Can Time-Varying Currency Risk Hedging Explain Exchange Rates?

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Abstract

Over the last decade foreign bond portfolio positions in US dollar assets have risen above the reciprocal US investor positions in foreign currencies. In periods of increased economic uncertainty, institutional investors hedge their international bond positions, which creates a net hedging demand for dollar assets that depreciates USD rates in both the forward and spot markets. We document the time-varying nature of this net hedging demand and show that it can account for approximately 30% of all monthly variation in the seven most important dollar exchange rates from 2012 to 2022.

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1 Introduction

Foreign portfolio positions in US bond markets have increased steadily in the past ten years. Figure 1 shows that the holdings of US bonds by the euro area, the United Kingdom, Canada, Australia, and New Zealand have more than doubled since 2012. In contrast, the holdings of US investors in most foreign bonds remained relatively low.[1]

With institutional investors holding half of total global financial assets (FSB (2021)), increasing gross and net international bond positions not only turns foreign institutional investors into important players in US bond markets, but also creates strong and time-varying demand for foreign exchange (FX) hedging.[2] Such currency hedging by institutional investors depends on the perceived exchange rate risk. Liao and Zhang (2021) document that the share of currency risk hedged by nine large Japanese insurance companies fluctuates greatly between 40% and 80%. Similarly, new evidence by Sialm and Zhu (2023) shows that the hedge ratio of US bond funds can vary over time between close to zero and up to 90%, depending on market conditions such as economic uncertainty. The average hedge ratio is 18%. Accordingly, the net hedging demand for USD forward contracts can greatly vary and become a major determinant of the exchange rate.

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

[1] US investment in foreign bonds (green line in Figure 1) exceeds foreign investment in US bonds (blue line in Figure 1) for Australia, New Zealand, and Canada. However, it has remained constant or decreased in the last 10 years.

[2] According to the Bank for International Settlement, BIS (2019), institutional investors increased their trading in FX swaps by almost 40% between 2013 and 2019. In the same period, institutional investors' trading in FX spot markets have increased by only 15%. As of April 2019, the average daily trading volume of FX swaps account for 50% of the total FX market turnover, while the market share of the average daily volume of FX spot trades reached 30%.

In this paper, we explore three research questions related to such FX risk hedging: Is the interaction between economic uncertainty and (negative) net US foreign bond positions in various currencies a key driver of the net hedging quantities — also referred to as hedging pressure — in forward markets? Does such time-varying hedging pressure influence the long-run and short-run dynamics of the forward and spot rates? What overall variation of the monthly dollar exchange rate in the seven most liquid currencies can be accounted for by this hedging channel of exchange rate determination?

The theory of optimal hedging has distinguished between a pure hedging component sensitive to expected FX volatility and speculative motive which seeks excess returns (Anderson and Danthine (1981)). Our data does not allow us to clearly separate the derivative positions along different trading motives. However, we focus on the net demand of fund institutions for which the hedging motive is likely to dominate. We find no evidence that the aggregate net hedging position of all funds yields any positive excess return what would support a speculative motive on the direction of the exchange rate.[3]

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) hedging pressure emanating from investment funds, which typically have market making banks as their counterparty.

But global banks themselves feature a limited risk-bearing capacity (Gabaix and Maggiori (2015)) and tend to off-set forward rate exposure through a combination of spot rate and bond transaction at matched maturities (synthetic forwards). Given this covered interest parity (CIP) arbitrage relationship between the forward and spot rate, a larger net hedging

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

demand for dollar balances tends to simultaneously appreciate both the dollar forward and spot rate; their monthly changes feature a high correlation of 0.99.[4]

Our empirical analysis proceeds in four steps to elucidate this hedging channel of exchange rate determination. First, we investigate in Section 4 the fundamental determinants of (net) hedging pressure in the seven most liquid currency pairs. As we focus on the quantitatively large and increasing hedging demands of institutional investors, we conjecture that a measure of economic uncertainty like the CBOE volatility index (VIX) should represent important explanatory variables for their time-varying hedging pressure. However, as US and non-US investors have contrarian hedging demands with respect to non-US and US bonds, the net hedging demand should be proportional to the net foreign investment position (NIP) in any currency pairs. We confirm that the VIX, the NIP and, importantly, their interaction do indeed drive more than 30% of all variation in the hedging pressure emanating from institutional investors.

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

[4]See also Krohn and Sushko (2022) for a detailed examination of the close relationship between spot and swap rates as well as a strong co-movement of liquidity in the two markets. Some work still emphasizes the importance of CIP deviations since the global financial crisis as an expression of limited arbitrage between the dollar interest rate earned in the cash market and the synthetic dollar interest rate (Du et al. (2018b)). But we note that such CIP deviations are of limited quantitative importance for the overall exchange rate dynamics, as 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.

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

Third, we decompose changes in the hedging pressure into four components based on an error correction model that distinguishes between a short-term component predicted by innovations to economic uncertainty and the error correction term capturing the long-run equilibrium adjustment of (derivative) asset supply. These components feature statistically strong correlations in opposite directions with the monthly dollar spot rate changes and allow us to distinguish between the short- and long-run dynamics of exchange rate changes. An error correction model for the spot rate in (contemporaneous) components of hedging pressure accounts for approximately 23% of the monthly spot rate variation.

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

Finally, we highlight that our analysis suffers from a number of measurement shortcomings that deserve to be highlighted. We construct measures of net hedging pressure based on CLS data that capture only a certain share of the overall institutional derivative demand. New and more complete documentation of derivative contracts—for example through the European Market Infrastructure Regulation (EMIR) data initiative—can diminish the attenuation biases inherent in our analysis. For the US net asset positions in bonds, we draw on US treasury data, which are also subject to numerous measurement and reporting issues (Coppola et al. (2021)). The hedging behavior of institutional investors is likely to be subject to considerable heterogeneity across investor types and countries, which only investor level derivative data can reveal. Improving all three 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 (see, for example, Rogoff (1996); Froot and Rogoff (1995); Frankel and Rose (1995)). The more recent literature emphasizes the role of international capital flows in determining exchange rates (Froot and Ramadorai (2005); Gabaix and Maggiori (2015)). Hau and Rey (2006) and Camanho et al. (2022) stress the importance of increasing gross foreign equity holdings and their systematic rebalancing for the exchange rate dynamics. This paper differs in its focus on foreign bond positions and how structural imbalances in foreign bond exposure interact with fluctuations in economic risk to create a time-varying net hedging demand.

As a theoretical foundation, our empirical framework is predicated on the notion that currency supply by the global dealer banks is imperfectly elastic and that large currency demand shocks can persistently impact the exchange rate (Gabaix and Maggiori (2015); Koijen and Yogo (2020); Greenwood et al. (2020); Gourinchas et al. (2020)). In particular, we conjecture that large currency shocks can originate in time-varying hedging demands for foreign bond positions, if their bilateral size is highly asymmetric. The causal logic follows what Liao and Zhang (2021) have termed the "hedging channel" of exchange rate determination: Asymmetric hedging demands between domestic and foreign investors in the forward rate market alter the forward rate and spill into spot rate changes because of arbitrage between the forward and spot markets. Czech et al. (2021) also examine this hedging channel in a recent study. They emphasize the negative consequences on domestic bond markets generated by the hedging channel due to margin call requirements for British insurance companies and pension funds during the recent COVID crisis. We improve on the understanding of the hedging channel by using a much richer data set that characterizes the hedging pressure for a large set of global institutional investors.

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

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

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

Our econometric approach falls short of the more ambitious attempt in Koijen and Yogo (2020) and Jiang et al. (2022) to identify a full system of asset supply and demand equations for FX balances. On the other hand, the error correction model in components of the hedging pressure estimated in this paper allows us to distinguish between the short- and long-run dynamics of the exchange rate adjustment, and is both transparent and parsimonious.

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

Two recent papers also address investment and currency choices and their relationship with exchange rates. Lilley et al. (2022) show that US purchases of foreign bonds can explain 35% of the quarterly variation in the US dollar for the period 2007-19. In their analysis, net US capital flows do not exhibit strong explanatory power for the exchange rate. In contrast, we stress the important role that existing net US bond holdings play in explaining the US dollar via the hedging channel. Furthermore, Adrian and Xie (2020) find that 37% of exchange rate fluctuations are explained by quarterly changes in foreign banks' demand for US dollars; however, it is difficult to evaluate how much of the banks' demand is due to intermediation services and so originates from other investor groups. Our analysis differs in its focus on the hedging decisions of non-bank financial institutions, a sector that represents an increasingly large and important part of the economy.[6]

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 Krishna-

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

murthy (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 in periods of increased economic uncertainty via the FX derivative market. 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 BIS. In spite of this incomplete coverage, we believe that it provides a fairly representative picture of the 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. Thus, FX swap contracts amount to follow-up contracts that simply extend the maturity of the currency hedge. In order to correctly capture the total stock of all net hedging in a currency, net hedging pressure from swaps needs to be added to that of outright forward contracts.

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

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

CLS provides two types of designations for market participants. First, CLS uses historical transaction patterns to identify market participants as price-takers and market-makers. Second, CLS categorises aggregate FX outstanding positions based on four institutional designations: (1) corporates; (2) funds (investment, pension, hedge, and sovereign wealth funds); (3) non-bank financial firms (insurance companies, brokers and clearing houses); and (4) banks. The first three types of institutions are generally considered price-takers while banks are the market-makers.[7] In the remainder of this paper, we focus on the hedging positions of the funds. On the demand side, they account for the largest volume share in the forward rate market irrespective of the exchange rate under consideration. For example, funds are a counterparty in 65% of all outstanding interest in forwards for the EURUSD rate. Their counterparty is 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 euros (EUR) and a short (long) position in US dollars (USD). To characterize the net hedging behavior of funds in a currency c, we follow the literature for commodity futures markets (see, e.g., Kang et al. (2020)) and define as hedging pressure the difference between all outstanding short and long positions by funds in US dollars scaled by the average outstanding contracts in currency c over the current and

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

last three quarters; formally

$$HP_{c,t} = 100 \times \frac{Dollar\ Short\ Positions_{c,t}^{Fund} - Dollar\ Long\ Positions_{c,t}^{Fund}}{\frac{1}{4}\sum_{i=0,1,2,3} Outstanding\ Interest_{c,t-i}^{Market}}. \quad (1)$$

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 average the outstanding interest over the current and the last three quarters to use a more time-invariant denominator.[8]

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

The buy and sell components of the hedging pressure, i.e., the daily buy and sell volume of forwards by funds, are plotted as 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 a speculative trading from a pure hedging motive. However, when we compute the daily profitability of the aggregate net fund positions, i.e., the product between the net short positions in US dollar rates and the return on the respective daily spot rate, we find no evidence for any profitability of this net aggregate position. This suggest that the speculative motive is likely to be secondary at the aggregate level. Figure A.3 in the Internet Appendix shows the

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

frequency distribution of the daily profit of aggregate net derivative positions by funds. The average daily net outstanding dollar short position of all funds is 60 billion USD, and the average daily profit is -54 million USD. A t-test for the null hypothesis of a zero profitability yields a t-statistics of -0.8387 and a p-value of -0.4017. If speculative FX trading were important, we would expect the daily profits to be significantly positive both in an economic and statistical sense.

3.2 Net Investment Positions

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

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

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

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

The monthly net investment positions constitute an imperfect structural proxy for the underlying net hedging pressure. Three aspects contribute to an imperfect alignment. First, the TIC data used for calculating the net investment positions in bonds are compiled based on the location of the institution in which the security is kept and is therefore subject to misclassification of the ultimate investor residence (see Coppola et al. (2021) for a comparison between the true economic bilateral investment positions and those sourced from TIC data). Second, the long-run holdings of bonds include all investor types, not just fund investors.[9] Third, equity funds can also contribute to the hedging pressure $HP_{c,t}$ even though we ignore their net investment positions in the calculation of the $NIP_{c,t}$, which is limited to bond holding. Fourth, both investment institutions and their investors can have different risk aversions and risk perceptions, so that the currency risk exposure captured by the $NIP_{c,t}$ can translate into very different levels of risk hedging and hedging pressure $HP_{c,t}$. In spite of these measurement discrepancies and attenuation effects, we conjecture a structural relationship between both variables, namely that a larger net investment position in bonds predicts a more positive hedging pressure from funds, particularly in times of high uncertainty.

3.3 FX Data, Uncertainty, and the Basis

We focus on monthly US dollar spot and forward rates with respect to the seven most liquid currencies: Euro (EUR), British pound (GBP), Japanese yen (JPY), Swiss franc (CHF), Canadian dollar (CAD), Australian dollar (AUD), and New Zealand dollar (NZD), all sourced from Bloomberg. The exchange rates are quoted in units of foreign currency per USD. An increase in the exchange rate corresponds to appreciation of the USD and 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

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

period (September 2012-March 2022).

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

To capture the time-varying component of hedging pressures even better, we consider the Chicago Board Options Exchange's Volatility Index (VIX_t) that is based on S&P 500 index options, as a measure of valuation uncertainty in the equity market. The risk measure concerns the US economy and is not specific to any particular currency rate. However, if higher uncertainty triggers more symmetric hedging of foreign portfolio positions by US and foreign investors, the quantitative imbalance in their respective holdings (i.e. the $NIP_{c,t}$) *interacted* with the degree of uncertainty should predict the hedging pressure. We therefore use interaction terms $NIP_{c,t} \times VIX_t$ as additional explanatory variables.[10]

Lastly, we incorporate into our analysis the so-called Treasury basis constructed by Du et al. (2018a) and sourced from Wenxin Du's website.[11] Formally, the Treasury basis is defined as the difference between the yield on a cash position in the US Treasury denoted $y^\$_{c,t}$ and a synthetic dollar yield derived from a cash position in foreign government bonds, that earns $y^*_{c,t}$ in foreign currency c, and swapping into US dollars,

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

Jiang et al. (2021) show that this Treasury basis represents a time-varying premium that international investors are willing to pay for holding US dollar denominated safe assets rather than treasuries in other currencies. The $Basis_{c,t}$ tends to widen in periods of financial

[10]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.

[11]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).

distress, when a high demand for safe dollar assets generates a yield gap between US and foreign government bonds. At a monthly frequency, the component $f_{c,t} - s_{c,t}$ is small, as the forward rate $f_{c,t}$ closely tracks the spot rate $s_{c,t}$. We note that the panel correlation between monthly changes in the Treasury basis and monthly changes in the VIX is modest at -15%.

3.4 Funds and Other Market Participants

We focus on fund investors as the main source of demand variation in FX forward markets. To justify this choice, we consider briefly other market participants and discuss their importance 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 each investor group add up to zero. This is illustrated in Figure 4 Panels A–D, which plots the positional imbalance (relative to all outstanding contract volume) for funds, banks, corporates, and non-bank financial institutions, respectively. As banks are the liquidity providers in the market, their net position in forward contracts turns negative if funds demand more hedging of their foreign (bond) investment position. Over the 10-year period 2012-22, the percentage forward positional imbalance of funds (i.e. hedging pressure) tended to become more positive in all seven dollar exchange rates, whereas banks took 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.[12] Only for the CHFUSD rate do we see larger positive hedging demands by non-bank financial institutions—presumably the dollar risk hedging of large Swiss insurance companies.[13]

[12]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.

[13]We run a robustness test in which we include the percentage positional imbalances of non-bank financial institutions in the definition of the hedging pressure (otherwise limited to fund investors). Only for the CHFUSD rate do we find the increased explanatory power of hedging pressure under this alternative definition.

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

4 Determinants of Hedging Pressure

In this section, we explain the FX hedging behavior of funds as a function of two main variables, namely the US net investment positions in bonds and the level of macroeconomic uncertainty. Importantly, net imbalances in bilateral bond positions in the other currency should interact with macroeconomic uncertainty and also account for the time-varying hedging pressure. We first explore the long-run relationships in levels, and in a second step characterize the short-run dynamics using monthly changes in the respective variables.

In Table 2, Columns (1)-(3), we regress the monthly hedging pressure $HP_{c,t}$ in currency c on the contemporaneous US net foreign investment positions $NIP_{c,t}$, the monthly economic uncertainty captured by the VIX_t and their interaction term. Formally,

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

where α_c denotes a currency fixed effect. The univariate regression in Column (1) shows a positive coefficient estimate for $NIP_{c,t}$, which is statistically significant at the 1% level. An increase of NIP by 47 percentage points (or 1 SD) increases the hedging pressure by 15.2 percentage points ($= 47 \times 0.324$), which amounts to roughly 12 standard deviations of its monthly change given by 1.25. In other words, when foreign holdings of US bonds exceeds the reciprocal US holdings of foreign bonds, the hedging demand for shorting the dollar exceeds the demand for shorting foreign currencies and creates positive hedging pressure. Additionally, higher uncertainty is associated with significantly higher hedging pressure (against the background of generally positive NIP values). As shown in Column (2), a one standard deviation increase in uncertainty (= 6.76) increases hedging pressure by 2.48 percentage points ($= 6.76 \times 0.365$) or almost 200% of the standard deviation of its monthly change. Under the full specification in Column (3), the point estimates for the coefficients on $NIP_{c,t}$ and VIX_t stay positive and significant, but now the added interaction between NIP and uncertainty is also positive and statistically significant. This suggests that if changes in NIP are positive (negative), higher uncertainty is associated with disproportionately larger (smaller) dollar short positions, or equivalently disproportionately higher (lower) hedging pressure. We note that our parsimonious specification has considerable explanatory power and explains roughly 30% of total (level) variation for the hedging pressure variable.

We defined both hedging pressure $HP_{c,t}$ and the net investment positions $NIP_{c,t}$ relative to outstanding interest and total investment, respectively. This implies a bounded support. While both variables cannot feature a unit root, their evolution nevertheless shows a low degree of mean reversion. As shown in Table A.5 of the Internet Appendix, the Levin-Lin-Chu test fails to reject the null hypothesis that each of the two level variables is integrated. However, the residuals of the linear regression of hedging pressure on its three explanatory variables in Table 2, Column (3), appear stationary and we can reject the null of non-stationarity at the 12% level. This is indicative of a stable long-run (cointegration) relationship captured in Table 2, Column (3), and motivates an error correction model.

To characterize the short-run dynamics for changes in the hedging pressure $\Delta HP_{c,t}$, we estimate the relationship stated in Eq. 4 in differences, and add the error correction term $HP_{c,t-1} - \hat{\beta}_1 NIP_{c,t-1} - \hat{\beta}_2 VIX_{c,t-1} - \hat{\beta}_3(NIP_{c,t-1} \times VIX_{t-1})$ as additional control variable. Table 2, Columns (4)-(5), report the regression results for the error correction model. The error correction term in Columns (4) and (5) has the expected negative sign and is statistically highly significant. This indicates a slow mean reversion of hedging pressure to a (stable) long-run relationship that links the level of net hedging in any currency to the net investment position and its interaction with economic uncertainty. However, the overall explanatory power of the error correction model for short-run dynamics of hedging pressure is very low as indicated by the low R^2 of only 4%. Overall, short-run monthly changes in hedging pressure are not very predictable based on monthly changes of our explanatory variables.

In the absence of a large positive net investment position (for example at $NIP = 0$), a positive innovation $\Delta VIX > 0$ correlates negatively with contemporaneous changes in hedging pressure ΔHP in Table 2, Column (5). This short-run reduction in outstanding net hedging positions suggests that the supply of forward contracts (by banks) diminishes under increased economic uncertainty. A leftward supply curve shifts can more than compensate a modest rightward demand curve shift if the supply side is even more volatility sensitive than the demand side.

However, the contemporaneous correlation between ΔHP and ΔVIX turns positive for very positive values of the net investment position. For example, for countries with net investment positions at or above the 75 percentile of around 80%, such as Switzerland and Japan, a monthly increase in uncertainty given by a one standard deviation of the monthly VIX change (= 5.55) implies an increase in hedging pressure by 0.05 percentage points ($80 \times 0.0603/100 \times 5.55 - 0.0394 \times 5.55 = 0.05$). This corresponds to 4% (= 0.05/1.25) of the standard deviation of monthly hedging pressure changes over all seven currency pairs. The cross-sectional (short-run) dynamics of aggregate derivative trading by funds faced with varying levels of economic uncertainty is thus influenced by the level of net bond holding vis-à-vis the US.

5 Exchange Rate Effects of Hedging Pressure

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

Analogous to the previous section, we start our analysis with a level regression of exchange rates on hedging pressure and the two-year yield spread. Table 3, Panel A, Column (2), shows that the exchange rate level covaries positively with the hedging pressure and negatively with the yield spread between foreign and US bonds. Intuitively, low foreign bond yields make net positions in dollar denominated bonds attractive and the associated long-run bond inflows can appreciate the dollar relative to the foreign currency. At the same time, larger net investments in USD bond markets come with more net FX hedging captured by (the level of) $HP_{c,t}$. The explanatory power of this simple (level) regressions is high in light of an adjusted R^2 of 42%. Corresponding level regressions for the forward rate in 3, Panel B, Column (2), generate almost identical results. A cointegration test suggests that the regression residuals are stationary unlike the two explanatory variables (see Table A.5 in the Internet Appendix).

5.1 Short-Run FX Dynamics and Hedging Pressure Changes

Stationary residuals in the level regressions of Column (2) suggest a simple error correction model for the short-run exchange rate dynamics given by

$$\Delta s_{c,t} = \alpha_c + \gamma_t + \beta_1 \Delta HP_{c,t} + \beta_2 \Delta(y^*_{c,t} - y^{\$}_{c,t}) + \beta_3 ECT_{c,t-1} + \epsilon_{c,t+1}, \tag{5}$$

where $\Delta s_{c,t}$ denotes the monthly change in the spot rate of foreign currency c vis-à-vis the US dollar, α_c and γ_t denote currency and time fixed effect, respectively, $\Delta HP_{c,t}$ represents the monthly change in hedging pressure, $\Delta(y^*_{c,t} - y^\$_{c,t})$ captures the monthly change in the spread between the two-year foreign currency government bond yield and the two-year US Treasury yield, and $ECT_{c,t-1}$ denotes error correction term given by the residual of the level regression in Column (2). Positive values of $\Delta s_{c,t}$ denote a dollar appreciation.

Table 3, Panel A, Columns (3)-(6), shows the panel regression results with changes in the spot exchange rate as a dependent variable. In Panel B, we present analogous results for the three-month forward rate change as an alternative dependent variable. As spot rate changes and forward rate changes are highly correlated at 99%, we expect the same factors to explain both the spot rate and the forward rate dynamics.

For both the spot and forward rate change, we find in Column (3), Panel A and B, respectively, a similar negative coefficient estimate for $\Delta HP_{c,t}$, which is statistically significant at the 1% level. A point estimate of around -0.52 implies that a one-standard deviation increase of the monthly hedging pressure change (1.25) depreciates the dollar rate by 0.65%, or roughly a quarter of its monthly standard deviation (2.46). This demonstrates an economically meaningful relationship between changes in hedging pressure and both the spot and forward rate change. Monthly changes in hedging pressure from funds explain alone roughly 7% of the contemporaneous monthly variation in the exchange rate.

Panel A, Column (4), presents the regression results when adding changes in the government yield spread and the Treasury basis as additional explanatory variables. We include changes in the US Treasury basis following recent findings by Jiang et al. (2021).[14] In contrast to changes in the basis, yield spread changes between foreign and US two-year bonds

[14]They show that positive changes in the basis coincide with an immediate depreciation of the dollar and exhibit explanatory power for a dollar currency basket in a much longer sample dating back to 1991. We highlight that our analysis here is limited to a time span of only 10 years, but seeks to explain the entire cross-section of seven dollar exchange rates. As documented in Panel A, Column (4), we do not find statistically significant correlations between exchange rate changes and changes in the basis. This finding differs from Jiang et al. (2021) who find such a relationship for a dollar basket (including Norway and Sweden) over a much longer period in quarterly data from 1991Q2 to 2017Q2.

are statistically highly significant. A monthly yield spread increase in favor of the foreign bond yield by one standard deviation (15.44) comes with a 0.56% depreciation of the respective dollar rate. This is in line with the traditional uncovered interest parity relationship (UIP), which requires positive innovations to the yield spread to predict a future dollar depreciation. An alternative explanation (based on capital flows) is that foreign fund investors could find it less attractive to maintain their large net US bond positions when the yield spread between foreign and US bonds evolves in favor of the foreign bond. Rebalancing then consists of swapping dollar positions for foreign currency holdings, which should depreciate dollar rates. This can also account for the observation that a widening yield spread in favor of foreign bonds coincides with a depreciating dollar.

Our preferred specification in Column (5) adds the error correction term as an additional explanatory variable and its coefficient is negative and statistically highly significant. Yet the coefficients for the changes in hedging pressure, $\Delta HP_{c,t}$, and in yield differences, $\Delta(y^*_{c,t} - y^\$_{c,t})$ remain quantitatively unchanged. The error correction model accounts for roughly 18% of the overall monthly variation of both the spot and forward rate. This represents a very high adjusted R^2 by the standards of empirical exchange rate modelling.

We also note that at monthly frequencies, additional lagged terms of the hedging pressure change 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.

Overall, these panel regressions suggest that monthly increases in the hedging pressure are associated with a short-run depreciation in the dollar spot rate. The conjectured underlying relationship is that time-varying macroeconomic uncertainty triggers variations in the dollar short positions of foreign funds seeking to insure their dollar investment against exchange rate risk. In the long-run, more fundamental forces like the yield spreads (or changing investment opportunities in general) influence net asset positions in bonds and account for the positive correlation between the exchange rate level and the net hedging level.

We highlight that the logic of "flight to safety" implies the opposite movement for the dollar exchange rates (Baele et al. (2020)). If investors seek an increased dollar bond investment in times of more uncertainty, we expect dollar inflows to increase the demand for dollar balances and appreciate dollar exchange rates in line with limited supply elasticity for dollar balances. By contrast, increased hedging of existing bond positions implies a short-term dollar rate depreciation whenever macroeconomic uncertainty increases.

As a robustness check, we estimate the error correction model also on a daily, weekly, and quarterly frequency. The results are reported in Table A.4 with corresponding summary statistics of the variables documented in Table A.3. Across all frequencies, the coefficient estimate for contemporaneous changes in hedging pressure is statistically and economically significant. We also find that the coefficient estimate on the basis change becomes statistically significant at the daily frequency and the estimate is negative, as in Jiang et al. (2021). However, lagged values of the explanatory variables are generally not statistically significant, which is consistent with a low degree of short-run predictability for exchange rate changes.

5.2 A Decomposition of Hedging Pressure Changes

Like any quantity measure in financial markets, hedging pressure is influenced both by derivative demand and supply forces. Our discussion so far focused on the (short-term) demand determination of hedging pressure which can rationalize the negative coefficients found Table 3, Panels A and B, Columns (3)-(6). In this section, we decompose changes in hedging pressure into four components, which feature different combinations of asset supply and demand effects and therefore imply different exchange rate sensitivities. The components are computed as the fitted values from the linear regression in Table 2, Column (5), so that:

$$\Delta HP_{c,t} = \widehat{\Delta HP}_{c,t}^{\Delta VIX} + \widehat{\Delta HP}_{c,t}^{\Delta (NIP \times VIX)} + \widehat{\Delta HP}_{c,t}^{ECT} + \Delta HP_{c,t}^{Residual}. \qquad (6)$$

The first two components in Eq. 6 capture changes in hedging pressure that coincide with changes in market uncertainty. A positive shock to VIX increases hedging demand (i.e. a right shift of the asset demand function), but can simultaneously reduce the supply (i.e. a left shift of the asset supply function), if banks become more reluctant to accommodate increases in net outstanding interest. Such a combination of a positive asset demand and negative supply shocks predicts a particularly large price response in terms of the expected dollar depreciation.

The long-run relationship between the observed net hedging pressure and market conditions is described in Table 2, Column (3). It also denotes the long-run equilibrium supply of forward contracts in each currency and the error correction term (ECT) characterizes the (temporary) asset supply shortfall. Banks can meet such a shortfall in the medium and long run by adjusting the liability structure of their balance sheet. For example, they can increase their dollar funding at the expense of euro funding to satisfy any increased demand for net short positions in the USD. The hedging pressure component $\widehat{\Delta HP}_{c,t}^{ECT}$ captures the gradual closing of any asset supply gap between short- and long-run supply. Such a gradual closing of a supply shortfall (i.e. a move of the supply curve) predicts *ceteris paribus* a positive correlation between $\widehat{\Delta HP}_{c,t}^{ECT}$ and the spot and forward rate changes.

To test these conjectures about the components of the hedging pressure, we repeat the benchmark regression for the (log) spot rate change, $\Delta s_{c,t}$ in Table 3, Panel A, Column (5), and replace changes in total hedging pressure by its four components. Table 4 reports the corresponding results. The table shows that the components of hedging pressure that is explained by monthly changes in the VIX, or its interaction with the net investment position (NIP), drives the previous negative correlation between dollar rate changes and changes in *total* hedging pressure. The regression coefficients for these components are almost 10 times more negative than the coefficient (of -0.45) obtained for total hedging pressure in Table 3, Column (5).

By contrast, the hedging pressure component $\widehat{\Delta HP}_{c,t}^{ECT}$ that captures the long-run asset supply adjustment yields a large positive coefficient of 3.37. In other words, the gradual mean reversion of hedging pressure to its long-run equilibrium level features the opposite positive correlation with spot and forward rate changes compared to (short-term) volatility shocks that generate a strong negative correlation between hedging pressure and the dollar rates. We also note that error correction model for the spot rate with decomposition of institutional hedging pressure into its components in Table 4, Column (5), accounts for 23% of the total monthly spot rate variation compared to only 15% when we use total institutional hedging pressure in Table 3, Column (5).

6 A VAR Model of the Exchange Rate

In this part of our analysis, we estimate a simple VAR model, which allows us to describe the impulse response function in Section 6.1 and undertake a forecast error variance decomposition in Section 6.2.

We estimate a VAR composed of only two variables, namely hedging pressure, $HP_{c,t}$ and the log spot exchange rate $s_{c,t}$. VAR models are often estimated in levels because specifications in difference tend to be less robust to specification issues such as incorrect long-run restrictions supported by pretests (Gospodinov et al. (2013)).[15] To improve the stationarity properties of the panel we subtract (for each currency pair) fitted time trends from each variable and obtain thus two panels for which we can reject the null hypothesis of non-stationarity (see Table A.5). We order the variables to form the vector $\mathbf{x}'_{c,t} = [HP_{c,t}, s_{c,t}]$ and obtain the structural form

$$\mathbf{Ax_t} = \mathbf{Bx_{t-1}} + \mathbf{u_t}, \tag{7}$$

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

[15] Specifically, we bypass the pretests required for a vector error correction model, i.e., cointegration tests and tests on the selection of the cointegration rank, both of which suffer from low power. Note also that estimates from a VAR in levels are consistent even in the presence of a unit root or cointegration, while falsely imposing a unit root by differencing the data renders the estimators inconsistent (Kilian and Lütkepohl (2017)).

Multiplying Eq. 7 by the inverse matrix $\mathbf{A^{-1}}$ produces the reduced form representation with the matrix $\mathbf{C} = \mathbf{A^{-1}B}$ for lagged coefficients and a variance-covariance $\mathbf{\Sigma} = (\mathbf{A'A})^{\mathbf{-1}}$. We estimate the VAR with one lag, as suggested by the Akaike information criterion (AIC), and remove a linear trend from hedging pressure and the spot rate before including them in the VAR to address concerns about non-stationarity.

The variable ordering for the VAR is motivated by several observations. First, we restrict hedging pressure to respond contemporaneously to FX prices and so assume that FX hedging decisions by funds take time to respond to changes in FX prices. Moreover, we assume that hedging decisions by funds depend on forward-looking risk evaluations that could involve the second moment of the exchange rate change, but not recent level changes.

6.1 Impulse Response Functions

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

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

6.2 Variance Decomposition

Finally, we use the VAR to evaluate the overall contribution of elementary hedging shocks to variance in the spot exchange rate. Figure 6 shows the forecast error variance decomposition of the stacked dollar rates. Hedging pressure shocks account for a large proportion of the exchange rate forecast error variance, ranging from 8% in the short run to 29% after 20 months. To put the number into context, note that Koijen and Yogo (2020) find that short-term rates and debt quantities account for 8% and 2% of the variation in exchange rates, respectively. Thus, a contribution of about 30% to exchange rate variation generated by shocks to hedging pressure is economically significant and validates the hedging channel of exchange rate determination. This economic significance is even more remarkable in light of the measurement problems listed in Section 3.1. CLS covers only about 20% of the total outstanding positions in FX derivatives, which implies that the non-attenuated significance of hedging pressure for the exchange could well be higher.

7 Conclusion

Our exploration of the "hedging channel" for exchange dynamics started from the observation that US net asset positions in bonds have become increasingly negative over the last decade. Such increasing overseas funding of dollar denominated bonds can generate massive FX hedging demands from foreign funds, which increasingly dominate FX derivative markets. At the same time, global banks, as liquidity providers, face more stringent capital requirements, and limit their liquidity provision to arbitrage between the spot and forward rates. Under these circumstances, time-varying hedging demands that follow the funds' risk perceptions can significantly impact both the forward and spot rate dynamics, as shown in this paper.

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Table 1: Summary Statistics

We show summary statistics for various monthly variables pooled over seven different US currency pairs, namely c = EURUSD, GBPUSD, JPYUSD, CHFUSD, CADUSD, AUDUSD, NZDUSD. The variables include the log nominal spot exchange rate, $s_{c,t}$, expressed as foreign currency per USD; the log one-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 month-end observations and are reported in percentage terms, the Treasury basis is in basis points, and the interaction term $NIP_{c,t} \times VIX_t$ is divided by 100. The Δ symbol denotes differences from the previous month. The sample covers the period September 2012-March 2022. The Treasury basis is reported only until March 2021.

	Obs.	Mean	S.D.	Median	P25	P75	Min	Max
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Level variables								
$s_{c,t}$	805	70.37	164.35	15.51	−11.43	34.09	−53.68	482.15
$f_{c,t}$	805	70.28	164.29	16.14	−11.67	34.20	−53.61	482.03
$(y^*_{c,t} - y^\$_{c,t})$	805	−0.40	1.32	−0.35	−1.08	0.15	−3.60	2.92
$Basis_{c,t}$	721	−5.24	27.99	1.31	−24.97	13.48	−88.77	60.01
$HP_{c,t}$	805	12.20	8.13	12.77	6.19	16.83	−4.35	32.82
$NIP_{c,t}$	805	28.27	47.02	33.36	−18.15	78.76	−55.38	92.70
VIX_t	805	17.58	6.76	15.87	13.41	19.20	9.51	53.54
$NIP_{c,t} \times VIX_t$	805	5.05	8.78	4.96	−2.78	11.91	−10.98	44.95
Monthly differences								
$\Delta s_{c,t}$	798	0.19	2.46	0.17	−1.33	1.79	−7.74	9.13
$\Delta f_{c,t}$	798	0.19	2.46	0.16	−1.32	1.77	−7.98	9.04
$\Delta(y^*_{c,t} - y^\$_{c,t})$	798	−1.61	15.44	−1.70	−9.78	4.92	−91.12	91.10
$\Delta Basis_{c,t}$	714	−0.03	6.28	0.10	−3.87	3.81	−28.50	27.69
$\Delta HP_{c,t}$	798	0.17	1.25	0.16	−0.59	0.92	−5.47	5.31
$\Delta NIP_{c,t}$	798	0.13	2.40	−0.00	−0.53	0.66	−13.48	22.96
ΔVIX_t	798	0.04	5.55	−0.09	−2.74	2.15	−19.39	21.27
$\Delta(NIP_{c,t} \times VIX_t)$	798	0.03	3.00	0.02	−0.86	0.98	−16.43	17.49

Table 2: Determinants of Hedging Pressure

We report pooled panel regressions in which the monthly (net) hedging pressure, $HP_{c,t}$, in seven US dollar currency pairs is regressed on the foreign net asset position, $NIP_{c,t}$, of the respective country with the US, the monthly CBOE volatility index (VIX_t), and the interaction term $NIP_{c,t} \times VIX_t$. Columns (4)-(5) estimate an error correction model based on the cointegration vector $HP_{c,t} - \hat{\beta}_1 NIP_{c,t} - \hat{\beta}_2 VIX_{c,t} - \hat{\beta}_3 (NIP_{c,t} \times VIX_t)$. Robust, two-way clustered standard errors by currency and time are shown in the parentheses. We denote by *, ** and *** the significance levels at the 10%, 5% and 1%, respectively. The sample period starts on September 28, 2012 and ends on March 31, 2022.

Dep. variables:	Hedging Pressure, $HP_{c,t}$			$\Delta HP_{c,t}$	
	(1)	(2)	(3)	(4)	(5)
$NIP_{c,t}$	0.3237***		0.2702***		
	(0.1240)		(0.1008)		
VIX_t		0.3653***	0.2466***		
		(0.0827)	(0.0903)		
$NIP_{c,t} \times VIX_t$			0.2078***		
			(0.0538)		
$\Delta NIP_{c,t}$				−0.0081	−0.0191
				(0.0185)	(0.0186)
ΔVIX_t					−0.0394***
					(0.0118)
$\Delta(NIP_{c,t} \times VIX_t)$					0.0603***
					(0.0132)
Error correction term					
$HP_{c,t-1} - \hat{\beta}_1 NIP_{c,t-1} - \hat{\beta}_2 VIX_{t-1} - \hat{\beta}_3 (NIP_{c,t-1} \times VIX_{t-1})$				−0.0321***	−0.0297***
				(0.0119)	(0.0101)
Currency FEs	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.1821	0.1622	0.3088	0.0173	0.0397
Observations	805	805	805	798	798

Table 3: Exchange Rates Dynamics and Hedging Pressure

We report in Panels A and B panel regressions for the (log) spot rate and the (log) three month forward rate, respectively. Columns (1)-(2) provide regressions results in levels and Columns (3)-(6) in monthly differences. Columns (5)-(6) estimated an error correction model using errors of the level regression in Column (2). The explanatory variables are the (net) hedging pressure from investment funds, $HP_{c,t}$, the spread of the two-year foreign treasury yield minus the two-year US Treasury yield, $(y^*_{c,t} - y^\$_{c,t})$, and the currency basis, $Basis_{c,t}$. 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).

Panel A: Spot Market

Dep. variable:	Spot Rate, $s_{c,t}$		Spot Rate Changes, $\Delta s_{c,t}$			
	(1)	(2)	(3)	(4)	(5)	(6)
$HP_{c,t}$	0.5251***	0.2607**				
	(0.1418)	(0.1170)				
$y^*_{c,t} - y^\$_{c,t}$		−5.4685***				
		(1.0350)				
$\Delta HP_{c,t}$			−0.5198***	−0.5078***	−0.4507***	−0.3148***
			(0.1799)	(0.1691)	(0.1592)	(0.0784)
$\Delta(y^*_{c,t} - y^\$_{c,t})$				−0.0363**	−0.0362**	−0.0622***
				(0.0151)	(0.0153)	(0.0117)
$\Delta Basis_{c,t}$				−0.0023	−0.0027	0.0068
				(0.0129)	(0.0140)	(0.0240)
Error Correction Term						
$s_{c,t-1} - \hat{\beta}_1 HP_{c,t-1} - \hat{\beta}_2(y^*_{c,t-1} - y^\$_{c,t-1})$					−0.0669***	−0.0722***
					(0.0179)	(0.0172)
Currency FEs	Yes	Yes	Yes	Yes	Yes	Yes
Time FEs	No	No	No	No	No	Yes
Adjusted R^2	0.1317	0.4215	0.0696	0.1134	0.1479	0.1809
Observations	805	805	798	714	714	714

Table 3 continued

Panel B: Forward Market

Dep. variable:	Forward Rate, $f_{c,t}$		Forward Rate Changes, $\Delta f_{c,t}$			
	(1)	(2)	(3)	(4)	(5)	(6)
$HP_{c,t}$	0.5084***	0.2565**				
	(0.1395)	(0.1168)				
$y^*_{c,t} - y^\$_{c,t}$		−5.2084***				
		(1.0328)				
$\Delta HP_{c,t}$			−0.5195***	−0.5081***	−0.4514***	−0.3154***
			(0.1791)	(0.1691)	(0.1592)	(0.0784)
$\Delta(y^*_{c,t} - y^\$_{c,t})$				−0.0348**	−0.0348**	−0.0609***
				(0.0152)	(0.0154)	(0.0117)
$\Delta Basis_{c,t}$				−0.0002	−0.0007	0.0089
				(0.0127)	(0.0138)	(0.0242)
Error Correction Term $s_{c,t-1} - \hat{\beta}_1 HP_{c,t-1} - \hat{\beta}_2(y^*_{c,t-1} - y^\$_{c,t-1})$					−0.0668***	−0.0723***
					(0.0179)	(0.0172)
Currency FEs	Yes	Yes	Yes	Yes	Yes	Yes
Time FEs	No	No	No	No	No	Yes
Adjusted R^2	0.1279	0.4003	0.0698	0.1105	0.1450	0.1784
Observations	805	805	798	714	714	714

Table 4: Exchange Rate Dynamics and Hedging Pressure Decomposition

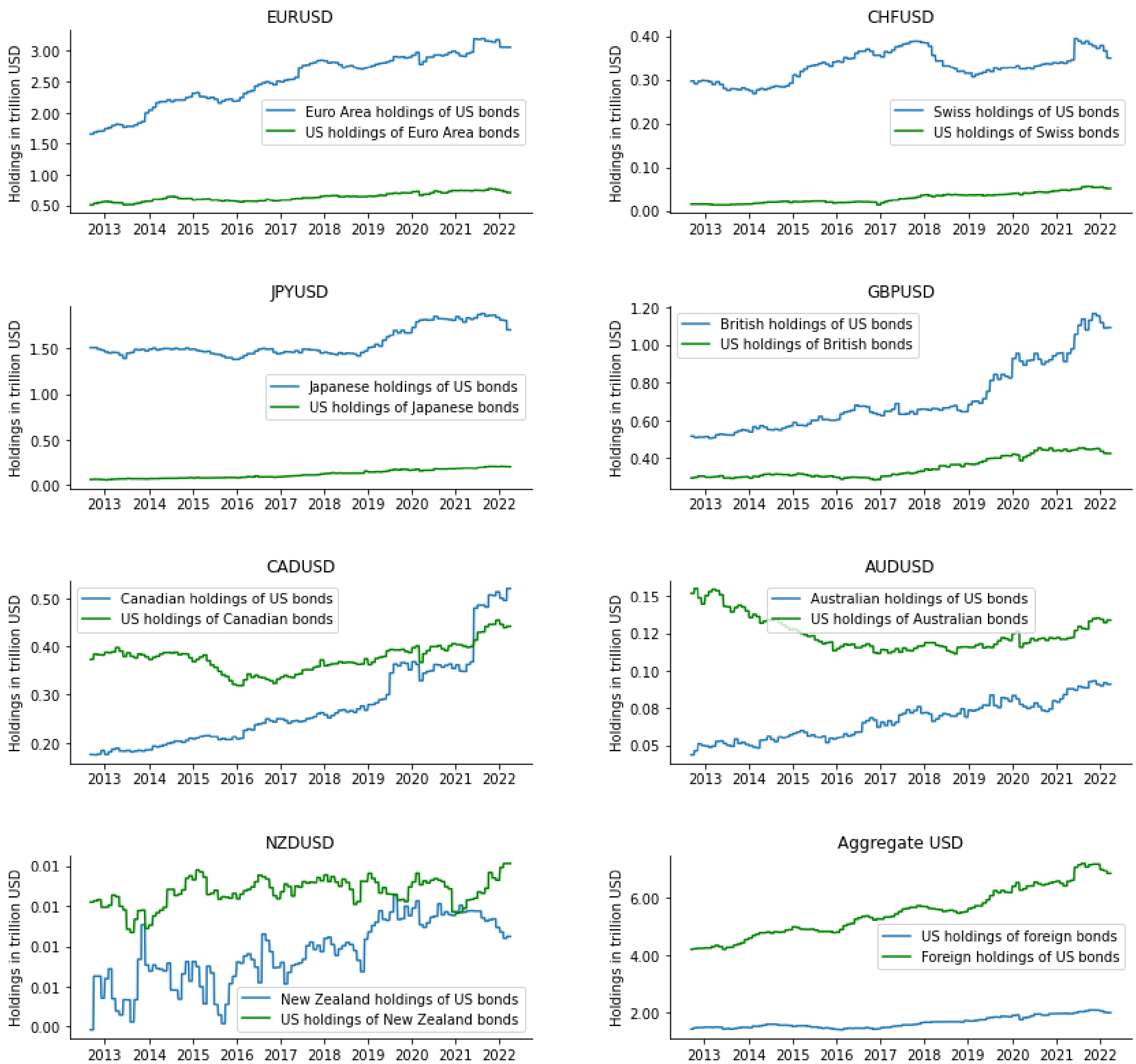
We repeat the benchmark regression for the (log) spot rate change $\Delta s_{c,t}$ in Table 3, Panel A, Column (5). The changes in hedging pressure are decomposed into four components based on the linear regression in Table 2, Column (5), hence

$$\Delta HP_{c,t} = \widehat{\Delta HP}_{c,t}^{\Delta VIX} + \widehat{\Delta HP}_{c,t}^{\Delta(NIP\times VIX)} + \widehat{\Delta HP}_{c,t}^{ECT} + \Delta HP_{c,t}^{Residual}.$$

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, $\Delta Basis_{c,t}$. The error correction term is based on the cointegration vector $s_{c,t} - \hat{\beta}_1 HP_{c,t} - \hat{\beta}_2(y^*_{c,t} - y^\$_{c,t})$. 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.

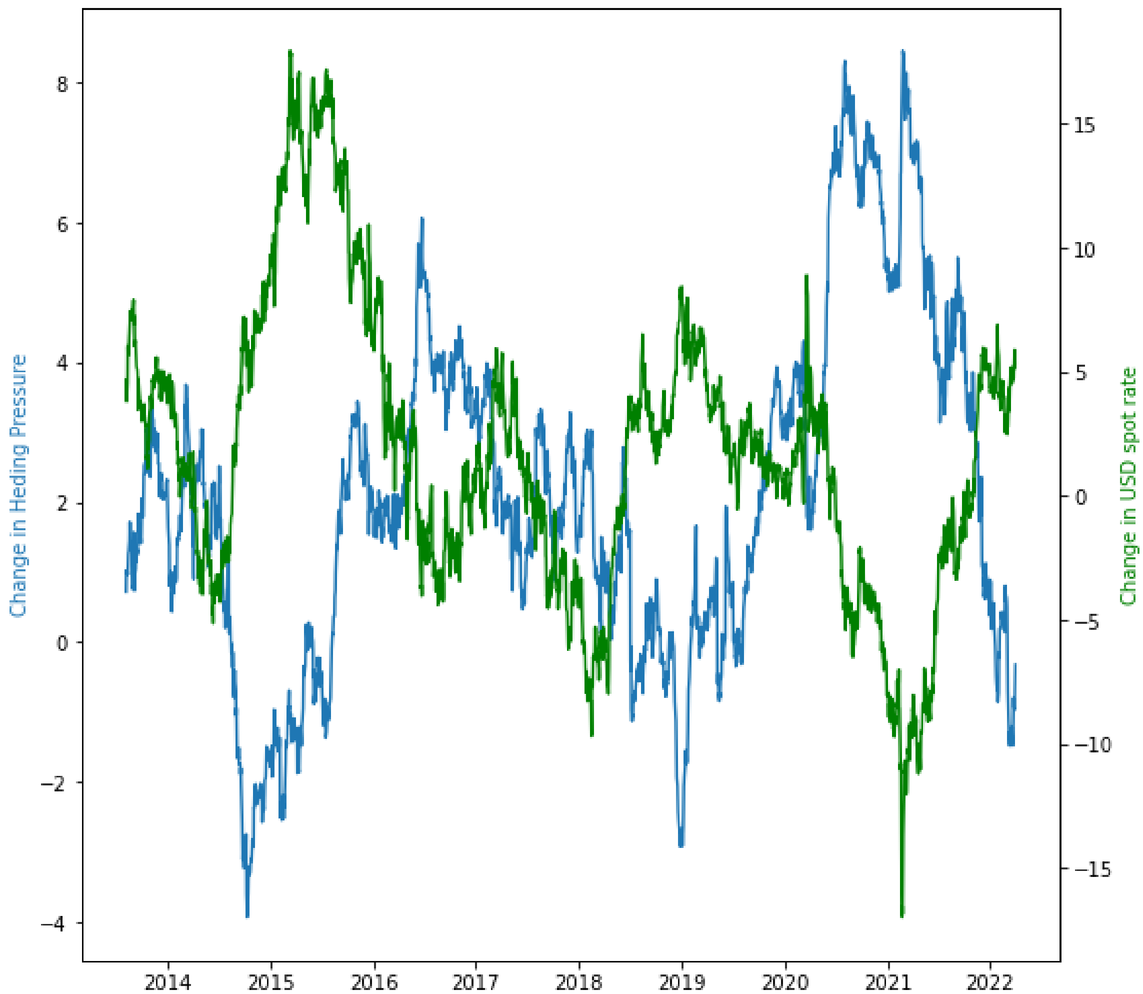
Dep. variable:	Spot Rate Changes, $\Delta s_{c,t}$				
	(1)	(2)	(3)	(4)	(5)
$\widehat{\Delta HP}_{c,t}^{\Delta VIX}$	−2.9934**				−3.4851***
	(1.2070)				(1.1299)
$\widehat{\Delta HP}_{c,t}^{\Delta(NIP\times VIX)}$		−3.3749**			−4.0312***
		(1.5550)			(1.4498)
$\widehat{\Delta HP}_{c,t}^{ECT}$			2.0798**		3.3710***
			(0.9879)		(1.1719)
$\Delta HP_{c,t}^{Residual}$				−0.3888**	−0.4302***
				(0.1649)	(0.1474)
$\Delta(y^*_{c,t} - y^\$_{c,t})$	−0.0448***	−0.0382**	−0.0384**	−0.0357**	−0.0435***
	(0.0131)	(0.0161)	(0.0160)	(0.0158)	(0.0118)
$\Delta Basis_{c,t}$	0.0124	−0.0020	−0.0016	−0.0043	0.0101
	(0.0176)	(0.0148)	(0.0153)	(0.0144)	(0.0138)
Error correction term					
$s_{c,t} - \hat{\beta}_1 HP_{c,t} - \hat{\beta}_2(y^*_{c,t} - y^\$_{c,t})$	−0.0716***	−0.0785***	−0.0880***	−0.0713***	−0.0753***
	(0.0160)	(0.0165)	(0.0178)	(0.0177)	(0.0185)
Currency FEs	Yes	Yes	Yes	Yes	Yes
Time FEs	No	No	No	No	No
Adjusted R^2	0.1605	0.1021	0.1075	0.1343	0.2306
Observations	714	714	714	714	714

Figure 1: International Bond Holdings Across Exchange Rates



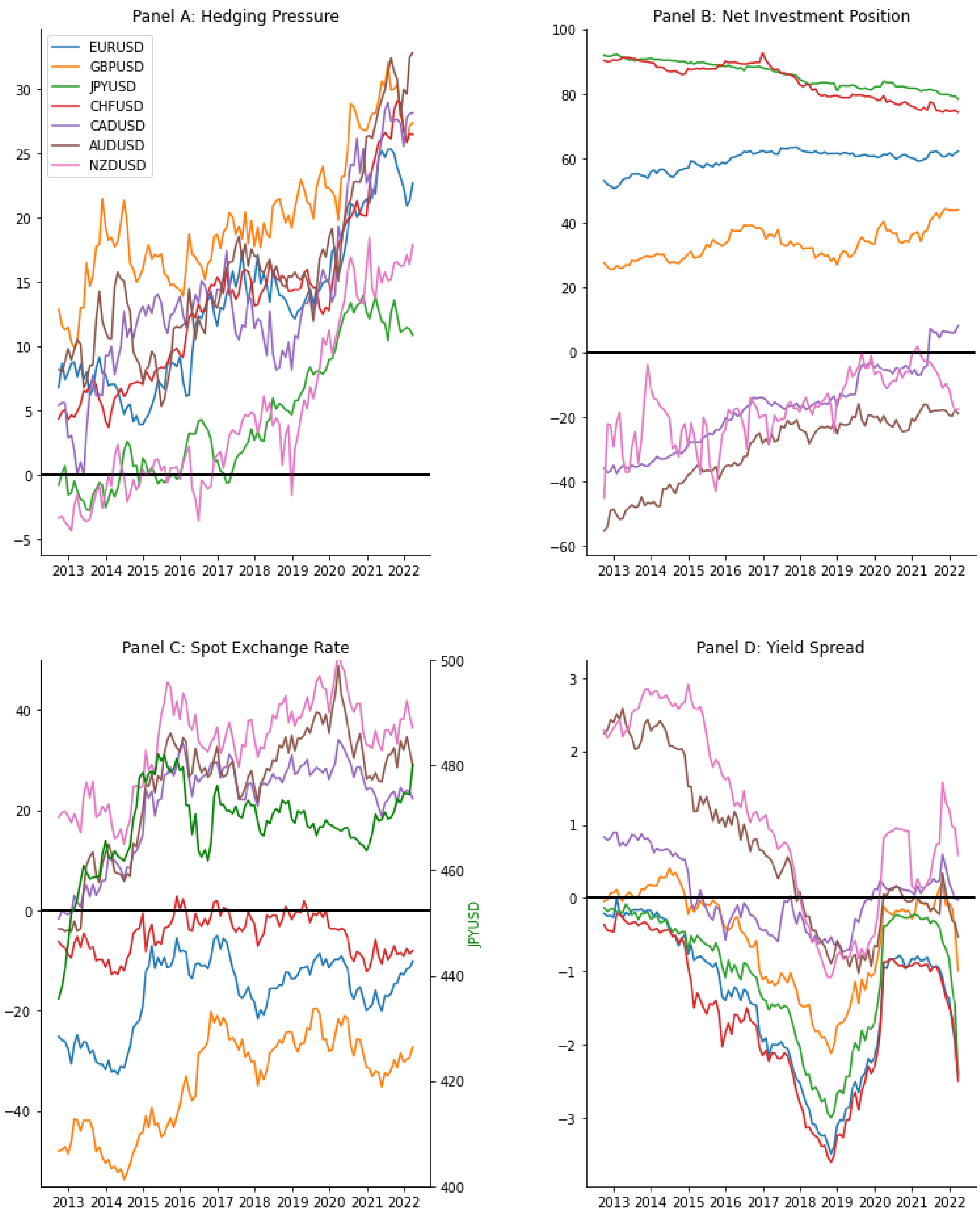
Notes: We plot the foreign long-term bond holdings in US bonds (blue line) and the US holdings of foreign long-term bonds (green line) over the period 2012-22 for seven different currency areas. The vertical scale denotes trillions of USD. The last panel shows the aggregate values. Source: Treasury International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

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



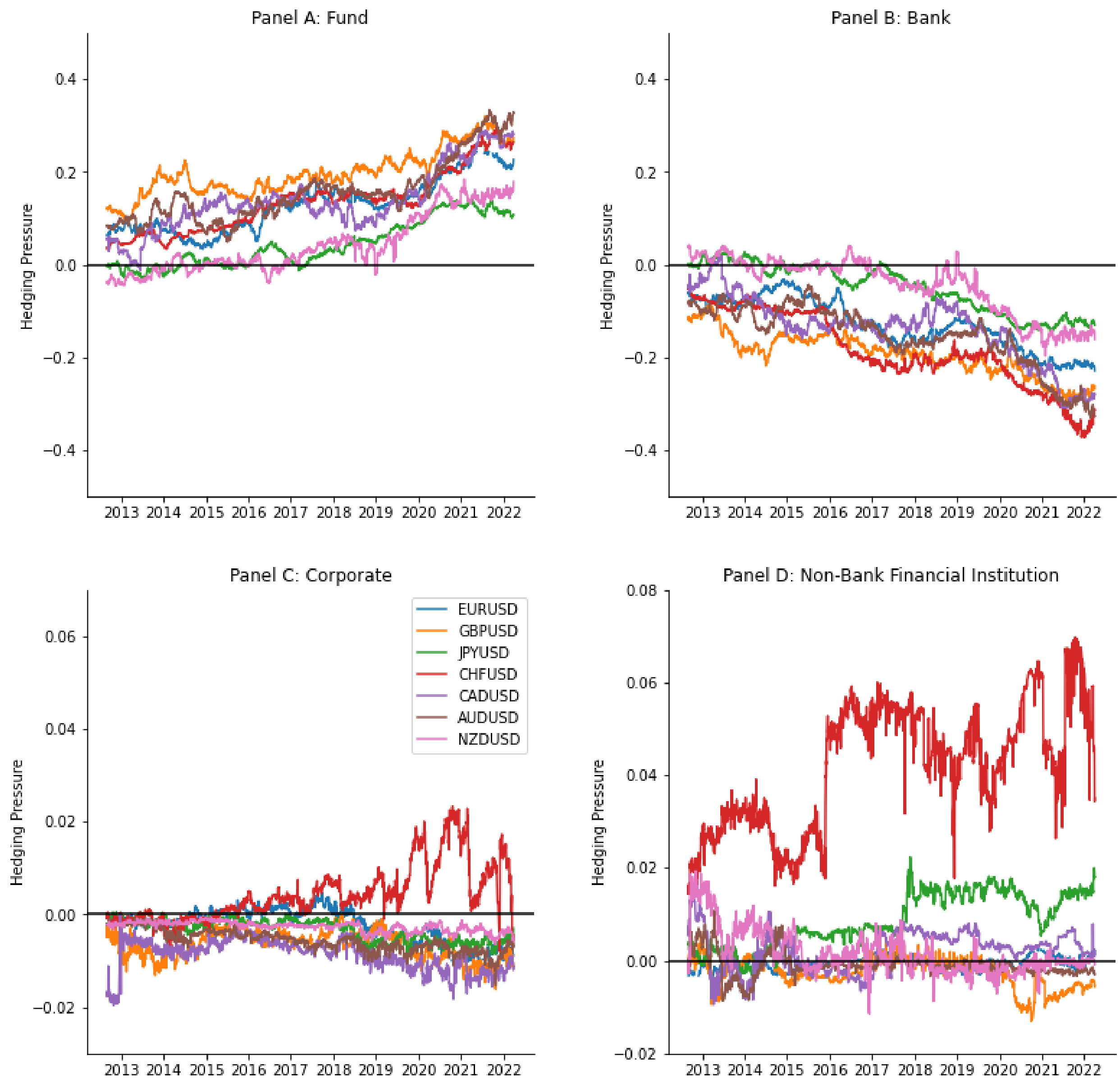
Notes: We graph the annual change in the hedging pressure emanating from forward contracts of funds (as reported by CLS) and the annual change in the (log) US dollar spot exchange rates. Both measures are computed as the cross-sectional average over all seven currencies. The negative correlation is -0.66.

Figure 3: Hedging Pressure and Net Investment Positions



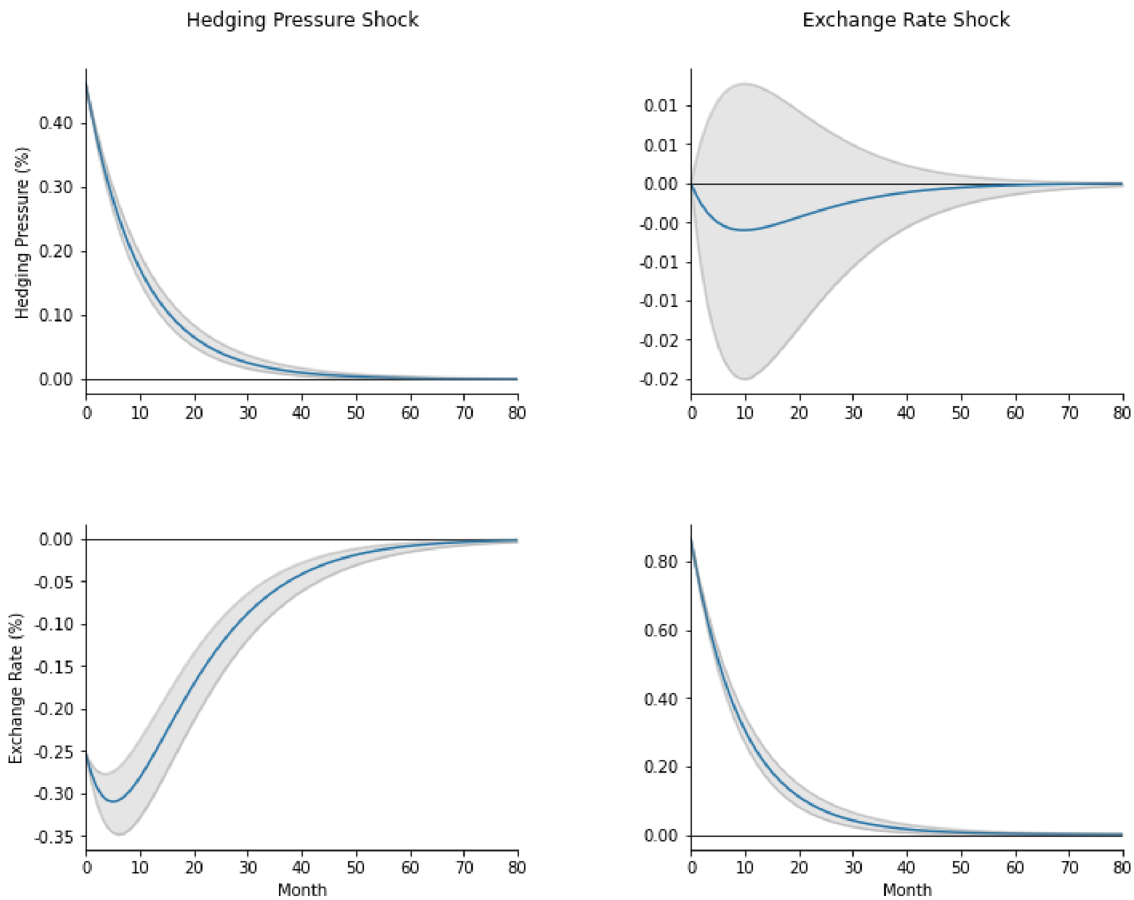
Notes: For seven dollar exchange rates, we plot hedging pressure in Panel A, the corresponding US net foreign investment positions in Panel B, the spot exchange in Panel C, and the difference between the foreign and US two-year government yield in Panel D. Note that in Panel C the Japanese yen spot rate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

Figure 4: Net Forward Positions by Investor Type



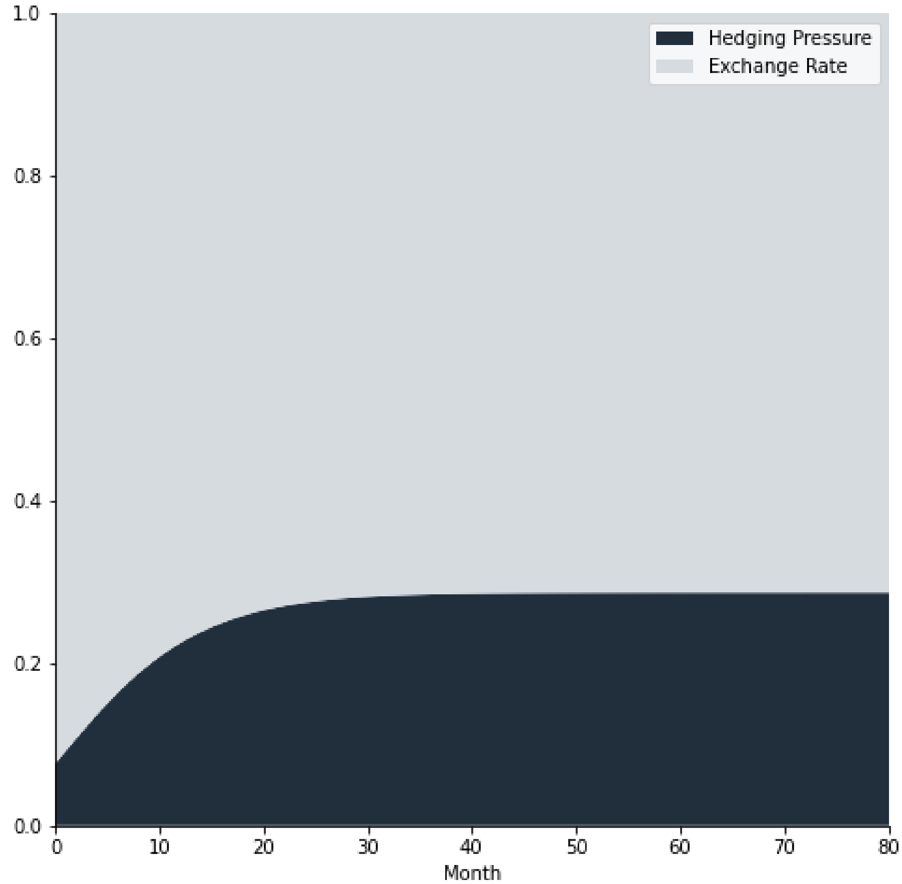
Notes: We show the (percentage) net outstanding forward positions (relative to the total outstanding contract volume) by type of market participant in the seven most liquid exchange rate markets. The CLS data distinguishes funds, banks, corporates, and non-bank financial institutions. We define as hedging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

Figure 5: Impulse Response Functions



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

Figure 6: Forecast Error Variance Decomposition of the Dollar



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

Internet Appendix

Can Time-Varying Currency Risk Hedging Explain Exchange Rates?

A Appendix 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. Source: CLS.

	Swap		Forward		Total		Total
	Mean	S.D.	Mean	S.D.	Mean	S.D.	March 2022
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
EURUSD	2360.35	263.96	314.88	43.61	2675.22	276.62	2763.85
GBPUSD	973.56	192.86	146.44	28.18	1120.01	211.74	1480.73
USDJPY	1315.53	303.66	158.24	33.36	1473.77	320.84	1914.43
USDCHF	385.13	48.79	51.11	13.67	436.24	59.63	553.99
USDCAD	331.83	100.72	74.37	19.03	406.20	115.98	633.39
AUDUSD	461.15	102.82	83.46	19.76	544.61	115.51	770.43
NZDUSD	101.82	26.75	24.38	5.97	126.20	29.95	170.23
Total	5929.38		852.87		6782.25		8287.04

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

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

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

Table A.3: Summary Statistics: Different Frequencies

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

	Daily Sample			Weekly Sample			Quarterly Sample		
	Obs.	Mean	S.D.	Obs.	Mean	S.D.	Obs.	Mean	S.D.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$s_{c,t}$	17381	70.27	164.22	3500	7028.60	16424.13	819	70.28	164.38
$f_{c,t}$	17380	70.18	164.16	3499	7020.72	16419.90	819	70.19	164.31
$(y^*_{c,t} - y^{\$}_{c,t})$	16374	-39.45	133.15	3493	-39.81	133.01	819	-0.40	1.32
$Basis_{c,t}$	15079	-4.84	28.08	3110	-4.96	28.03	735	-5.17	28.11
$HP_{c,t}$	17381	12.08	8.02	3500	1208.02	801.81	819	12.22	8.22
$\Delta s_{c,t}$	17381	0.01	0.56	3493	4.27	126.37	812	0.19	2.47
$\Delta f_{c,t}$	17379	0.01	0.56	3491	4.21	126.23	812	0.19	2.47
$\Delta(y^*_{c,t} - y^{\$}_{c,t})$	16374	-0.08	3.74	3480	-36.62	733.57	812	-1.58	18.29
$\Delta Basis_{c,t}$	14790	-0.00	2.50	3098	-0.00	3.93	728	-0.03	5.72
$\Delta HP_{c,t}$	17374	0.01	0.27	3493	3.83	59.34	812	0.16	1.27

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, $\Delta Basis_{c,t}$. The error correction term is based on the cointegration vector $s_{c,t} - \hat{\beta}_1 HP_{c,t} - \hat{\beta}_2(y^*_{c,t} - y^{\$}_{c,t})$. In all regression we add one lagged term of the change in hedging pressure, $\Delta HP_{c,t-1}$, and the change in the relative yield, $\Delta(y^*_{c,t-1} - y^{\$}_{c,t-1})$, as additional controls. All specifications include a constant that is not reported in the table. Robust, two-way clustered standard errors by currency and time are shown in the parentheses. We denote by *, ** and *** the significance levels at the 10%, 5%, and 1%, respectively. The sample period starts on September 29, 2012 and ends on March 9, 2021.

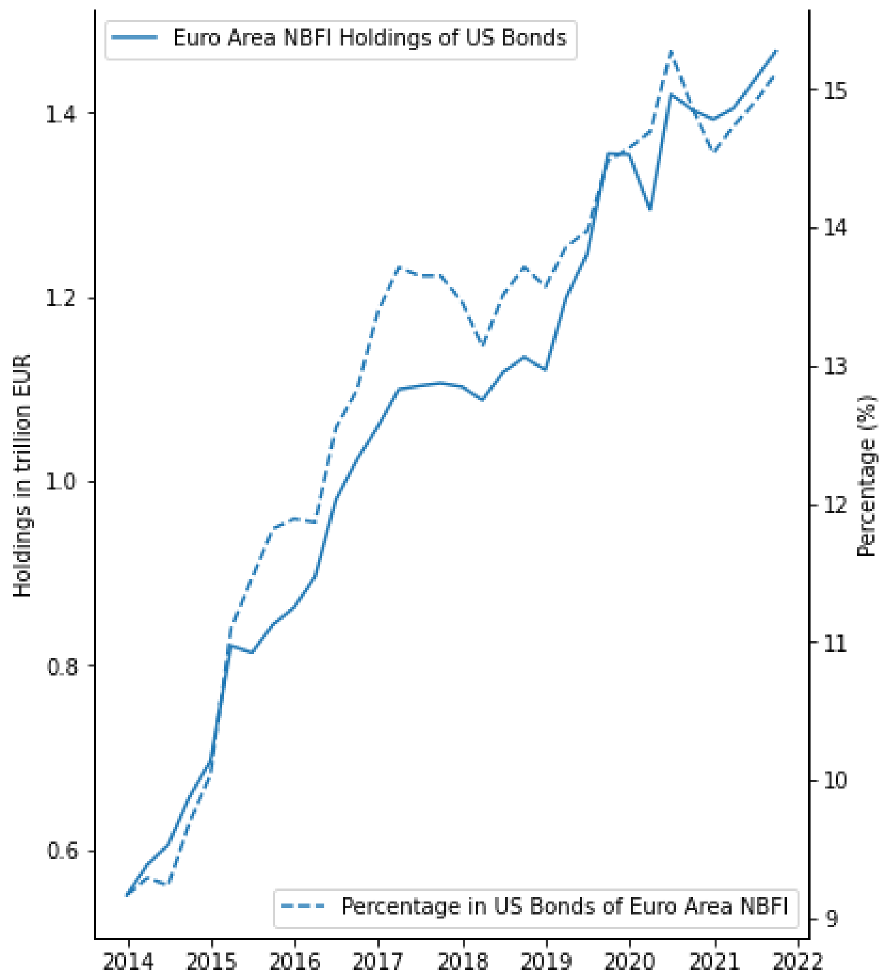
Dep. variable:	Spot Rate Changes, $\Delta s_{c,t}$			
	Daily	Weekly	Monthly	Quarterly
	(1)	(2)	(3)	(4)
$\Delta HP_{c,t}$	−0.2368***	−0.3293***	−0.2969***	−0.3812***
	(0.0765)	(0.1101)	(0.0853)	(0.1450)
$\Delta HP_{c,t-1}$	0.0160	−0.0210	−0.0218	0.0481
	(0.0170)	(0.0439)	(0.0619)	(0.0443)
$\Delta(y^*_{c,t} - y^{\$}_{c,t})$	−0.0412***	−0.0046	−0.0620***	−0.0231
	(0.0139)	(0.0040)	(0.0119)	(0.0242)
$\Delta(y^*_{c,t-1} - y^{\$}_{c,t-1})$	−0.0035	0.0027	0.0016	−0.0081**
	(0.0026)	(0.0047)	(0.0094)	(0.0040)
$\Delta Basis_{c,t}$	−0.0217**	−1.1768	0.0067	0.0189
	(0.0093)	(1.2467)	(0.0243)	(0.0324)
Error correction term				
$s_{c,t} - \hat{\beta}_1 HP_{c,t} - \hat{\beta}_2(y^*_{c,t} - y^{\$}_{c,t})$	−0.0040***	−0.0171***	−0.0721***	0.0024
	(0.0013)	(0.0043)	(0.0175)	(0.0126)
Currency FEs	Yes	Yes	Yes	Yes
Time FEs	Yes	Yes	Yes	Yes
Adjusted R^2	0.0741	0.0505	0.1760	0.0691
Observations	12595	3072	707	2163

Table A.5: Stationarity Tests

For various panel variables, we report test statistics for the null hypothesis of integration of order one, namely the Levin-Lin-Chu bias-adjusted t-statistics and in brackets the corresponding p-values. The Levin-Lin-Chu test is based on the regression, $\Delta x_{c,t} = \phi x_{c,t-1} + z'_{c,t}\gamma_c + \theta_c \Delta x_{c,t-1} + u_{c,t}$, where $x_{c,t}$ is the variable of interest, and the variable $z_{c,t}$ captures panel-specific means and/or time trends. Column (1) reports test statistics based a fitted mean and Column (2) those where we fit an additional time trend, respectively. The variables of interest are the hedging pressure from investment funds, $HP_{c,t}$; the net bond investment positions, $NIP_{c,t}$; the interaction between the net bond investment positions and the VIX given by $NIP_{c,t} \times VIX_t$; the spot rates, $s_{c,t}$; and the relative treasury yields, $(y^*_{c,t-1} - y^\$_{c,t-1})$. In addition, we test stationarity for two cointegration vectors.

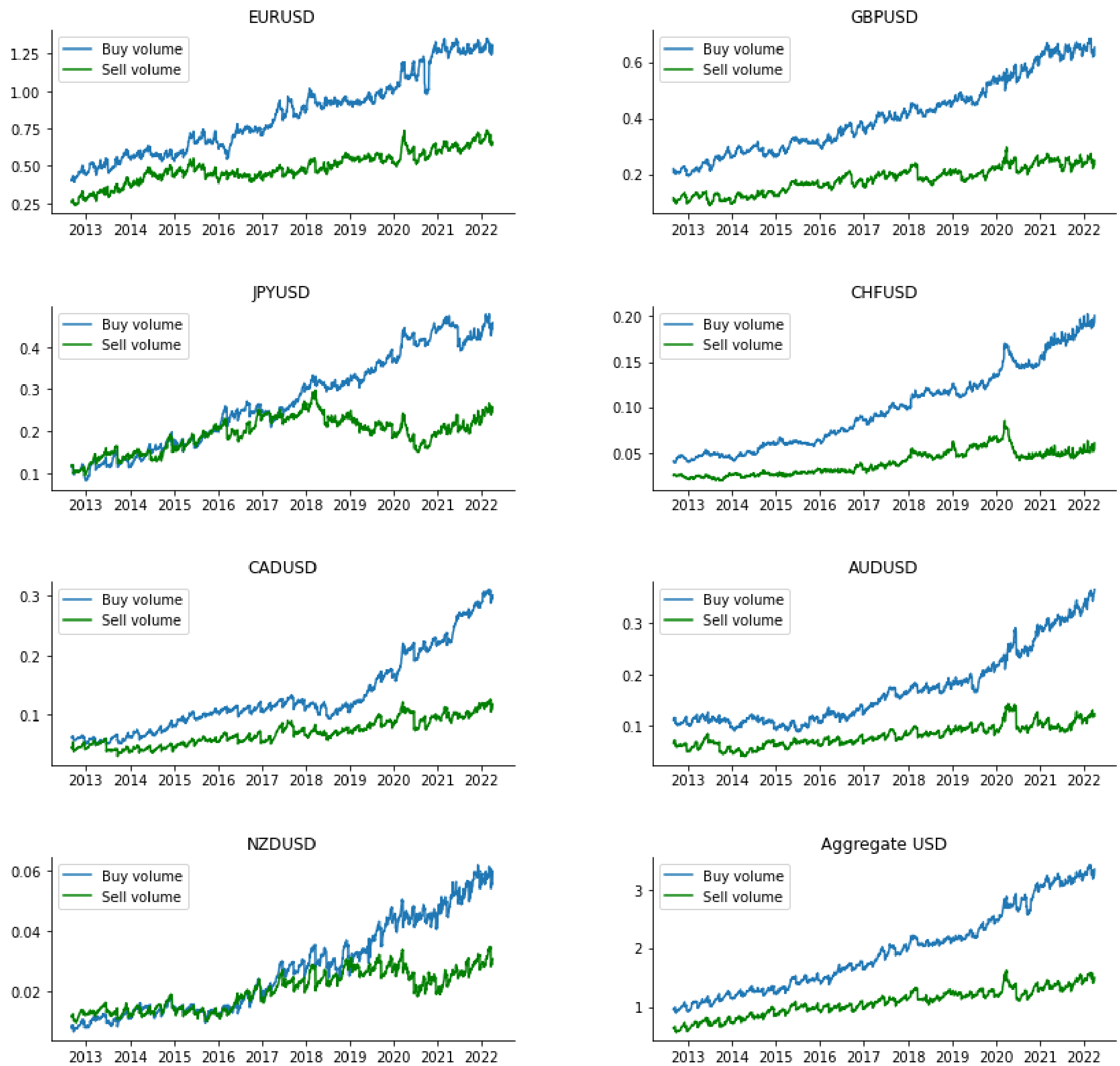
	Levin-Lin-Chu adjusted t-statistics (p-values)	
	(1)	(2)
$HP_{c,t}$	1.2436	-1.3770^{*}
	(0.8932)	(0.0843)
$NIP_{c,t}$	0.0050	-1.0487
	(0.5020)	(0.1472)
$NIP_{c,t} \times VIX_t$	-5.3503^{***}	-8.1450^{***}
	(0.0000)	(0.0000)
$s_{c,t}$	-2.8914^{***}	-1.3439^{*}
	(0.0019)	(0.0895)
$(y^*_{c,t} - y^\$_{c,t})$	0.5481	2.0381
	(0.7082)	(0.9792)
Error Correction Terms		
$HP_{c,t} - \hat{\beta}_1 NIP_{c,t} - \hat{\beta}_2 VIX_{c,t} - \hat{\beta}_3 (NIP_{c,t} \times VIX_t)$	-1.7996^{**}	-4.2791^{***}
	(0.0360)	(0.0000)
$s_{c,t} - \hat{\beta}_1 HP_{c,t} - \hat{\beta}_2 (y^*_{c,t} - y^\$_{c,t})$	-2.0961^{**}	-1.4811^{*}
	(0.0180)	(0.0693)
Linear Time Trend	No	Yes
Observations	805	805

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



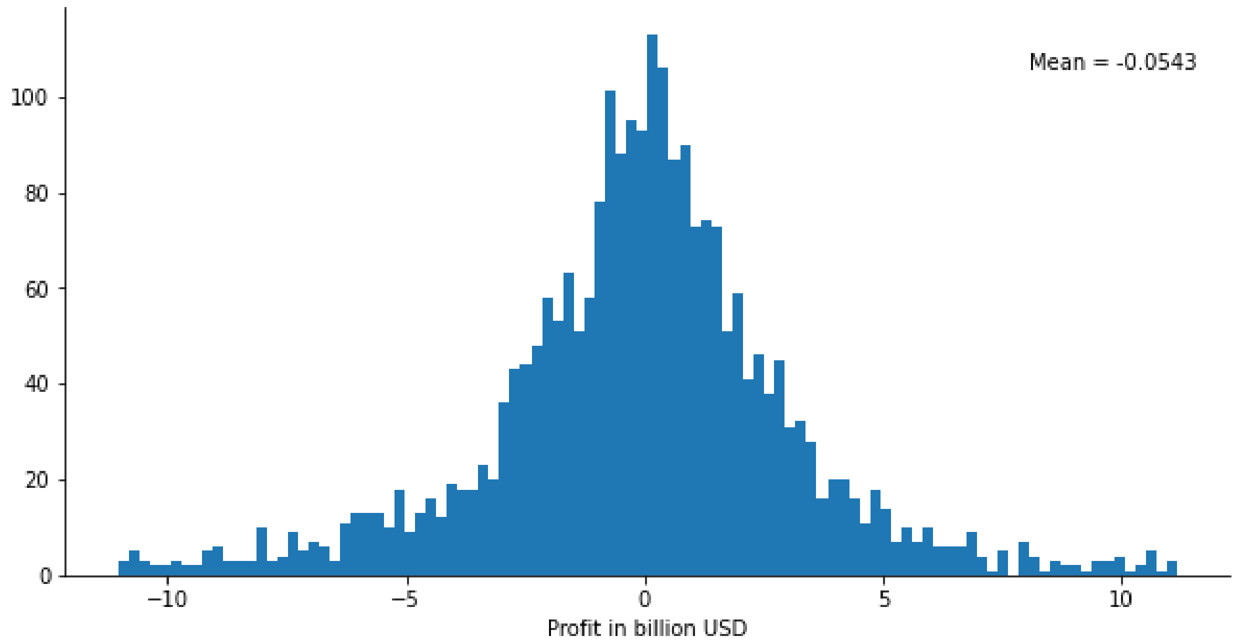
Notes: For all euro area non-bank financial institutions, we plot the long-term bond holdings for the period 2014-21. The left axis and non-dashed line denote the bond holdings in trillions of EUR, and the right axis and the dashed line report the percentage of US bonds in the overall bond portfolio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

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.