aggregate net bond holdings show a significant increase in favor of non-US investors. Similarly, Du and Huber (2023) find that USD securities in foreigners' portfolio increased by six fold over the past two decades.

[2] According to the Bank for International Settlement, BIS (2022), institutional investors increased their trading in hedging instruments, such as FX swaps (forwards) by 90% (122%) between 2013 and 2022. In the same period, institutional investors' trading in FX spot markets have decreased by 15%. As of April 2022, the average daily trading volume of FX swaps (forwards) account for 51% (16%) of the total FX market turnover, while the market share of the average daily volume of FX spot trades amounts to 28%.

what are the determinants of net hedging positions, and how do they relate to net international bond holdings and time-varying economic uncertainty? Second, how do changes in currency hedging positions influence both contemporaneous forward and spot exchange rates? Third, how price elastic is the currency hedging demand of institutional investors, or in other words, are variations in the net positions mostly influenced by net demand shocks? Fourth, to what extent can time-varying net hedging quantities explain the monthly exchange rate dynamics?

Our analysis draws on a data set provided by Continuous Linked Settlement Group (CLS). CLS is the world's largest multi-currency cash settlement system and settles approximately 50% of all transactions in FX derivatives. CLS provides daily gross and net derivative positions outstanding by counterparty type (i.e., funds, banks, corporates, and non-bank financial institutions), currency, and maturity. These data allow us to proxy the (net) derivative positions emanating from investment funds, which typically have market making banks as their counterparty. We refer to the (standardized) *net* FX derivative hedging positions by investment funds as (FX) hedging pressure.

The recent finance literature applies factor analysis to exchange rates and explains changes in the cross-section of dollar rates based on the "dollar factor". The latter is constructed from sorting currencies on yield spreads between currencies and extracting the first principal component of portfolio returns (Lustig et al. (2011); Verdelhan (2018)). We find that the correlation between the average change in hedging pressure (for a basket of seven dollar currencies) and the dollar factor amounts to -40%. In other words, the dollar factor represents a proxy for hedging pressure in dollar exchange rates. This is not surprising, as the difference between the foreign interest rate and the US interest rate correlate negatively (at -0.58) with net US bond positions, which in turn are the source of the hedging pressure by international fund investors. Thus, direct measurement of the hedging behavior of institutional investors allows us to reinterpret the dollar factor as the direct consequence of international risk trading.

Our empirical analysis proceeds in four steps to elucidate the hedging channel of exchange rate determination. First, we investigate in Section 4 the fundamental determinants of (net) hedging pressure in the seven most liquid currency pairs. We conjecture that a measure of economic uncertainty like the CBOE volatility index (VIX) should represent an important explanatory variable for the equilibrium quantity of FX risk hedging. In addition, the demand for hedging by funds should be especially responsive to the interaction between the net foreign investment position (NIP) and uncertainty. This is because US and non-US investors have contrarian FX hedging demands with respect to non-US and US bonds, respectively, such that the net hedging demand should be proportional to the NIP in any currency pair. We confirm that the VIX, and its interaction with NIP significantly contribute to the determination of hedging pressure. Moreover, panel regressions show that a large proportion of the (time-averaged) long-run evolution of hedging pressure in any currency is explained by the long-run evolution of net investment positions in the corresponding bond markets.

Second, we use panel regressions in Section 5 to establish the link between changes in the equilibrium hedging pressure (according to CLS data) and changes in the corresponding forward and spot rates. The contemporaneous relationships are economically and statistically significant at various frequencies (i.e. quarterly, monthly, weekly, daily) and do not differ much between forward and spot rates. For example, a 10 percentage point increase in the monthly hedging pressure is associated with a dollar rate depreciation by 5%. We also find that yield spreads between foreign and US (two-year) government bonds have additional explanatory power for both forward and spot rate changes. We find no explanatory power of the bilateral currency basis.[3]

Third, we identify in Section 6 the demand elasticity for net dollar hedging and find that it is very exchange rate (price) inelastic. This allows us to interpret variations in the equilibrium hedging pressure as mostly demand determined. To identify the price elasticity of hedging, we construct three different instruments based on capital ratios of dealer banks.

[3]For the equally weighted average currency basis, we confirm the evidence by Jiang et al. (2021) showing explanatory power for bilateral exchange rates over the past 10 years.

Following He et al. (2017), we use as a first instrument changes to the capital ratio of dealer banks defined as the aggregate value of market equity divided by aggregate market equity plus aggregate book debt of primary dealers. A concern here is that aggregate equity market valuation could influence both bank capital ratios and the hedging demand.[4] In the spirit of Gabaix and Koijen (2020), we define alternatively two granular instruments based on cross-sectional differences in capital ratios of (i) dealer and non-dealer banks (GIV1) and (ii) bank asset size-weighted and equal-weighted aggregates (GIV2). We find a very price inelastic net hedging demand for all three instruments, which implies that the observed equilibrium quantity (i.e. hedging pressure) is strongly influenced by demand shifts and variations in the derivative supply conditions can have large effects on the equilibrium exchange rate. The estimated elasticity of FX derivative demand implies that a 1% dollar appreciation reduces the aggregate net hedging demand for dollar positions by only -0.49%, which corresponds to approximately 40 billion USD.

Fourth, we estimate a parsimonious VAR model comprising hedging pressure, and the log exchange rate in Section 7. Positive shocks to hedging pressure generate a strong dollar depreciation that peaks after 5 months before decaying slowly. Lastly, a variance decomposition shows that time variation in hedging pressure can account for roughly 30% of all exchange rate variation in the seven most liquid currencies.

The theory of optimal hedging has distinguished between a pure hedging component sensitive to expected FX volatility and a speculative motive which seeks excess returns (Anderson and Danthine (1981)). Our data does not allow us to clearly separate the derivative positions along different trading motives. However, we focus on the net demand of fund institutions for which the hedging motive is likely to dominate. We find no evidence that the aggregate net hedging position of all funds yields any positive excess return what would

[4]In particular, we cannot exclude that foreign investors might also hedge equity positions and valuation effects can then contribute to the hedging pressure (see Nathan and Ben Zeev (2022)).

support a speculative motive on the direction of the exchange rate.[5]

Finally, we highlight that our analysis suffers from a number of measurement shortcomings that deserve to be highlighted. We construct measures of hedging pressure based on CLS data that capture only a certain share of the overall institutional derivative demand. New and more complete documentation of derivative contracts—for example through the European Market Infrastructure Regulation (EMIR) data initiative—can diminish the attenuation biases inherent in our analysis. For the US net asset positions in bonds, we draw on US treasury data, which are also subject to numerous measurement and reporting issues (Coppola et al. (2021)). The hedging behavior of institutional investors is likely to be subject to considerable heterogeneity across investor types and countries, which only investor level data can reveal. Improving both measurement dimensions provides a fruitful avenue for future research.

2 Related Literature

Research on exchange rates has always struggled to connect currency movements to macroeconomic and financial variables — an empirical conundrum labelled the "disconnect puzzle" (see, e.g., Meese and Rogoff (1983); Rogoff (1996); Froot and Rogoff (1995); Frankel and Rose (1995); Obstfeld and Rogoff (2000)). The more recent literature emphasizes the role of imperfect capital markets and international capital flows in determining exchange rates (Froot and Ramadorai (2005); Adrian et al. (2010); Gabaix and Maggiori (2015); Koijen and Yogo (2020); Greenwood et al. (2020); Adrian and Xie (2020); Itskhoki and Mukhin (2021); Gourinchas et al. (2022); Lilley et al. (2022)). For example, Hau and Rey (2006) and Camanho et al. (2022) stress the importance of increasing gross foreign equity holdings and their systematic rebalancing for the exchange rate dynamics. The theoretical foundation underlying this literature and our empirical work rests on the idea that currency supply

[5] The average daily aggregate net hedging (short) position of funds is 60 billion USD and the average daily profitability of this position based on the daily spot rate change is −54 million USD. Profitability is insignificantly different from zero in a statistical sense.

by global dealer banks and currency demand by institutional investors is imperfectly price elastic, so that currency supply and/or demand shocks can persistently impact the exchange rate (Hau et al. (2010)). Our paper differs from the existing literature in its focus on foreign bond holdings of non-bank financial institutions and how structural imbalances in foreign bond exposure create a net hedging demand that can significantly affect exchange rates.[6]

The breakdown of covered interest parity (CIP) after the Great Financial Crisis highlights the importance of financial intermediaries' constraints and adds empirical support for the notion of limited FX arbitrage as well as limited FX market depth. But in spite of a new literature documenting CIP violation (Ivashina et al. (2015); Rime et al. (2017); Du et al. (2018b,a); Abbassi and Bräuning (2021); Cenedese et al. (2021)), the FX derivative markets in FX forwards and swaps are still closely tied to the FX spot market. FX risk management concerns push banks to offset forward rate exposure through a combination of spot rate and bond transactions at matched maturities. Given such covered interest parity arbitrage between the forward and spot rate, a larger net hedging demand for dollar balances tends to simultaneously depreciate both the dollar forward and spot rate: their monthly changes feature a high correlation of 0.99.[7] Following Liao and Zhang (2021), we refer to the spillover of hedging activity from derivative rates into spot rates as the "hedging channel" of exchange rate determination. While our work is related to Liao and Zhang (2021), our analysis differs in its focus on exchanges rate determination rather than arbitrage between forward and spot markets. Second, we directly measure the hedging activity using CLS data and estimate a high exchange rate elasticity for hedging pressure, which allows us to interpret the latter as mostly demand determined.

[6]Specifically, we focus on funds — a sector managing a large and increasing share of global assets. According to FSB (2021), in 2020 (2012) investment funds and pension funds together hold 44% (39%) of total financial assets in advanced economies, while banks hold 34% (40%). They increased their asset holdings from 2012 to 2020 by 64%. This is the highest increase compared to other entities, such as insurance corporations (41%), or banks (25%) (FSB (2021)).

[7]See also Krohn and Sushko (2022) for a detailed examination of the close relationship between spot and swap rates as well as a strong co-movement of liquidity in the two markets. We also note that the standard deviation of monthly CIP deviations for a three-month maturity amounts to only 5% of the corresponding variation in monthly changes of either the forward or spot rates.

Alongside the FX literature, research has shown a greater interest in financial intermediaries and their role in explaining asset prices (see, e.g., He and Krishnamurthy (2013); Brunnermeier and Sannikov (2014); Adrian et al. (2014); He et al. (2017); He and Krishnamurthy (2018)). In particular, He et al. (2017) show that the equity capital ratio of US primary dealers is a significant explanatory variable for asset prices through a liquidity supply channel. We use this same supply channel to estimate the demand elasticity for FX derivatives. A highly inelastic derivative demand underpins the hedging channel of exchange rate determination and explains why time-varying outstanding interest in FX derivatives partially accounts for exchange rate dynamics.

Recent studies by Sialm and Zhu (2023) and Du and Huber (2023) shed light onto the question why and when institutional investors use currency derivatives. For example, Sialm and Zhu (2023) show that US bond funds have an average hedge ratio of 18% which fluctuates over time depending on market conditions. In particular, they find that a one standard deviation increase in quarterly economic uncertainty augments a fund's hedge ratio by roughly 6 percentage points or one third of its mean. We complement these findings by demonstrating the implications of such time varying hedging behavior for exchange rate dynamics.

Our empirical approach also relates to Jiang et al. (2021), who link dollar exchange rate movements to the global demand for safe dollar denominated assets. They identify a time-varying (negative) convenience yield that foreign investors forsake for the benefit of stable dollar returns and propose the treasury basis as a suitable empirical proxy for this "preference factor". Our empirical model incorporates this separate source of exchange rate dynamics, but we find little evidence that variation in the currency basis has much explanatory power for bilateral nominal exchange rate changes over the last 10 years.

A distinct empirical literature investigates the predictive and explanatory power of FX order flow for spot rates (Evans and Lyons (2002, 2005, 2006); Rime et al. (2010); Menkhoff et al. (2016); Ranaldo and Somogyi (2021)) or FX swap rates (Cenedese et al. (2021); Syrstad and Viswanath-Natraj (2022)). Order flow statistics are predicated on trade initiation and their relationship with investors' fundamental investment and hedging decisions is at best indirect and contingent on the order execution strategy of both investors and intermediaries. In contrast, the hedging pressure examined in this paper represents a classical market quantity influenced both by asset supply and demand as modeled in Appendix B.

Last, but not least, we also contribute to the literature on the special role of the United States and the dollar in the international financial system (Gourinchas and Rey (2007); Gourinchas et al. (2019); Gourinchas and Rey (2022); Farhi and Maggiori (2018); Caballero and Krishnamurthy (2008); Caballero et al. (2008), Stein (2018)). In particular, the United States' large negative net positions in international fixed income investments have an economically significant effect on its currency via the FX derivative market. We show that the privileged role of the dollar as a prime issuance currency for bonds thus comes with the burden of a dollar depreciation if foreign investors seek increased currency protection.

3 Data and Variable Definitions

3.1 CLS Data and Hedging Pressure

A unique feature of our analysis is the use of outstanding forward and swap positions. The data on outstanding FX derivative positions in all seven currencies against the US dollar comes from the CLS group. CLS is a US financial institution that specializes in settlement services in the FX market. CLS tracks FX outright forward and swap positions outstanding by tenor and market participant type. Related settlement data from CLS has been used to explore asymmetric information and liquidity issues in the FX market across different types of market participants (Ranaldo and Somogyi (2021); Cespa et al. (2022); Ranaldo and de Magistris (2022)). To our knowledge, we are the first to use CLS data on outstanding interest to explore the role of net hedging positions by funds for the medium and long-run evolution of exchange rates.

We highlight two data limitations. First, the data on outstanding FX derivative contracts dates back only to September 2012, which limits our data span to a 10-year period from September 2012 to March 2022. Second, it covers only a proportion of all traded FX derivatives contracts. The notional value of outstanding FX derivatives contracts reported by CLS is approximately 20% of the notional value of all outstanding forwards and FX swaps traded OTC and reported by the Bank for International Settlements (BIS). In spite of this incomplete coverage, we believe that it provides a fairly representative picture of the global hedging dynamics in the most liquid dollar rates.

We aggregate the data on FX swaps and forwards as both contracts can be used for hedging the currency risk associated with future cash flows in foreign currencies. Institutional investors usually hedge long-term bond investments by rolling over one- or three-month FX forwards with swaps. For example, a euro-area investor can hedge her future cash flows from 10-year USD bonds by rolling over three-month forward contracts that allow the future selling of dollars for euros at a fixed exchange rate with FX swap contracts. Thus, FX swap contracts amount to follow-up contracts that extend the maturity of the currency hedge. In order to correctly capture the total stock of all net hedging in a currency, net hedging pressure from swaps needs to be added to that of outright forward contracts.

Forward contracts often have banks as their counterparty. In a second step, banks often eliminate their FX exposure through a synthetic hedge, which combines a spot transaction in, e.g., the EURUSD rate (selling USD for EUR) with short and long bond positions in the USD and EUR bond markets, respectively. This implies that increased hedging of net dollar bond investments by foreign fund investors triggers selling of USD for foreign currency by banks, which tends to depreciate the dollar spot rate. Any consecutive swap contracts, which simply extends the maturity of the FX hedge, does not trigger any new USD selling, but requires a parallel maturity extension of the bank's short and long bond positions in USD and EUR bonds, respectively. It is helpful to think of forward contracts as those initiating a hedge and consecutive swap contracts as those extending this FX hedge in terms of its maturity.

It is worth noting that in our data sample swaps outstanding positions are more than six times larger than forwards positions for all seven currencies. Table A.1 in the Internet Appendix breaks down the total average daily amount outstanding of FX derivatives into forward and swap contracts. The average daily amount outstanding of swaps aggregated over the currencies is approximately 6 trillion USD, whereas the corresponding number for forwards is only 0.8 trillion USD. The Table also reveals the most liquid currencies. The average daily amount outstanding of swaps and forwards is the highest for the EURUSD rate and amounts to 2.7 trillion USD, followed by the JPYUSD rate with 1.5 trillion USD and GBPUSD rate with 1.1 trillion USD. The amount outstanding for the other currencies is below 0.5 trillion USD and smallest for the NZDUSD rate, with only 0.1 trillion USD. In the rest of the paper, we refer to the sum of forwards and swaps positions as outstanding forwards. We also highlight that the daily variations in outstanding forwards is large. For the EURUSD rate it is 275 billion USD per day, or more than 10% of the outstanding amount. This suggests that time-varying hedging has potentially a large quantitative impact on FX forward rates.

CLS provides two types of designations for market participants. First, CLS uses historical transaction patterns to identify market participants as price-takers and market-makers. Second, CLS categorises aggregate FX outstanding positions based on four institutional designations: (1) corporates; (2) funds (investment, pension, hedge, and sovereign wealth funds); (3) non-bank financial firms (insurance companies, brokers and clearing houses); and (4) banks. The first three types of institutions are generally considered price-takers while banks are the market-makers.[8] In the remainder of this paper, we focus on the hedging positions of the funds. On the demand side, they account for the largest volume share in the forward rate market irrespective of the exchange rate under consideration. For example, funds are a counterparty in 65% of all outstanding interest in forwards for the EURUSD rate. Their counterparty are mostly banks as liquidity providers.

[8]For more information on CLS data, see Ranaldo and Somogyi (2021).

We categorize forward contracts as USD short (long) positions if funds sell (buy) forward US dollar contracts in currency c. For example, a long (short) position in EURUSD corresponds to a long (short) position in euros (EUR) and a short (long) position in US dollars (USD). To characterize the net hedging behavior of funds in a currency c, we follow the literature for commodity futures markets (see, e.g., Kang et al. (2020)) and define as hedging pressure the difference between all outstanding short and long positions by funds in US dollars scaled by the average outstanding contracts in currency c over the current and previous 11 months; formally

$$HP_{c,t} = 100 \times \frac{Dollar\ Short\ Positions_{c,t}^{Fund} - Dollar\ Long\ Positions_{c,t}^{Fund}}{\frac{1}{12}\sum_{i=0}^{11} Outstanding\ Interest_{c,t-i}^{Market}}. \tag{1}$$

We note that the outstanding interest in currency c at the market level represents the sum of short and long positions over all market participants. We take the moving average of the outstanding interest to obtain a more stable denominator.[9]

The summary statistics in Table 1 show that hedging pressure is generally positive when pooled over the seven currencies. In other words, the dollar risk hedging demand exceeds the reciprocal hedging demand for foreign currency risk by approximately 12%. The evolution of the hedging pressure, depicted in Figure 3, Panel A, shows that this hedging pressure increases over time for all seven currencies in favor of more net dollar risk hedging by fund institutions. Only for the NZDUSD and the JPYUSD rates do we observe an initial balanced net hedging position that turns strongly positive as for all other currency rates.

The buy and sell components of hedging pressure, i.e., the daily buy and sell volume of forwards by funds, are plotted in Figure A.2 in the Internet Appendix. The wedge between the buying and selling of dollar protection increases over time for all currencies. We can relate the increasing demand for dollar risk hedging to the net investment positions in bonds of US and foreign funds in each currency, discussed in the next section.

[9] As a robustness test, we scale the net fund position only by the contemporaneous outstanding interest (with $i = 0$), and find qualitatively similar results for much of our analysis. However, hedging pressure becomes less volatility-dependent in this case.

Finally, we point out that our measure of net hedging is likely to include speculative trading in the FX derivative market. There is no obvious method to separate a speculative trading from a pure hedging motive. However, we present two arguments suggesting that speculative trading is not the predominant motive in our FX derivatives data.

First, when we compute the daily profitability of the aggregate net fund positions, i.e., the product between the net short positions in US dollar rates and the return on the respective daily spot rate, we find no evidence for any profitability of this net aggregate position. Specifically, Figure A.3 in the Internet Appendix shows the frequency distribution of the daily profit of aggregate net derivative positions by funds. The average daily net outstanding dollar short position of all funds is 60 billion USD, and the average daily profit is -54 million USD. A t-test for the null hypothesis of a zero profitability yields a t-statistics of -0.8387 and a p-value of -0.4017. If speculative FX trading were important, we would expect the daily profits to be significantly positive both in an economic and statistical sense.

Second, data from the Commitments of Traders (COT) compiled by the Commodity Futures Trading Commission (CFTC) allows a classification of funds into hedge funds and non-levered funds with speculative and non-speculative trading motives, respectively. The speculative trading of hedge funds in FX future markets shows a relatively low correlation of 12% with the overall OTC hedging pressure, unlike the FX future trading of non-levered funds with a correlation of 36%. This suggests that the quantitatively larger OTC market in trading by funds is also dominated by non-speculative trading motives.

3.2 Net Investment Positions

Here we draw on the monthly long-term bond holdings (TIC) compiled by the US Treasury. The focus on international bond positions is motivated by the observations that the exchange rate risk of bond portfolios is often fully or partially hedged, whereas equity portfolios have a considerably lower hedge ratio (Levich et al. (1999)). Accordingly, international bond positions are a major source of hedging demand and their asymmetric size represents a source of (net) hedging pressure.[10]

Formally, we define the percentage net (long-term) investment position of foreign residents in US bonds as

$$NIP_{c,t} = 100 \times \frac{\textit{Foreign Positions in US Bonds}_{c,t} - \textit{US Positions in Foreign Bonds}_{c,t}}{\textit{Foreign Positions in US Bonds}_{c,t} + \textit{US Positions in Foreign Bonds}_{c,t}}. \quad (2)$$

We plot the net investment positions in Figure 3, Panel B. For countries like Japan or Switzerland, net investment position in bonds is very positive at 80% to 90%, as Japanese and Swiss investments in US bond markets largely exceeds the reciprocal overseas bond investments by US residents in Switzerland or Japan, respectively. For the traditional carry trade currencies of Australia and New Zealand, this net investment position was initially negative at the start of our sample period (September 2012), but evolved to a more balanced position by the end of our sample period (March 2022).

The monthly net investment positions constitute an imperfect structural proxy for the underlying net hedging pressure. Five aspects contribute to an imperfect alignment. First, the TIC data used for calculating the net investment positions in bonds are compiled based on the location of the institution in which the security is kept and is therefore subject to misclassification of the ultimate investor residence (see Coppola et al. (2021) for a comparison between the true economic bilateral investment positions and those sourced from TIC data). Second, the long-run holdings of bonds include all investor types, not just fund investors.[11] Third, equity funds can also contribute to the hedging pressure $HP_{c,t}$ even though we ignore their net investment positions in the calculation of the $NIP_{c,t}$, which is limited to bond holdings. Fourth, foreign investor positions in US bonds do not necessarily imply that the

[10] Alternative data sources that provide information on cross-border bond holdings, such as the Coordinated Portfolio Investment Survey (CPIS) or specifically the data constructed by Bénétrix et al. (2019), have additional limitations such as lower reporting frequency or limited data coverage for the cross-section of currencies.

[11] For euro area institutional investors we have data on holdings of US bonds from the ECB's Statistical Data Warehouse (see Figure A.1). The Figure shows that a very similar trend can be observed among euro area-based institutional investors: Their investments in the US dollar have increased by 160% over the past 10 years. Moreover, a comparison of TIC and ECB data reveals that roughly half of the US bond holdings of euro area residents are held by euro area institutional investors.

bonds are denominated in US dollar, even though Maggiori et al. (2020) show that this is predominantly the case. Fifth, both investment institutions and their ultimate investors can have different risk aversions and risk perceptions, so that the currency risk exposure captured by the $NIP_{c,t}$ can translate into very different levels of risk hedging and hedging pressure $HP_{c,t}$.

In spite of these measurement discrepancies and attenuation effects, we conjecture a structural relationship between both variables, namely that a larger net investment position in bonds predicts a more positive hedging pressure from funds, particularly in times of high uncertainty.

3.3 FX Data, Uncertainty, and the Basis

We focus on monthly US dollar spot and forward rates with respect to the seven most liquid currencies: Euro (EUR), British pound (GBP), Japanese yen (JPY), Swiss franc (CHF), Canadian dollar (CAD), Australian dollar (AUD), and New Zealand dollar (NZD), all sourced from Bloomberg. The exchange rates are quoted in units of foreign currency per USD. An increase in the exchange rate corresponds to an appreciation of the USD and a depreciation of the foreign currency. We express the end of the month exchange rate quotes in natural logs $s_{c,t} = \ln S_{c,t}$ or use log differences $\Delta s_{c,t} = s_{c,t} - s_{c,t-1}$ in some specifications. Table 1 reports summary statistics on the pooled exchange rate series for the 10-year sample period (September 2012-March 2022).

We take data on the spread between the two-year foreign currency government bond yield and the two-year US Treasury yield, $y^*_{c,t} - y^\$_{c,t}$, from Bloomberg. In our sample, the US Treasury yield exceeds on average the foreign currency yield (see Table 1). Figure 3, Panels C and D, shows the seven exchange rate and yield spread series, respectively.

To capture the time-varying component of hedging pressures even better, we consider the Chicago Board Options Exchange's Volatility Index (VIX_t) that is based on S&P 500 index options, as a measure of valuation uncertainty in the equity market. The risk measure concerns the US economy and is not specific to any particular currency rate. However, if higher uncertainty triggers more symmetric hedging of foreign portfolio positions by US and foreign investors, the quantitative imbalance in their respective holdings (i.e. the $NIP_{c,t}$) *interacted* with the degree of uncertainty should predict the hedging pressure. We therefore use interaction terms $NIP_{c,t} \times VIX_t$ as additional explanatory variables.[12]

Lastly, we incorporate into our analysis the so-called Treasury basis constructed by Du et al. (2018a) and sourced from Wenxin Du's website.[13] Formally, the Treasury basis is defined as the difference between the yield on a cash position in the US Treasury denoted $y^{\$}_{c,t}$ and a synthetic dollar yield derived from a cash position in foreign government bonds, that earns $y^{*}_{c,t}$ in foreign currency c, and swapping into US dollars,

$$Basis_{c,t} = y^{\$}_{c,t} - y^{*}_{c,t} + (f_{c,t} - s_{c,t}). \tag{3}$$

Jiang et al. (2021) show that this Treasury basis represents a time-varying premium that international investors are willing to pay for holding US dollar denominated safe assets rather than treasuries in other currencies. The $Basis_{c,t}$ tends to widen in periods of financial distress, when a high demand for safe dollar assets generates a yield gap between US and foreign government bonds. At a monthly frequency, the component $f_{c,t} - s_{c,t}$ is small, as the forward rate $f_{c,t}$ closely tracks the spot rate $s_{c,t}$. We note that the panel correlation between monthly changes in the Treasury basis and monthly changes in the VIX is modest at -15%.

3.4 Funds and Other Market Participants

We focus on fund investors as the main source of demand variation in FX forward markets. To justify this choice, we consider briefly other market participants and discuss their importance

[12]Sialm and Zhu (2023) use a broader quarterly measure of economic uncertainty developed by Ahir et al. (2022) to explain FX risk hedging decisions by US bonds funds. As a robustness check, we substitute the VIX with a monthly US economic policy uncertainty index (News Coverage about Policy-related Economic Uncertainty) constructed by Baker et al. (2016) and find quantitatively and qualitatively similar results.

[13]We flip the sign of the treasury premium available at `https://sites.google.com/site/wenxindu/data` so that our definition of the Treasury basis follows Jiang et al. (2021).

as a source of hedging pressure. In aggregate, the net demand for any derivative is by definition zero. Accordingly, net hedging positions and their changes across all four investor groups add up to zero. This is illustrated in Figure 4, Panels A–D, which plots the positional imbalance (relative to all outstanding contract volume) for funds, banks, corporates, and non-bank financial institutions, respectively. As banks are the liquidity providers in the market, their net position in forward contracts turns negative if funds demand more hedging of their foreign (bond) investment position. Over the 10-year period 2012-22, the percentage forward positional imbalance of funds (i.e. hedging pressure) becomes more positive in all seven dollar exchange rates, whereas banks take the opposite negative position as liquidity providers. Funds and banks clearly dominate the market in terms of outstanding forward contracts, whereas the forward positions of corporates and non-bank financial institutions are only one-tenth of those taken by fund investors.[14] Only for the CHFUSD rate do we see larger positive hedging demands by non-bank financial institutions—presumably the dollar risk hedging of large Swiss insurance companies.

The dominance of funds in the FX derivative market is documented further in Table A.2, where we report the market share of funds in outstanding buy and sell volumes for each currency. The table shows that funds have increased their market share in outstanding positions of FX derivatives and, in particular, outstanding positions in derivatives that sell the US dollar. For example, from 2012 to 2022, funds have increased their market share in outstanding forwards that buy (sell) the EUR against the USD from 63% (36%) to 95% (47%).

For completeness, we conduct our main analysis of the 'hedging channel" also for other investor types and report the results in Table A.5.

[14]For the euro, the limited hedging by non-bank financial institutions, such as insurance companies, is consistent with recent findings by Faia et al. (2022). They show that insurance companies and pension funds in the euro area hold almost all their non-financial corporate debt in EUR and only a small share in USD. In contrast, other financial institutions in the euro area, such as investment funds, held half of their corporate debt in USD over the period 2013-21.

4 Determinants of Hedging Pressure

In this section, we explain the FX hedging behavior of funds as a function of two main variables, namely the US net investment positions in bonds and the level of macroeconomic uncertainty. Importantly, net imbalances in bilateral bond positions should interact with macroeconomic uncertainty and also account for the time-varying hedging pressure.

In Table 2, Columns (1)-(4), we regress monthly changes in hedging pressure, $\Delta HP_{c,t}$, in currency c on monthly changes in contemporaneous US net foreign investment positions, $\Delta NIP_{c,t}$, monthly changes in economic uncertainty captured by ΔVIX_t and their interaction term. Formally,

$$\Delta HP_{c,t} = \alpha_c + \beta_1 \Delta NIP_{c,t} + \beta_2 \Delta VIX_t + \beta_3 \Delta(NIP_{c,t} \times VIX_t) + \epsilon_{c,t}, \tag{4}$$

where α_c denotes currency fixed effects.

The coefficient estimates for $\Delta NIP_{c,t}$ is not significant on its own, as shown in Column (1). Similarly, higher uncertainty correlates only weakly and negatively with hedging pressure as shown in Column (2). By contrast, the hedging demand is better explained by the interaction of the NIP (in bonds) and the VIX. For countries with a negative NIP (i.e., Australia, Canada, and New Zealand), a volatility increase reduces the net hedging demand, whereas the opposite can be expected for countries with a strongly positive NIP in bonds.

In Column (4) we add time fixed effects to the model, which absorb all changes in the VIX as the collinear variable. However, the positive coefficient on the interaction term $\Delta(NIP_{c,t} \times VIX_t)$ remains unchanged at 0.058. If we compare two countries at the 75th and 25th percentile of the NIP distribution at 78.8 and -18.2, respectively, the NIP difference implies that the former experiences a relative increase in the hedging pressure by 0.313 ($0.058 \times 97 \times 5.55/100$) for a one standard deviation increase in the VIX (5.55). This corresponds to approximately 25% (0.313/1.25) of the standard deviation of monthly hedging pressure changes in the sample. The asymmetric effect of market uncertainty on hedging pressure by funds is therefore economically large.

We note that the overall explanatory power of the model of hedging pressure is low as indicated by the low overall R^2 of only 3%. However, the *Between* R^2, which represents the R^2 of the time averaged cross sectional panel, is surprisingly large at 37%. While the model does not account well for monthly changes in hedging pressure, it captures a large amount of the (time-averaged) long-run relationship between hedging pressure and the net investment positions across currencies. Figure A.4 visualizes the finding. It plots the average monthly changes in hedging pressure against the average monthly change in NIP. Apart from the Swiss Franc, average changes in net investment positions positively correlate with average changes in hedging pressure.[15] For example, average monthly changes of Australia's and Canada's NIPs have been the most positive in our sample, while average monthly changes of their demand for shorting the dollar have been the most positive, too. Thus, the evolution of NIPs explain the evolution of the net hedging positions between countries and across currencies.

5 Exchange Rate Effects of Hedging Pressure

At the aggregate level of a dollar currency basket, Figure 2 illustrates the negative association between weighted average dollar exchange rate changes (measured over annual intervals) and the corresponding aggregate changes for hedging pressure. More net short-selling by foreign funds is related to a depreciating dollar spot rate against a basket of foreign currencies. The negative correlation (over yearly intervals) is extremely strong at -0.66.

To examine this relationship further, we regress the monthly change in the spot rate of foreign currency c vis-à-vis the US dollar, $\Delta s_{c,t}$, on contemporaneous monthly changes in hedging pressure, $\Delta HP_{c,t}$, monthly changes in the spread between the two-year foreign currency government bond yield and the two-year US Treasury yield, $\Delta(y^*_{c,t} - y^\$_{c,t})$, and

[15] The Swiss Franc is the outlier in our sample most likely due to the large Swiss insurance sector whose FX derivative trading is not captured in our measure of hedging pressure. In fact, if we remove the Swiss Franc from our sample, the *Between* R^2 increases to 90%.

monthly changes in the Treasury basis, $\Delta Basis_{c,t}$. Formally,

$$\Delta s_{c,t} = \alpha_c + \gamma_t + \beta_1 \Delta HP_{c,t} + \beta_2 \Delta(y^*_{c,t} - y^{\$}_{c,t}) + \beta_3 \Delta Basis_{c,t} + \epsilon_{c,t}, \tag{5}$$

where α_c and γ_t denote currency and time fixed effects, respectively. Positive values of $\Delta s_{c,t}$ denote a dollar appreciation.

In Table 3, Columns (1)-(4), shows the panel regression results with changes in the monthly spot exchange rate as a dependent variable, whereas Columns (5)-(8) present analogous results for monthly changes in the three-month forward rate. As spot rate changes and forward rate changes are highly correlated at 99%, we expect the same variables to explain both the spot rate and the forward rate dynamics.

For both monthly spot and forward rate changes, we find in Column (1) and (5), respectively, a similar negative coefficient estimate for $\Delta HP_{c,t}$, which is statistically significant at the 1% level. The point estimate of around -0.52 implies that a one-standard deviation increase of the monthly hedging pressure change (1.25) comes with a 0.65% dollar rate depreciation, or roughly a quarter of its monthly standard deviation (2.46). Monthly changes in hedging pressure from funds alone can account for roughly 7% of the contemporaneous monthly variation in the exchange rate.

For the EURUSD rate in 2020, such a change in hedging pressure by one standard deviation corresponds to a monthly change in net outstanding interest by 37 billion USD. A one percent EURUSD rate depreciation then corresponds to a net dollar hedging pressure increase by 56 billion USD. This demonstrates an economically meaningful relationship between changes in hedging pressure and both the spot and forward rate change.

Columns (2) and (6) in Table 3 present the regression results when adding changes in the government yield spread and the Treasury basis as additional explanatory variables.[16] In contrast to changes in the basis, yield spread changes between foreign and US two-year bonds are statistically highly significant. A monthly yield spread increase in favor of the foreign bond yield by one standard deviation (15.44) comes with a 0.56% depreciation of the respective dollar rate. This is in line with the traditional uncovered interest parity (UIP) relationship, which requires positive innovations to the yield spread to predict a future dollar depreciation.

An alternative explanation (based on capital flows) is that foreign fund investors could find it less attractive to maintain their large net US bond positions when the yield spread between foreign and US bonds evolves in favor of the foreign bond. Rebalancing then consists of swapping dollar positions for foreign currency holdings, which should depreciate dollar rates. This can also account for the observation that a widening yield spread in favor of foreign bonds coincides with a depreciating dollar. We test this portfolio channel further by replacing the change in yield differences, $\Delta(y^*_{c,t} - y^\$_{c,t})$, with the change in the NIP, $\Delta NIP_{c,t}$. This regression specification in Column (3) and (7) produces the expected positive coefficient. However, the regression coefficient reaches only a 10% significance level. We conclude that time-varying hedging decisions by bond funds captured by $\Delta HP_{c,t}$ have more explanatory power for forwards and spot rates than bond allocation decisions captured by $\Delta NIP_{c,t}$.

Lastly, we add time fixed effects to our regression and show the results in Columns (4) and (8), respectively. The magnitude of the coefficient for hedging pressure decreases slightly, but remains highly significant. At monthly frequencies, additional lagged terms of the hedging pressure change or the two-year yield spread change are statistically insignificant and do not

[16] We include changes in the US Treasury basis following recent findings by Jiang et al. (2021). They show that positive changes in the basis coincide with an immediate depreciation of the dollar and exhibit explanatory power for a dollar currency basket in a much longer sample dating back to 1991. We highlight that our analysis here is limited to a time span of only 10 years, but seeks to explain the entire cross-section of seven dollar exchange rates. Additionally, our Treasury basis is computed using a collection of interest rate swaps and cross-currency basis swaps (see Du et al. (2018a)). This is different to Jiang et al. (2021) who use one-year forward contracts in their main analysis. Nevertheless, our results remain robust when using the one-year basis from outright forward contracts, showing no significant correlations between bilateral exchange rate changes and bilateral basis changes.

improve the model fit as shown in Table A.4, Column (3), of the Internet Appendix.

As a robustness check, we estimate the model at different frequencies (daily, weekly, and quarterly) and present the results in Table A.4, along with corresponding summary statistics in Table A.3. The results reveal that changes in hedging pressure have a statistically and economically significant impact across all frequencies. At the daily frequency, the basis change also becomes statistically significant, and show a negative point estimate as in Jiang et al. (2021). However, lagged values of explanatory variables are generally not statistically significant, indicating limited short-term predictability for exchange rate changes. Additionally, different yield spread maturities and inclusion of the VIX do not significantly alter the coefficient of hedging pressure.

6 Identifying the Hedging Demand Elasticity

As an equilibrium quantity, hedging pressure is jointly determined by the net demand for FX forward contracts and the banks' liquidity supply. Appendix B sets up a simultaneous equation system for both demand and supply as a function of the exchange rate and spells out our identification strategy more formally.

We are particularly interested in the exchange rate elasticity of the hedging demand, because a highly price inelastic hedging demand allows us to interpret the observed equilibrium quantities as mostly demand determined. At the same time, liquidity supply shocks from dealer banks then have large price effects on the exchange rate. Liquidity supply effects and their strong short-run impact on the exchange rate have been documented in the recent literature on periodic CIP deviations (Du et al. (2018b)).

We propose three different IV estimators to discern the price elasticity of the FX hedging demand. All three instruments are based on the idea that the liquidity supply of dealer banks in derivative markets is constrained by their capital ratios and that shocks to the capital ratio identify the price elasticity of the net hedging demand. Following He et al.

(2017), we measure a bank's capital ratio (CR) as the equity value relative to its asset value at market prices.[17] In other words, higher bank equity valuations augment the capacity for a net derivative supply.

Our first instrument z_t is simply based on the average (log) changes for capital ratio of the largest (primary) dealer banks in the FX market. Formally,

$$z_t = \sum_{i}^{N} \Gamma_i \Delta ln(CR_{i,t}), \tag{6}$$

where summation occurs over all banks i, the dummmy $\mathbb{1}_{\text{i is Dealer Bank}}$ marks by one primary dealer banks defined by the New York Fed, and the weight Γ_i is defined as

$$\Gamma_i = \frac{\mathbb{1}_{i \text{ is Dealer Bank}}}{\sum_i^N \mathbb{1}_{i \text{ is Dealer Bank}}}. \tag{7}$$

Figure A.5 plots the cross-sectional average of the daily changes in hedging pressure (blue line) and the average daily changes of the capital ratio of dealer banks (black line). The correlation between the two variables amounts to 8% and is statistically significant at the 1 percent level.

While the average capital ratio of dealer banks is unlikely to directly affect the hedging demand of investment funds, other financial variables could influence both the capital ratio and the hedging demand; thus invalidating our identification. In particular, economic uncertainty could depress banks' equity capital ratio and simultaneously foster more hedging by funds. We therefore refine the above identification strategy based on granular instruments proposed by Gabaix and Koijen (2020). In particular, we use *differences* in the capital ratio of dealer banks relative to all banks, which eliminates general stock market and bank sector valuation effects from the IV and retains only valuation effects idiosyncratic to the dealer banks. The respective granular instrument is then defined by weights

[17] We use the *average* capital ratio of primary dealers as our first instrument. This is slightly different to He et al. (2017), who use the *aggregate* capital ratio of all primary dealers. However, all results are qualitatively very similar for either definition.

$$\Gamma_i = \frac{\mathbb{1}_{i \text{ is Dealer Bank}}}{\sum_i^N \mathbb{1}_{i \text{ is Dealer Bank}}} - \frac{1}{N}. \tag{8}$$

This granular instrument (GIV1) uses the capital ratios not only of the primary dealer banks, but of all commercial banks available in the global Compustat database, where $N = 756$.[18] Table A.6, reports summary statistics for the bank capital ratios and instruments (Panel A) as well as the market statistics (Panel B) at daily frequency. We construct capital ratios based on total debt rather than long-term debt as in He et al. (2017).

A second granular instrument (GIV2) uses the fact that banks with FX trading activity tend to be large in terms of the assets under management. Therefore, we define alternative weights in Eq. 6 as the difference of the size and equal weighted capital ratios for all banks measured in 2012, namely

$$\Gamma_i = \frac{Assets_{i,2012}}{\sum_i^N Assets_{i,2012}} - \frac{1}{N}. \tag{9}$$

The size-based granularity instrument is conceptually closest to Gabaix and Koijen (2020) and is applied in Camanho et al. (2022). It also turns out to be the strongest of the three instruments and is therefore our preferred instrument.

Based on these instruments for the hedging pressure, $\Delta HP_{c,t}$, we can again estimate Eq. 5 using a 2SLS method. Under the assumption that the instrument captures (exogenous) supply shifts for FX hedging contracts, the 2SLS coefficient directly identifies the (inverse of) the demand elasticity as shown in Appendix B. As as our instruments are not currency specific, we focus on a dollar basket, i.e., the cross-sectional average dollar rate over the seven currencies. Generally, what should matter for US primary dealers in terms of derivative supply capacity is the aggregate provision of net dollar short positions, whereas the foreign currency leg of the specific forward contract may be of secondary importance. We resort to a daily data frequency to ensure that the instrument is sufficiently strong.

[18]The data is sourced from the Compustat Bank Fundamentals database and the Compustat Global database. The latter is filtered for banks using the Standard Industrial Classification (SIC). We classify banks with SIC equal to 602, 603, 606, 608, 609, 62 and 6712.

Table 4, Panels A and B, present the first and second stage results, respectively. We standardize the coefficients so that they convey the effect of a one-standard deviation shock. Column (0) in Panel B reports the OLS coefficients for comparison. The coefficient estimates for all three instruments in Panel A, Columns (1)-(3), are positive and highly significant. This implies that lower capital ratios, and thus tighter constraints on bank capital, decrease the supply of dollar short positions. The Montiel Olea-Pflueger (MOP) effective F-statistics are 10.5 and 15.7 for the GIV1 and GIV2, respectively, which indicates sufficiently strong instruments.

Table 4, Panel B, reports these second stage results. The fitted values of hedging pressure feature negative and statistically highly significant coefficients in Columns (1)-(3).[19] Thus, as as the dollar depreciates, larger net dollar short positions are demanded by institutional investors. Intuitively, hedging dollar-denominated assets becomes more relevant or urgent for foreign funds as the dollar loses value. The point estimates in Panel B, Columns (1)-(3), are of similar economic magnitude and range from -2.34 to -2.04, respectively. The implied exchange rate elasticity for the net dollar hedging demand follows as $1/-2.041 = -0.49$ in Column (3) — a relatively price inelastic demand. Thus, a 1% dollar appreciation is associated with a reduced net dollar hedging demand of -0.49%, which represents approximately 40 billion USD in 2020.[20]

We highlight that the GIV coefficients are almost six times larger compared to the OLS coefficient in Column (0), characterizes the equilibrium relationship between daily exchange rate changes and daily changes in hedging pressure. In Appendix B we show that the considerably more negative GIV estimate implies that the price elasticity of the hedging supply is larger than that of the hedging demand.

Our low price elasticity estimate accords with other results in the literature. Study-

[19] We do not find the conventional negative relationship between the asset price and the quantity in demand. Instead, we find that the desired forward buying of dollars against foreign currency increases in the price of the dollar.

[20] The average open interest in the market, i.e., the denominator of hedging pressure, amounts to 8.16 trillion in 2020. Thus, a net demand reduction of -0.49% corresponds to a 40 billion USD reduction in net dollar short positions ($=-0.49\% \times 8.16$ trillion USD).

ing periodic quarter-end CIP deviations associated with temporary supply reduction of EU banks in the forward market, Wallen (2020) finds that investment funds hardly respond in their hedging demand forward rate variations. Similarly, Du and Huber (2023) document that investors' hedging demand is not deterred by rising hedging costs, captured by CIP deviations. This confirms a highly price inelastic demand curve. Such a highly price inelastic hedging demand implies that any shift in the demand curve has an economically significant impact on equilibrium quantities (see Figure B.1 that visualizes this logic). In other words, the hedging pressure statistics is very sensitive to hedging demand shocks and for this reason primarily reflects demand shocks.

7 A Simple VAR Model of the Exchange Rate

Next, we estimate a simple VAR model, which allows us to describe the impulse response function in Section 7.1 and undertake a forecast error variance decomposition in Section 7.2.

We estimate a VAR composed of only two variables, namely hedging pressure, $HP_{c,t}$ and the log spot exchange rate $s_{c,t}$. We order the variables to form the vector $\mathbf{x}'_{c,t} = [HP_{c,t}, s_{c,t}]$ and obtain the structural form

$$\mathbf{A}\mathbf{x_t} = \mathbf{B}\mathbf{x_{t-1}} + \mathbf{u_t}, \tag{10}$$

where $\mathbf{A}$ is a (lower) triangular 2×2 matrix, $\mathbf{B}$ is an unconstrained 2×2 matrix and $\mathbf{u_t}$ is a vector of serially uncorrelated elementary innovations that have a unit diagonal matrix as their variance-covariance matrix.

Multiplying Eq. 10 by the inverse matrix $\mathbf{A^{-1}}$ produces the reduced form representation with the matrix $\mathbf{C} = \mathbf{A^{-1}B}$ for lagged coefficients and a variance-covariance $\mathbf{\Sigma} = (\mathbf{A'A})^{\mathbf{-1}}$. We estimate the VAR with one lag, as suggested by the Akaike information criterion (AIC), and remove a currency-specific linear trend from hedging pressure and the spot rate before including them in the VAR. We reject the null hypothesis of a unit root for both the detrended log exchange rates and the detrended hedging pressure series under a variety of test statistics reported in Table A.7.[21] The variable ordering for the VAR is rationalized by the following two assumptions. First, we assume that funds' hedging decisions take time and respond (if at all) only to lagged exchange rates. In other words, funds have a highly price inelastic demand, which is supported by our earlier finding. Second, we argue that hedging decisions by funds depend mostly on forward-looking risk evaluations that involve the expected second moment of the exchange rate change.

7.1 Impulse Response Functions

Figure 5 plots the impulse response functions. The first column reports the response of the two endogenous variables to an orthogonalized one-standard deviation shock to hedging pressure. On impact, hedging pressure increases by 0.50%, and slowly converges to its original level over the next three years. Most importantly, the dollar depreciates contemporaneously by −0.25% and continues to fall to −0.32% for the next 6 months before reverting slowly. Convergence to the original exchange rate level takes approximately four years. This confirms our previous results that larger dollar (net) short positions of funds in the derivative market, relative to all outstanding positions, puts downward pressure on dollar exchange rates.

In the second column of Figure 5, we display the response to a one-standard deviation shock to the exchange rate. By construction, the contemporaneous response on hedging pressure is zero. But even in the months following the shock, the response of hedging pressure is insignificantly different from zero. We note that the results are virtually identical if we replace the dollar spot rate with its corresponding forward rate.

[21] Robustness considerations argue for a VAR specification in levels instead of differences. Inference based on differences tends to be fragile under (incorrect) long-run restrictions supported by pretests (Gospodinov et al. (2013)). Furthermore, estimates from a VAR in levels are consistent even in the presence of a unit root, while falsely imposing a unit root by differencing the data renders the estimators inconsistent (Kilian and Lütkepohl (2017)).

7.2 Variance Decomposition

Finally, we use the VAR to evaluate the overall contribution of elementary hedging pressure shocks to the variance of the spot exchange rate. Figure 6 shows the forecast error variance decomposition of the stacked dollar rates. Hedging pressure shocks account for a large proportion of the exchange rate forecast error variance, ranging from 8% in the short run to 29% after 20 months. To put the number into context, we note that Koijen and Yogo (2020) find that short-term rates and debt quantities account for 8% and 2% of the variation in exchange rates, respectively. Thus, a contribution of about 30% to exchange rate variation generated by shocks to the hedging pressure statistics is economically significant and validates the hedging channel of exchange rate determination.

This economic significance is even more remarkable in light of the measurement problems listed in Section 3.1. CLS covers only about 20% of the total outstanding positions in FX derivatives, which implies that the non-attenuated significance of hedging pressure for the exchange could well be higher.

8 Conclusion

Our exploration of the "hedging channel" for exchange dynamics starts from the observation that US net asset positions in bonds have become increasingly negative over the last decade. Such increasing overseas funding of dollar denominated bonds can generate massive FX hedging demands from foreign funds, which have come to dominate FX derivative markets. At the same time, global banks, as liquidity providers, face more stringent capital requirements, which limits their balance sheet capacity for synthetic dollar funding through the supply of FX forward and swap contracts. Under these circumstances, a time-varying and price inelastic hedging demand can significantly impact both the forward and spot rate dynamics, as shown in this paper.

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Table 1: Summary Statistics

We show summary statistics for various monthly variables pooled over seven different US currency pairs, namely c = EURUSD, GBPUSD, JPYUSD, CHFUSD, CADUSD, AUDUSD, NZDUSD. The variables include the log nominal spot exchange rate, $s_{c,t}$, expressed as foreign currency per USD; the log three-month forward exchange rate, $f_{c,t}$, also quoted as foreign currency per USD; the yield spread defined as the two-year foreign treasury yield minus the two-year US Treasury, $(y^*_{c,t} - y^\$_{c,t})$; the Treasury basis, $Basis_{c,t}$; hedging pressure, $HP_{c,t}$; and net investment positions $NIP_{c,t}$. All series are based on month-end observations and are reported in percentage terms, the Treasury basis is in basis points, and the interaction term $NIP_{c,t} \times VIX_t$ is divided by 100. The Δ symbol denotes differences from the previous month. The sample covers the period September 2012-March 2022. The Treasury basis is reported only until March 2021.

	Obs.	Mean	S.D.	Median	P25	P75	Min	Max
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Level variables								
$s_{c,t}$	805	70.37	164.35	15.51	−11.43	34.09	−53.68	482.15
$f_{c,t}$	805	70.28	164.29	16.14	−11.67	34.20	−53.61	482.03
$(y^*_{c,t} - y^\$_{c,t})$	805	−0.40	1.32	−0.35	−1.08	0.15	−3.60	2.92
$Basis_{c,t}$	721	−0.05	0.28	0.01	−0.25	0.13	−0.89	0.60
$HP_{c,t}$	805	12.20	8.13	12.77	6.19	16.83	−4.35	32.82
$NIP_{c,t}$	805	28.27	47.02	33.36	−18.15	78.76	−55.38	92.70
VIX_t	805	17.58	6.76	15.87	13.41	19.20	9.51	53.54
$NIP_{c,t} \times VIX_t$	805	5.05	8.78	4.96	−2.78	11.91	−10.98	44.95
Monthly differences								
$\Delta s_{c,t}$	798	0.19	2.46	0.17	−1.33	1.79	−7.74	9.13
$\Delta f_{c,t}$	798	0.19	2.46	0.16	−1.32	1.77	−7.98	9.04
$\Delta(y^*_{c,t} - y^\$_{c,t})$	798	−1.61	15.44	−1.70	−9.78	4.92	−91.12	91.10
$\Delta Basis_{c,t}$	714	−0.00	0.06	0.00	−0.04	0.04	−0.28	0.28
$\Delta HP_{c,t}$	798	0.17	1.25	0.16	−0.59	0.92	−5.47	5.31
$\Delta NIP_{c,t}$	798	0.13	2.40	−0.00	−0.53	0.66	−13.48	22.96
ΔVIX_t	798	0.04	5.55	−0.09	−2.74	2.15	−19.39	21.27
$\Delta(NIP_{c,t} \times VIX_t)$	798	0.03	3.00	0.02	−0.86	0.98	−16.43	17.49

Table 2: Determinants of Hedging Pressure

We report pooled panel regressions in which the monthly (net) hedging pressure, $HP_{c,t}$, in seven US dollar currency pairs is regressed on the foreign net investment position, $NIP_{c,t}$, of the respective country with the US, the monthly CBOE volatility index (VIX_t), and the interaction term $NIP_{c,t} \times VIX_t$. Robust, two-way clustered standard errors by currency and time are shown in the parentheses. We denote by *, ** and *** the significance levels at the 10%, 5% and 1%, respectively. The sample period starts on September 28, 2012 and ends on March 31, 2022.

Dep. variable:	Hedging Pressure Changes, $\Delta HP_{c,t}$			
	(1)	(2)	(3)	(4)
$\Delta NIP_{c,t}$	-0.012		-0.022	-0.036^{**}
	(0.017)		(0.018)	(0.018)
ΔVIX_t		-0.025^{*}	-0.043^{***}	
		(0.013)	(0.012)	
$\Delta(NIP_{c,t} \times VIX_t)$			0.058^{***}	0.058^{***}
			(0.013)	(0.017)
Currency FEs	Yes	Yes	Yes	Yes
Time FEs	No	No	No	Yes
R^2 (Between)	0.311	-	0.371	0.345
R^2 (Overall)	0.001	0.0128	0.026	0.219
Observations	798	798	798	798

Table 3: Exchange Rates Dynamics and Hedging Pressure

We report panel regressions for the (log) spot rate and the (log) three month forward rate, respectively. The explanatory variables are monthly changes in (net) hedging pressure from investment funds, $\Delta HP_{c,t}$, monthly changes in the spread of the two-year foreign treasury yield minus the two-year US Treasury yield, $\Delta(y^*_{c,t} - y^{\$}_{c,t})$, monthly changes in the currency basis, $\Delta Basis_{c,t}$, and monthly changes in the foreign net investment position, $\Delta NIP_{c,t}$. All specifications include currency fixed effects not reported in the table. Robust, two-way clustered standard errors by currency and time are shown in the parentheses. We denote by *, ** and *** the significance levels at the 10%, 5%, and 1%, respectively. The sample period starts on September 28, 2012 and ends on March 31, 2022 (or March 31, 2021 when the Basis is included).

Dep. variable:	Spot Rate Changes, $\Delta s_{c,t}$				Forward Rate Changes, $\Delta f_{c,t}$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta HP_{c,t}$	-0.520^{***}	-0.508^{***}	-0.525^{***}	-0.344^{***}	-0.519^{***}	-0.508^{***}	-0.524^{***}	-0.345^{***}
	(0.180)	(0.169)	(0.186)	(0.087)	(0.179)	(0.169)	(0.185)	(0.087)
$\Delta(y^*_{c,t} - y^{\$}_{c,t})$		-0.036^{**}		-0.061^{***}		-0.035^{**}		-0.060^{***}
		(0.015)		(0.012)		(0.015)		(0.012)
$\Delta Basis_{c,t}$		-0.002	0.010	0.007		-0.000	0.011	0.010
		(0.013)	(0.016)	(0.024)		(0.013)	(0.016)	(0.024)
$\Delta NIP_{c,t}$			0.057^{*}				0.056^{*}	
			(0.034)				(0.034)	
Currency FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FEs	No	No	No	Yes	No	No	No	Yes
Adjusted R^2	0.070	0.113	0.074	0.140	0.070	0.111	0.075	0.138
Observations	798	714	714	714	798	714	714	714

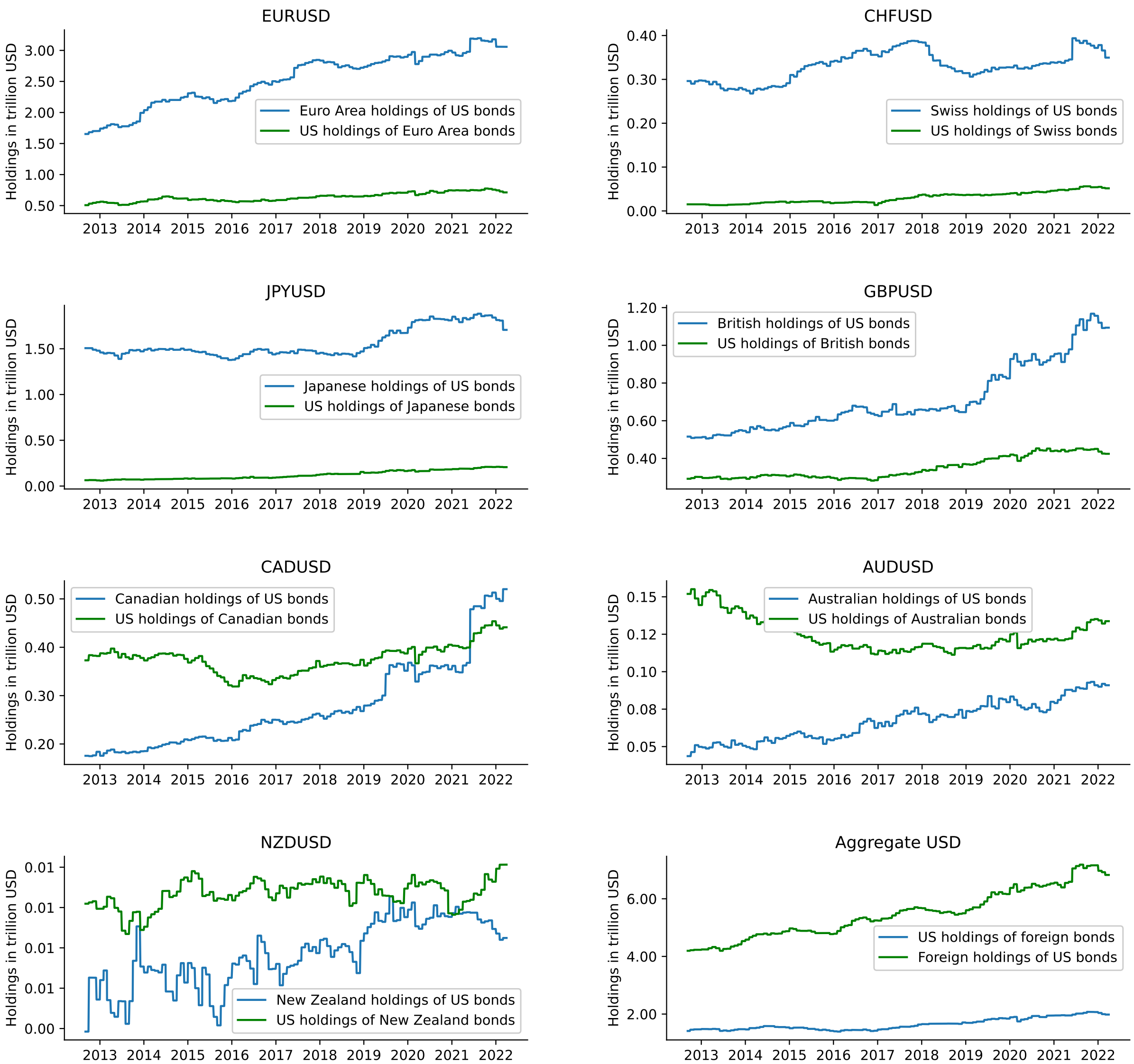
Table 4: Exchange Rate Elasticity of the Hedging Demand

We report 2SLS regressions of daily (log) spot rate changes, Δs_t, on the instrumented aggregate daily change of net hedging pressure in seven spot rates, ΔHP_t. Hedging pressure is instrumented by a weighted average of (log) bank capital ratio changes (i.e. market value of equity relative to market value of assets), where three instruments $z_t = \sum_i^N \Gamma_i \Delta ln(CR_{i,t})$ are defined for three different weights specified in Eqs. (7)-(9). The first instrument IV0 follows He et al. (2017)) and is refined by two granular instruments GIV1 and GIV2. Additional controls include changes in the daily spread of the two-year foreign treasury yield minus the two-year US Treasury yield, $\Delta(y_t^* - y_t^\$)$, and changes in the daily CBOE volatility index (ΔVIX_t). All series are cross-sectional averages over our 7 currencies and divided by their standard deviation. All specifications include a constant that is not reported in the table. MOP denotes the Montiel Olea-Pflueger (MOP) F-statistics. The Newey-West heteroskedasticity-and-autocorrelation-consistent asymptotic standard errors are reported in parentheses with a lag length of $T^{1/4}$ as suggested by Greene (2011). We denote by *, ** and *** the significance levels at the 10%, 5%, and 1%, respectively.

Panel A: First Stage			
Dep. variable:	Daily Hedging Pressure Changes, ΔHP_t		
	IV0	GIV1	GIV2
	(1)	(2)	(3)
z_t	0.109***	0.090***	0.114***
	(0.027)	(0.028)	(0.029)
$\Delta(y_t^* - y_t^\$)$	0.110***	0.102***	0.101***
	(0.024)	(0.024)	(0.024)
ΔVIX_t	0.016	−0.005	0.004
	(0.031)	(0.028)	(0.029)

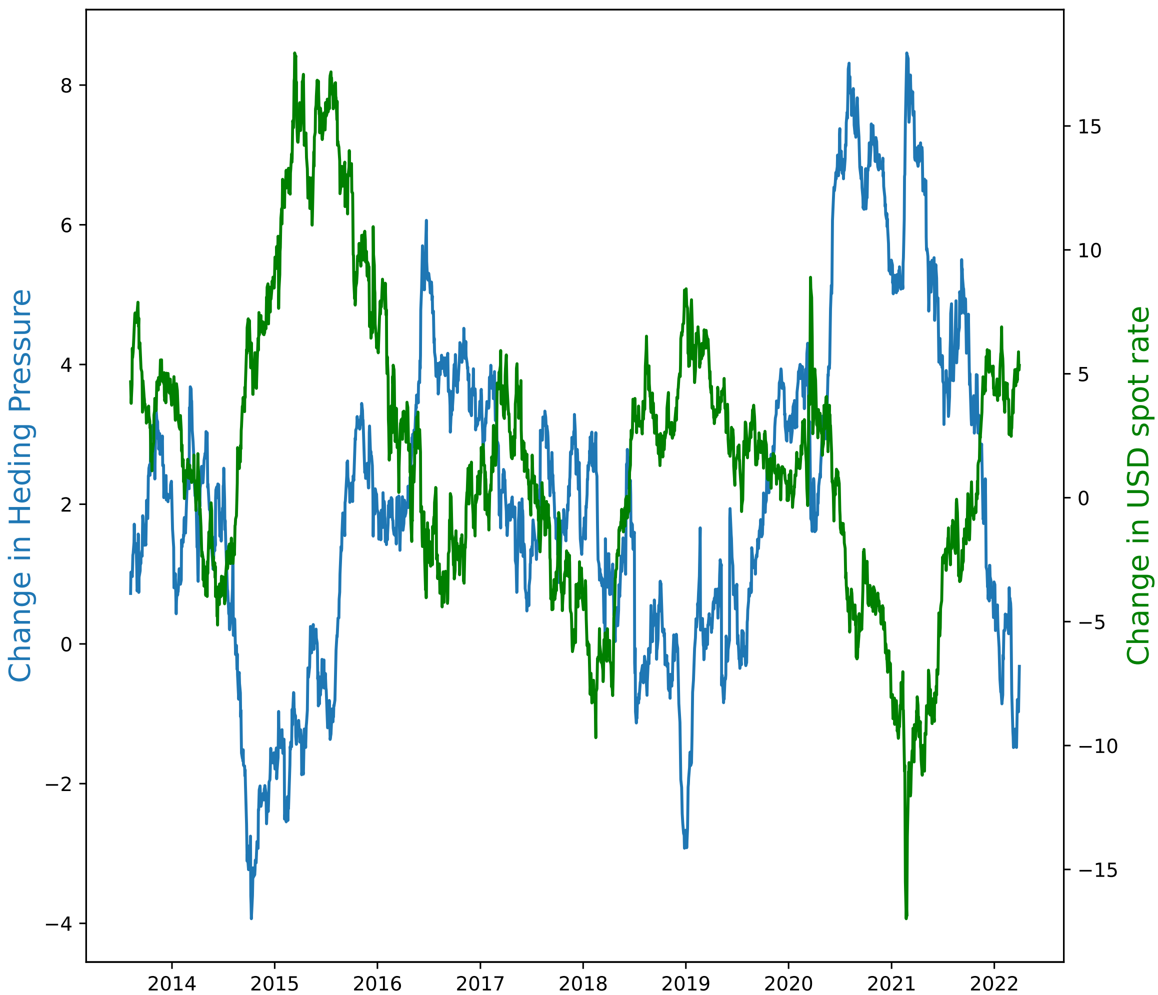
Panel B: Second Stage				
Dep. variable:	Daily Spot Rate Changes, Δs_t			
	OLS	IV0	GIV1	GIV2
	(0)	(1)	(2)	(3)
ΔHP_t	−0.362***			
	(0.043)			
$\widehat{\Delta HP_t}$		−2.335***	−2.270***	−2.041***
		(0.440)	(0.505)	(0.362)
$\Delta(y_t^* - y_t^\$)$	−0.294***	−0.097	−0.104	−0.127**
	(0.028)	(0.063)	(0.067)	(0.054)
ΔVIX_t	0.155***	0.090*	0.092*	0.099***
	(0.029)	(0.041)	(0.040)	(0.034)
Observations	2,409	2,409	2,409	2,409
MOP Effective F-statistics	-	15.343	10.486	15.705
Implied Demand Elasticity	-	−0.428	−0.440	−0.490

Figure 1: International Bond Holdings Across Exchange Rates



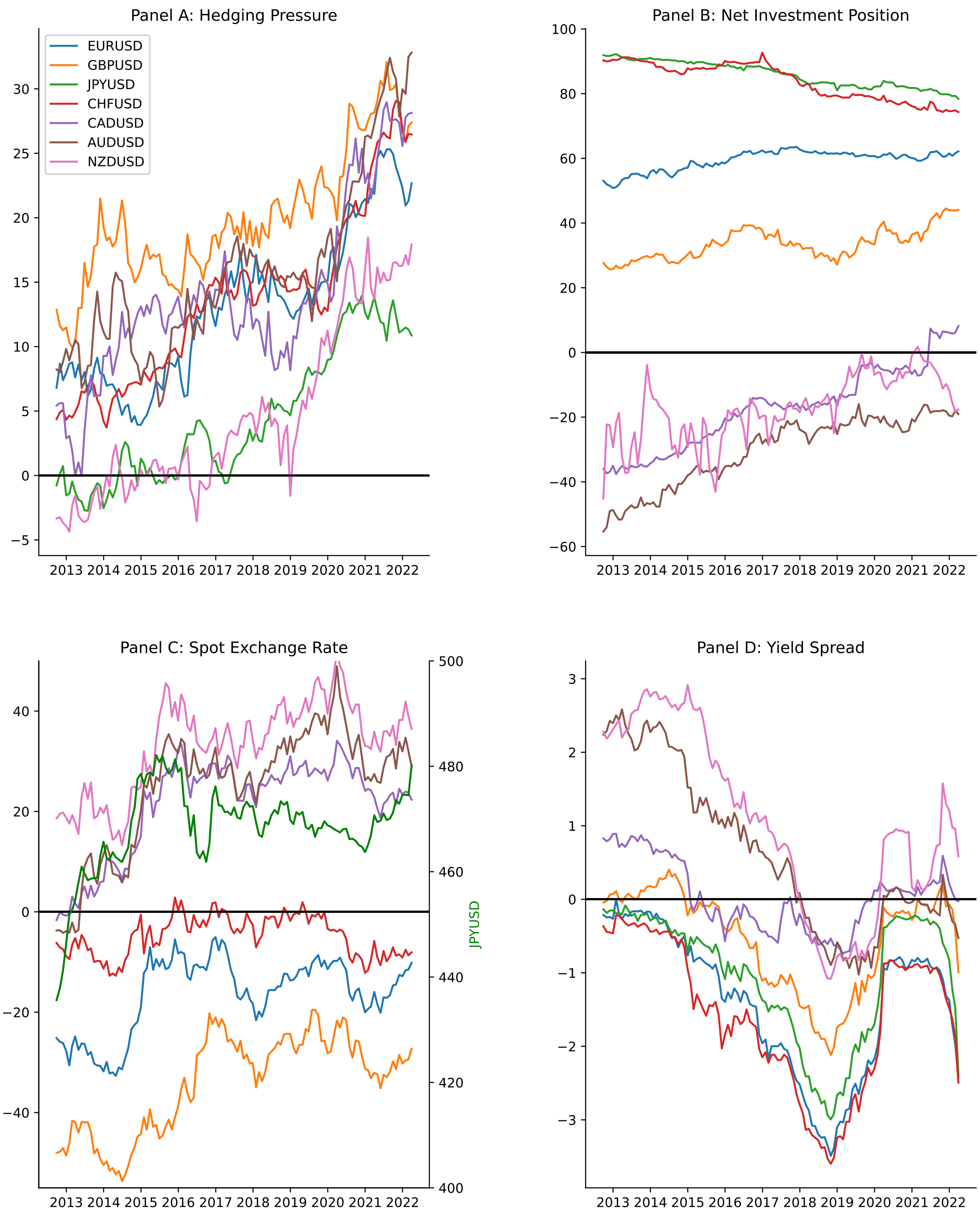
Notes: We plot the foreign long-term bond holdings in US bonds (blue line) and the US holdings of foreign long-term bonds (green line) over the period 2012-22 for seven different currency areas. The vertical scale denotes trillions of USD. The last panel shows the aggregate values. Source: US Treasury International Capital (TIC) System.

Figure 2: Hedging Pressure From Funds and the US Dollar Spot Rate



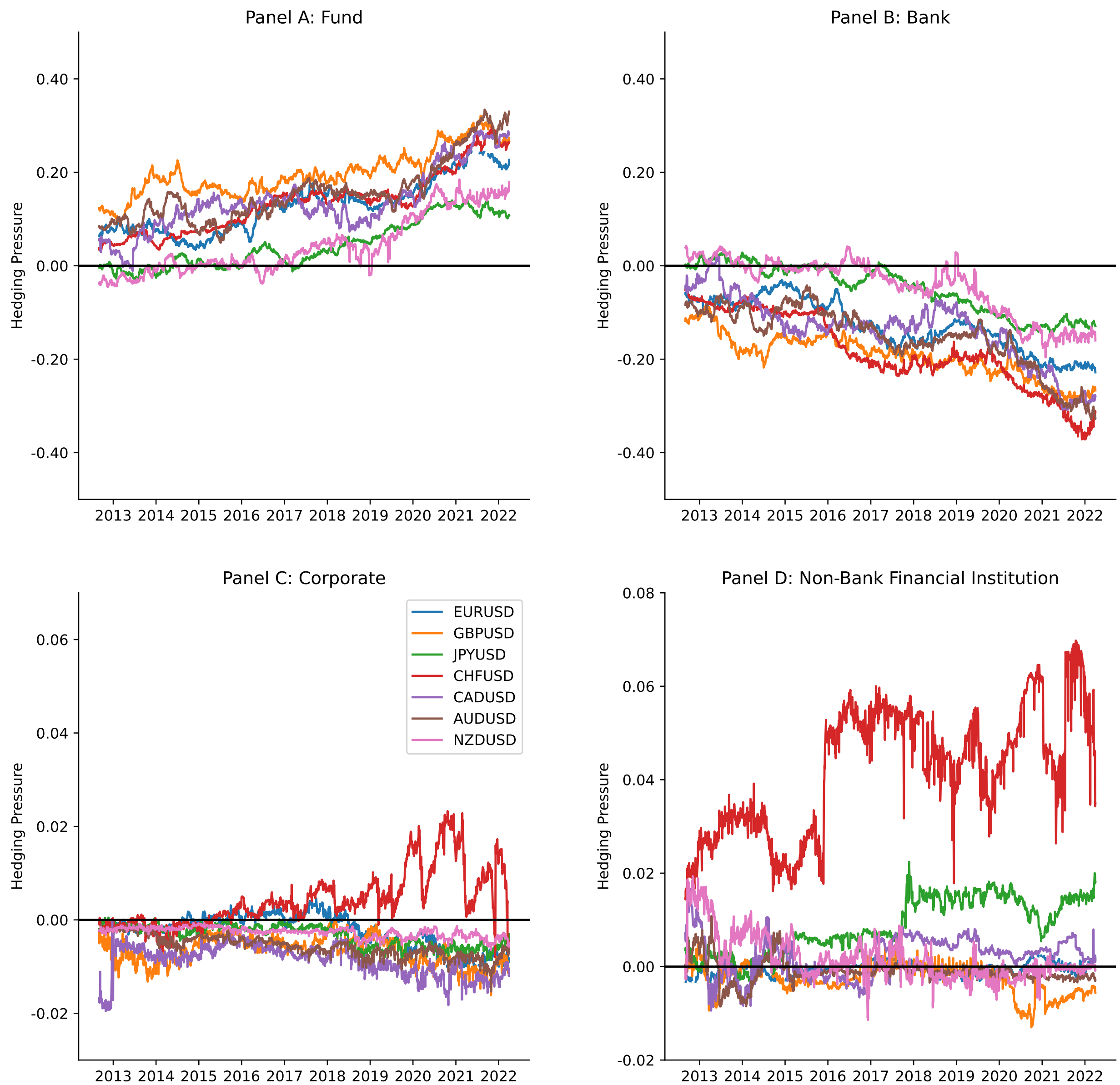
Notes: We graph the annual change in hedging pressure emanating from forward contracts of funds (as reported by CLS) and the annual change in the (log) US dollar spot exchange rates. Both measures are computed as the cross-sectional average over all seven currencies. The negative correlation is -0.66. Source: CLS and Bloomberg.

Figure 3: Hedging Pressure and Net Investment Positions



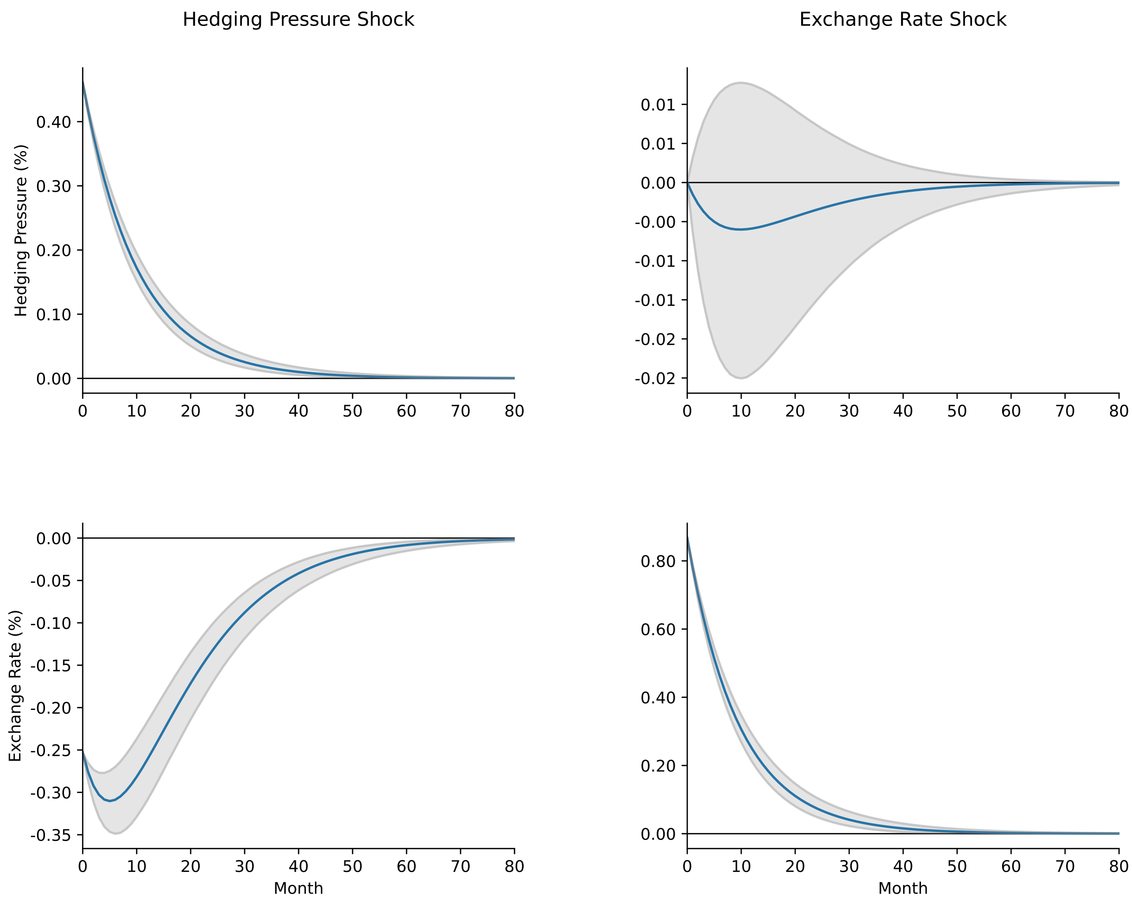
Notes: For seven dollar exchange rates, we plot hedging pressure in Panel A, the corresponding US net foreign investment positions in Panel B, the spot exchange in Panel C, and the difference between the foreign and US two-year government yield in Panel D. Note that in Panel C the Japanese yen spot rate is plotted against the right hand side vertical axis. Sources: CLS, TIC and Bloomberg.

Figure 4: Net Forward Positions by Investor Type



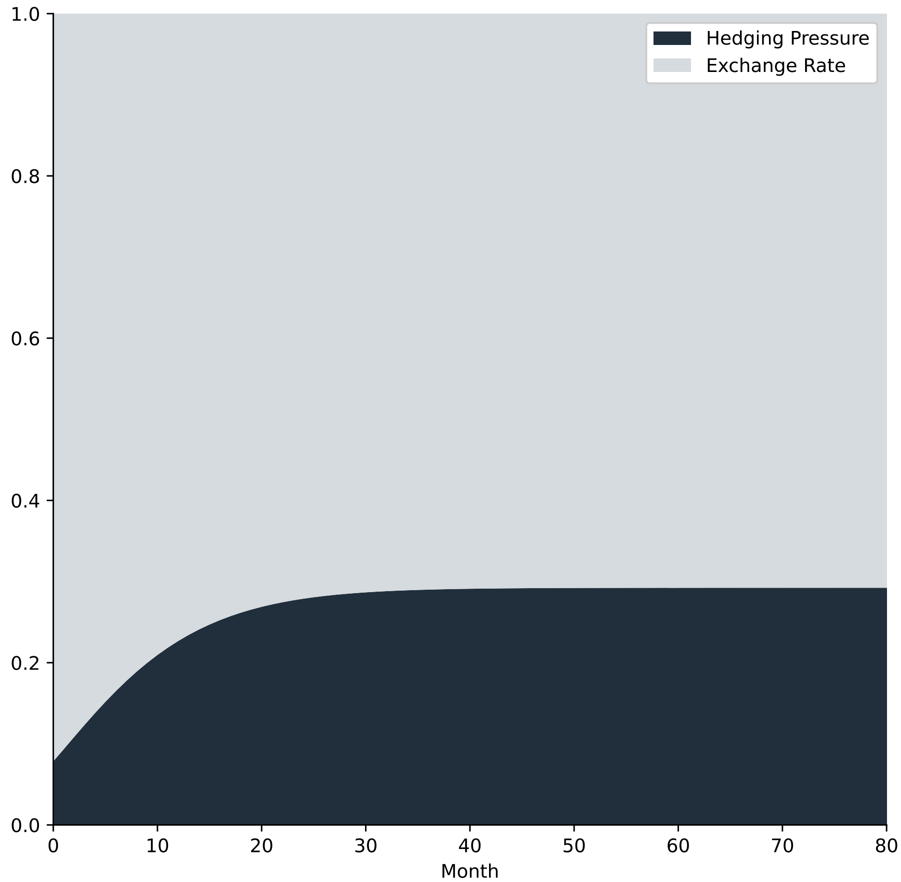
Notes: We show the (percentage) net outstanding forward positions (relative to the total outstanding contract volume) by type of market participant in the seven most liquid exchange rate markets. The CLS data distinguishes funds, banks, corporates, and non-bank financial institutions. We define as hedging pressure the net positions of the funds in the first panel. Source: CLS.

Figure 5: Impulse Response Functions



Notes: We plot the impulse response functions of a (pooled) vector autoregression (VAR) with a triangular ordering consisting of (1) the bilateral (net) hedging pressure, $HP_{c,t}$; and (2) the log exchange rate, $s_{c,t}$. The order of listing of the variables corresponds to the order in the VAR. An increase in the exchange rate corresponds to a US dollar appreciation. The shocks are identified using a Cholesky decomposition. The blue line represents the median response, and the grey shaded areas are the 95% confidence bands. Standard errors are generated using 10,000 Monte Carlo simulations. The sample period is September 2012-March 2022.

Figure 6: Forecast Error Variance Decomposition of the Dollar



Notes: We show the forecast error variance decomposition for exchange rates of a (pooled) vector autoregression (VAR) with a triangular variable ordering consisting of (1) the bilateral (net) hedging pressures; and (2) the (log) spot exchange rate. Shocks to hedging pressure explain up to 29% of the spot rate variance. The sample period is September 2012-March 2022, and monthly observations for the seven most liquid exchange rates are pooled.

Internet Appendix

Can Time-Varying Currency Risk Hedging Explain Exchange Rates?

A Additional Tables and Figures

Table A.1: Notional Amount Outstanding by Currency Rate

For the period September 2012-March 2022, we report the mean and standard deviation of daily notional amounts outstanding in billions of USD for swap and forward contracts and their sum (total) by currency pair.

	Swap		Forward		Total		Total
	Mean	S.D.	Mean	S.D.	Mean	S.D.	March 2022
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
EURUSD	2,360.35	263.96	314.88	43.61	2,675.22	276.62	2,763.85
GBPUSD	973.56	192.86	146.44	28.18	1,120.01	211.74	1,480.73
USDJPY	1,315.53	303.66	158.24	33.36	1,473.77	320.84	1,914.43
USDCHF	385.13	48.79	51.11	13.67	436.24	59.63	553.99
USDCAD	331.83	100.72	74.37	19.03	406.20	115.98	633.39
AUDUSD	461.15	102.82	83.46	19.76	544.61	115.51	770.43
NZDUSD	101.82	26.75	24.38	5.97	126.20	29.95	170.23
Total	5,929.38		852.87		6,782.25		8,287.04

Table A.2: Fund Share in Forward Buy and Sell Volumes by Exchange Rate

We show the percentage position size of funds in buy and sell volume by currency and in aggregate. Reported are the mean percentage shares in Columns (1) and (4) and the shares for the years 2012 and 2022 in Columns (2), (3), and (5),(6), respectively.

	Buy Volume			Sell Volume		
	Mean	2012	2022	Mean	2012	2022
	(1)	(2)	(3)	(4)	(5)	(6)
EURUSD	0.63	0.34	0.95	0.36	0.24	0.47
GBPUSD	0.69	0.48	0.81	0.34	0.31	0.37
JPYUSD	0.39	0.24	0.49	0.25	0.20	0.26
CHFUSD	0.41	0.19	0.65	0.20	0.11	0.25
CADUSD	0.58	0.38	0.84	0.39	0.32	0.43
AUDUSD	0.55	0.38	0.81	0.35	0.31	0.39
NZDUSD	0.39	0.20	0.67	0.36	0.27	0.38
All rates	0.54	0.34	0.77	0.32	0.24	0.38

Table A.3: Summary Statistics Different Frequencies

We show summary statistics for various variables pooled over seven different US currency pairs, namely $c =$ EURUSD, GBPUSD, JPYUSD, CHFUSD, CADUSD, AUDUSD, NZDUSD at a daily, weekly, and quarterly frequency. The variables include the log nominal spot exchange rate, $s_{c,t}$, expressed as foreign currency per USD; the log three-month forward exchange rate, $f_{c,t}$, also quoted as foreign currency per USD; the yield spread defined as the two-year foreign treasury yield minus the two-year US Treasury, $(y^*_{c,t} - y^\$_{c,t})$; the Treasury basis, $Basis_{c,t}$; and hedging pressure, $HP_{c,t}$. All series are based on day-, week-, quarter-end observations. The Δ symbol denotes differences from the previous day, week and quarter respectively. The sample covers September 2012-March 2022. The Treasury basis is reported only until March 2021.

	Daily Sample			Weekly Sample			Quarterly Sample		
	Obs.	Mean	S.D.	Obs.	Mean	S.D.	Obs.	Mean	S.D.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Level variables									
$s_{c,t}$	17,381	70.27	164.22	3,500	70.29	164.24	273	70.28	164.58
$f_{c,t}$	17,380	70.18	164.16	3,499	70.21	164.20	273	70.19	164.51
$(y^*_{c,t} - y^\$_{c,t})$	16,374	−39.45	133.15	3,493	−0.40	1.33	273	−0.40	1.32
$Basis_{c,t}$	15,079	−4.84	28.08	3,110	−4.96	28.03	245	−5.17	28.15
$HP_{c,t}$	17,381	12.09	8.02	3,500	12.09	8.02	273	12.24	8.24
Differences									
$\Delta s_{c,t}$	17,381	0.01	0.56	3,493	0.04	1.26	266	0.57	4.29
$\Delta f_{c,t}$	17,379	0.01	0.56	3,491	0.04	1.26	266	0.57	4.29
$\Delta(y^*_{c,t} - y^\$_{c,t})$	16,374	−0.08	3.74	3,480	−0.37	7.34	266	−4.83	31.75
$\Delta Basis_{c,t}$	14,790	−0.00	2.50	3,098	−0.00	3.93	238	−0.09	10.02
$\Delta HP_{c,t}$	17,374	0.01	0.27	3,493	0.04	0.58	266	0.50	2.13

Table A.4: Exchange Rates Dynamics and Hedging Pressure at Different Frequencies

This table shows the results of our benchmark regression of spot rate changes $\Delta s_{c,t}$ on changes in hedging pressure from investment funds $\Delta HP_{c,t}$ for different frequencies: daily, weekly, monthly, and quarterly. Additional variables include changes in the spread of the two-year foreign treasury yield over the two-year US Treasury yield, $\Delta(y^*_{c,t} - y^\$_{c,t})$, and changes in the respective currency basis, $\Delta Basis_{c,t}$. In all regression we add one lagged term of the change in hedging pressure, $\Delta HP_{c,t-1}$, and the change in the relative yield, $\Delta(y^*_{c,t-1} - y^\$_{c,t-1})$, as additional controls. All specifications include a constant that is not reported in the table. Robust, two-way clustered standard errors by currency and time are shown in the parentheses. We denote by *, ** and *** the significance levels at the 10%, 5%, and 1%, respectively. The sample period starts on September 29, 2012 and ends on March 9, 2021.

Dep. variable:	Spot Rate Changes, $\Delta s_{c,t}$			
	Daily	Weekly	Monthly	Quarterly
	(1)	(2)	(3)	(4)
$\Delta HP_{c,t}$	-0.260^{***}	-0.359^{***}	-0.346^{***}	-0.304^{***}
	(0.091)	(0.119)	(0.092)	(0.091)
$\Delta HP_{c,t-1}$	0.020	-0.017	-0.006	0.025
	(0.017)	(0.043)	(0.072)	(0.145)
$\Delta(y^*_{c,t} - y^\$_{c,t})$	-0.040^{***}	-0.005	-0.061^{***}	-0.058^{***}
	(0.014)	(0.004)	(0.012)	(0.013)
$\Delta(y^*_{c,t-1} - y^\$_{c,t-1})$	-0.006^{**}	0.000	0.004	0.013^{*}
	(0.002)	(0.005)	(0.009)	(0.007)
$\Delta Basis_{c,t}$	-0.022^{**}	-0.019^{**}	0.007	0.031
	(0.009)	(0.008)	(0.025)	(0.035)
Currency FEs	Yes	Yes	Yes	Yes
Time FEs	Yes	Yes	Yes	Yes
Adjusted R^2	0.076	0.052	0.141	0.150
Observations	13500	3,072	707	231

Table A.5: Analysis for Different Market Participants

We report regression for monthly (log) spot rate changes, $\Delta s_{c,t}$, on changes in hedging pressure from corporates and non-bank financial institutions, $\Delta HP_{c,t}$, using data from CLS. Additional variables include changes in the spread of the two-year foreign treasury yield over the two-year US Treasury yield. The regressions are performed with and without the Swiss Franc. All specifications include a constant that is not reported in the table. Robust, two-way clustered standard errors by currency and time are shown in the parentheses. We denote by *, ** and *** the significance levels at the 10%, 5%, and 1%, respectively. The sample period starts on September 29, 2012 and ends on March 9, 2021.

Dep. variable:	Spot Rate Changes, $\Delta s_{c,t}$					
	Corporates			Non-Bank Financial Institutions		
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta HP_{c,t}$	0.274	1.267**	0.724	−0.902	−2.268***	−1.341**
	(0.501)	(0.575)	(0.492)	(0.739)	(0.800)	(0.548)
$\Delta(y^*_{c,t} - y^\$_{c,t})$	−0.039***	−0.041***	−0.065***	−0.038***	−0.040***	−0.065***
	(0.013)	(0.014)	(0.014)	(0.013)	(0.014)	(0.015)
Currency FEs	Yes	Yes	Yes	Yes	Yes	Yes
Time FEs	No	No	Yes	No	No	Yes
Include CHF	Yes	No	No	No	Yes	No
Adjusted R^2	0.062	0.068	0.139	0.072	0.094	0.136
Observations	798	684	684	798	684	612

Table A.6: Summary Statistics for Daily Sample

Panel A reports summary statistics on 756 commercial banks with data available on the Compustat Bank Fundamentals database and the Compustat Global database (filtered for banks using SIC codes 602, 603, 606, 608, 609, 62, and 6712) for the period 2012-2022. Our definition of (primary) dealer banks follows the labeling by the New York Fed available at `https://www.newyorkfed.org/markets/primarydealers`. Data on one primary dealer (i.e. Cantor Fitzgerald) is missing. The equity capital ratio, $CR_{i,t}$, of bank i is computed as the value of market equity divided by the sum of market equity and long-term and current book debt. Panel B states summary statistics for three instruments, z_t^0, z_t^1 and z_t^2, constructed according to Eq. 6 with weights defined in Eqs. B.12, 8, and 9, respectively. Panel C shows summary statistics for various daily variables pooled over seven different US currency pairs, namely c = EURUSD, GBPUSD, JPYUSD, CHFUSD, CADUSD, AUDUSD, NZDUSD. The variables include the log nominal spot exchange rate, s_t, expressed as foreign currency per USD; the log three-month forward exchange rate, f_t, also quoted as foreign currency per USD; hedging pressure, HP_t; the yield spread defined as the two-year foreign treasury yield minus the two-year US Treasury, $(y_t^* - y_t^\$)$; and the CBOE volatility index, VIX_t. The Δ symbol denotes differences from the previous day. The sample covers the period September 2012-March 2022.

	Obs.	Mean	S.D.	Median	P25	P75	Min	Max
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Bank Data								
Book Assets (mil USD)	1,779,230	91,303	356,767	1,794	753	8,543	94	3,954,687
Book Debt (mil USD)	1,704,382	18,354	77,723	123	40	704	0.00	1,177,661
Market Equity (mil USD)	1,779,230	6,048	24,064	206	66	1,246	0.00	514,470
$CR_{i,t}$	1,704,382	0.57	0.24	0.59	0.42	0.76	0.00	0.99
$\Delta ln(CR_{i,t})$	1,703,665	−0.00	0.05	0.00	0.00	0.00	−9.85	6.31
Panel B: Instruments								
z_t^0	2,410	0.02	1.00	0.03	−0.40	0.46	−10.00	10.20
z_t^1	2,410	0.00	1.00	0.02	−0.47	0.46	−8.20	9.13
z_t^2	2,410	0.00	1.00	0.00	−0.49	0.49	−9.87	10.66

Table A.6 continued.

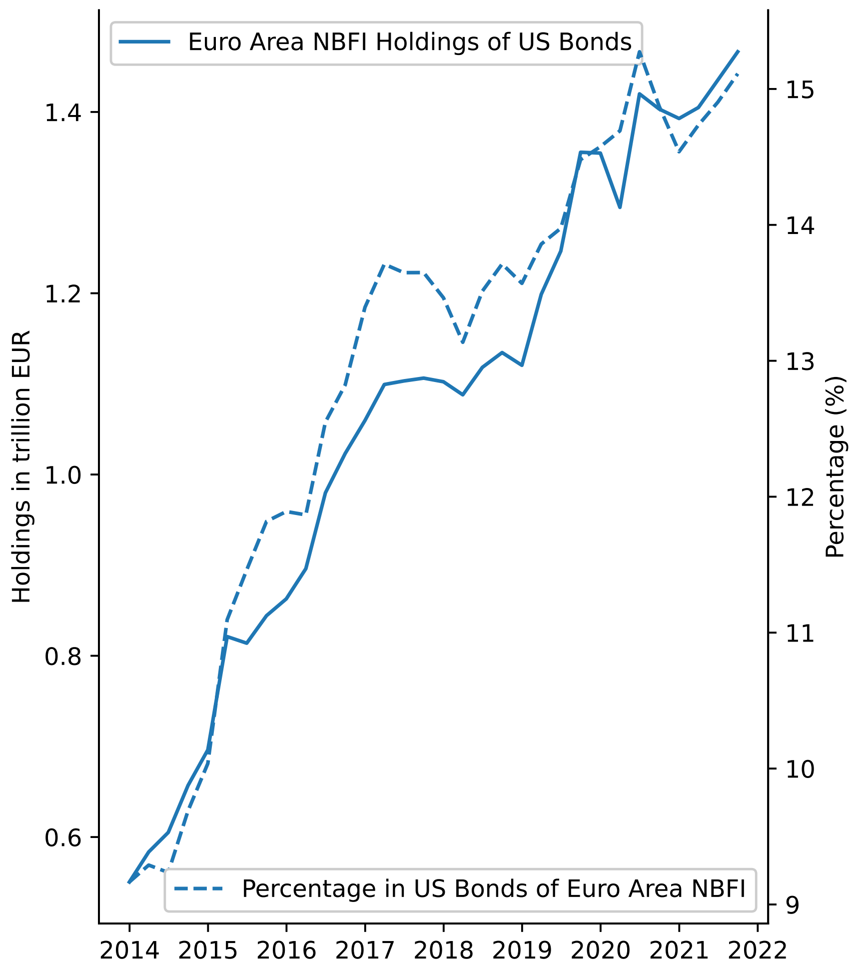
	Obs.	Mean	S.D.	Median	P25	P75	Min	Max
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel C: Market Data								
Level variables								
$s_{c,t}$	$2,410$	70.27	7.61	72.94	68.53	75.88	51.92	85.35
$f_{c,t}$	$2,410$	70.18	7.45	72.80	68.39	75.63	52.12	85.07
$HP_{c,t}$	$2,410$	14.81	6.39	14.16	9.17	17.35	6.34	29.28
$(y^*_{c,t} - y^\$_{c,t})$	$2,410$	−0.40	0.84	−0.28	−0.96	0.23	−2.15	0.83
VIX_t	$2,410$	17.20	7.09	15.20	12.91	19.22	9.14	82.69
Daily differences								
$\Delta s_{c,t}$	$2,410$	0.02	1.00	0.02	−0.57	0.61	−7.53	5.46
$\Delta f_{c,t}$	$2,410$	9.42	1.00	9.77	9.18	10.15	7.00	11.42
$\Delta HP_{c,t}$	$2,410$	0.05	1.00	0.04	−0.45	0.58	−11.26	11.21
$\Delta(y^*_{c,t} - y^\$_{c,t})$	$2,410$	−0.03	1.00	−0.03	−0.49	0.43	−6.82	8.67
ΔVIX_t	$2,410$	0.00	1.00	−0.04	−0.38	0.30	−9.47	13.35

Table A.7: Stationarity Tests

For the two linearly detrended panel variables, hedging pressure, $HP_{c,t}$, and the log spot exchange rate, $s_{c,t}$, we report test statistics for the null hypothesis of the presence of a unit root and in brackets the corresponding p-values. The tests include the Levin-Lin-Chu test, the Im, Pesaran and Shin test, and Fisher-type tests using the Augmented Dickey-Fuller test and the Phillips–Perron test. The Levin-Lin-Chu test assumes a common unit root process, while all other tests assume individual unit root processes. The p-values for the Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

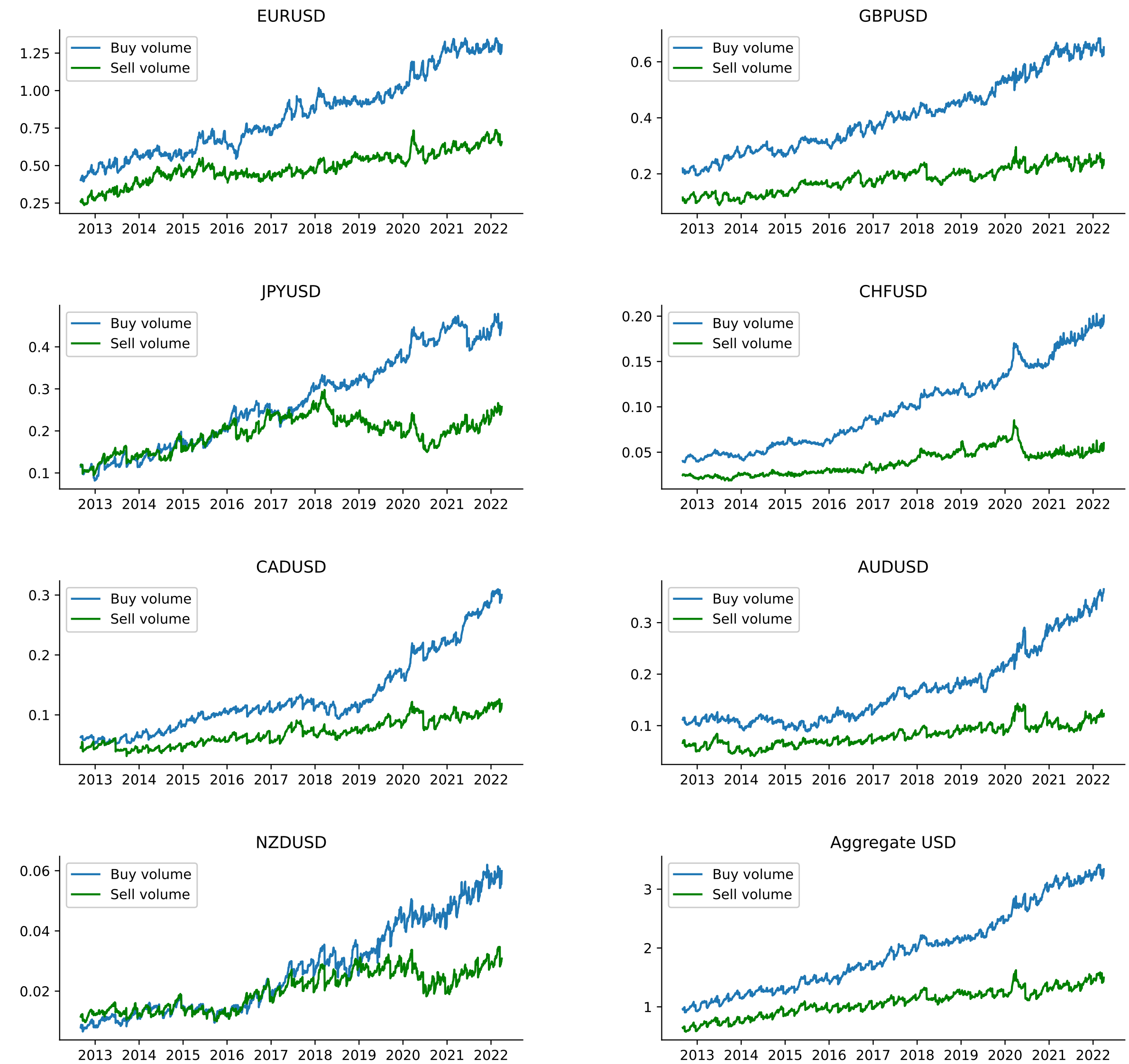
Variable	$HP_{c,t}$	$s_{c,t}$
Levin-Lin-Chu t-statistic	−1.51314	−1.57649
	(0.0651)	(0.0575)
Im, Pesaran and Shin W-statistic	−2.73197	−2.48201
	(0.0031)	(0.0065)
Augmented Dickey-Fuller Fisher Chi-square	28.8856	28.5710
	(0.0108)	(0.0119)
Phillips–Perron Fisher Chi-square	26.1697	27.6045
	(0.0246)	(0.0160)

Figure A.1: US Bond Holding by Euro Area Non-Bank Institutions



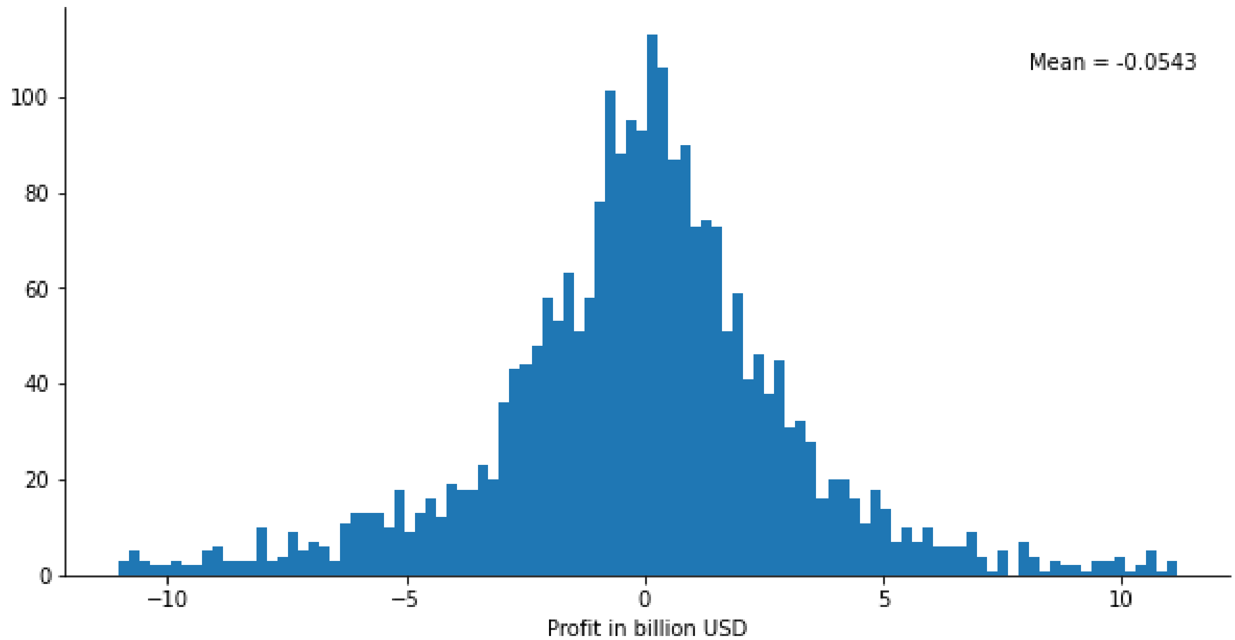
Notes: For all euro area non-bank financial institutions, we plot the long-term bond holdings for the period 2014-21. The left axis and non-dashed line denote the bond holdings in trillions of EUR, and the right axis and the dashed line report the percentage of US bonds in the overall bond portfolio of euro area non-bank financial institutions. Source: ECB Statistical Data Warehouse.

Figure A.2: Buy and Sell Volume of Funds.



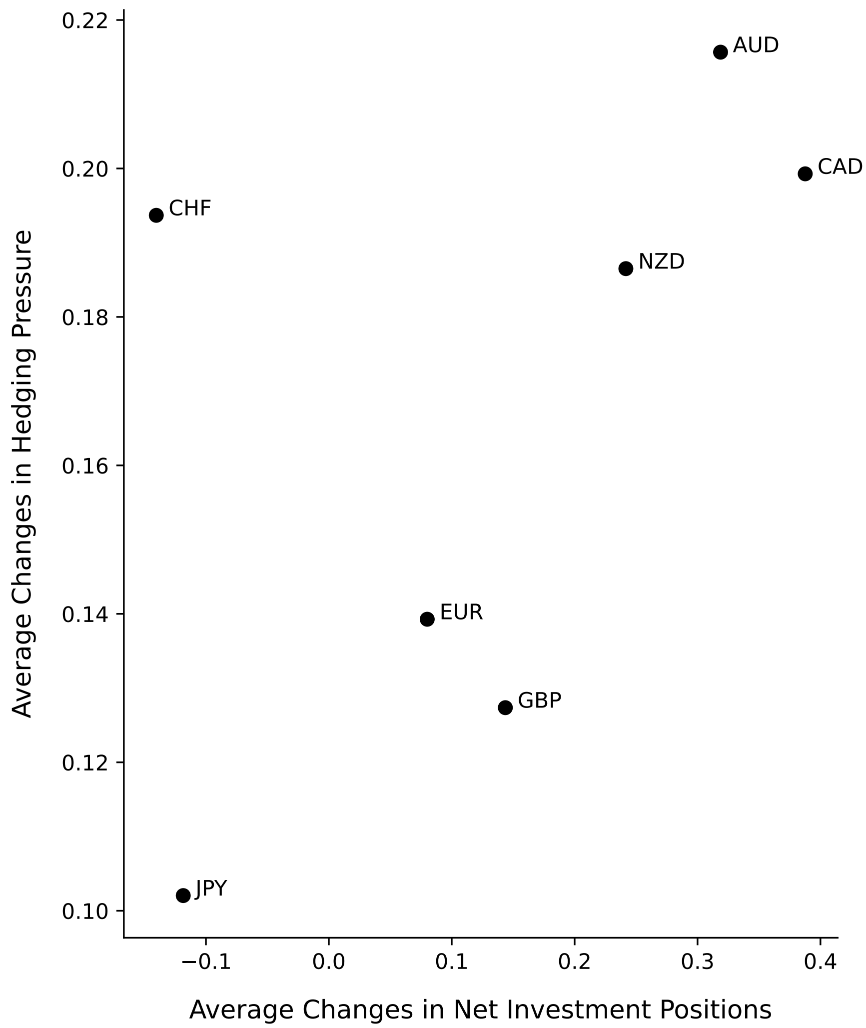
Notes: We plot buy and sell volumes of the base currency in trillion USD for funds. The bottom right figure shows the aggregate over all seven currencies. Source: CLS.

Figure A.3: Profitability of Funds' FX Forward Positions.



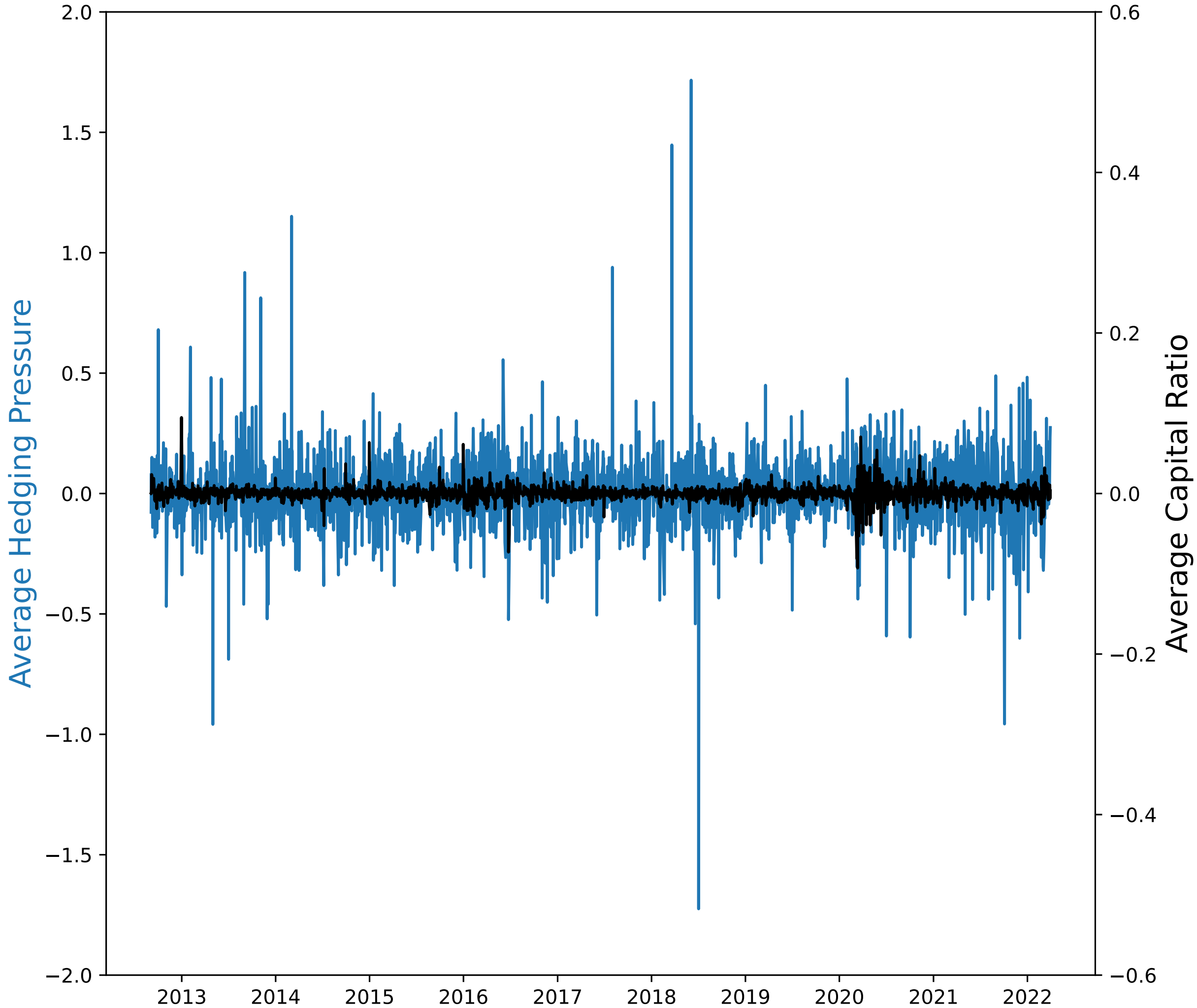
Notes: We plot the daily profit of funds' aggregate FX derivative positions (in USD) computed as the product between net short positions (in USD) and the daily return on the spot rate. The average daily aggregate net hedging (short) position of funds is 60 billion USD and the average daily profit based on the daily spot rate changes is −54 million USD. A test of the null hypothesis of a zero mean yields a t-statistics of −0.8387 with a p-value of 0.4017. Sources: CLS and Bloomberg.

Figure A.4: Average Changes in Hedging Pressure and Average Changes in Net Investment Positions.



Notes: We plot the average monthly change in hedging pressure against the average monthly change in net investment positions per currency or country. The correlation between the two variables amounts to 55%. If the Swiss Franc (CHFUSD) is not taken into account, the correlation is 92% and significant at the 1% level. Source: CLS and TIC data.

Figure A.5: Average Hedging Pressure and Intermediary Capital Ratio.



Notes: We plot the cross-sectional average daily changes in hedging pressure in blue and the daily change in intermediaries' capital ratio in black constructed by He et al. (2017). The correlation between the two variables is 5% and significant at the 1% level. Source: CLS and Compustat.

B Demand and Supply of FX Derivative Contracts

In this section, we first lay out a system of demand and supply equations for FX derivatives. Second, we show how (granular) instruments for supply shifts allow identification of the price elasticity of demand and highlight the exclusion restrictions specific to each IV estimation. Third, we point out the relationship to the equations for the vector autoregression (VAR) in Section 7 of the paper.

General Setup. Institutional investors vary their demand for hedging contracts, which can depend on the price of the forward rate. The supply of FX forwards is determined by a price elastic linear supply curve from a group of global dealer banks. We assume perfect arbitrage between the spot and forward market undertaken by global dealer banks through the synthetic hedging policies. Under constant yields for the dollar and foreign interest rate, covered interest parity implies that that forward rate changes match spot rate changes, i.e. $\Delta f = \Delta s$. Formally, we assume the following demand and supply equations for derivative contracts,

$$\Delta HP_t^d = \phi^d \Delta s_t + \epsilon_t^d \tag{B.1}$$

$$\Delta HP_t^s = \phi^s \Delta s_t + \epsilon_t^s, \tag{B.2}$$

where ΔHP_t^d and ΔHP_t^s denote changes to the derivative demand and supply, respectively, Δs denotes the equilibrium price change, ϕ^d and ϕ^s denote the elasticity of demand and supply, respectively, and ϵ_t^d and ϵ_t^s denote demand and supply shocks, respectively.

Under market clearing, we have $\Delta HP^s = \Delta HP^d$, and can rewrite B.1 and B.2 as

$$\Delta s_t = \frac{1}{\phi^d}\Delta HP_t - \frac{1}{\phi^d}\epsilon_t^d \tag{B.3}$$

$$\Delta s_t = \frac{1}{\phi^s}\Delta HP_t - \frac{1}{\phi^s}\epsilon_t^s. \tag{B.4}$$

Furthermore, the equilibrium price and quantity (i.e. the hedging pressure) changes can be expressed in terms of the supply and demand shocks as

$$\Delta s_t = \frac{1}{\phi^d - \phi^s}\left(\epsilon_t^s - \epsilon_t^d\right) \tag{B.5}$$

$$\Delta HP_t = \frac{\phi^d}{\phi^d - \phi^s}\left(\epsilon^s - \frac{\phi^s}{\phi^d}\epsilon^d\right). \tag{B.6}$$

Ordinary-Least-Square Regression. An OLS regression of spot rate changes on the equilibrium hedging pressure changes analagous to Eq. 5 implies for the OLS coefficient

$$\beta^{OLS} = \frac{\mathbb{E}[\Delta HP_t \Delta s_t]}{\mathbb{E}[\Delta HP_t^2]} = \frac{\mathbb{E}[\Delta HP_t(\frac{1}{\phi^d}\Delta HP_t - \frac{1}{\phi^d}\epsilon_t^d)]}{\mathbb{E}[\Delta HP_t^2]} = \frac{1}{\phi^d} + \frac{\mathbb{E}[\Delta HP_t(-\frac{1}{\phi^d}\epsilon_t^d)]}{\mathbb{E}[\Delta HP_t^2]}. \tag{B.7}$$

The OLS coefficient identifies the inverse of the demand elasticity only in the absence of demand shocks ϕ_t^d; it is generally smaller than the inverse of the demand elasticity $\frac{1}{\phi^d}$ for $\mathbb{E}[\Delta HP_t(-\frac{1}{\phi^d}\epsilon_t^d)] < 0$.

Instrumental Variable Regression. Suppose we have an instrument x_t that shifts the supply equation B.2, such that

$$\Delta HP_t^s = \phi^s \Delta s_t + \alpha^s x_t + \epsilon_t^s. \tag{B.8}$$

The IV regression then allows for an unbiased estimation of (the inverse of) the demand elasticity $\frac{1}{\phi^d}$. Formally,

$$\beta^{IV} = \frac{\mathbb{E}[x_t \Delta s_t]}{\mathbb{E}[x_t \Delta HP_t]} = \frac{\mathbb{E}[x_t(\frac{1}{\phi^d}\Delta HP_t - \frac{1}{\phi^d}\epsilon_t^d)]}{\mathbb{E}[x_t \Delta HP_t]} = \frac{1}{\phi^d} + \frac{\mathbb{E}[x_t(-\frac{1}{\phi^d}\epsilon_t^d)]}{\mathbb{E}[x_t \Delta HP_t]} = \frac{1}{\phi^d}, \tag{B.9}$$

where the last step follows from the exclusion restriction $\mathbb{E}[x_t \epsilon_t^d] = 0$.

Granular Instrumental Variable Regression. Our particular supply shifter are changes to dealer bank valuations and such valuation effects may plausibly correlate other macroeconomic variables that influence hedging demands. We therefore resort to granular instrumental variable (GIV) proposed by Gabaix and Koijen (2020). The supply equation B.2 is disaggregated at the bank level and expressed as

$$\Delta HP_{i,t}^s = \phi_i^s \Delta s_t + \lambda_i \eta_t + u_{i,t}^s, \tag{B.10}$$

where $\Delta HP_{i,t}^s$ denotes the derivative supply of bank i, η_t are shocks common to all banks and $u_{i,t}^s$ the idiosyncratic supply shocks specific to bank i with $\mathbb{E}[u_{i,t}^s \eta_t] = 0$. The market clearing condition becomes $\Delta HP_t^d = \sum_i^N w_i \Delta HP_{i,t}^s = \Delta HP_t$, where weights w_i with $\sum_i^N w_i = 1$ denote the importance of any particular bank i in the aggregate derivative supply. Importantly, we can now formulate weaker exclusion restriction that involve only the idioscyratic supply shocks, namely $\mathbb{E}[u_{i,t}^s \epsilon_t^d] = 0$ for all banks i.

We do not directly observe the idiosyncratic supply shocks $u_{i,t}^s$, but can proxy their sum with a weighted average of changes to banks' (log) capital ratio, $\Delta ln(CR_{i,t})$. The granular instrumental variable (GIV) takes on the form

$$z_t \equiv \sum_i^N \Gamma_i \Delta ln(CR_{i,t}) = \sum_i^N \Gamma_i(\lambda_i \eta_t + u^s_{i,t}) = \sum_i^N \Gamma_i u^s_{i,t}, \tag{B.11}$$

where Γ_i denotes weights such that $\sum_i^N \Gamma_i \lambda_i = 0$, $\sum_i^N \Gamma_i = 0$ and $\sum_i^N \Gamma_i w_i \neq 0$. In our application we pick in particular

$$\Gamma_i = \frac{\mathbb{1}_{i \text{ is Dealer Bank}}}{\sum_i^N \mathbb{1}_{i \text{ is Dealer Bank}}} - \frac{1}{N} \quad \text{and} \quad \Gamma_i = \frac{Assets_{i,2012}}{\sum_i^N Assets_{i,2012}} - \frac{1}{N}. \tag{B.12}$$

The granular instruments again provide a consistent estimation of (the inverse of) the demand elasticity as

$$\beta^{GIV} = \frac{\mathbb{E}[z_t \Delta s_t]}{\mathbb{E}[z_t \Delta HP_t]} = \frac{\mathbb{E}[z_t(\frac{1}{\phi^d}\Delta HP_t - \frac{1}{\phi^d}\epsilon^d_t)]}{\mathbb{E}[z_t \Delta HP_t]} = \frac{1}{\phi^d} + \frac{\mathbb{E}[z_t(-\frac{1}{\phi^d}\epsilon^d_t)]}{\mathbb{E}[z_t \Delta HP_t]} = \frac{1}{\phi^d}, \tag{B.13}$$

where the last step follows from the weaker (granular) exclusion restriction $\mathbb{E}[u^s_{i,t}\epsilon^d_t] = 0$ for all banks i. It is a weaker condition as it involves only the idiosyncratic bank supply shocks.

Implications for the Elasticity of Supply. Comparing the coefficient estimates β^{OLS} and β^{GIV} in Table 4, we find that

$$\beta^{GIV} - \beta^{OLS} = \frac{\phi^s}{\phi^d(\phi^d - \phi^s)} \frac{\mathbb{E}[(\epsilon^d)^2]}{\mathbb{E}[\Delta HP_t^2]} < 0, \tag{B.14}$$

where $\phi^d = \frac{1}{\beta^{GIV}} < 0$. For $\phi^s < 0$, it follows that the elasticity of supply is more elastic than elasticity demand (i.e. $|\phi^s| > |\phi^d|$) as illustrated in Figure B.1.

Vector Autoregression. We use a simple Vector Autoregression (VAR) that is composed of hedging pressure, $HP_{c,t}$ and the log spot exchange rate $s_{c,t}$. We order the variables to form the vector $\mathbf{x}'_{c,t} = [HP_{c,t}, s_{c,t}]$ and obtain the structural form

$$\mathbf{A x_t} = \mathbf{B x_{t-1}} + \mathbf{u_t}, \tag{B.15}$$

where $\mathbf{A}$ is a (lower) triangular 2×2 matrix, $\mathbf{B}$ is an unconstrained 2×2 matrix and $\mathbf{u_t}$ is a vector of structural shocks, i.e.,

$$\mathbf{A} = \begin{bmatrix} a_{11} & 0 \\ a_{21} & a_{22} \end{bmatrix}, \quad \mathbf{B} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}, \quad \mathbf{u_t} = \begin{bmatrix} \epsilon^q_t \\ \epsilon^p_t \end{bmatrix}. \tag{B.16}$$

If we abstract from the panel structure of our data, we can write the structural form into the following system of two equations

$$HP_t = c_{11}HP_{t-1} + c_{12}s_{t-1} + \frac{a_{22}\epsilon_t^q}{a_{11} - a_{22}} \tag{B.17}$$

$$s_t = c_{21}HP_{t-1} + c_{22}s_{t-1} + \frac{-a_{21}\epsilon_t^1 + a_{11}\epsilon_t^p}{a_{11} - a_{22}}, \tag{B.18}$$

where and $\mathbf{C} = \mathbf{A^{-1}B} = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix}$.

In Eqs. B.17 and B.18, we observe that the hedging pressure is influenced solely by elementary shocks ϵ_t^1 to the equilibrium quantity, whereas the spot rate is influenced by both quantity and price shocks ϵ_t^q and ϵ_t^p, respectively. For a highly price inelastic (vertical) demand function, shocks to the equilibrium quantity involve mainly demand shocks. To see this note that we can derive the equilibrium effects of demand and supply shocks on the absolute quantity of hedging from Eqs. B.5 and B.6 as

$$|\frac{\partial \Delta HP_t}{\partial \epsilon_t^d}| = \frac{\phi^s}{\phi^d - \phi^s} \tag{B.19}$$

$$|\frac{\partial \Delta HP_t}{\partial \epsilon_t^s}| = \frac{\phi^d}{\phi^d - \phi^s}. \tag{B.20}$$

If $|\phi^s| > |\phi^d|$, this implies that shocks to the equilibrium quantity (i.e. ϵ^q) in the VAR are a consequence of (mostly) hedging demand shocks.

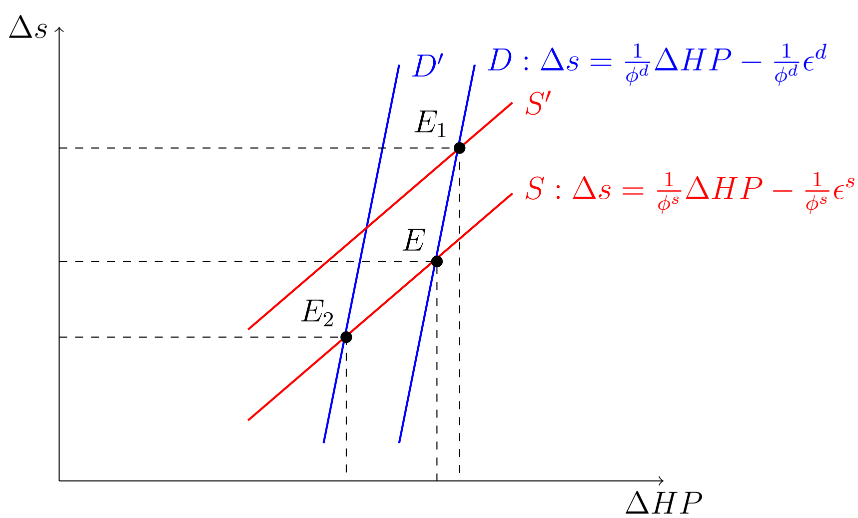


Figure B.1: Supply and Demand of FX forwards.