Can Time-Varying Currency Risk Hedging Explain Exchange Rates?

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October, 2024

Abstract

The rise in the 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 can influence spot exchange rates through CIP arbitrage. Using capital structure changes of (dealer) banks as a supply shifter, we show that net derivative demand for dollar short positions by investment funds has a negative slope in the value of the dollar similar to the supply by dealer banks, but is more price elastic. This can explain why a dollar currency index and the net dollar hedging have an extremely strong negative correlation of −66% in the last decade, which represents a notable exception to the disconnect puzzle.

JEL Codes: E44, F31, F32, G11, G15, G23

Keywords: Exchange Rate, Hedging Channel, Institutional Investors

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Conflict-of-interest disclosure statement

Leonie Bräuer
I have nothing to declare.

Harald Hau
I have nothing to declare.

Acknowledgments and Disclaimer

We thank Federico Baldi Lanfranchi, Falk Bräuning (discussant), Luca Gemmi (discussant), Zhengyang Jiang, Eric Jondeau, Arvind Krishnamurthy, Ingomar Krohn, Gordon Liao, Burton Hollifield, Thomas Maurer, Stankovic Ognjen, Angelo Ranaldo (discussant), Walker Ray, Alessandro Rebucci, Jean-Charles Rochet, Michael Rockinger, Leslie Sheng Shen (discussant), Fabricius Somogyi, Olivier Scaillet, Vladyslav Sushko (discussant), Olav Syrstad, Fabio Trojani, and Ganesh Viswanath-Natraj for their comments, as well as seminar participants at the University of Lausanne, the University of Zürich, the Geneva Finance Research Institute, the 12th Workshop on Exchange Rates organized by the BIS, the Banca d'Italia and the ECB, the Young Swiss Economists Meeting, the SFS Cavalcade North America 2023, the European Finance Association 2023, and the American Finance Association 2024.

Harald Hau gratefully acknowledges financial support from the Hong Kong Institute for Monetary and Financial Research. This paper represents the views of the author(s), which are not necessarily the views of the Hong Kong Monetary Authority, Hong Kong Academy of Finance Limited, or Hong Kong Institute for Monetary and Financial Research. The above-mentioned entities except the author(s) take no responsibility for any inaccuracies or omissions contained in the paper. The authors also declare that they have no relevant or material financial interests that relate to the research described in this paper.

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 turn foreign bond investors into important players in the US bond market and create a large demand for foreign exchange (FX) hedging.[2]

Such currency hedging by international investors varies over time. Sialm and Zhu (2023) show that the hedge ratio of US bond funds fluctuates between close to zero and up to 90%, with an average rate at 18%.[3] The supply conditions of derivative contracts may also vary substantially as banks face time-varying balance sheet capacities to accommodate the derivative demand. As a consequence, the net dollar short positions in USD forward contracts of (buy side) investors—referred to as hedging pressure—can fluctuate substantially. The main contribution of this paper is to explore these equilibrium fluctuations and relate them to movements in the dollar 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 exchange rates, and the corresponding basket of dollar rates. More net short selling of dollar forwards (i.e., an increase shown by the blue line) coincides with a decline in the dollar (i.e., a decrease shown by the green line) relative to the other currencies. The negative correlation of yearly changes features an astonishing -66%, indicating a strong economic relationship that is a notable exception to the so-called "exchange rate disconnect" puzzle.

In this paper, we address three research questions related to FX risk hedging. First, what

[1]Figure 1 shows the gross bilateral bond holdings of seven countries vis-à-vis the US, namely the 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 have 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. Over the same period, their trading in FX spot markets has 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%.

[3]Similarly, Liao and Zhang (2021) document that the share of currency risk hedged by nine large Japanese insurance companies fluctuates greatly between 40% and 80%.

are the determinants of net hedging positions, and how do they relate to net international bond holdings and time-varying economic uncertainty? Second, how are changes in net currency hedging connected to both contemporaneous forward and spot exchange rates? Third, what is the price elasticity of the hedging demand? And can the structure of the hedging demand rationalize the extremely high negative correlation between changes in the net hedging demand and dollar appreciations depicted in Figure 2?

Empirical research has documented that the currency supply of dealer banks is price inelastic and increases in the value of the currency (Hau and Rey (2006), Hau et al. (2010), Camanho et al. (2022), Abbassi and Bräuning (2021)). But the structure of currency demand is much less explored, including FX derivative demand, which is characterized by large and increasing dollar short positions of foreign institutional investors seeking to hedge their exposure in dollar denominated assets. A key insight of this paper is to show that this large net hedging demand (for dollar short positions) decreases in the value of the dollar and is more price elastic than the currency supply. In the language of classical economics, the hedging demand is a Giffen good as institutional investors seek to sell fewer dollars (short) as the price of the dollar increases. As a consequence, both demand and supply shocks tend to generate a negative correlation between the aggregate net (dollar) hedging quantity and the value of the dollar. This can rationalize the extremely large negative correlation between the equilibrium amount of net hedging (i.e., hedging pressure) and the dollar value shown in Figure 2.

We highlight that the global imbalance in net dollar bond investments is a key element to account for the important role of hedging for exchange rate determination. In a symmetric world in which US and non-US investors hold foreign bond positions of similar magnitude and hedge these foreign investments to the same degree, any global shock to hedging demand or supply would be neutral as such changes have the opposite sign for US and non-US investor with a zero net effect. But the dollar dominance in the global fixed income market creates a condition for substantial asymmetry in hedging demands and this asymmetry in turn makes time-varying hedging a potential potent channel for exchange rate determination.

Exchange rate economics has generally struggled to find economic or financial variables that feature a high correlation with the exchange rate (Obstfeld and Rogoff (2000); Itskhoki and Mukhin (2021)) — a feature often referred to as the "exchange rate disconnect puzzle". The observed equilibrium quantity of net short position in FX forward and Swap contracts represents a notable exception and at the same time hints at the increasing quantitative importance of FX derivative markets in influencing exchange rates. We refer to the (standardized) net dollar short positions held by investment funds as "hedging pressure".

For simplicity, we consider the forward and spot markets as one single currency market integrated by covered interest rate parity (CIP) arbitrage.[4] The exchange rate market, depicted in Figure 3, can then be represented simply by classical demand and supply functions for changes in net hedging (x-axis) that show a lower demand and supply for appreciations of the dollar (y-axis).[5] If both the supply and net hedging demand for dollar short positions feature a negative slope, it is intuitive that (independent) hedging demand and supply shocks *both* tend to generate a negative correlation between the dollar value and net dollar hedging (i.e., the net outstanding FX short positions in dollars), which rationalizes the evidence in Figure 2.

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. The FX hedging positions of corporates and non-bank institutions are quantitatively less important, which justifies our focus on investment funds.

[4]We do not question whether CIP deviations exist in practice, but do not consider them to be pertinent to the analysis in this paper.

[5]Plotting the diagram in terms of net hedging (i.e., dollar short positions or negative dollar holding) implies that the supply curve for dollar balances has a negative slope.

Main Findings

Our empirical analysis proceeds in three steps to elucidate a hedging channel of exchange rate determination. First, we investigate in Section 4.1 the fundamental determinants of (net) hedging pressure in the seven most liquid currency pairs. As hedging motives are strongest for international bond investors (Bräuer and Hau (2024)), we conjecture that the long-run net hedging pressure in any currency is determined by a country's net investment position in bonds vis-à-vis the US. While there is little statistical evidence for a short-run relationship between the net investment position in bonds (NIP) and hedging pressure, we find that long-run changes in net bond investment positions accounts for 31% of the cross-sectional long-run variation in hedging pressure. Measures of economic uncertainty like the CBOE volatility index (VIX) show only a weak relationship to the net amount of short dollar positions. Here we show that the interaction between the level of net hedging pressure and changes to the VIX relate to *lower rather than higher* net equilibrium hedging quantities. Again, a downward sloped hedging demand curve as depicted in Figure 3 can rationalize why an outward shift in the hedging demand under greater market uncertainty can translate into lower equilibrium quantities of hedging.

Second, we explore in Section 4.2 the contemporaneous relationship between changes in hedging pressure and the USD exchange rate. For the dollar currency index, we report the above-mentioned strong negative correlation of −66% at the annual frequency. We also provide panel regressions for the seven most liquid currencies that confirm the strong negative relationship between changes in hedging pressure 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 (i.e., net dollar short selling) is associated with a dollar depreciation of 5%. The almost identical negative covariance of both the forward and spot rate with our measure of net hedging pressure justifies why our analysis abstracts from any segmentation between the spot and forward market. We also find that changes to the yield spread between foreign and US (two-year) government bonds have additional explanatory power for both forward and spot rate changes. However, we find no additional explanatory power of the bilateral currency basis.[6]

Third, we identify in Section 4.3 the demand elasticity for net dollar hedging and find that it has a negative sign (like the currency supply), but it is more (price) elastic as depicted in Figure 3. To identify the price elasticity of the hedging demand, we construct four different instruments related to changes in the capital structure of dealer banks. The plausibility of the exclusion restriction draws on the fact that the instruments are strongly (or even exclusively in the case of GIV3) influenced by idiosyncratic equity issuance events at individual dealer banks that are triggered by a tightening regulatory environment after the 2008/9 banking crisis and not a reaction to (short-term) FX market conditions. Based on He et al. (2017), we use as a first instrument (IV0) average daily (log) changes to the capital ratio of dealer banks, where the capital ratio is defined as the average value of bank market equity divided by market equity plus book debt. A concern here is that economic factors influencing equity prices (and bank capital ratios) could simultaneously affect hedging demand.[7] In the spirit of Gabaix and Koijen (2023), we define alternatively two granular instruments based on cross-sectional differences in capital ratios between (i) primary dealer and non-dealer banks (GIV1) and (ii) size-weighted and equal-weighted bank assets (GIV2). Both instruments are refined by eliminating the largest principal components and aggregate macroeconomic shocks to ensure that general valuation effects that concern all banks in the same manner are excluded. In addition, we construct a third granular instrument (GIV3) based on daily (log) changes in the number of outstanding bank shares between a size and equal-weighted bank sample. The latter approach eliminates all stock price effects from the instrument and captures pure capital measures with respect to bank equity (i.e., bank equity issuance

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

[7]In particular, we cannot exclude the possibility that foreign investors hedge their equity positions also and that associated valuation effects contribute to the hedging pressure (see Nathan and Ben Zeev (2022)).

and share buybacks) in the bank size-weighted cross-section. Bank capital measures are infrequent, typically require shareholder approval, and are unlikely to represent a short-term response to FX market conditions.

We find a negative price-inelastic net hedging demand for all four instruments, which implies that dollar appreciations reduce the desire of investment funds to short-sell the dollar. For liquidity supplying banks, a high dollar value could signal lower future expected dollar returns, which makes the supply of dollar short positions (i.e., the acquisition of long foreign FX position) more attractive. However, it is less obvious why investment funds might also reduce their demand for dollar hedging if the dollar value increases. For investment funds, FX risk hedging could be path dependent: A dollar appreciation associated with a high dollar value generates a positive fund return for foreign investors and could change the risk aversion of some funds (and thus hedging demand) if they are mostly concerned with avoiding negative fund returns over a longer performance measurement period. Evidence for time-varying loss aversion is provided by Liu et al. (2022).

A more price elastic hedging demand, compared to hedging supply, implies that the observed equilibrium quantity (i.e., hedging pressure) is strongly influenced by variations in the derivative supply conditions, which simultaneously, but inversely, affect the USD exchange rate. The estimated elasticity of FX derivative demand (pooled across 7 foreign currencies) implies that a 1% dollar appreciation reduces the aggregate net hedging demand for dollar short positions by -0.44%, which corresponds to approximately USD 21 billion.

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)). The aggregate CLS data does not allow us to clearly separate the derivative positions along different trading motives.[8] The CLS data provides

[8] Bräuer and Hau (2024) provide microeconomic evidence on derivative trading motives of European investment funds using regulatory contract-level data. They show that speculative FX derivative positions are generally very dispersed and thus tend to cancel each other in the net demand. A weak systematic correlation of funds' speculative positions with future exchange rate changes is found only for a specific group of funds characterized by a high foreign investment share, large fund size, and medium to high expense ratios.

no evidence that the aggregate net hedging position of all funds yields any positive excess return, which could rationalize a speculative hedging motive on the direction of the exchange rate.[9]

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 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 gross foreign equity holdings and their

[9]The average daily aggregate net hedging (short) position of European funds is USD 60 billion and the average daily profitability of this position based on the daily spot rate change is USD −54 million. Profitability is *not* significantly different from zero in a statistical sense.

systematic rebalancing for exchange rate dynamics. The theoretical foundation underlying this literature rests on the idea that currency supply 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 also provides an FX market analysis in terms of currency supply and demand, but complements previous work by its focus on structural imbalances in foreign bond exposure as a source of a time-varying net hedging demand.[10] While Koijen and Yogo (2020) and Lilley et al. (2022) explore the relationship between bond flows and exchange rates, they do not account for the role of currency hedging in derivative markets. We highlight that time-varying net hedging of foreign bond exposures is comparable to net bond flows in terms of transaction volume. For example, net bond flows into the US from the seven most important currency areas have a monthly standard deviation of USD 71bn in the period 2012-2022, while the monthly standard deviation of net dollar short position changes in forwards and swaps is USD 41bn.

The breakdown of the covered interest parity (CIP) after the Great Financial Crisis highlights the importance of financial intermediaries' constraints and adds empirical support to the notion of limited FX arbitrage as well as limited FX market depth. But in spite of a new literature documenting CIP violations (Ivashina et al. (2015); Rime et al. (2017); Du et al. (2018b,a); Abbassi and Bräuning (2021); Cenedese et al. (2021)), the FX derivative market in FX forwards and swaps is still closely tied to the FX spot market. FX risk management pushes 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

[10]Specifically, we focus on funds—a sector managing a large and increasing share of global assets. According to FSB (2021), investment funds and pension funds together held 44% (39%) of total financial assets in advanced economies in 2022 (2012), while banks held 34% (40%). They increased their asset holdings from 2012 to 2020 by 64%. This is the largest increase across all entities, such as insurance corporations (41%), or banks (25%).

feature a high correlation of 0.99.[11] Following Liao and Zhang (2021), we refer to the spillover of hedging activity from derivative rates into spot rates as a "hedging channel" of exchange rate determination. While our work is related to Liao and Zhang (2021), our analysis differs in its focus on exchange rate determination rather than arbitrage between forward and spot markets. Second, we directly measure the hedging activity using CLS data and show that the net demand for dollar hedging decreases in the dollar's value. This implies that *both* demand and supply shocks for dollar short positions generate a negative correlation between equilibrium hedging quantities (i.e., hedging pressure) and the dollar value.

The international asset pricing literature has related dollar exchange rate movements to a (global) dollar risk factor that affects all dollar cross rates simultaneously (Lustig et al. (2011); Verdelhan (2018)). Our evidence on a hedging channel provides a deeper institutional rationale why such common factor structure exists and highlights a channel through which it can operate. We highlight that the correlation between the aggregate changes 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.

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 variations in the bilateral 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

[11]See also Krohn and Sushko (2022) for a detailed examination of the close relationship between spot and swap rates as well as the 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.

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 are 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.

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. The identified negative slope for the net hedging demand can rationalize the strong negative co-movement between the dollar value and the net outstanding dollar short positions.

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). Despite this incomplete coverage, we believe that the data provide 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. 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.

Generally, banks act as liquidity providers in FX derivative markets. They 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 positive net dollar bond investments by foreign fund investors triggers a 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 a bank's short and long bond positions in USD and EUR bonds, respectively. It is helpful to think of forward contracts as contracts that initiating a hedge and consecutive swap contracts as ones that 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 swap contracts aggregated over the currencies is approximately USD 6 trillion, whereas the corresponding number for forward contracts is only USD 0.8 trillion. 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 USD 2.7 trillion, followed by the JPYUSD rate with USD 1.5 trillion, and GBPUSD rate with USD 1.1 trillion. The amount outstanding for the other currencies is below USD 0.5 trillion and is smallest for the NZDUSD rate, with only USD 0.1 trillion. 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 variation 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 potentially has 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 (mutual, exchange-traded, money market, hedge, pension, 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 market-makers.[12] In the remainder of this paper, we focus on the hedging positions of the funds. On the demand side, these 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 63% of all outstanding interest in forwards for the EURUSD rate. Their counterparty are mostly banks as liquidity providers.

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 Euro (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

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

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

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

outstanding interest to obtain a more stable denominator.[13]

The summary statistics in Table 1 show that hedging pressure is generally positive when pooled over the seven currencies. In other words, dollar risk hedging demand exceeds the reciprocal hedging demand for foreign currency risk by approximately 12%. The evolution of hedging pressure, depicted in Figure 4, Panel A, shows that it 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 in line with 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.

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 speculative trades from pure hedging trades in our aggregate CLS data. However, we present four arguments suggesting that speculative trading as opposed to currency risk hedging might not be the predominant effect determining net aggregate FX derivative demand.

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 of profitability in 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 USD 60 billion, and the average daily profit is USD -54 million. A t-test for the null hypothesis of zero profitability yields a t-statistics of -0.8387 and a p-value of -0.4017. We concede that looking at realized returns does not necessarily inform

[13]As a robustness test, we scale the net fund position by the contemporaneous outstanding interest (with $i = 0$), and find qualitatively similar results for much of our analysis.

us about ex-ante expectations of returns that might motivate speculative trades. However, rational expectations exclude systematic (long-run) deviations between ex-ante beliefs and ex-post realizations.

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 overall OTC hedging pressure, unlike the FX future trading of non-levered funds with a correlation of 36%. This suggests that the non-speculative trading motive of funds also dominates in the quantitatively larger OTC market.

Third, expectations about future currency returns as reported by Consensus Economics do not correlate with our measure of hedging pressure. More precisely, a regression of monthly changes in hedging pressure on monthly changes in expected currency returns does not produce a statistically significant coefficient. New contract-level evidence from European investment funds in Bräuer and Hau (2024) suggests that speculative positions in FX derivatives are very heterogeneous and dispersed across funds so that they do not aggregate to an economically significant net demand unlike derivative positions motivated by currency hedging of foreign bond investments.

Fourth, to exploit carry trade returns, speculators acquire the high-yield currency and short the low-yield currency. Typically, they implement the carry trades synthetically through forward and swap positions (Brunnermeier et al. (2008)). During our sample period (2012-22), US yields were on average higher than those in other currencies apart from the AUD and NZD as shown in Figure 4, Panel D. Therefore, carry speculators should have shortened the foreign currencies rather than the dollar, and if they were dominating the market, hedging pressure (defined as net dollar short positions) should on average be negative, which is not what we find.

3.2 Net Investment Positions in Bonds

Here we draw on 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); Bräuer and Hau (2024)). Accordingly, international bond positions are a major source of hedging demand and their asymmetric size represents a source of (net) hedging pressure.[14]

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 4, Panel B. For countries like Japan or Switzerland, the net investment position in bonds is strongly positive at 80% to 90%, as Japanese and Swiss investments in US bond markets largely exceeds reciprocal overseas bond investments by US residents in Swiss or Japanese bonds, 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 at the end of our sample period (March 2022).

The monthly net investment positions constitute an imperfect structural proxy for 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).

[14] 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 a cross-section of currencies.

Second, the long-run holdings of bonds include all investor types, not just fund investors.[15] Third, equity funds can also contribute to 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 bonds are denominated in US dollars, 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 our variables, namely that a larger net investment position in bonds over the long-run predicts more positive hedging pressure from funds.

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 use data on the spread between the two-year foreign currency government bond yield

[15] For euro area institutional investors we have data on holdings of USD denominated bonds from the ECB's Statistical Data Warehouse (see Figure A.1). The Figure shows that a similar trend can be observed among euro area based institutional investors: Their investment in the US dollar has 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.

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 4, Panels C and D, shows the seven exchange rate and yield spread series, respectively.

An additional variable of interest is market uncertainty measured by the Chicago Board Options Exchange's Volatility Index (VIX_t) based on S&P 500 index options. This risk measure concerns the US economy and is not specific to any particular currency rate. If higher uncertainty shifts the hedging demand by US and foreign investors in a similar way, then we expect that the interaction of the net hedging level (i.e., $HP_{c,t}$) and changes of the VIX to represent a suitable explanatory variable.[16]

Lastly, we incorporate into our analysis the so-called Treasury basis constructed by Du et al. (2018a) and sourced from Wenxin Du's website.[17] Formally, the Treasury basis is defined as the difference between the yield on a cash position in US Treasuries denoted by $y^\$_{c,t}$ and a synthetic dollar yield derived from a cash position in foreign government bonds, that earns $y^*_{c,t}$ in foreign currency c, and swapped 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 safe bonds 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 variable and monthly changes in the VIX is modest

[16]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.

[17]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).

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 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 5, 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 greater 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 currencies vis-à-vis the US dollar, 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.[18] Only for the CHFUSD rate do we see larger positive hedging demands by non-bank financial institutions—which we presume is dollar risk hedging by 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, particularly, in outstanding derivative positions that sell the US dollar. For example, from 2012 to 2022, funds have increased their market share

[18]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.

in outstanding forwards that buy (sell) the EUR against the USD from 63% (36%) to 95% (47%).

4 Empirical Analysis

4.1 Determinants of Hedging Pressure

In this section, we explore how the equilibrium level of hedging pressure relates to demand-side factors such the net bilateral bond position vis-à-vis the US and economic uncertainty.

As US and foreign investors face currency exposure in an opposite direction, the net hedging pressure should accord with the net bond investment position of these groups. It is also interesting to explore the relationship between net hedging and economic uncertainty as measured by the VIX and its interaction with net hedging pressure. In Table 2, Columns (1)-(3), 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 the product $HP_{c,t} \times \Delta VIX$. Formally,

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

where α_c denotes a currency fixed effects.

The coefficient estimates for $\Delta NIP_{c,t}$ in Column (1) are not statistically significant and the explanatory power of monthly changes in the net bond investment is low as indicated by the low overall R^2 of 0.1%. However, the *Between* R^2, which represents the R^2 of the time averaged cross sectional panel, is relative large at 31%. While changes to the net (bilateral) bond position do not account for changes in the hedging pressure at a monthly frequency, there exists a strong long-run relationship between (time-averaged) changes in hedging pressure and the net investment positions across currencies. Figure A.4 visualizes this finding. It plots the average monthly changes in hedging pressure against the average monthly changes in NIPs. Apart from the Swiss Franc, average changes in net investment positions positively correlate with average changes in hedging pressure.[19] For example, average monthly changes of Australia's and Canada's NIPs are the most positive in our sample, while average monthly changes of their demand for shorting the dollar are the most positive, too. Thus, the evolution of NIPs can explain the evolution of the net hedging positions across currencies.

The relationship between $\Delta HP_{i,t}$ and ΔVIX in Columns (2) is negative, albeit statistically weak. This is also true if we use in Column (3) the interaction term $HP_{c,t} \times \Delta VIX_t$ as the regressor. The fact that higher economic uncertainty does not increase the observed equilibrium amount of hedging is surprising at first. An outward shift in the hedging demand curve should normally predict more hedging pressure rather than less. However, if the demand curve features a negative slope in the dollar value as shown in Section 4.3, we can rationalize a negative coefficient.[20]

In light of the exchange rate disconnect puzzle it is not surprising that we cannot identify economic fundamentals that have strong explanatory power for intertemporal changes in hedging pressure. As we show in the following section, hedging pressure features a very high correlation with exchange rate movements, and the latter are disconnect from prominent macroeconomic and financial fundamentals. Substantial explanatory power for exchange rates requires a variable featuring a similar disconnect.

4.2 Hedging Pressure and the Exchange Rate

At the aggregate level of a dollar currency basket, Figure 2 illustrates the negative association between equally weighted average dollar exchange rate changes (measured over annual intervals) and the corresponding aggregate changes in hedging pressure. More net short

[19]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%.

[20]Note also that the sign of the coefficient on VIX is not in line with speculators unwinding carry trade positions as in Brunnermeier et al. (2008). If such carry trades are implemented through dollar long positions, their reduction should increase hedging pressure in times of uncertainty.

selling of the dollar 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.[21]

To structure our analysis, we consider a simple demand and supply model of the FX derivative market, in which the demand by institutional investors and the supply by dealer banks for hedging contracts depends on the exchange rate in the following manner

$$\Delta HP_t^d = \phi^d \Delta s_t + \epsilon_t^d$$
$$\Delta HP_t^s = \phi^s \Delta s_t + \epsilon_t^s,$$

where ΔHP_t^d and ΔHP_t^s denote changes to the net derivative demand and supply of dollar short positions, respectively, $\Delta s > 0$ denotes a (log) dollar appreciation, ϕ^d and ϕ^s denote the elasticity of demand and supply, respectively. All other influences on the exchange rate are represented by demand and supply shocks ϵ_t^d and ϵ_t^s, respectively.[22]

It is straightforward to show (see Appendix B) that independent supply and demand shocks generate a correlation between the equilibrium quantity of hedging pressure changes and US dollar appreciations given by

$$Corr[\Delta HP, \Delta s] = \Phi \times \frac{\phi^d Var(\epsilon^s) + \phi^s Var(\epsilon^d)}{|\phi^d|\, Var(\epsilon^s) + |\phi^s|\, Var(\epsilon^d)},$$

for a parameter $\Phi \lessapprox 1$. Thus, negative supply and demand elasticities, $\phi^d < 0$ and $\phi^s < 0$, can rationalize the strong negative correlation $Corr[\Delta HP, \Delta s] \gtrapprox -1$ documented in Figure 2.

To examine the relationship between hedging pressure and the exchange rate 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

[21] The correlation between daily hedging pressure changes and daily spot rate changes amounts to -0.38, which is still very high. This correlation becomes more negative at -0.75 during particularly volatile market episodes such as during the COVID-19 pandemic (February 2020 to May 2020).

[22] Note that under constant interest rates for the US and foreign countries, covered interest parity implies that forward rate changes match spot rate changes, i.e., $\Delta f = \Delta s$.

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

In Table 3, Columns (1)-(4) show the panel regression results with changes in the monthly spot exchange rate as the dependent variable, and 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 in the change in monthly hedging pressure change (1.25) is associated with a 0.65% US dollar depreciation, which is 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.

Columns (2) and (6) in Table 3 present the regression results after adding changes in the government yield spread and the Treasury basis as additional explanatory variables.[23] 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

[23] 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 over 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 countries' 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 correlation between bilateral exchange rate changes and bilateral basis changes.

foreign bond yield of 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 dollar depreciations.

An alternative explanation (based on capital flows) is that foreign fund investors may 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 foreign bonds. Rebalancing then consists of swapping dollar positions for foreign currency holdings, which should lead to a dollar depreciation. This could also account for the observation that a widening yield spread in favor of foreign bonds tends to 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 shown in Column (3) and (7) produces an expected positive coefficient. However, the regression coefficient is statistically significant at a 10% level only. 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 a monthly frequency, additional lagged terms of changes in hedging pressure or the two-year yield spread change are statistically insignificant and do not 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 a daily frequency, the basis change is statistically significant, and has 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 the inclusion of the VIX do not significantly alter the coefficient on hedging pressure.

In the Internet Appendix we further show that this "hedging channel" result applies to other investor types also but it is most pronounced for funds. Specifically, Table A.5 reports the results of substituting hedging pressure of funds, like in the baseline regression, for hedging pressure emanating from two other market participants reported by CLS: corporates in Column (1)-(3) and non-bank financial institutions in Column (4)-(6). Excluding the Swiss Franc, which appears as an outlier for both entities (see Figure 5), and incorporating time fixed effects, we find in Column (6) that only hedging pressure by non-bank financial institutions significantly explains the spot exchange rate. The estimate implies that a one-standard deviation increase in monthly hedging pressure change (0.19) corresponds to a 0.25% depreciation in the dollar exchange rate, which is about half of the effect size of the estimates relating to hedging by funds.

4.3 Dealer Bank Capital Issuance Events as FX Supply Shifters

While recent research on exchange rates has emphasised a limited currency supply elasticity as important for our understanding of exchange rate dynamics (Hau and Rey (2006); Gabaix and Maggiori (2015); Abbassi and Bräuning (2021); Camanho et al. (2022)), we are not aware of any paper that is concerned with the demand elasticity for a currency and in particular the demand for FX derivative positions. If the supply and demand elasticity share the same negative sign, it is straightforward to show that both demand and supply shocks to the FX derivative market generate a negative correlation between the dollar value and hedging pressure (see Appendix B) in line with the evidence in the previous chapter. This section discusses four aggregate banking sector variables that are not directly influenced by FX market conditions, but relate to dealer banks' ability to supply liquidity in the FX markets. We use these supply shifting instruments in Section 4.6 to identify a negative slope for the derivative demand curve.

A key component of the Basel framework is to impose capital charges on banks for credit risk. Bank assets are grouped into "buckets" and associated with each bucket is a fixed capital charge derived from a Value at Risk model under the IRB approach.[24] A larger inventory of derivative positions (that cannot be netted) increases the bank's "Risk Weighted Assets" (*RWA*). In general bank hedge their net FX derivative exposure through a synthetic hedge involving a combination of FX spot and repo transactions (in the case of FX forwards) or just repo transactions (in the case of FX swaps), which creates additional capital charges. This implies that the supply capacity of a dealer banks in the FX derivative market is constrained by its available regulatory capital (*Bank Capital*) and the minimum required capital ratio α; formally

$$\frac{Bank\ Capital}{RWA} \geq \alpha. \tag{6}$$

As the above constraint becomes binding for any dealer banks, its supply capacity for additional FX derivative contracts ceases. In practise, global banks will impose limits on the risk weighted assets of their trading desks that reflect the tightness of the regulatory constraint, as explored in Barbiero et al. (2024). The latter also show that total bank capital has considerable explanatory power for measures of daily trading desk-specific internal Value at Risk limits.

For European banks, the regulatory capital constrain are monitored at the end of each quarter, which can generate a predictable periodicity in the supply of FX derivatives contracts by dealer banks. As repo financing in the USD market generates relatively higher capital charges compared to synthetic swap financing, European banks exchange dollar repo financing against dollar long positions in FX swaps around quarter ends (Borio et al. (2018)), which triggers temporary spikes in the cross-currency basis as shown in Du et al. (2018b).

[24]The exact bank capital charge for the credit risk of OTC derivatives depends on a fixed component proportional to the notional plus a variable component proportional to the (positive) market value of a contract claim against the counterparty (Goulding (2019)).

This evidence represents a powerful empirical demonstration that bank capital regulation matters for the liquidity supply in FX derivative markets and impacts exchange rates.[25].

Following the 2007-8 financial crisis, the minimum required capital ratio α was increased, which forced banks to raise new bank capital.[26] Profitable banks could increase their capital through retained earning, but low bank profitability often meant that capital increases had to be achieved thought issuance of new Tier 1 capital. Any such new capital issuance by one of the large dealer bank characterizes a granular increase in the FX liquidity supply. We track such discrete liquidity supply shocks by defining four different aggregate bank balance sheet variable. These four variables are the instruments z_t that shift the supply of FX derivative contracts according to

$$\Delta HP_t^s = \phi^s \Delta s_t + \alpha^s z_t + \epsilon_t^s, \tag{7}$$

and fulfill the exclusion restriction $E(z_t \epsilon_t^d) = 0$ with respect to demand shocks ϵ_t^d. We propose four such instruments of increasing plausibility with respect the validity of the exclusion restriction.

Instrumental Variable IV0. Our first instrument follows He et al. (2017) and is based on banks' capital ratio (CR) defined as the market value of equity relative to the sum of the market value of equity and the book debt. The regulatory capital ratios of banks (like Tier 1) are based on accounting values rather than market values. However, accounting values are available only at the end of each quarter, whereas outstanding equity and its market price are observed at a daily frequency. Moreover, relevant capital measure like equity issuance and/or stock repurchases often occur within an accounting period and are undertaken at market

[25] A second source of quarter-end liquidity shocks in FX derivative markets can be a desire to hedge a bank's on-balance sheet market risk, which can also reduce risk-weighted asset and improving its capital adequacy ratio as argued by Abbassi and Bräuning (2021)

[26] A variety of new or tighter regulatory measures have been introduced since the global finance crisis under Basel III, including a higher minimum common equity capital ratio (from 2% to 4%), capital conservation buffers, countercyclical capital buffers, certain liquidity requirements (LCR, NSFR) and leverage ratios, moving beyond the sole focus on RWAs (see the BIS website).

prices. A capital ratio based on market values can thus capture granular improvements of a banks' balance sheet at a higher (daily) frequency and is therefore better suited to identify short-term changes in the liquidity supply of dealer banks. We note that the (log) capital ratio calculated for market equity values exhibits a significant positive correlation with the (log) capital ratio calculated using book equity, with a correlation of 37%.

Our first instrument z_t is simply is defined as the average (log) changes in the capital ratio of $N = 20$ largest primary dealer banks as defined by the New York Fed.[27] Formally,

$$z_t = \sum_{i}^{N} \Gamma_i \Delta ln(CR_{i,t}), \tag{8}$$

with the weight Γ_i defined as

$$\Gamma_i = \frac{\mathbb{1}_{i \text{ is Dealer Bank}}}{\sum_i^N \mathbb{1}_{i \text{ is Dealer Bank}}}. \tag{9}$$

where summation occurs over all banks i and the dummy $\mathbb{1}_{\text{i is Dealer Bank}}$ takes on the value of one for any dealer bank. Figure A.5 plots the cross-sectional average of 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 a 1 percent level.

While the average capital ratio of dealer banks is unlikely to directly affect hedging demand of investment funds, other financial variables could influence both the capital ratio and the hedging demand which would invalidate our identification choice. For example, economic uncertainty could depress the equity capital ratio of some banks and simultaneously trigger more hedging demand by funds. We therefore refine the above identification strategy based on granular instruments Gabaix and Koijen (2023).

[27]We use for our first instrument the *average* capital ratio of primary dealers constructed using *total debt*. This is slightly different to He et al. (2017); they measure the *aggregate* capital ratio of primary dealers using long-term debt only. However, all results are qualitatively very similar for either definitions.

Granular Instrumental Variables GIV1 and GIV2. Next, we use a sample of $N = 640$ commercial banks to construct granular instruments capturing *relative* variations in the capital ratio of dealer banks. The sample includes all international banks active in the FX market in the period 2012 to 2022.[28] Table A.6 reports summary statistics for bank capital ratios and instruments (Panel A) as well as the market statistics (Panel B) at a daily frequency. The capital ratio (CR) at market values is available for roughly 1.2 million bank days.

For the GIV construction, we calculate the daily log changes in the capital ratio, $\Delta ln(CR)$, and subtract bank fixed effects. In addition, we subtract the first 3 (or 5) largest principle components and denote the resulting idiosyncratic capital ratio change by $\Delta ln(CR_{i,t})^*$.[29] Principle components analysis captures macroeconomic valuation effects that are common to a large number of banks and not idiosyncratic to a specific bank.

One identification concern relates to "sporadic factors" due to non-recurring (sporadic) aggregate events that affect several banks simultaneously. To address this we eliminate large capital ratio changes that affect more than one dealer bank on any given day. To do so we follow the procedure proposed in Gabaix and Koijen (2023). First, we calculate the squared idiosyncratic shocks ($\hat{u}^2_{i,t} = [\Delta ln(CR_{i,t})^*]^2$) of each bank i on day t and normalise it by the square of the bank's previous idiosyncratic volatility ($\sigma^2_{u_{i,t-1}}$). The higher the ratio defined as $b_{i,t} = \hat{u}^2_{i,t}/\sigma^2_{u_{i,t-1}}$, the more abnormal is the daily change in the bank's capital ratio. Let $\mathcal{B}$ denote the set of daily bank capital ratio changes of the second largest value of day t. If the second largest value is among the 5% largest shocks across all $\mathcal{B}$, we exclude day t from the sample, because more than one bank features an abnormal change in its capital ratio on the same day. For example, among extreme observations in $\mathcal{B}$ are days like the onset of COVID-19 in March 2020 or the day of the Brexit referendum in the United Kingdom

[28]The data is sourced both from the Compustat Bank Fundamentals database and the Compustat Global database. Banks are identified by the Standard Industrial Classifications (SICs) equal to 602, 603, 606, 608, 609, 62 and 6712.

[29]Subtracting an alternative larger number of principle components has little effect on the elasticity estimate.

in June 2016. These events are not granular in the sense that they affected multiple banks simultaneously and are therefore "macroeconomic" in nature. Our sample selection process assures that we estimate the demand elasticity only for those days when at most one bank experiences an extreme (i.e., idiosyncratic) change in its capital ratio.

The daily capital ratio change is also influenced by changes in book debt reported at quarter-ends. We are not able to pinpoint the exact (intra-quarter) day on which capital measures with respect to debt (or AT1 capital) become effective and alter the capital ratio. Hence, we exclude quarter-end days to focus on capital ratio changes triggered by equity value changes only.[30]

Based on Eq. (9), we define two granular instruments, where we use the (filtered) change of the log capital ratio, $ln(\Delta CR_{i,t})^*$, which is purged of principle components, bank and time fixed effects, and sporadic effects. Our first granular instrument (GIV1) uses as weights Γ_i the *differences* between the (equal) dealer bank (dummy) weights and (equal) full sample weight ($N = 640$), that is

$$\Gamma_i = \frac{\mathbb{1}_{i \text{ is Dealer Bank}}}{\sum_i^N \mathbb{1}_{i \text{ is Dealer Bank}}} - \frac{1}{N}. \tag{10}$$

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. (11) as the *difference* of size-based and equal weights (with size measured in terms of total bank assets in 2012), that is

$$\Gamma_i = \frac{Assets_{i,2012}}{\sum_i^N Assets_{i,2012}} - \frac{1}{N}. \tag{11}$$

The size-based granularity instrument is conceptually closest to Gabaix and Koijen (2023) and is applied in Camanho et al. (2022). It also turns out to be the strongest of the three instruments and therefore is our preferred instrument.

[30]We highlight that our results are robust to including the days with high sporadic factors or quarter-end days. However, the $F-$statistics in the first stage of the GIV regression is three times smaller (below 10), if we run the analysis on the full sample comprising all days.

It is best practice to include a narrative check on the largest events that dominate the granular instruments. Do the largest capital ratio shocks ($\Delta ln(CR)^*$) indeed capture bank-specific events that alter the capital constraints of dealer banks? We identify the 10 largest capital ratio improvements among large dealer banks and the full sample of all banks, respectively, and list the 20 events in Appendix Table A.7. The largest capital ratio improvements in the full bank sample all relate to new equity issuance. And even among the dealer banks, 5 out of the 10 largest positive changes can be traced to new equity issuance. Such equity issuance events are clearly idiosyncratic events and therefore lend themselves to the construction of granular instruments. Whenever an extreme capital ratio improvement is based on a (large) valuation effect rather than an equity issuance events, the event also appears to be particular to the respective bank. Large idiosyncratic valuation effects generally represent earning surprises, which enter the regulatory capital ratio at quarter-end through retained earnings or losses.

Granualar Instrumental Variable GIV3. A remaining endogeneity concern is that changes to the bank capital ratio at market prices are influenced by bank equity returns and not only by the equity measures even if changes to the number of outstanding shares account for most of the large variations in the capital ratio. Stock returns can aggregate various macroeconomic effects specific to dealer banks and are not filtered out when constructing the granular instrument. We therefore define a third granular instrument (GIV3) which replaces the change in the log capital ratio, $\Delta ln(CR_{i,t})$, by the change in the log number of outstanding shares, $\Delta ln(OS_{i,t})$. Formally,

$$z_t = \sum_{i}^{N} \Gamma_i \Delta ln(OS_{i,t}), \tag{12}$$

with the weight Γ_i defined as in Eq. (11). This third granular instrument (GIV3) captures *only* the idiosyncratic equity capital measures of large versus small banks, namely new equity issuance and share buybacks. Such capital measures are very infrequent and generally need board or even shareholder approval. Thus, these capital measures require planning months in advance and they are unlikely to represent a short-term response to FX market developments.

4.4 Estimating the Elasticity of the Hedging Demand

Based on these four instruments for the hedging pressure, $\Delta HP_{c,t}$, we estimate Eq. (5) using a 2SLS method. Under the assumption that the instruments capture (exogenous) supply shifts for FX hedging contracts, the 2SLS coefficient directly identifies the inverse of the demand elasticity as shown in Appendix B.

As our instruments are not currency specific, we focus on a basket of dollar rates, 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 is of secondary importance. Estimation is undertaken at a daily data frequency to ensure that the instrument is sufficiently strong.

Table 4, Panels A and B, present the first and second stage results, respectively. Column (1) in Panel B reports the OLS coefficients for comparison. The coefficient estimates for all four instruments in Panel A, Columns (2)-(5), are positive and highly significant. This implies that lower capital ratios or fewer outstanding shares and therefore tighter constraints on bank capital, decrease the supply and equilibrium quantity of dollar short positions. The Montiel Olea-Pflueger (MOP) effective F-statistics are 30.7 and 33.2 for the GIV1 and GIV2, respectively, which indicates strong instruments. Only GIV3 based on change in the outstanding bank shares represents a somewhat weaker instrument with an effective F-statistics of 10.8.

Table 4, Panel B, reports the second stage results. The fitted values of hedging pressure have *negative* and statistically highly significant coefficients in Columns (2)-(4). Thus, as the dollar appreciates, smaller net dollar short positions are demanded by institutional investors.

The point estimates in Panel B, Columns (2)-(4), are of comparable economic magnitude and range from -6.42 to -3.96, respectively. The coefficient for GIV3 in Panel B, Column (5) is also negative, but smaller at -2.21. The higher standard error of 1.71 suggests a less precise point estimate, which can be explained by a weaker first-stage regression. We concede that there is a trade-off between the precision of the 2SLS estimates and the contestability of the instrument, which is lowest in the case of GIV3 based entirely on idiosyncratic bank equity issuances or redemptions.

The implied exchange rate elasticity for the net dollar hedging demand follows as $-\frac{1}{3.96} = -0.25$ in Column (3)—suggesting relatively price elastic demand. Thus, a 1% dollar appreciation is associated with a reduced net dollar hedging demand of -0.25%, which represents approximately USD 21 billion in 2022.[31]

In Appendix B we show that a positive first stage coefficient (in Panel A) implies that the elasticity of the hedging supply is still more negative, that is more price inelastic than the demand, $\frac{1}{\phi^s} < \frac{1}{\phi^d} < 0$, under the traditional assumption that the supply of net dollar short positions decreases in the price of the dollar ($\phi^s < 0$).[32] A negative elasticity for both the demand and the supply of FX derivatives implies that both hedging supply shocks by dealer banks (due to time-varying regulatory constrains) and hedging demand shocks generate a negative correlation between the dollar value and the equilibrium short (dollar) interest the derivative market. This feature can account for the high negative correlation of 0.66% between the dollar value and hedging pressure documented in Figure 2. Such a strong nexus between hedging quantities and the exchange rate also suggests that derivative markets play an important role in exchange rate determination, which is a new insight.

As the demand for (net) dollar balances increases through less short selling with a higher dollar price, hedging contracts have the features of a Giffen good as dollar price and dollar

[31] The average daily total open interest in the market, i.e., the denominator of hedging pressure, amounts to USD 8.3 trillion in 2022 (see Column (7) Table A.1). Thus, a net demand reduction of -0.25% corresponds to a USD 21 billion reduction in net dollar short positions (= $-0.25\% \times$ USD 8.3 trillion).

[32] Camanho et al. (2022) estimate dollar supply elasticities for the currency spot market and find that a 1% dollar depreciation is associated with 5.3 billion USD equity outflows.

demand are positively related. What is the underlying logic for this finding? One possible explanation is that the hedging policies of bond funds are often discretionary and path dependent. A dollar appreciation tends to increase the portfolio return of foreign fund invested in US assets and predicts better performance over any preset period, while it has the opposite effect on US funds invested overseas. If positive (negative) returns decrease (increase) the loss aversion of funds, we expect the net hedging pressure to decrease in response to a dollar appreciation. This can rationalize a downward-sloping demand curve for (net) dollar short positions implied by out finding of negative hedging demand elasticities.

Previous research has argued that the demand for hedging positions is relatively price inelastic and did not suggest a negative demand elasticity. Studying periodic quarter-end CIP deviations associated with temporary supply reduction of EU banks in the forward market, Wallen (2020) finds that investment funds' hedging demand hardly responds to forward rate fluctuations. Similarly, Du and Huber (2023) document that investors' hedging demand is not affected by rising hedging costs, captured by CIP deviations, which also suggests a relatively price inelastic demand curve. More research into the hedging behavior of institutional investors and its effect on exchange rates is required.

5 Conclusion

Our exploration of a "hedging channel" of exchange rate dynamics starts from the observation that US net asset positions in bonds have become increasingly negative over the last decade. Increasing deamnd for dollar denominated bonds by overseas investors generates massive FX hedging demand from foreign funds, which have come to dominate FX derivative markets. At the same time, global dealer banks, as FX liquidity providers, face time-varying capital constraints which depend on irregular and idiosyncratic capital measures to comply with the bank capital requirements set by bank regulators. Equity issuances by dealer banks free up balance sheet capacity for synthetic dollar funding in a granular manner and generate aggregate supply shocks for FX forward and swap contracts.

Capital ratio changes around bank equity issuance events can be used for the construction of granular instruments and allow us to identify a price elastic net hedging demand from the institutional bond investors. Importantly, this hedging demand (for net dollar short positions) has a *negative* slope like the supply function. In other words, less net hedging is desired as the dollar appreciates: A one percent dollar appreciation is associated with a demand decrease (for dollar short positions) of roughly 21 billion dollars.

Negative slopes for the demand and supply of dollar short positions imply that both supply and demand shocks can generate a negative correlation between changes in net dollar short positions (i.e., hedging pressure) and the dollar exchange rate. This can rationalize the strong negative correlation of 66% found for dollar (index) returns over the last decade. Our findings represent a notable exception to the "exchange rate disconnect puzzle" and indicate the growing importance of derivative markets for the determination of exchange rates. Further exploration of this hedging channel provides a promising path towards an empirically accurate theory of exchange rate determination.

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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 $HP_{c,t} \times \Delta VIX_t$ 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 up to 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
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
$HP_{c,t} \times \Delta VIX_t$	798	−0.01	0.96	−0.01	−0.22	0.19	−4.68	4.60

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 change in the foreign net investment position, $\Delta NIP_{c,t}$, of the respective country with the US, the monthly change in the CBOE volatility index, ΔVIX_t, and its interaction term of hedging pressure (in levels), $HP_{c,t} \times \Delta VIX_t$. The latter term is scaled by the factor 1/100. 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:	Monthly Hedging Pressure Changes, $\Delta HP_{c,t}$		
	(1)	(2)	(3)
$\Delta NIP_{c,t}$	-0.012		-0.010
	(0.017)		(0.02)
ΔVIX_t		-0.025^{*}	
		(0.013)	
$HP_{c,t} \times \Delta VIX_t$			-0.131^{*}
			(0.078)
Currency FEs	Yes	Yes	Yes
Time FEs	No	No	No
R^2 (Between)	0.311	-	0.202
R^2 (Overall)	0.001	0.0128	0.010
Observations	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:	Monthly Spot Rate Changes, $\Delta s_{c,t}$				Monthly 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

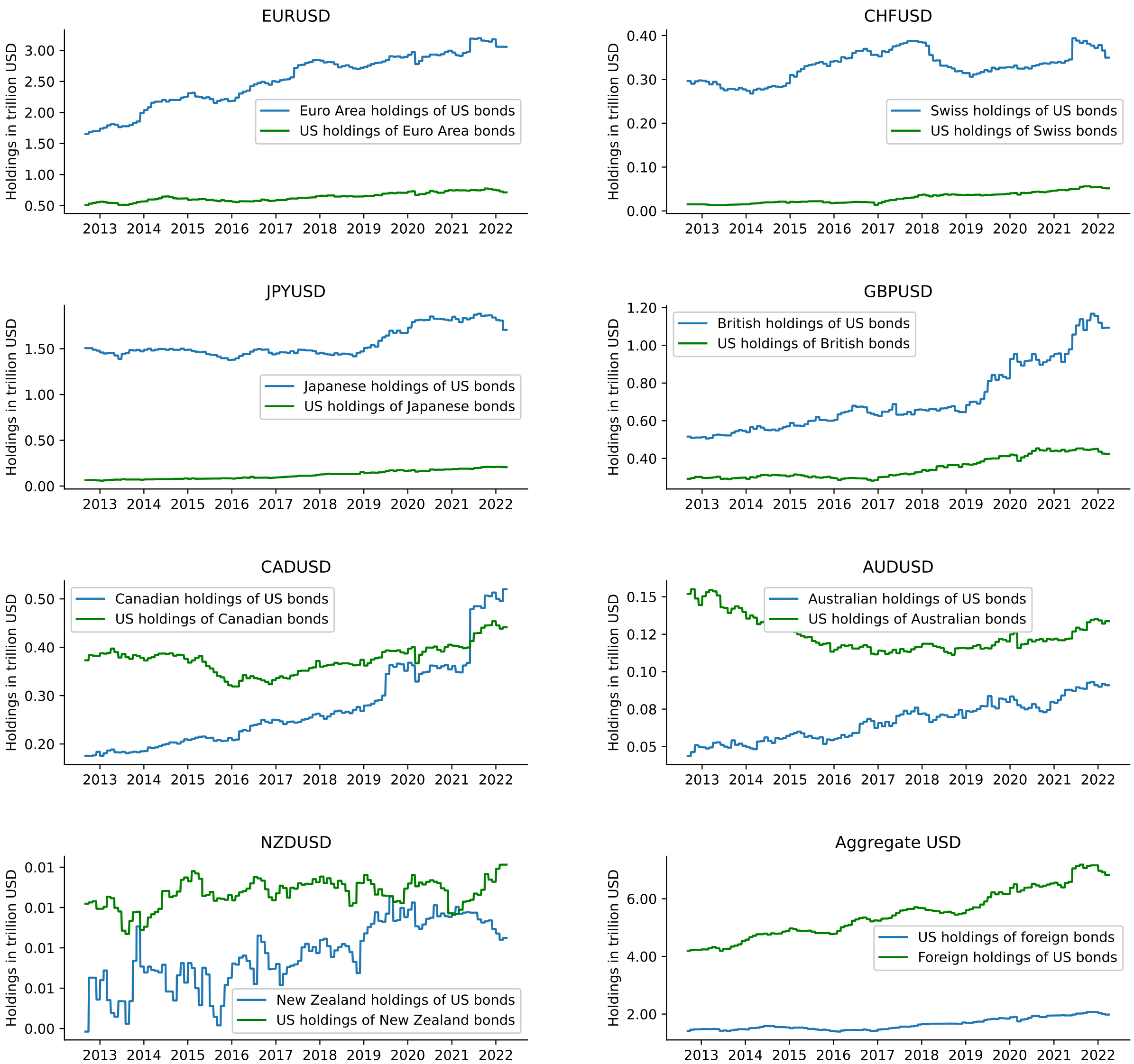
Table 4: Exchange Rate Elasticity of the Hedging Demand

We report 2SLS regressions of daily (log) spot rate changes for an equal-weighted dollar index, Δs_t, on the instrumented aggregate daily change of average net hedging pressure in seven currencies, ΔHP_t. The average hedging pressure (for all seven currencies) 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 is based on the (equal-weighted) capital ratios of dealer banks similar to He et al. (2017), whereas GIV1 and GIV2 represent two granular instruments based on differences in bank capital ratios. GIV3 replaces the changes to log bank capital ratios (in GIV2) by the changes to log outstanding bank shares to obtain a price-independent equity issuance instrument. 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	GIV3
	(2)	(3)	(4)	(5)
z_t	1.293***	0.079***	0.068***	5.220***
	(0.387)	(0.014)	(0.012)	(1.585)
$\Delta(y_t^* - y_t^{\$})$	0.007***	0.006***	0.006***	0.006***
	(0.002)	(0.002)	(0.002)	(0.001)
ΔVIX_t	−0.002	0.000	−0.001	−0.005***
	(0.002)	(0.002)	(0.002)	(0.002)

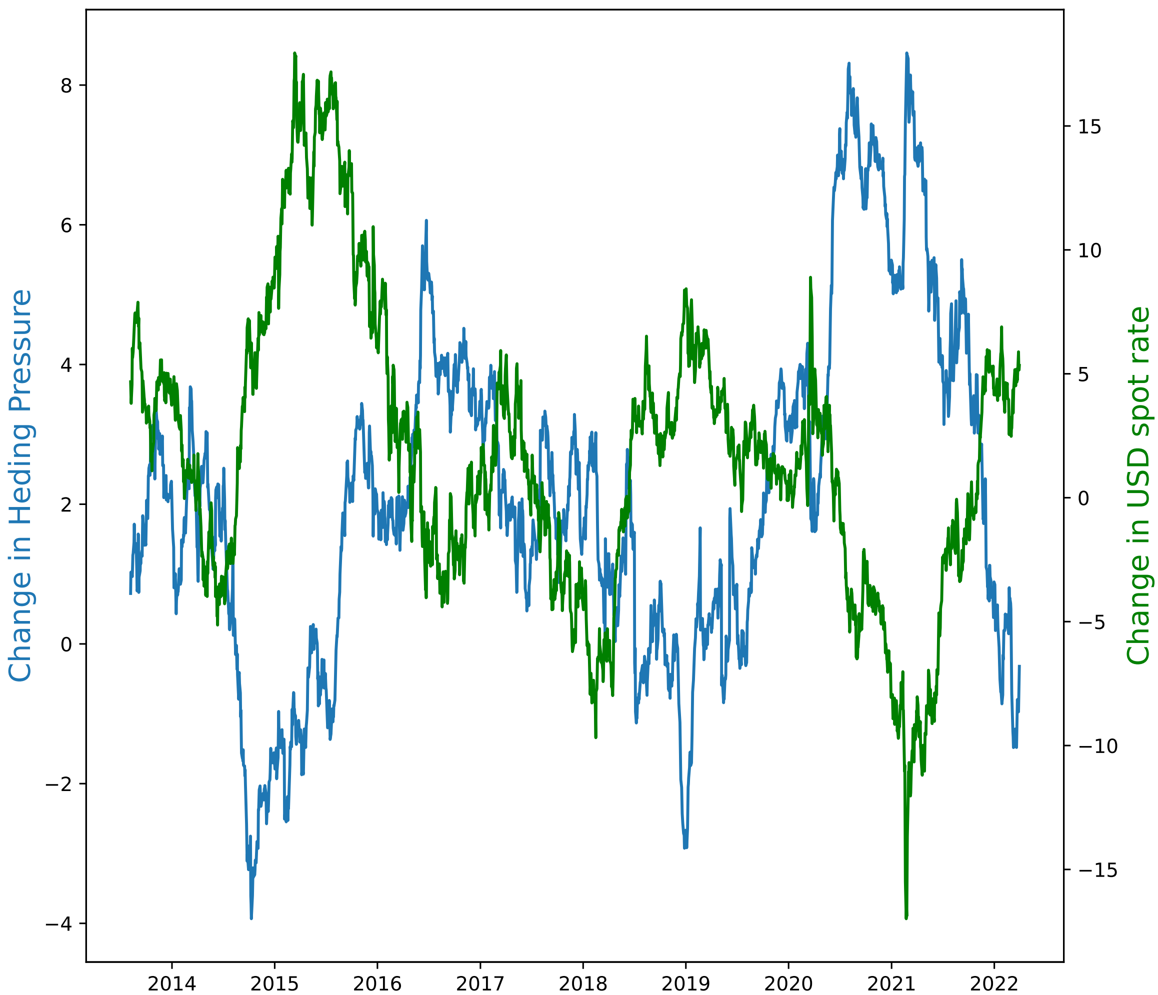
Panel B: Second Stage					
Dep. variable:	Daily Spot Rate Changes, Δs_t				
	OLS	IV0	GIV1	GIV2	GIV3
	(1)	(2)	(3)	(4)	(5)
ΔHP_t	−0.864***				
	(0.095)				
$\widehat{\Delta HP_t}$		−6.420***	−4.799***	−3.962***	−2.206
		(1.514)	(0.801)	(0.671)	(1.710)
$\Delta(y_t^* - y_t^{\$})$	−0.045***	−0.010	−0.021***	−0.026***	−0.034***
	(0.004)	(0.012)	(0.008)	(0.007)	(0.012)
ΔVIX_t	0.036***	0.007	0.015*	0.017**	0.029***
	(0.006)	(0.007)	(0.008)	(0.007)	(0.011)
Observations	2,398	2,398	2,164	2,164	2,398
MOP Effective F-statistics	-	11.141	30.702	33.247	10.847
Implied Demand Elasticity	-	−0.156	−0.208	−0.252	−0.453

Figure 1: International Bond Holdings across Exchange Rates



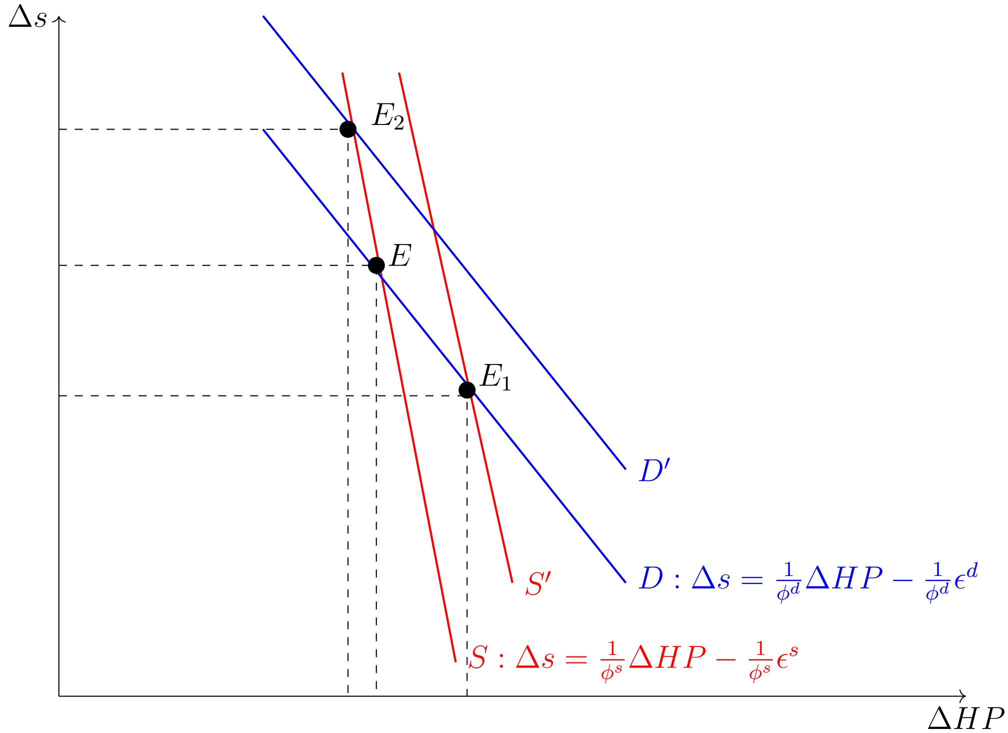
Notes: We plot the foreign long-term bond holdings in US bonds (blue line) and US holdings of foreign long-term bonds (green line) over the period 2012-22 for seven different currency areas. The vertical scale denotes trillions of USD. The last panel shows the aggregate values. Source: US Treasury International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

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



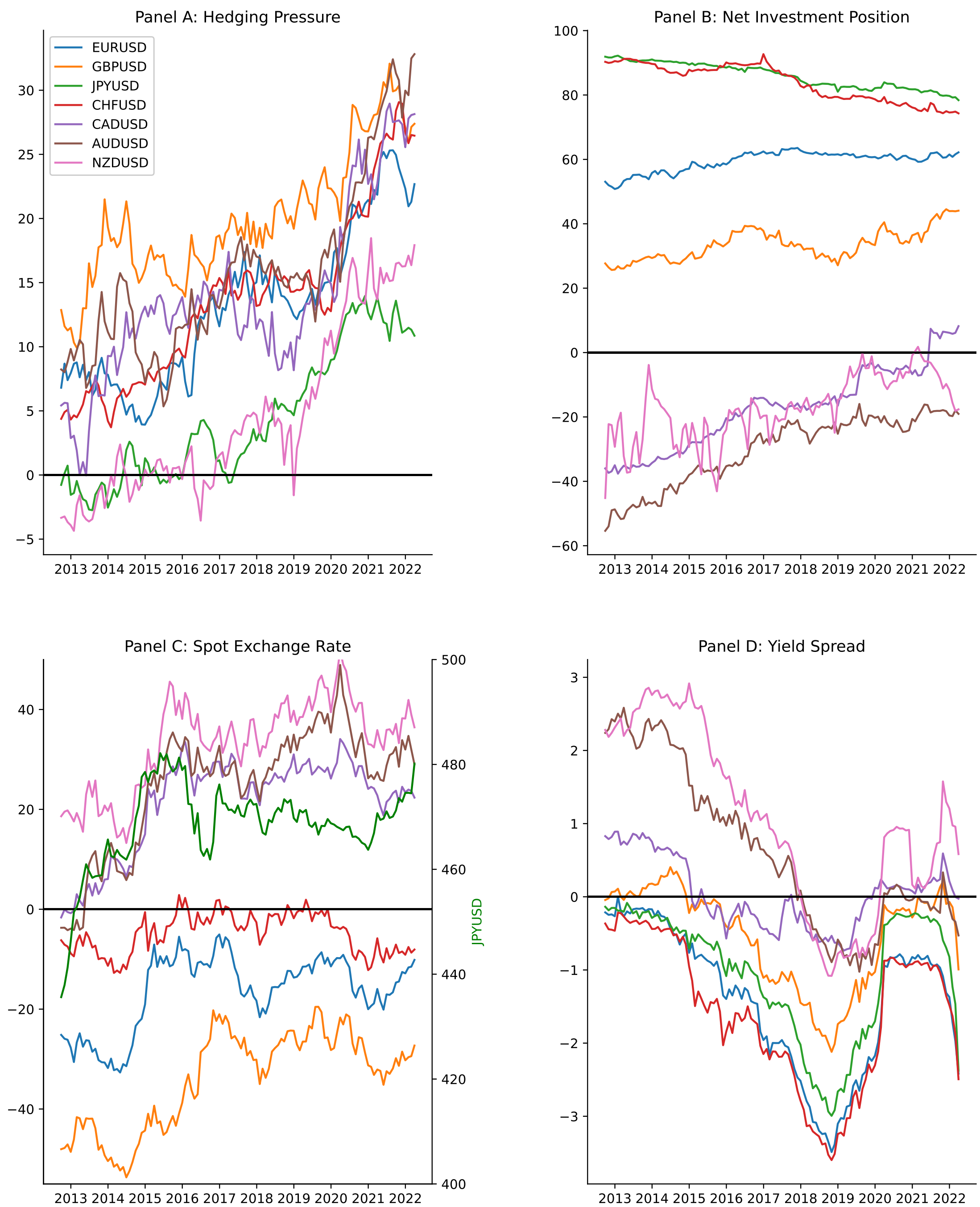
Notes: We graph the annual change in aggregate hedging pressure emanating from forward contracts of funds (as reported by CLS) and the annual change in the average (log) US dollar spot exchange rates across all seven currencies. A higher US dollar spot rate corresponds to a dollar appreciation and greater hedging pressure corresponds to more (net) short selling of the dollar by fund investors. The negative correlation is −0.66. Source: CLS and Bloomberg.

Figure 3: Supply and Demand of Dollar Short Positions (FX Forwards and Swaps)



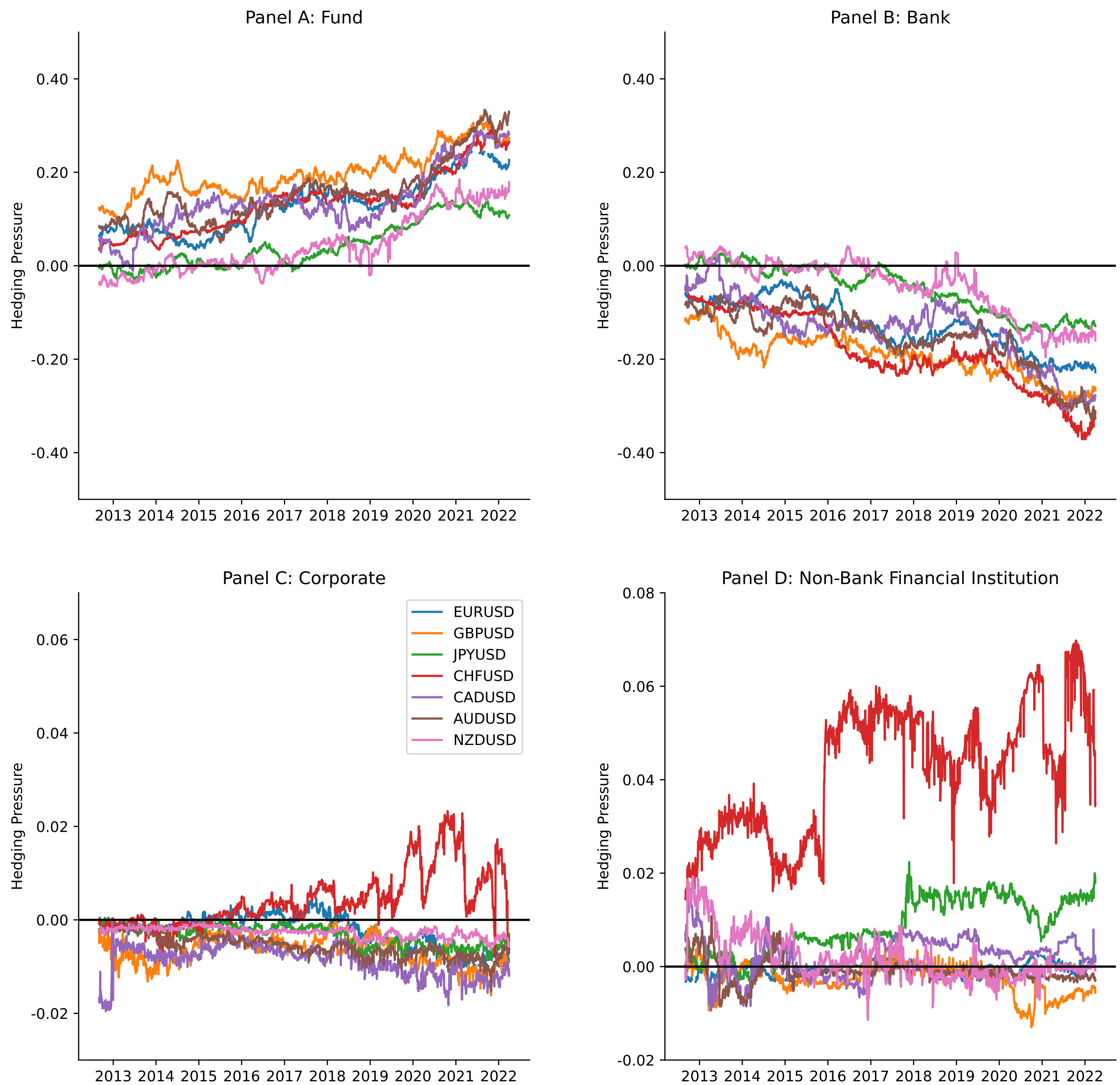
Notes: The x-axis shows changes in hedging pressure, ΔHP, defined as increases in net derivative short positions in dollars (relative to the total outstanding interest) and the y-axis represents exchange rate changes, Δs, defined as dollar appreciation. Both supply shocks (S to S') and demand shocks (D to D') generate a negative correlation between exchange rate changes and changes in hedging pressure, respectively.

Figure 4: Hedging Pressure and Net Investment Positions



Notes: For seven dollar exchange rates, we plot hedging pressure in Panel A (i.e., the percentage net outstanding short positions in dollars by investment funds), the corresponding (bilateral) net foreign investment positions in dollar denominated bonds in Panel B, the spot exchange in Panel C (quoted as foreign currency to the dollar), 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 5: Net Dollar Short Positions by Investor Type



Notes: We show the percentage net outstanding dollar short positions (relative to the total outstanding contract volume) by type of market participant in the seven most liquid exchange rate markets. The CLS data distinguish between 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.

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
JPYUSD	1,315.53	303.66	158.24	33.36	1,473.77	320.84	1,914.43
CHFUSD	385.13	48.79	51.11	13.67	436.24	59.63	553.99
CADUSD	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 volumes 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 for 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 up to 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 regressions 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 regressions 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	Yes	No	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 640 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. The change in the shares outstanding of bank i is denoted as $ln\Delta(OS_{i,t})$. Panel B states summary statistics for four instruments, z_t^0, z_t^1, z_t^2 and z_t^3, constructed according to Eq. (8) and (12) with weights defined in Eqs. (9), (10), and (11). 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)	1,212,364	103,542	379,075	1,973	784	11,915	94	3,954,687
Book Debt (mil USD)	1,163,723	20,057	78,908	131	41	976	0	1,177,661
Market Equity (mil USD)	1,212,364	70,58	26,719	235	77	1750	0	514,470
CR_i	1,163,723	0.59	0.23	0.61	0.44	0.77	0.00	1.00
$\Delta ln(CR_i)$	1,163,720	0.00	0.03	0.00	−0.00	0.00	−5.01	4.61
$\Delta ln(CR_i)^*$	1,163,720	−0.00	0.53	−0.01	−0.15	0.14	−31.02	45.95
$\Delta ln(OS_i)$	1,595,120	0.00	0.01	0.00	0.00	0.00	−3.15	4.94
Panel B: Instruments								
z_t^0 (IV0)	2,399	0.00	0.01	0.00	−0.00	0.01	−0.09	0.12
z_t^1 (GIV1)	2,164	0.01	0.24	0.01	−0.12	0.14	−1.17	1.40
z_t^2 (GIV2)	2,164	0.01	0.29	0.00	−0.15	0.17	−1.65	1.37
z_t^3 (GIV3)	2,399	−0.00	0.00	0.00	−0.00	0.00	−0.01	0.03

Table A.6 continued.

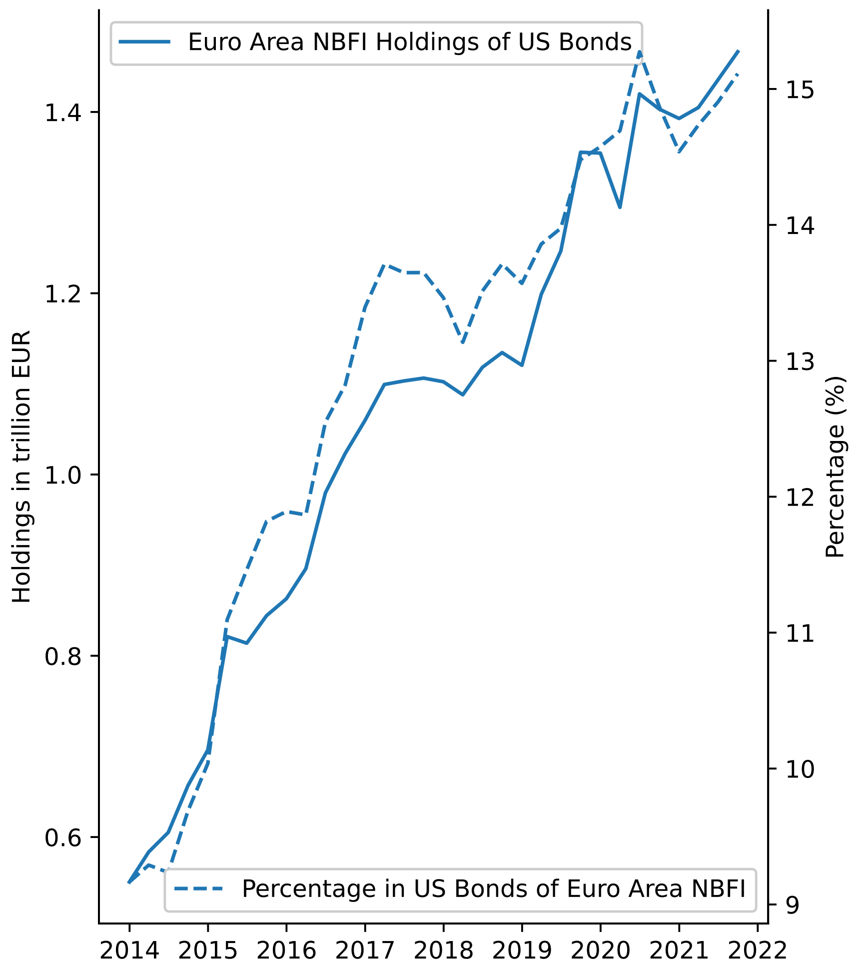
	Obs.	Mean	S.D.	Median	P25	P75	Min	Max
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel C: Market Data								
Level variables								
$s_{c,t}$	2164	70.38	7.46	72.97	68.83	75.88	52.03	82.54
$f_{c,t}$	2164	70.37	7.42	72.93	68.80	75.84	52.09	84.87
$HP_{c,t}$	$2,410$	14.81	6.39	14.16	9.17	17.35	6.34	29.28
$(y^*_{c,t} - y^\$_{c,t})$	2164	-0.42	0.84	-0.28	-1.07	0.18	-2.15	0.83
VIX_t	2164	16.93	6.00	15.16	12.90	19.16	9.14	65.54
Daily differences								
$\Delta s_{c,t}$	2164	0.00	0.39	0.01	-0.23	0.24	-2.97	1.28
$\Delta f_{c,t}$	2164	0.00	0.64	0.01	-0.23	0.24	-9.19	8.19
$\Delta HP_{c,t}$	2164	0.01	0.15	0.01	-0.07	0.09	-1.72	1.72
$\Delta(y^*_{c,t} - y^\$_{c,t})$	2164	-0.12	2.58	-0.10	-1.32	1.09	-17.85	22.68
ΔVIX_t	2163	0.00	1.82	-0.09	-0.73	0.57	-10.26	25.92

Table A.7: Narrative Check of Granular Instrument

We report the largest idiosyncratic shocks to capital ratios, $\Delta ln(CR_{i,t})^*$ in Eq. (B.11), used for the granular instrumental variable of our sample of primary dealer banks (Panel A) and all banks (Panel B). The event type column indicates whether the event is due to an equity issuance or an equity valuation effect. The two instances where the capital ratio shocks can be linked to an equity valuation effect for the Japanese banks Nomura and Mizuho coincide with actions taken by the Bank of Japan (BOJ) in 2016. Specifically, on 16 February the BOJ announced that negative rates would apply on 23 trillion yen of reserves and at its policy meeting on 29 July, the BOJ announced additional measures to strengthen monetary easing. Other valuation effects include the Bank of Nova Scotia's dividend announcement on 26 May 2020, Wells Fargo's involvement in merger speculation on 14 May 2020, and Mizuho's share price increase that coincides with a speech by the Japanese prime minister reaffirming his commitment to implementing economic reforms aimed at stimulating corporate investment and boosting economic growth on 4 June 2013.

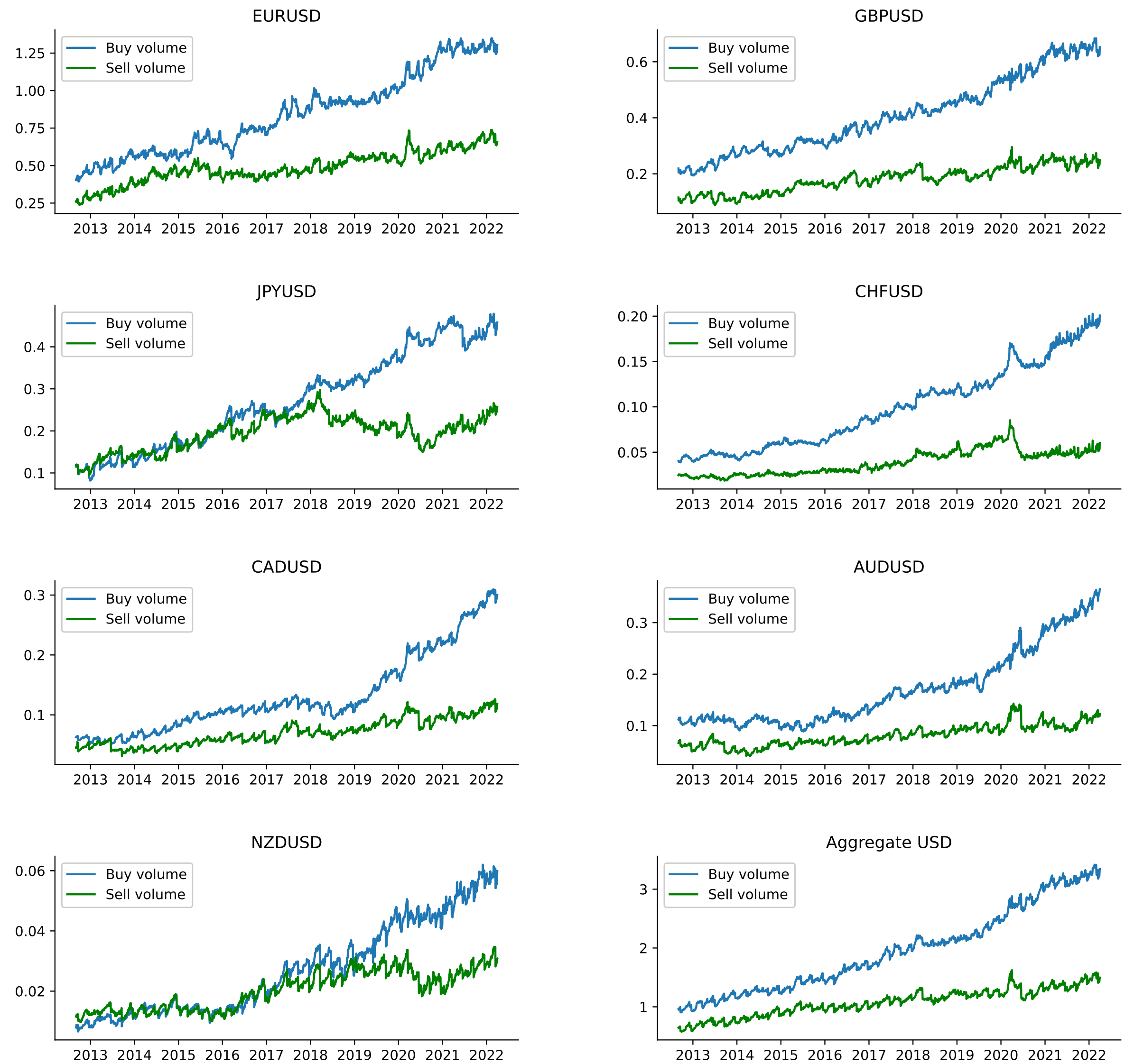
Date	Bank Name	$\Delta ln(CR_{i,t})^*$	Event Type
Panel A: Primary Dealer Banks, $N = 20$			
10-04-2017	Deutsche Bank AG	13.13	Equity Issuance
06-06-2014	Deutsche Bank AG	7.26	Equity Issuance
05-10-2020	Morgan Stanley	5.85	Equity Issuance
16-02-2016	Mizuho Financial Group Inc	5.58	Equity Valuation
08-06-2017	Credit Suisse Group	5.26	Equity Issuance
16-02-2016	Nomura Holdings Inc	5.05	Equity Valuation
26-05-2020	The Bank of Nova Scotia	5.01	Equity Valuation
14-05-2020	Wells Fargo & Co	4.84	Equity Valuation
08-04-2013	Credit Suisse Group	4.80	Equity Issuance
04-06-2013	Mizuho Financial Group Inc	4.71	Equity Valuation
Panel A: All Banks, $N = 640$			
2018-08-13	Santander UK PLC	45.68	Equity Issuance
2012-09-27	Steuben Trust Co	41.90	Equity Issuance
2020-06-08	SouthState Corporation	33.06	Equity Issuance
2013-04-22	Star Financial Group Inc	30.71	Equity Issuance
2014-04-10	Bankwell Financial Group Inc	30.50	Equity Issuance
2015-07-22	Northern States Financial Corp	29.64	Equity Issuance
2013-03-15	Jacksonville Bancorp Inc/FL	26.51	Equity Issuance
2017-03-24	First Sound Bank	24.66	Equity Issuance
2013-04-16	First Security Group Inc	24.46	Equity Issuance
2015-07-09	Centrue Financial Corp	24.38	Equity Issuance

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



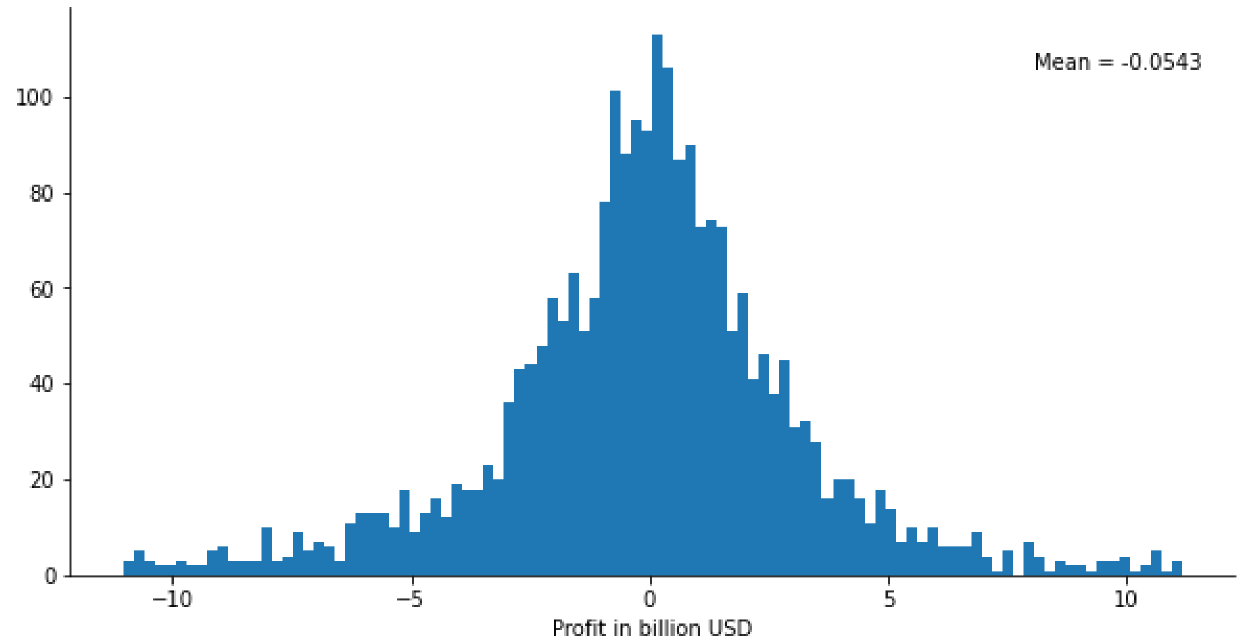
Notes: For all euro area non-bank financial institutions, we plot long-term bond holdings for the period 2014-21. The left axis and non-dashed line denote bond holdings in trillions of EUR, and the right axis and the dashed line report the percentage of USD-denominated bonds in the overall bond portfolios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

Figure A.2: Buy and Sell Volume of Funds



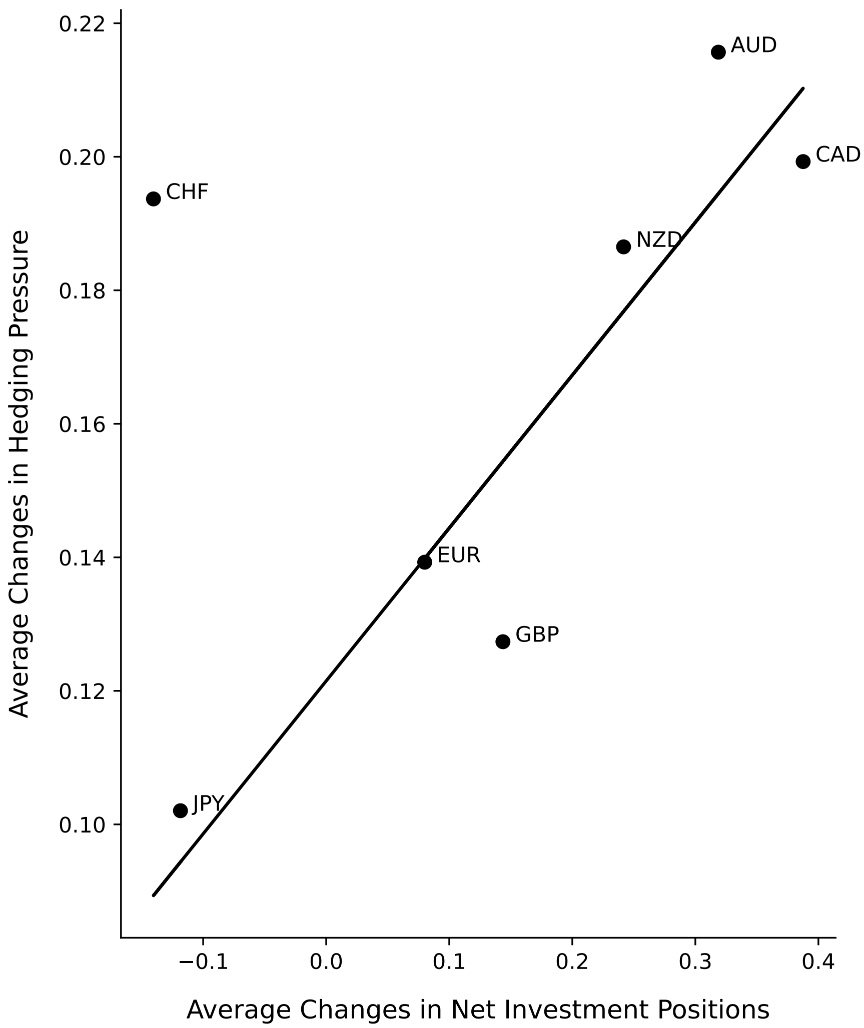
Notes: We plot buy and sell volumes of the base currency in trillion USD for funds. The bottom right figure shows the aggregate over all seven currencies. Source: CLS.

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



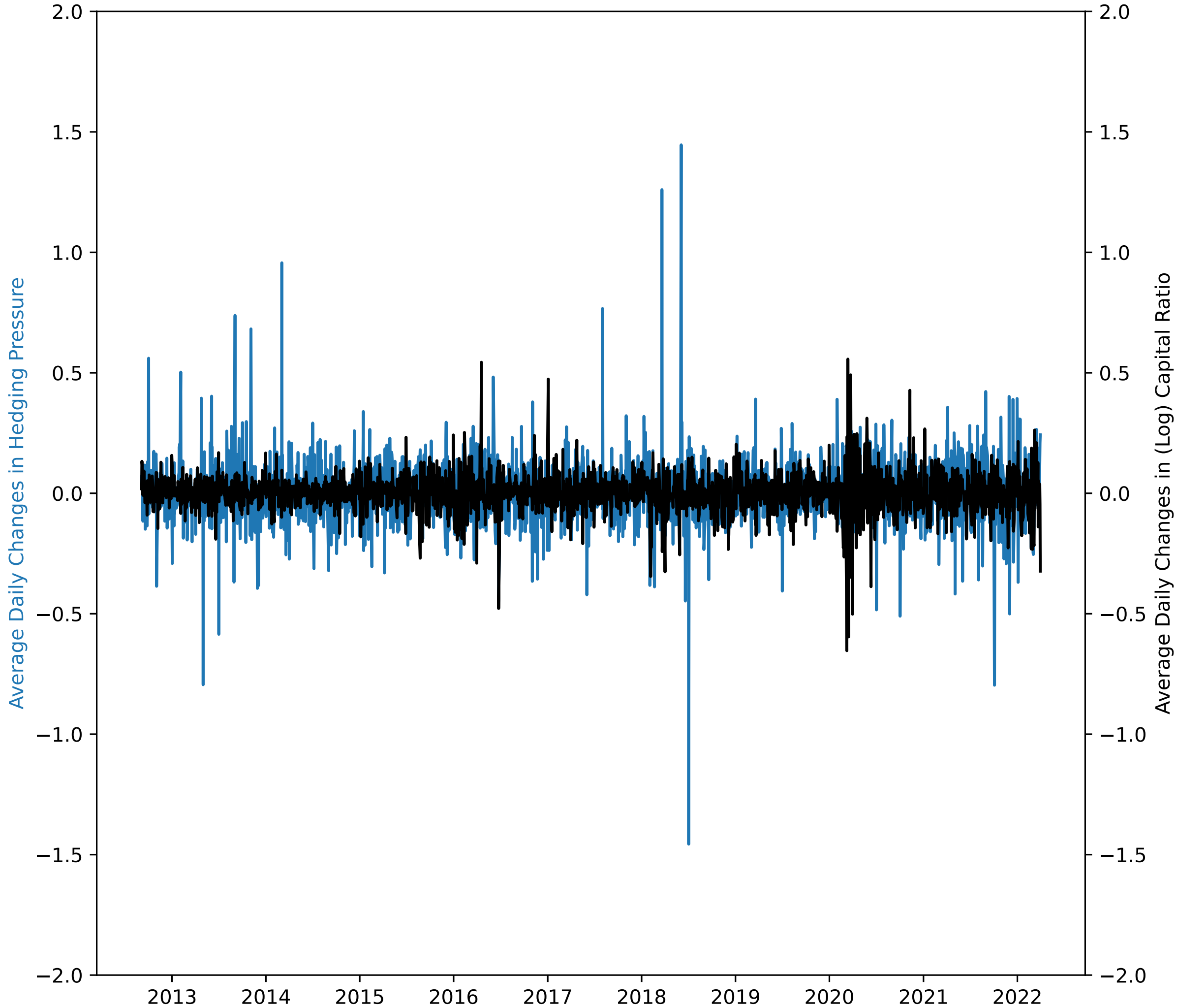
Notes: We plot the daily profit of funds' aggregate FX derivative positions (in USD) computed as the product between net short positions (in USD) and the daily return on the spot rate. The average daily aggregate net hedging (short) position of funds is 60 billion USD and the average daily profit based 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 omitted from the sample, the correlation is 92% and significant at the 1% level. The fitted linear line excludes the CHF. Source: CLS and TIC data.

Figure A.5: Average Hedging Pressure and Bank Capital Ratio Change



Notes: We plot the cross-sectional average daily changes in hedging pressure in blue and the average daily changes in primary dealers' capital ratio in black. The latter is computed as the average value of market equity divided by the sum of market equity and book debt similar to 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. If both supply and demand elasticities are negative, we obtain a perfect negative correlation between the change in hedging pressure ΔHP_t and a dollar appreciations Δs_t for uncorrelated supply and demand shocks. 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.

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 of 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 interest rates for the US and foreign countries, covered interest parity implies 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 net derivative demand and supply of dollar short positions, respectively, Δs denotes the (log) dollar appreciation, 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

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

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

If supply and demand shocks are uncorrelated ($\mathbb{E}[\epsilon^d \epsilon^s] = 0$), we obtain the expression

$$Corr[\Delta HP, \Delta s] = \Phi \times \frac{\phi^d Var(\epsilon^s) + \phi^s Var(\epsilon^d)}{|\phi^d|\, Var(\epsilon^s) + |\phi^s|\, Var(\epsilon^d)},$$

where we define

$$\Phi \equiv \left[1 + \frac{\left[\phi^d - \phi^s\right]^2}{\left[|\phi^d| \frac{\sigma(\epsilon^s)}{\sigma(\epsilon^d)} + |\phi^s| \frac{\sigma(\epsilon^d)}{\sigma(\epsilon^s)} \right]^2} \right]^{-\frac{1}{2}} \lessapprox 1.$$

Thus, for $\phi^d < 0$ and $\phi^s < 0$, we obtain the strong negative correlation $Corr[\Delta HP, \Delta s] \gtrapprox -1$ documented in Figure 2.

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

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

The OLS coefficient identifies the inverse of the demand elasticity only in the absence of demand shocks, ϵ_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 z_t that shifts the supply equation B.2, such that

$$\Delta HP_t^s = \phi^s \Delta s_t + \alpha^s z_t + \epsilon_t^s. \qquad \text{(B.8)}$$

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

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

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

Granular Instrumental Variable Regression. The (disaggregate) supply equation B.2 at the bank level can be expressed as

$$\Delta HP^s_{i,t} = \phi^s_i \Delta s_t + \lambda_i \eta_t + u^s_{i,t}, \tag{B.10}$$

where $\Delta HP^s_{i,t}$ denotes the derivative supply of bank i, η_t describes shocks common to all banks with a factor structure $\eta_t = \sum_{f=1}^{r} \lambda^f_i \eta^f_t$ and $u^s_{i,t}$ represents the idiosyncratic supply shocks specific to bank i with $\mathbb{E}[u^s_{i,t}\eta_t] = 0$. Importantly, we can now formulate exclusion restrictions that involve only idiosyncratic supply shocks, namely $\mathbb{E}[u^s_{i,t}\epsilon^d_t] = 0$ for all banks i.

We do not directly observe idiosyncratic supply shocks $u^s_{i,t}$, but can proxy them with idiosyncratic changes in the dealer bank's (log) capital ratio, $\Delta ln(CR_{i,t})$. Large capital ratio changes are mostly influenced by idiosyncratic capital measures (like equity issuance or share buybacks) that change the (Tier 1) capital ratio and alter the balance sheet capacity of a dealer bank to accommodate FX derivatives among risk-weighted assets. To purge potential macroeconomic factors from our supply shock proxy, we subtract the first $p = 3$ (or 5) principle components (as well as firm fixed effect α_i and time fixed effects α_t) to obtain a (filtered) supply proxy

$$\Delta ln(CR_{i,t})^* = \Delta ln(CR_{i,t}) - \sum_{f=1}^{p} \lambda^f_i \eta^f_t - \alpha_i - \alpha_t. \tag{B.11}$$

The granular instrumental variable (GIV) then takes on the form

$$z_t \equiv \sum_i^N \Gamma_i \Delta ln(CR_{i,t})^* \tag{B.12}$$

where Γ_i denotes weights defined alternatively as

$$\Gamma_i = \frac{\mathbb{1}_{i \text{ is Dealer Bank}}}{\sum_i^N \mathbb{1}_{i \text{ is Dealer Bank}}} - \frac{1}{N} \quad \text{and} \quad \Gamma_i = \frac{Assets_{i,2012}}{\sum_i^N Assets_{i,2012}} - \frac{1}{N}. \tag{B.13}$$

In our empirical analysis we remove days when capital ratio shocks are likely to be correlated. These include end-of-the-quarter dates with their periodic update of the book value of debt. We also remove dates marked by what Gabaix and Koijen (2023) call "sporadic factors". These are non-recurrent events that simultaneously influence the capital ratios of multiple banks in an economically significant manner.

Days affected by sporadic factors are identified as follows: For each time observation, we compute the ratio $b_{i,t} = \frac{\hat{u}^2_{i,t}}{\sigma^2_{u_{i,t-1}}}$, where the (squared) capital ratio shocks $\hat{u}_{i,t} = \Delta ln(CR_{i,t})^*$

are divided by the variance of the bank's previous idiosyncratic volatility, $\sigma^2_{u_{i,t-1}}$. Let bank j represent the bank with the second largest values $b_{j,t}$ on day t and $\mathcal{B}$ the set of 5% largest shocks $b_{i,t}$ in the entire sample. If the second largest bank shock on day t is in this set ($b_{j,t} \in \mathcal{B}$), we exclude day t from the sample. In total we omit 129 trading days from our sample.

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

$$\beta^{GIV} = \frac{\mathbb{E}[z_t \Delta s_t]}{\mathbb{E}[z_t \Delta HP_t]} = \frac{\mathbb{E}[z_t(\frac{1}{\phi^d}\Delta HP_t - \frac{1}{\phi^d}\epsilon_t^d)]}{\mathbb{E}[z_t \Delta HP_t]} = \frac{1}{\phi^d} + \frac{\mathbb{E}[z_t(-\frac{1}{\phi^d}\epsilon_t^d)]}{\mathbb{E}[z_t \Delta HP_t]} = \frac{1}{\phi^d}, \tag{B.14}$$

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. Using the instrument z and omitting the time subscript, we can rewrite Eq. (B.3) and (B.4) in reduced form as

$$\begin{aligned} \Delta s &= \frac{-\alpha}{\phi^s - \phi^d} z + \frac{\epsilon^d - \epsilon^s}{\phi^s - \phi^d} \\ &= \pi_1 z + v_1 \end{aligned} \tag{B.15}$$

and

$$\begin{aligned} \Delta HP &= \phi^d\left(\pi_1 z + v_1\right) + \epsilon^d \\ &= \frac{-\phi^d \alpha}{\phi^s - \phi^d} z + \left(\frac{\phi^d(\epsilon^d - \epsilon^s)}{\phi^s - \phi^d}\epsilon^d\right) \\ &= \pi_2 z + v_2. \end{aligned} \tag{B.16}$$

From the first stage we know that

$$\pi_2 = \frac{Cov(\Delta HP, z)}{Var(z)} = \frac{Cov\left(\frac{-\phi^d\alpha^s}{\phi^s-\phi^d}z + \left(\frac{\phi^d(\epsilon^d-\epsilon^s)}{\phi^s-\phi^d}\epsilon^d\right), z\right)}{Var(z)} = \frac{-\phi^d\alpha^s}{\phi^s - \phi^d} > 0. \tag{B.17}$$

If we assume that $\phi^s < 0$, then the positive supply effect of the instrument ($\alpha^s > 0$) and the negative hedging demand elasticity estimate ($\phi^d < 0$) imply $0 > \phi^s > \phi^d$ or $\frac{1}{\phi^s} < \frac{1}{\phi^d} < 0$.