The Implications of CIP Deviations for International Capital Flows*

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Abstract

We study the implications of deviations from covered interest rate parity for international capital flows using novel data covering euro-area derivatives and securities holdings. Consistent with a dynamic model of currency risk hedging, we document that investors' holdings of USD bonds decrease following a widening in the USD-EUR cross-currency basis (CCB). This effect is driven by investors with larger FX rollover risk and hedging mandates, and it is robust to instrumenting the CCB. These shifts in bond demand significantly affect bond prices. Our findings shed light on a new determinant of international capital flows with important consequences for financial stability.

Keywords: Institutional Investors, Currency Hedging, FX Swap, Derivatives, Foreign Exchange.

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An important no-arbitrage pricing condition in foreign exchange (FX) markets is the covered interest rate parity (CIP).[1] Yet, since the Great Financial Crisis, FX markets have been exhibiting significant and persistent deviations from the CIP, referred to as the *cross-currency basis* (CCB) (Du et al., 2018). These deviations are particularly large in times of financial turmoil. Therefore, a first-order concern for global financial stability is that foreign investors withdraw from US dollar capital markets during such episodes and amplify the crisis (Shin, 2023). The Fed repeatedly reacted to this concern by intervening directly in FX swap markets, which serve as the main source of US dollar funding and hedging for foreign investors (Bahaj and Reis, 2022; Kekre and Lenel, forthcoming).[2] Whereas prior literature has mostly focused on the sources of CIP deviations, this work explores their consequences for international capital markets.

For this purpose, we combine two regulatory datasets that jointly cover the universe of FX derivatives and bond holdings in the euro area (EA). EA non-bank investors hold a total of EUR 2 trillion in USD bonds, of which approximately 40% are currency-risk-hedged using FX derivatives contracts with substantially shorter maturities (2.3 months) than the bonds (8.9 years). In a simple dynamic model, we show that this maturity mismatch implies that investors are exposed to cross-currency basis rollover risk: When the CCB widens, the net cost of rolling over hedging positions increases, which reduces demand for USD assets by EA investors. In line with these predictions, we find empirically that EA investors significantly rebalance from USD to EUR bonds in response to a wider CCB. Exploiting the granularity of our data, we show that this effect is driven by investors with larger FX rollover risk and currency hedging mandates. Moreover, we find that CCB-induced portfolio rebalancing significantly affects US corporate bond prices, consistent with an investor demand channel. These results are robust to instrumenting the CCB with a granular instrumental variable (GIV), which we construct using entity-level data on FX positions. Taken in combination, our findings suggest a causal impact of FX derivatives market frictions on international capital markets.

To guide our empirical investigation, we first develop a dynamic model of international capital and FX derivatives markets with limited arbitrage. In the model, EA investors allocate their portfolios between long-term assets denominated in EUR and USD and trade short-term FX derivatives. Because EA investors cannot directly borrow in USD,

[1] The CIP holds when the domestic risk-free interest rate is equal to the currency-risk–hedged foreign risk-free rate, referred to as the synthetic rate. Such a synthetic rate can be achieved by exchanging, for example, USD against EUR in the spot market to earn the risk-free euro rate while simultaneously entering into a forward contract that fixes the future exchange rate, which, as a bundle, is called an "FX swap."

[2] FX swaps have become the main source of international USD funding for foreign financial institutions, with an outstanding amount of $80 trillion globally (Eren et al., 2020; Borio et al., 2022; Shin, 2023).

those derivatives markets are essential to hedge currency risk. In contrast, currency arbitrageurs can directly borrow in dollars but face convex balance sheet costs, which generates an upward-sloping supply curve for FX forwards. This assumption accounts for the documented presence of frictions to currency dealer intermediation (Du et al., 2018; Huang et al., 2024). Due to the combination of a time-varying CCB and hedging maturity mismatch, EA investors are subject to rollover risk. A key insight of the model is that a widening of the CCB results in higher hedging costs, to which investors respond by reducing FX hedging positions and USD asset holdings. Moreover, shocks with high persistence increase investors' willingness to bear asset transaction costs, which results in both strong portfolio rebalancing and a weak impact on the CCB.

Guided by this theory, we empirically investigate the role of FX derivatives market frictions in international capital markets. To this end, we assemble a unique dataset containing confidential information on the entire universe of euro-area FX forward positions and bond holdings at the security level and merge several data sources available at the European Central Bank (ECB). We document several novel facts about currency risk hedging: (i) total gross volume in the USD-EUR FX derivatives market amounts to EUR 8 trillion—roughly equivalent to the size of the European repo market; (ii) FX positions have shorter maturity than bond holdings, with the average time to maturity of FX positions being 2.3 months compared with 8.9 years for USD bond holdings; and (iii) hedge ratios are heterogeneous across investors, with insurance companies hedging on average 38% of USD bond positions, investment funds 35%, and pension funds 57%. Instead, banks supply more hedging than they demand (-56%), with non-EA banks accounting for most of the net supply.

Our main analysis studies the relationship between investor behavior and the USD-EUR cross-currency basis. Across a series of empirical specifications, we consistently find significant reductions in euro-area investors' holdings of USD relative to EUR bonds in response to a widening of the CCB. Using granular fixed effects, we rule out the possibility that macroeconomic conditions or investor-specific exposure to aggregate shocks explain this correlation. However, the possible presence of currency-specific omitted variables and simultaneous supply and demand shocks could still bias our estimate. For example, an increase in the interest rate differential between the US and the EA may increase demand for USD bonds, and thereby widen the cross-currency basis and bias our OLS estimate.

We overcome this identification challenge by combining two approaches that take advantage of the granular nature of our data. First, motivated by the predictions of our model, we exploit heterogeneity across investors in their exposure to the CCB driven by rollover risk. To measure FX rollover risk exposure, we compute the investor-level share of FX hedging positions from the last quarter that matures in the current quarter. Second, we construct a granular instrumental variable for the CCB based on isolating idiosyncratic shifts in FX positions. Specifically, we purge daily investor-level FX positions from sector-by-country-wide shocks, which removes potentially confounding shocks at the aggregate, sector, and country level, as well as any combination of these. Due to the high concentration in the FX derivatives market, the remaining variation does not wash out in the aggregate (Gabaix, 2011). We follow Gabaix and Koijen (2024) and use the size-weighted average of this residual variation to aggregate FX demand shifts optimally. We show that these shifts result in significant movements in the CCB, which validates the instrument's relevance.

Using the granular instrumental variable, we first estimate the demand elasticity of FX positions. We find that a 1 bps widening of the CCB (7.5% of its standard deviation) reduces FX derivatives positions by 2% on average. The estimated coefficient suggests that FX demand is relatively inelastic, consistent with the presence of strong hedging motives (Liao and Zhang, 2021). We also find that FX demand elasticity is particularly large for investors with high rollover shares, emphasizing that these investors are more exposed to changes in the CCB.

Using the instrumental variable approach in our main analysis, we find that USD bond demand elasticity to the CCB remains highly significant. As expected from removing the confounding effects of changes in USD bond demand on the CCB, the IV estimate is slightly larger than the OLS estimate. We estimate that a 1 bps widening of the CCB reduces EA investors' holding of an average USD bond by 0.32% relative to EUR bonds. This magnitude aligns with existing estimates for the price elasticity of bonds and suggests that EA investors view currency-hedged USD and EUR bonds as close substitutes. It also implies economically significant international capital flows from large movement in the CCB, as expected in periods of crisis: The 5% largest observed shocks to the CCB are estimated to imply a decline of approximately EUR 100 billion in USD bond holdings by EA investors.

Furthermore, we find that the bond holdings of investors with high rollover risk exposure display a larger sensitivity to the CCB in both OLS and IV specifications. The difference between investors with high and low rollover risk is statistically significant and robust to including granular bond-by-time fixed effects when we compare the sensitivity across investors for the same bond at the same point in time. This finding suggests that the response of bond holdings to the CCB is driven by currency hedging activity rather than omitted macroeconomic confounders.

Whereas the baseline analysis is performed at bond level, we show that the results are consistent with portfolio-level regressions. The results also hold when additionally controlling for exchange rates (volatility) and when adjusting the instrument to heteroskedasticity in idiosyncratic volatility across investors as well as absorbing shocks to investors of different sizes (measured by gross FX positions).

We provide additional evidence on how CCB-driven portfolio rebalancing relates to hedging costs by exploring the FX hedging mandates of mutual funds. To this end, we extend our sample with data on mutual-fund-level bond holdings. According to a hedging cost channel, we expect funds with FX hedging mandates to be more sensitive to changes in the CCB since the mandate prevents them from reducing their FX position without reducing their USD bond position. Consistent with this hypothesis, we find that funds with hedging mandates exhibit a stronger reduction in USD bond holdings in response to a wider CCB than other funds in both OLS and IV specifications.

Finally, we explore the implications of CCB-driven investor rebalancing on asset prices. Our results suggest a decrease in demand for USD bonds following a widening in the CCB. Therefore, we expect the yields of exposed USD bonds to increase in response. We test this hypothesis by focusing on the secondary market yields of USD corporate bonds issued by US entities. Corporate bonds account for over half of the EA's USD bond portfolio. Due to some segmentation of bond markets, shifts in investor demand tend to be mirrored in bond prices (Coppola, forthcoming; Kubitza, 2023).

For the average bond in our sample, we document a weakly positive response in yields to an instrumented widening of the CCB. Consistent with our cross-sectional evidence on USD bond demand, we find that bonds held by investors with high rollover risk exhibit a strong and significant response to the CCB. US government debt yields exhibit a similar pattern, although without statistical significance—as expected from the low ownership of US treasuries by EA investors. In contrast, EA government debt held by high rollover investors experiences a significant decrease in yields following the rebalancing of EA demand to EUR bonds in response to a wider CCB. These results point to significant implications of CIP deviations for international asset prices.

Related Literature This paper builds on recent studies documenting persistent deviations from CIP since the Great Financial Crisis, driven by limits to intermediation capacity (Du et al., 2018; Andersen et al., 2019; Avdjiev et al., 2019; Correa et al., 2020; Cenedese et al., 2021; Rime et al., 2022; Du et al., 2023; Augustin et al., 2024; Moskowitz et al., 2024). Under such limits to arbitrage, international demand for USD funding and hedging have been shown to be a significant driver of the CCB (Aldunate et al., 2022; Kloks et al., 2024; Khetan, 2024), which emphasizes the importance of the USD as the international reserve currency (Coppola et al., 2024).[3] We extend this literature by investigating the consequences of CIP deviations for capital markets rather than its causes and focus on the interplay of institutional investors' currency hedging, portfolio allocations, and bond yields. Three closely related papers study consequences of CIP deviations—namely, for corporations' currency choice in bond issuances (Liao, 2020); foreign currency bank lending (Ivashina et al., 2015; Keller, 2024); and the impact of US monetary policy shocks on EA investors' risk-taking (Ahmed et al., 2021). Instead, we focus on the currency allocation of investors in the international bond market in response to fluctuations in the CCB.

Our analysis also connects to the literature on global capital allocation, surveyed by Florez-Orrego et al. (2023). Starting with French and Poterba (1991), a large literature documents the home bias of international investors (Coeurdacier and Rey, 2013). Maggiori et al. (2020) attribute home bias among investment funds to currency preferences, whereas Faia et al. (2022) examine the effects of currency preferences on yield differentials. Our finding that the CCB affects portfolio allocations suggests that frictions in FX derivatives markets may contribute to currency preferences. Thereby, we also complement the literature that links investor demand and exchange rates (Hau and Rey, 2004, 2006; Bruno and Shin, 2015; Camanho et al., 2022; Bräuer and Hau, 2023; Koijen and Yogo, 2024) by focusing on the CCB.

Prior literature has been constrained by the scarcity of available data on investor currency hedging activity. Du and Huber (2024) make significant progress by estimating industry-level hedge ratios based on hand-collected publications. They document that larger hedging demand in aggregate widens the CCB in a panel of currency pairs, which is consistent with our first-stage estimate's implication that idiosyncratic FX demand shifts reduce the USD-EUR CCB in the time series. Similarly, Sialm and Zhu (forthcoming) and Opie and Riddiough (2024) explore currency hedging by U.S. fixed-income and equity funds, respectively, based on hand-collected data from SEC filings. Alfaro et al. (2021) use a granular regulatory dataset on Chilean FX derivatives to study the currency hedging of nonfinancial firms. We extend these studies by exploiting detailed regulatory filings that cover the entire euro area.

Prior work on international macro-finance models also highlights the importance of currency risk in portfolio allocation (Campbell and Viceira, 2002; Campbell et al., 2010; Coeurdacier and Gourinchas, 2016). Traditionally, these models have studied optimal portfolios, assuming that currency risk is either fully hedged or unhedged. We contribute to this literature by jointly modeling currency portfolio allocation and hedging intensity

[3] Dávila et al. (2024) estimate the social cost of those CIP deviations based on price elasticity in the FX futures market.

in a model in which hedging is subject to endogenous CIP deviations, which generates cross-currency rollover risk.

1 Data

We create a novel panel data set that provides a complete account of euro-area investors' bond investments and their FX derivatives positions by combining detailed filings with European regulatory authorities. All financial variables are winsorized at the 1st and 99th percentiles. Appendix Table IA.1 provides an exhaustive overview of variable definitions and sources, and this section describes the main data sources and variables.

FX Derivatives The European Market Infrastructure Regulation (EMIR) adopted in 2012 requires that all investors report their derivatives transactions to European authorities. From the EMIR repository, made available to the ECB, we obtain contract-level information on all USD-EUR forward and swap positions of all euro-area investors starting in December 2018 (due to data quality) and ending in March 2024. We apply several filters to clean the data, which we detail in Appendix B. In particular, we homogenize information on swaps and forwards by converting each FX swap into two forward contracts. Investors are identified by their Legal Entity Identifier (LEI), which is used to obtain information on their domicile and sector following Lenoci and Letizia (2021). In most of the analyses, we focus on the FX market's most important financial sectors: banks (including dealers), investment funds, insurance companies, and pension funds. There are more than 16,000 entities, and they collectively account for nearly 90% of the total gross positions in the EA.

Throughout the paper, we define as *buy* positions those that require the investor to *buy* EURs against USDs in the future. With a buy position, the investor gains from a future weakening of the USD against the EUR. Hence, a buy position hedges the currency risk of USD-denominated assets. This is achieved either via a forward contract to buy EUR or via the long-dated leg of a swap whereby the investor that buys USD at the spot date commits to sell back the USD against EUR at maturity. We define an investor's net position as the difference between buy and sell positions.

The notional outstanding of each FX contract is measured in EUR. For contracts whose notional is originally denominated in USD, we convert the notional into EUR such that it is equal to the EUR amount exchanged at contract maturity. Therefore, changes in total notional outstanding do not mechanically result from exchange rate fluctuations.

Securities Holdings Our main analysis uses Securities Holdings Statistics by Sector (SHS-S) at the ECB, which provides confidential security-level information on the bond holdings of each euro-area country-sector pair (e.g., Dutch pension funds and German insurers). From SHS-S, we obtain the nominal amount of positions in EUR- and USD-denominated bonds of euro-area sectors at quarterly frequency from 2019Q1 to 2024Q1. Securities are identified by their International Security Identification Number (ISIN), which we use to enrich our data with information on the securities (e.g., currency denomination, issuance, and maturity dates) and their issuers (e.g., their industry and credit rating) from the ECB's Centralised Securities Database (CSDB). We exclude negative holdings, bonds with missing or multiple currency denominations, holdings reported in or after the quarter of bond maturity, and holdings reported before issuance.

We complement country-by-sector holdings from SHS-S with fund-level data from Lipper, which provides holdings data at market values at fund-by-bond level at quarterly frequency. We consider EUR and USD bond holdings of funds that are domiciled in the EA with EUR as their operating and reporting currency and that ever invested in USD assets. Importantly for our analysis, Lipper indicates whether a funds' share classes are mandated to hedge the foreign currency risk of holdings that are not denominated in the base currency.[4] We aggregate this indicator at fund level, and define funds with an FX hedging mandate for at least 10% of outstanding share classes on average as funds with a hedging mandate.

Bond Yields We retrieve secondary market yields of USD-denominated US corporate bonds at daily frequency from the Trade and Reporting Compliance Engine (TRACE), which records the near universe of U.S. corporate bond transactions. Merging TRACE data with SHS-S using 9-digit CUSIPs, we consider bonds with an average euro-area ownership share of at least 10% (relative to the amount outstanding). Data are cleaned of primary market trades and cancellations, corrections, and reversals following Dick-Nielsen (2014). We impute missing bond yields based on transaction prices and bond characteristics from Mergent FISD. Then, we aggregate bond yields to daily frequency by computing the transaction volume-weighted average daily yield. To remove variation in risk-free rates, we focus on yield spreads, defined as the difference between the daily secondary market yield and the treasury rate with the closest time to maturity. Determined by the availability of TRACE data, the final sample spans from April 2019 to August 2023. Finally, we use Mergent FISD to obtain information on maturity dates and credit ratings. We also consider US and EA government bond yields at daily frequency for 3

[4] Funds may have one or several share classes through which investors invest in the fund. Fund investments are pooled at fund level across share classes.

months and 1, 5, 10, and 20 years remaining to maturity. EA yields are from Thomson Reuters Datastream (which includes Austria, Belgium, Cyprus, Germany, Spain, Finland, France, Greece, Ireland, Italy, Lithuania, Netherlands, Portugal, Slovenia, and Slovakia) and US Treasury yields from FRED.

Cross-currency Basis We use Money Market Statistical Reporting (MMSR) to the ECB to extract information on spot and forward rates in the EA FX market. MMSR provides confidential information on all USD-EUR swap transactions by major EA banks. Using this data, we compute the daily transaction-volume-weighted average USD-EUR spot and forward rates for each maturity.

We define and measure deviations from covered interest-rate parity as the cross-currency basis (CCB). Following convention (Du et al., 2018), the τ-months CCB of EUR vis-à-vis the US dollar at time t, denoted by $\mathrm{CCB}_{t,\tau}$, is equal to the difference between the actual dollar interest rate and the synthetic dollar interest rate, obtained by converting the EUR interest rate into USD in the FX market:

$$\mathrm{CCB}_{t,\tau} = r_{t,\tau}^{USD} - \underbrace{\left(r_{t,\tau}^{EUR} - \frac{12}{\tau} \log \frac{F_{t,\tau}}{S_t} \right)}_{\text{Synthetic USD rate}}, \tag{1}$$

where $r_{t,\tau}^{USD}$ is the τ-months continuously compounded US dollar interest rate (USD LIBOR), $r_{t,\tau}^{EUR}$ the τ-months continuously compounded EUR interest rate (EURIBOR), S_t the USD-EUR spot exchange rate, and $F_{t,\tau}$ the τ-months USD-EUR forward rate.[5] We express exchange rates in units of EUR per USD—i.e., an increase in S_t is a depreciation of EUR relative to USD.

The CIP condition requires that $\mathrm{CCB}_{t,\tau} = 0$—i.e., that the return on direct USD investments corresponds to that of a synthetic USD investment. However, since the 2007–2008 financial crisis, $\mathrm{CCB}_{t,\tau}$ is typically negative (Du et al., 2018). Indeed, $\mathrm{CCB}_{t,\tau}$ is negative most of the time throughout our sample horizon (2018-2024) and based on the rates paid by euro-area counterparties (see Figure 2). In this case, directly investing in USD generates a lower return than swapping the EUR interest rate into USD. Hence, the more negative the $\mathrm{CCB}_{t,\tau}$, the higher the cost for euro-area investors (with EUR funding) to hedge their USD investments.

[5]Due to the cessation of LIBOR, it was replaced by the Secured Overnight Financing Rate (SOFR) in July 2023, which is adjusted to take the difference between secured and unsecured spreads into account.

2 Stylized Facts

We first use our novel dataset to document a series of salient facts about FX derivatives markets and USD bond holdings in the EA.

2.1 USD-EUR FX Derivatives Market

We compute the size of the USD-EUR FX derivatives market as the total notional amount outstanding of all USD-EUR FX contracts with at least one EA counterparty. The market has expanded from around EUR 6 trillion in 2019 to EUR 8 trillion in 2023 (see Appendix Figure IA.4). This approximately matches the size of the entire European repo market, which was EUR 10 trillion in 2022 (ICMA, 2023). The share of the FX market volume traded over the counter (OTC) approximately equals 70% and is stable throughout the sample horizon (see Appendix Figure IA.4).

Gross Positions Figure 1 (a) illustrates the distribution of gross positions in USD-EUR FX contracts across EA sectors. Banks dominate the market by accounting for more than 70% of gross positions, followed by investment funds (14%) and nonfinancial companies (8%). Financial investors (banks, investment funds, insurers, and pension funds) jointly account for nearly 90% of gross positions. Since the purpose of this paper is to study the hedging of financial assets, we focus on these four sectors.

Net Positions We further report each financial sector's net position in Figure 1 (b).[6] In contrast to gross positions, net positions are dominated by the investment fund sector, with a positive net position of more than EUR 500 billion. The pension fund sector has the second-largest net position of approximately EUR 100 billion. From 2019 to 2022, investment and pension funds have steadily increased their net positions, whereas banks have switched from being net buyers to net sellers. The banking sector is the largest and only net-selling sector, with a negative net position of approximately EUR 300 billion.

Global Banks as Intermediary Some global banks access direct USD funding through their US parent or subsidiary to hedge their USD FX positions. We document evidence for this behavior by splitting the sample into non-EA and EA investors based on the location of their parents. Consistently, we find that banks with non-EA parents are net

[6] According to EMIR regulation, FX contracts with maturity less than 3 days are considered spot contracts and therefore do not have to be reported (although they often are). This is the predominant reason for the spikes in net FX positions—especially for investment funds—in Figure Figure 1 (b).

suppliers of USD hedging in the EA, and display a net FX sell position of EUR 300 billion. In contrast, banks with EA parents exhibit a total net FX position of close to zero.

Hedging Costs Lastly, we quantify the contribution of CIP deviations to EA investors' hedging costs. The cross-currency basis at 3-month maturity (the typical maturity used by investors) has been negative most of the time during our sample (see Figure 2). We compute the basis-implied hedging cost paid by each investor based on the investor's average notional and maturity of FX derivatives in a given quarter on an annualized basis.[7] The net hedging cost peaked in 2022Q4 at EUR 3.4 billion. Whereas the majority of EA investors pay the CCB, some are net receivers because they sell future EUR. Net payers paid more than EUR 5 billion in 2022 in hedging costs.

2.2 USD Investments and FX Hedging

EA insurers, banks, and investment and pension funds jointly invest approximately EUR 2.3 trillion in USD bonds. These holdings consist of 61% of corporate bonds and correspond to 17% of combined EUR and USD bond holdings. Non-bank sectors exhibit a larger USD bond share (23%) and, within the USD bond portfolio, allocate a larger share to corporate bonds (65%). USD bond holdings include US treasuries and US corporate bonds (with both accounting for approximately 30% of holdings), but also a significant amount of non-EA and non-US corporate bonds (20%) and government bonds (10%) (see Appendix Figure IA.6).

Hedging Ratio and Maturity Mismatch We compute the portion of USD bonds that are currency-hedged for the entire EA. On average, EA non-bank investors hedge 43% of their USD bond holdings, whereas banks exhibit a negative hedge ratio of -56% (see Table 1). There is significant heterogeneity across non-bank sectors (see Table 2). Pension funds display the largest hedge ratio (57%), followed by insurers (38%) and investment funds (35%). Moreover, the average maturity of USD bond holdings of 8.9 years is significantly larger than that of FX derivatives positions of 2.3 months (see Table 2).

FX Hedging in the Time Series Figure 3 provides additional insight into the hedging activity of EA investors. Panel (a) displays net FX positions against the volume of USD

[7] More specifically, we first compute each investor's quarterly hedging cost paid, defined by $\mathcal{C}_{i,t} = N_{i,t}(\exp(-\tau/12 \times \text{CCB}_{t,\tau}) - 1)/(\tau/3)$, where $N_{i,t}$ is the quarterly average net notional of investor i and τ the quarterly average remaining time to maturity in months. Then, we annualize and aggregate across investors. Figure IA.4 displays the time series for aggregate hedging costs.

bond holdings at sector-by-quarter level. Both are scaled by total USD and EUR bond holdings to account for differences in sector size. The two sectors with the largest share of USD bonds (investment and pension funds) tend to have a larger net FX position than others (insurers and banks). Moreover, all non-bank sectors display a positive relationship between net FX positions and USD bond shares across time.

FX Hedging in the Cross Section Figure 3 (b) displays a binned scatter plot of net FX positions and USD investments in the cross-section of nonbanks. It plots net FX positions against the volume of USD-denominated bond holdings at country-by-sector-by-quarter level, both scaled by total bond holdings and purged of aggregate shocks using time fixed effects. The positive correlation implies that country-sectors with a larger USD bond share exhibit larger net FX hedging positions.[8]

3 Stylized Model

This section proposes a simple dynamic asset pricing model to study the joint determination of the CCB and portfolio currency allocations. In the model, European investors invest in USD-denominated assets while optimally hedging part of the associated currency risk by rolling over short-term forward contracts. We study the implications of this maturity mismatch between derivatives contracts and asset holdings in an environment in which the supply curve for forwards has finite elasticity in the CCB due to convex balance sheet costs of arbitrageurs. For tractability, we assume an OLG setup and fix the respective wealth of the different sectors to one. We expose the model environment in this section and relegate its full solution to the Appendix.

3.1 Environment

Let $(\Omega, \mathcal{F}, \mathbb{P})$ be a probability space that satisfies the usual conditions and assume that all stochastic processes are adapted. The economy evolves in continuous time with $t \in [0, \infty)$. Three infinitely lived agents with log utility and time discount rate ρ populate the economy: (i) a representative European investor hedging currency risk; (ii) a CIP arbitrageur with convex balance sheet costs; and (iii) an outside investor who stands ready to purchase risky USD assets for a low enough price.

[8] The relationship between FX positions and USD investments is not mechanically affected by changes in spot exchange rates because, by construction, we ensure that variation in FX positions is due to investor activity, and we absorb exchange rate variation with time fixed effects in Figure 3 (b).

Exchange Rate Process We postulate an exogenous log USD-EUR exchange rate process (exchanging 1 USD for $\exp(x_t)$ EUR): $dx_t = \mu^x dt + \sigma^x dZ_t^x$, in which μ^x and σ^x are, respectively, the drift and loading of the adapted Brownian process dZ_t^x.

Capital Markets From the perspective of the representative European investor, the return processes for investing in both risk-free and risky USD assets are given by $dR_t^d = (r^d + \mu^x)dt + \sigma^x dZ_t^x$ and $dR_t^a = (r^d + \mu^x + \varsigma_t)dt + \sigma^a dZ_t^a + \sigma^x dZ_t^x$, where r^d is the USD risk-free interest rate. The return process for the "risk-free" USD asset is affected by the exchange rate process in two ways: (i) it is risky due to exposure to currency risk through the currency risk factor dZ_t^x, and (ii) its drift incorporates the exchange rate drift μ^x. In the second equation, the return on the risky USD asset is exposed to an additional risk factor dZ_t^a that represents USD-specific market risk and requires a risk premium compensation ς_t. For simplicity, we assume no correlation between dZ_t^a and dZ_t^x. The parameter σ^a is the volatility loading on the US market risk factor. Finally, the European investor earns the EUR risk-free rate r^e when investing in the risk-free EUR asset without currency risk.

Derivatives Market Investors trade FX forward contracts, which may be used to hedge currency risk. When entering into a 1 USD nominal forward contract, investors agree at time t to purchase $\exp(f_{t,\tau})$ EUR for 1 USD at date τ. The net EUR payoff of such a contract is given by $\exp(f_{t,\tau}) - \exp(x_\tau)$. We capture the maturity mismatch between forwards and underlying assets documented in the previous section by restricting the derivatives contractual space to instantaneous forward contracts ($\lim \tau \to t$) and denote by $\theta_t dt = (f_t - x_t)$ the contract's instantaneous forward premium. The return process for buying FX contracts is then given by $dR_t^f = f_t - x_{t+dt} = (\theta_t - \mu^x)\, dt - \sigma^x dZ_t^x$. Because the European investor needs to sell USD forward to hedge a currency exposure from USD assets, the instantaneous gross cost of hedging is $-(\theta_t - \mu^x)$ and the benefit is the negative exposure to the exchange rate factor $\sigma^x dZ_t^x$.

Agents' Problems Agents maximize their lifetime logarithmic utility from consumption by choosing their consumption c_t and portfolio allocations subject to the subset of assets they access. For the European investor: portfolio weights in the USD risky asset w_t^a, in the USD risk-free asset $w_t^d > 0$, in the EUR risk-free asset w_t^e, and a derivatives contract position α_t. For the CCB arbitrageur: a portfolio weight in the USD risk-free asset $w_t^d > 0$ and a derivative contract position α_t^s. The outside investor is assumed to simply purchase any excess risky USD bond supply $\tilde{b}_t$ elastically with an expected return above $\overline{r}_t^a$.

Residual FX Demand Shock We model shocks in the FX market in reduced form by assuming that the residual demand for FX contracts d_t is subject to a Poisson shock that shifts across two states. In the steady state, the residual demand is given by d. Following the realization of the Poisson process with intensity λ, it increases from d to d'. In the shock state, d' moves back to d following another Poisson process with intensity λ'. Variations in d_t capture idiosyncratic demand for derivatives (e.g., driven by investor risk management behavior).

Market Clearing We solve for the Markov equilibrium of this problem with the following market clearing conditions: (i) FX contracts market $\alpha_t + \alpha_t^s + d_t = 0$ and (ii) risky USD asset market $w_t^a + \widetilde{b}_t = b$, where b is a fixed supply.

Financial Frictions The model features three financial frictions. First, the European investor cannot borrow in USD ($w^d \geq 0$), and thereby relies on FX derivatives to hedge currency risk. This assumption corresponds to the domestic nature of US repo markets (Correa et al., 2020). Second, we assume that the CIP arbitrageur faces a quadratic cost on the size of their balance sheet with modulating parameter χ (Andersen et al., 2019; Huang et al., 2024). Third, we assume that trading USD assets is subject to an exponential transaction cost of ν per transacted value. This assumption corresponds to nontrivial bid-ask spreads and the price pressure incurred in OTC bond markets (O'Hara et al., 2018).

3.2 Analysis

In Appendix A, we solve for the above model in closed form and derive the equilibrium prices and allocations. We derive three propositions from this solution.

Equilibrium Restrictions To keep our stylized model tractable and focused, we restrict the set of parameters that correspond to equilibria in which (i) uncovered interest rate parity (UIP) holds: $r^d + \mu^x - r^e = 0$; (ii) the CIP deviates negatively—i.e., the cross-currency basis is negative: $r^d + \theta_t - r^e < 0$; and (iii) the outside investor only enters the market in the shock state.[9]

Inaction Region We first show that the presence of positive transaction costs ν implies the existence of an inaction region in portfolio decisions: The residual demand shock needs

[9] The latter restriction is implemented by adding a small variation to $\overline{r}_t^a$: $\overline{r}^a(d) - \varepsilon = \overline{r}^a(d') = \varsigma(d)$, where $\varepsilon > 0$ is an infinitesimally small amount.

to be sufficiently large to trigger the sale of risky USD assets by the European investor. The threshold of this inaction region at which the investor starts selling USD assets is

$$d' - d > 2\left(\frac{1}{\chi} + \frac{1}{(\sigma^x)^2}\right)(\rho + \lambda + \lambda')\nu. \tag{C}$$

Model Predictions The model is characterized by three equations for each of the two states: $\{\theta(d), \varsigma(d), \alpha(d), \theta(d'), w^a(d'), \alpha(d')\}$. We derive three propositions and analyze the effect of FX derivatives' residual demand shock on FX and risky USD asset markets.

Proposition 1 (No Balance Sheet Cost Benchmark)**.** *In the absence of balance sheet costs to CCB arbitrageurs ($\chi \to 0$), the CIP holds in both states: $r^d + \theta(d) - r^e = r^d + \theta(d') - r^e = 0$, and prices and allocations remain unchanged following a (Poisson arrival) transition to the shock state: $w^a(d) = w^a(d')$, $\varsigma(d) = \varsigma(d')$, $\theta(d) = \theta(d')$, and $\alpha(d) = \alpha(d')$.*

Proposition 1 directly follows from the FOC condition of the CCB arbitrageur, which imposes that the CIP holds in the absence of balance sheet costs. Through this arbitrage condition, the CCB arbitrageur elastically supplies currency hedges to EA investors by borrowing USD risk-free, investing in EUR risk-free, and selling USD FX forwards without requiring any increase in the CCB.

Proposition 2 (Equilibrium Adjustment to FX Demand Shocks)**.** *Following a (Poisson arrival) transition to the shock state and assuming a set of parameters such that Condition (C) and equilibrium restrictions (i), (ii), and (iii) hold, adjustments to equilibrium allocation and prices are such that*

(a) the CCB becomes more negative (widens): $r^d + \theta(d') - r^e < r^d + \theta(d) - r^e < 0$;

(b) the European investor reduces hedging: $\alpha(d') < \alpha(d)$;

(c) the European investor sells USD assets: $w^a(d') < w^a(d)$.

According to Proposition 2, the European investor reacts to an upward shock to FX derivatives residual demand by selling USD assets and reducing FX hedging positions as the CCB widens. The increase in the residual FX demand results in a surge in hedging costs for European investors. EA investors trade off maintaining their hedging position at a higher cost with selling USD assets to reduce exposure to currency risk. When Condition (C) is met, the European investor reacts with a combination of the two, selling part of risky USD asset holdings to the elastic outside investor at a fire-sale cost ν and bearing the higher hedging cost for the remaining holdings. Those adjustments result in a net loss of wealth for the EA investor. Proposition 2 stresses the interdependence of asset and derivatives markets in general equilibrium. In the model, some inelasticity in the USD risky asset market is required for the hedging cost to react to an FX derivative supply shock.

Proposition 3 (Sensitivity to Expected Shock Duration)**.** *Assuming a set of parameters such that Condition (C) and equilibrium restrictions (i), (ii), and (iii) hold, the sensitivity of allocations and price adjustments to the Poisson shock are such that for a given shock size* $(d' - d)$*:*

(a) the amount of USD assets sold is increasing in the expected duration of the shock $(1/\lambda')$*:* $\partial(w^a(d) - w^a(d'))/\partial\lambda' < 0$*;*

(b) the sensitivity of the CCB is decreasing in the expected duration of the shock $(1/\lambda')$*:* $\partial(\theta(d) - \theta(d'))/\partial\lambda' > 0$*.*

Proposition 3 shows that the sensitivity of portfolio rebalancing and widening of the CCB have an opposite relationship to the expected duration of the shock captured by the inverse of λ'. The result is akin to that of d'Avernas et al. (2024) for the repo market, which is here applied to the CCB with similar intuition. When the shock is expected to be short-lived, the European investor is willing to pay a higher hedging cost for a short period of time to avoid paying the transaction cost. Conversely, when the shock is expected to be long-lived, the European investor is willing to liquidate its portfolio at a lower threshold in condition (C). Consequently, in this scenario, hedging demand is lower, and the CCB does not widen as much in equilibrium.

This result has important implications for the design of empirical work that studies the implications of FX market shocks for capital flows. Because the cross-elasticity of capital market allocations to the CCB is decreasing in expected shock duration, highly transitory shocks such as quarter-end or year-end spikes are likely to be associated with a large reaction in the CCB but only weak, if any, in capital markets, consistent with the findings of Du et al. (2018) and Wallen (2022). Those predictable and transitory shocks are therefore not suitable for identifying capital market reactions. In the next section, we develop an empirical strategy that deviates from previous literature by not relying on quarter-end shocks.

4 Empirical Strategy

In this section, we describe the empirical strategy for identifying the impact of fluctuations in the CCB on EA investors' USD asset holdings.

4.1 Empirical Specification and Fixed Effects

Our baseline specification is at country-sector-by-bond level and regresses quarterly changes in bond holdings on the CCB interacted with an indicator for USD denomination of bonds:

$$\Delta \log \text{Held}_{i,b,t} = \alpha \Delta \text{CCB}_t \times \text{USD}_b + u_{i,t} + v_{i,b} + w_{\text{industry}(b),t} + \varepsilon_{i,b,t}, \tag{2}$$

where the dependent variable is the log growth in the amount of bond b held by a country-sector pair i at quarter t. ΔCCB_t is the quarterly change in the quarterly average USD-EUR cross-currency basis (in ppt). The sample includes all EUR and USD bond holdings by EA insurers, pension funds, banks, and investment funds and runs from 2019q2 to 2024q1. According to our model, we expect that investors reduce USD relative to EUR bond holdings in response to a more negative (i.e., wider) CCB—i.e., $\alpha > 0$. We purge the dependent variable of variation in spot exchange rates by defining changes in USD holdings as $\Delta \log \text{Held}_{i,b,t} = \log(S_{t-1}/S_t)\text{Held}_{i,b,t} - \log \text{Held}_{i,b,t-1}$, where S_t is the quarterly average spot exchange rate in units of EUR per USD. Bond holdings are measured in nominal values to remove variation due to price changes. We use two-way-clustered standard errors at bond and country-by-currency-by-time levels.

By estimating the semi-elasticity α in regressions at bond level with granular fixed effects, we rule out many potentially confounding factors. For instance, this specification ensures that the results are not driven by time-invariant heterogeneity across securities, issuers, or investors. Country-sector-by-time fixed effects ($u_{i,t}$) absorb shocks that differently affect investors, and country-sector-by-bond fixed effects ($v_{i,b}$) absorb variation from time-invariant investor preferences. Thus, the regression effectively holds investors' total portfolio size fixed over time and examines variation in the portfolio share of different securities relative to investors' average investment preferences. For example, this specification absorbs any impact of fund flows on the demand for USD bonds when funds keep their portfolio allocation constant. Issuer industry-by-time fixed effects ($w_{\text{industry}(b),t}$) absorb shocks that differently affect bond issuers depending on their industry (including government). Thus, the estimate compares bonds issued within the same industry at the same point in time but with different currency denominations. This also alleviates the possible concern that demand for bonds in more internationally diversified industries differs from that in other industries.

4.2 Heterogeneity in Rollover Risk

Despite the detailed fixed effects, the main coefficient could still be biased by the presence of currency-specific omitted variables or simultaneous supply and demand shocks. For example, in our model, the equilibrium CCB is an increasing function of the USD asset demand. Therefore, a shock to USD demand would result in a reverse causality widening in the CCB. To address this identification challenge, first, we construct a measure for investors' exposure to changes in the CCB. Specifically, we consider the share of investors' maturing FX hedging contracts. For each country-sector pair i, we consider the set of hedgers in EMIR—i.e., investors that maintained an average net buy position in the previous 3 months. Among these hedgers' hedging positions outstanding at the lagged quarter end with a time to maturity of more than 7 days, we compute the share of notional that matures in the current quarter, denoted by $\%\text{FX mat}_{i,t}$. The larger the $\%\text{FX mat}_{i,t}$, the larger the rollover risk of hedgers in country-sector i, and therefore their exposure to changes in the CCB.

We then define the indicator variable $\text{High Rollover Risk}_{i,t} = 1\{\%\text{FX mat}_{i,t} > 0.99\}$ to flag the country-sector pairs most exposed to changes in the CCB, which approximately corresponds to the 75th percentile of $\%\text{FX mat}_{i,t}$. We use a triple-interaction term in Equation (2) that interacts $\text{USD}_b \times \Delta\text{CCB}_t$ with $\text{High Rollover Risk}_{i,t}$. The coefficient on this interaction term compares the response of USD bond holdings to the CCB by investors with high rollover risk with those with low rollover risk. Country-sector-by-time fixed effects ensure that the results are not driven by differences in investor-specific characteristics. In Appendix Table IA.3, we further document that portfolio allocations do not systematically differ across investors with different exposure to rollover risk.[10]

4.3 Granular Instrumental Variable

As a second strategy to address identification concerns, we construct a granular instrumental variable for the 3-month USD-EUR CCB from entity-level FX derivatives data.

Preliminaries We start with the set of all EA investors classified as banks, insurers, pension funds, investment funds, or nonfinancial companies and aggregate at parent level using their LEIs, excluding non-EA LEIs. We consider the total net position $Q_{i,t}$ of investor i on day t in USD-EUR FX forward contracts with a remaining time to maturity of between 2 and 4 months. To focus on investors who regularly use FX derivatives, we exclude those with nonzero positions for less than 1 month, those with an absolute net FX position of less than EUR 250,000 on average or more than one-third of the sample, and those with a standard deviation of their net position that exceeds two times their average

[10]In particular, the results in Appendix Table IA.3 suggest that rollover risk is not systematically related to a larger share of maturing bonds. Also, it is important to note that the sample excludes bonds that mature in the current quarter.

gross position. The final sample used to compute the granular instrumental variable contains close to 7,000 investors.

We detrend net positions $Q_{i,t}$ by their 3-month trailing average $\bar{Q}_{i,t} = \sum_{\tau=t-84}^{t-1} Q_{i,\tau}$ and define percentage deviation of positions as $\Delta Q_{i,t} = (Q_{i,t} - \bar{Q}_{i,t})/|\bar{Q}_{i,t}|$. To ensure high data quality, we consider the sample of $\Delta Q_{i,t}$ starting in the second quarter of 2019, motivated by a significant improvement in reporting quality in December 2018.

We winsorize $\Delta Q_{i,t}$ at the 1st and 99th percentiles. To isolate changes in FX demand, we focus on the set of investors who are *typical hedgers* of USD currency risk, defined as those who have maintained a long position in future EUR against USD on average in the past 3 months: $\mathcal{L}_t = \{i \geq 1 : \bar{Q}_{i,t} > 0\}$, in which $\mathcal{L}_t$ reflects the demand side of the market.[11] In the following, we use $\bar{Q}_{i,t}$ as a measure for investor size, and $\bar{Q}_{i,t}/\sum_i \bar{Q}_{i,t}$ as the (size) weight of investor i among all hedgers at time t.

Instrument Construction To extract idiosyncratic shocks to investors' FX positions, we build on the methodology proposed by Gabaix and Koijen (2024). We residualize $\Delta Q_{i,t}$ by controlling for the average maturity of outstanding positions and investor and sector-by-country-by-time fixed effects:

$$\Delta Q_{i,t} = \gamma \log(\mathrm{mat}_{i,t}) + u_i + v_{s,c,t} + w_{m,t} + \check{q}_{i,t}, \tag{3}$$

where $\log(\mathrm{mat}_{i,t})$ is the log average remaining time to maturity of investor i's FX positions. Investor fixed effects (u_i) absorb time-invariant heterogeneity. Sector-by-country-by-time fixed effects ($v_{s,c,t}$) absorb shocks that similarly affect all investors in sector s domiciled in country c. For example, they absorb the sector-specific effects of changes in a country's regulatory environment, trade surplus, or financial market conditions. Maturity bucket-by-time fixed effects ($w_{m,t}$) account for maturity-specific shocks, where maturity buckets are defined based on the thresholds of 2.75 and 3 months time to maturity. After purging $\Delta Q_{i,t}$ from such systematic variation, the remaining residual $\check{q}_{i,t}$ represents idiosyncratic changes in FX positions, which, for simplicity, we refer to as "idiosyncratic shocks."

Finally, we define granular shocks to FX hedging demand, GFX_t, as the difference between the size-weighted and equal-weighted average idiosyncratic shocks of typical

[11] In our sample, nearly half of investors are hedgers and their total net position corresponds to 1.5 to 3.5 times the (absolute) total net volume of non-hedgers, which indicates the significance of hedgers in the EA FX market (see Appendix Figure IA.1). Banks account for 37% of the total size of hedgers, followed by investment funds (24%), pension funds (18%), and nonfinancial companies (13%).

hedgers:

$$\text{GFX}_t = \frac{1}{\sum_{i \in \mathcal{L}_t} \bar{Q}_{i,t}} \sum_{i \in \mathcal{L}_t} \bar{Q}_{i,t} \check{q}_{i,t} - \frac{1}{|\mathcal{L}_t|} \sum_{i \in \mathcal{L}_t} \check{q}_{i,t}. \tag{4}$$

The construction follows Gabaix and Koijen's (2024) insight that this weighting corresponds to the most powerful instrument. In regressions at daily frequency, we define by ΔCCB_t the change in the cross-currency basis relative to its 3-month trailing average in percentage points, consistent with the definition of $\Delta Q_{i,t}$. In first-stage regressions, we regress ΔCCB_t on GFX_t:

$$\Delta\text{CCB}_t = \mu\text{GFX}_t + \Gamma' M_t + \varepsilon_t, \tag{5}$$

where M_t is a vector of control variables described in Table 3. We expect that $\mu < 0$—i.e., that demand shifts captured by GFX_t widen the CCB (i.e., render it more negative). To interpret μ in equation (5), it is useful to note that by definition, the size-weighted average idiosyncratic shock is equal to the percentage deviation in the aggregate net position of typical hedgers from its trailing average. Thus, μ is the price impact of a 1% idiosyncratic shock to typical hedgers' aggregate net position. In second-stage regressions, we use GFX_t as an instrument for the CCB.

Relevance A granular instrument is relevant if idiosyncratic shocks to hedgers' positions do not wash out in the aggregate (Gabaix, 2011). In particular, it depends positively on the skewness in the size distribution to create meaningful dispersion between size-weighted and equal-weighted observations. In our sample, the distribution of hedger size is highly fat-tailed. The largest 1% (10%) of hedgers account for 42% (86%) of the total size of all hedgers. This substantial skewness in investor size is confirmed by fitting the Pareto I density to the cross-sectional size distribution, with a Pareto rate of 0.97 among the 5% largest hedgers.

Exclusion Restriction Under regularity assumptions, the exclusion restriction holds if $\check{q}_{i,t}$ are truly idiosyncratic shocks (Gabaix and Koijen, 2024). Instead, if the exclusion restriction is violated, the instrumental variable GFX_t would pick up the effects of aggregate shocks on FX demand. Because shocks to hedging costs dampen hedging demand, this would likely bias the estimate of μ in equation (5) toward zero—i.e., make the results more conservative. Instead, we find a significantly negative estimate for μ. We also document that equal-weighted average FX positions are negatively correlated with our instrument, which is consistent with GFX_t capturing plausibly exogenous variation in hedging cost.

Moreover, the estimate is unaffected by the inclusion of a variety of macroeconomic control variables that are potential confounders, such as government bond rates or financial market volatility. Finally, we use the principal components of residuals $\check{q}_{i,t}$ to control for aggregate factors, following Gabaix and Koijen (2023).[12]

The identification is potentially threatened by aggregate shocks that affect small and large investors differently and are not absorbed in equation (3). For example, less sophisticated investors may pay higher markups in FX markets (Hau et al., 2021). For this reason, we include investor fixed effect u_i in Equation (3), which absorbs time-invariant differences in markups. Moreover, sector-by-country-by-time fixed effect $v_{s,c,t}$ absorbs variation in markups over time specific to sector s in country c. Thus, potentially confounding variation is restricted to differential shocks to markups *within* a country-sector—which is concerning only if it correlates with investor weights, since it is otherwise averaged out in the construction of GFX_t.

Robustness To address remaining identification concerns, we perform two robustness analyses. First, we exploit the fact that GFX_t is constructed from *net* positions, whereas potential confounders such as markups typically depend on *gross* investor size, which reflects sophistication. We sort investors based on terciles of their average 3-month trailing gross volume and include gross volume tercile-by-time fixed effects in Equation (3). We then use the residuals to construct an alternative instrument.

Second, we address the concern that investors may not exhibit the same level of idiosyncratic volatility, negatively affecting identification. For heteroskedastic shocks, Gabaix and Koijen (2024) suggest using weights that are inversely proportional to their variance. We implement this in a robustness analysis and estimate idiosyncratic volatility from residuals $\check{q}_{i,t}$

5 CCB Elasticity of FX Derivatives Positions

This section presents results of the first-stage regression on GFX_t and estimates the elasticity of FX derivatives positions.

[12]Investors with different volatilities of $\check{q}_{i,t}$ are likely to have different exposures to the factors. Therefore, in each quarter, we sort investors into 20 groups based on the respective time-series standard deviation of their residuals $\check{q}_{i,t}$ and compute the group-by-day-level average residual. Principal components are then based on the panel of 20 groups.

5.1 First-stage Results

We test the relevance of the instrument by regressing changes in the CCB on GFX_t in columns (1) and (2) in Table 3. Consistent with Proposition 2, we find a significantly negative coefficient: The CCB becomes more negative (i.e., widens) following idiosyncratic FX demand shocks. The point estimate implies that a 7.7% (EUR 8.8 billion) increase in the total net position of hedgers is associated with a 1 bps reduction in the CCB. The magnitude of the effect emphasizes FX hedging supply constraints (Du et al., 2018). Small demand shifts are sufficient to generate significant changes in the CCB, with an average value of -9.7 bps.

In column (2), we include a variety of macroeconomic control variables, such as FX positions' average remaining time to maturity, risk-free rates, stock market returns and volatility, spot rate volatility, and dollar strength (following Avdjiev et al., 2019) as well as the first three principal components of investors' idiosyncratic shocks. Controlling for these variables removes the potential impact of monetary policy and financial market conditions, as well as unobserved aggregate shocks. The result is highly robust in terms of both magnitude and statistical significance. This suggests that the variation in GFX_t is orthogonal to these potential macroeconomic confounders, which supports the validity of our empirical strategy. Appendix Figure IA.2 further shows that the correlation between ΔCCB_t and GFX_t is visible throughout the full sample distribution.

5.2 FX Demand Elasticity

Equipped with a relevant instrument, we can now test the second prediction of Proposition 2, that EA investors reduce their FX positions in response to a widening of the CCB. Columns (3) and (4) in Table 3 report estimated demand (semi-)elasticity ϕ from the following second-stage regression at daily frequency:

$$\overline{\Delta Q}_t = \phi \Delta\text{CCB}_t + \Gamma' M_t + \varepsilon_t. \tag{6}$$

ϕ is the (semi-)elasticity of $\overline{\Delta Q}_t$ to an increase in the CCB. The outcome variable is the equal-weighted average of detrended investor-level FX positions across EA banks, investment funds, insurers, and pension funds.

OLS Estimates We first report the OLS estimate in column (3). The estimated coefficient is significantly positive and implies that investors reduce their FX positions by 0.09% in response to a 1 bps decrease (i.e., widening) in the CCB. This suggests very inelastic FX demand. However, the OLS estimate suffers from simultaneity bias: It conflates demand and supply shocks, which have opposite effects on the CCB.

IV Estimates Column (4) reports our baseline estimate when instrumenting ΔCCB_t with GFX_t. The estimate implies that investors reduce their FX positions by 1.98% in response to a 1 bps decrease (i.e., widening) in the CCB, which is statistically significant at the 1% level. The magnitude is also economically significant. It implies that a 17 bps decrease in the cross-currency basis (corresponding to the 5th percentile of ΔCCB) reduces net FX positions by 34% (= 0.17×1.98). Elasticity based on the IV estimate is more than 20 times larger than the OLS estimate. This suggests that the latter indeed suffers from substantial simultaneity bias, which is reduced by using the instrumental variable approach.

Heterogeneity across Sectors We investigate differences across sectors in Figure 4 (a) by estimating Equation (6) separately for different sectors. The sensitivity of FX positions to the CCB is the highest for insurers and banks (between 3 and 4) and slightly lower for pension funds (close to 3). In contrast, investment funds display substantially lower elasticity (close to 1). The result suggests that investment funds reduce their hedging activity by less than other investors in response to higher hedging costs. A potential explanation is the heterogeneity in regulatory frameworks across sectors.[13]

FX Rollover Risk We study the role of FX rollover risk in columns (5) to (8). For this purpose, we consider the panel of FX positions at investor-by-day level and focus on hedgers—i.e., entities with a positive trailing average net FX position. We measure rollover risk at investor-month level as the share of an investor's FX hedging contracts outstanding at the prior month's end that matures in the current month. In columns (5) and (6), we estimate Equation (6) separately for investors with low and high rollover risk, defined as those with at least (less than) 66% of outstanding positions maturing in the current month. We find that investors with low rollover risk display an elasticity below 0.5, which is not statistically significant. In contrast, the elasticity is equal to 3.02 and statistically significant for investors with high rollover risk. However, the difference between investors is not statistically significant in the pooled sample (column 7). We conjecture that this may be explained by high variability in the FX positions of investors with low rollover risk (e.g., from seasonality or aggregate shocks). In the specification reported in column (8), we absorb a large part of this variability by including granular fixed

[13] Bank, insurer, and pension fund regulations are based on risk-based capital requirements, which trade off different types of risk (among others, credit, duration, and currency risk). Instead, investment fund risk-taking is not directly regulated. However, many funds follow strict mandates to hedge currency risk, which reduces their sensitivity to changes in hedging costs.

effects at investor-by-calendar month and time levels. As a result, the interaction between the instrumented CCB and rollover risk indicator is significantly positive. This exercise highlights rollover risk exposure as a significant determinant of FX demand elasticity.

6 CCB Elasticity of Bond Holdings

This section returns to the paper's main focus and estimates the elasticity of EA investor USD bond holdings to fluctuations in the CCB.

6.1 Baseline Results

OLS Estimates In Panel (A) of Table 4, we report the semi-elasticity of EA bond holdings to fluctuations in CCB, estimated using Equation (2). In column (1), we report the OLS estimate from regressing bond holdings on the CCB interacted with an indicator for US dollar denomination. The estimated coefficient is significantly positive and implies that USD bond holdings decrease by 0.2% relative to EUR bonds in response to a 1 bps decrease (i.e., widening) in the CCB.

Rollover Risk: OLS Estimates In columns (2) and (3), we examine differences across investors depending on their FX derivatives rollover risk using the OLS approach. Because bond holdings are at country-by-sector level, we aggregate the rollover risk measure to this level, as described in Section 4.1, and exclude observations for which the measure is either missing or its variation is absorbed by fixed effects. We estimate that the CCB elasticity of bond holdings is approximately twice as large for investors with high rollover risk than other investors. This result is not driven by time-invariant or currency-invariant differences between these types of investors (e.g., due to their investment preferences), which are absorbed by country-sector-time fixed effects. These results highlight the hedging cost channel as the primary driver and rule out several alternative channels. For example, an important potential confounder is exchange rate volatility, which might widen the CCB and negatively affect USD bond demand. However, it seems unlikely that FX derivatives rollover risk drives the sensitivity to exchange rate volatility.

IV Estimates We further strengthen the identification by instrumenting the CCB with the quarterly average of GFX_t in columns (4) to (7).[14] As a result, the estimated CCB

[14]In Internet Appendix C, we show that, in the time series, GFX_t also correlates significantly with the CCB at this lower frequency.

elasticity of bond holdings increases to 0.32, which implies that USD bond holdings decrease by 0.32% relative to EUR bond holdings in response to a 1 bps decrease in the CCB. The larger magnitude of the IV estimate suggests that the OLS estimate partly remains biased by shocks that affect both bond demand and CCB.

Rollover Risk: IV Estimates We find that the impact of rollover risk on CCB elasticity is robust to instrumenting the CCB (columns 5 and 6). In addition, in column (7), we show that the different elasticity across investors with high and low rollover risk remains significantly positive after including bond-by-time fixed effects, which absorb any bond-specific shocks (such as variation in USD $\times$ CCB).[15] Thus, the coefficient of interest identifies differences in bond demand within a particular bond and period, driven entirely by differences in investors' FX derivatives rollover risk.

Aggregate Effect The baseline estimate reports the elasticity for the average bond weighted by the number of observations. To grasp the implications for aggregate flows, we also compute the estimate weighted by the lagged nominal value of bond holdings. The holdings-weighted estimate that corresponds to column (4) is 0.29, which implies that (for the average EUR invested) USD-denominated bond holdings decline by 0.29% *relative* to EUR-denominated bonds in response to a 1 bps more negative CCB. Adjusting by the average USD portfolio share, this estimate translates into a decline by approximately 0.24% in the EA's *total* USD bond holdings.[16] This aggregate elasticity is economically significant: It implies that the 5% largest declines in CCB are associated with a 4% (-0.17×0.24) decrease in total USD-denominated bond holdings. Since EA banks, insurers, and investment and pension funds jointly hold EUR 2.3 trillion of USD-denominated bonds in 2024Q1, this corresponds to approximately EUR 94 billion of USD bonds being disposed of.

[15]These detailed fixed effects require that for each bond-by-quarter observation, at least one low-rollover-risk and one high-rollover-risk country-sector holds the bond, which reduces the overall sample size.

[16]Because the fixed effects hold portfolio size constant, Equation (2) provides an estimate for the differential change in USD- relative to EUR-denominated bond portfolio weights w^D and w^E:

$$\alpha \Delta \mathrm{CCP}_t = \frac{\Delta w^D}{w^D_{t-1}} - \frac{\Delta w^E}{w^E_{t-1}}.$$

Rearranging this equation and using that $w^D = 1 - w^E$ gives that the semi-elasticity of USD bond demand is equal to

$$\frac{\Delta w^D}{w^D_{t-1}} = \alpha \Delta \mathrm{CIP}_t (1 - w^D_{t-1}).$$

The average USD portfolio share w^D_{t-1} is 17%.

Relation to Previous Literature We note that the estimated CCB elasticity is close to estimates for the price elasticity of EA bond markets that have been documented in previous literature. For example, Jansen (2023) estimates a price elasticity of 4.31 and Koijen et al. (2021) of 3.21 for EA investors' demand for EA government bonds, which translates into a semi-elasticity with respect to yields of 0.38 and 0.29, respectively, for bonds with 8.9 years duration (the average time to maturity of USD bond holdings). Consistently, we document that our baseline estimate is largely unaffected by the inclusion of rating-by-time or time to maturity-by-time fixed effects (see Appendix Table IA.4), which suggests that investors substitute between bonds with different currency denominations but similar credit and interest rate risk.

Hedge Ratios The CCB elasticity of bond holdings is, on average, substantially lower than the CCB elasticity of FX positions. Thus investors, on average, reduce their hedge ratios in response to higher hedging costs. However, in contrast to FX positions, differences in the elasticity of bond holdings across investor types are muted, as we document in Figure 4 (b).[17] Thus, the cross-sector differences in FX demand observed in Table 3 translate into differences in the elasticity of the hedge ratio. Banks, insurers, and pension funds substantially reduce their hedge ratios in response to a more negative cross-currency basis. Instead, the hedge ratio of investment funds is less responsive to CCB changes, consistent with either particularly strong or particularly weak hedging mandates.

6.2 Heterogeneity

We also uncover heterogeneity across bond characteristics, which reflects differences in currency hedging motives. On the one hand, investors may trade off currency with interest rate and credit risk. In this case, when hedging currency risk becomes more expensive, investors may rebalance more from bonds with higher interest rates and credit risks. On the other hand, investors may prefer to hedge less risky bonds, since currency risk accounts for a larger share of the total investment risk.

Issuer Type and Maturity First, in Figure 4 (c), we find that CCB elasticity tends to be larger for corporate than for government bonds. It is also larger for long-term (with

[17] In contrast to the aggregate dynamics depicted in Figure 3 (a), we do not find a significant difference between the CCB elasticity of banks and nonbanks. A potential explanation is the different level of observation across analyses. Whereas different business models of banks confound aggregate dynamics (e.g., whether banks act as dealers in the FX market), the granular fixed effects in the empirical specification in Equation (2) absorb heterogeneity in banks' (time-invariant) investment preferences. As a result, the estimate is likely driven by banks with demand for long-term USD assets.

at least 5 years remaining to maturity) than short-term bonds. This is consistent with investors who trade off interest rate risk with currency risk.

Credit Rating Second, in the cross-section of credit ratings, we find a U-shaped pattern. Within the investment-grade segment, elasticity is largest for the least risky bonds—i.e., with an AAA rating (Figure 4 (c)). AAA-rated bonds display an approximately one-third larger CCB elasticity than A- and BBB-rated bonds. This result suggests that investors in highly rated USD bonds are particularly sensitive to changes in the CCB. Currency risk is economically significant relative to the credit risk of these bonds and drives currency risk and hedging demand. Moreover, investors in higher-rated bonds may be more risk-averse. At the same time, high-yield bonds display an elasticity similar to that of AAA-rated bonds, which suggests that investors in these bonds trade off the bonds' (substantial) credit risk with currency risk and that this channel dominates other explanations due to large differences in credit risk.

6.3 Portfolio-level Estimates

Our baseline estimates reflect portfolio adjustments at the intensive margin (e.g., adjusting the size of existing holdings) because the log specification requires a preexisting country-sector bond holding. To assess the relevance of extensive margin adjustments (e.g., investors purchasing securities for the first time), in Panel (B) of Table 4 we also examine the portfolio share of USD bonds (relative to all USD and EUR bonds). We focus on investors with a nonnegligible preference for investing in USD.[18] Both OLS and IV estimates for the CCB elasticity of the USD portfolio share are significantly positive (columns 1 and 4), which implies that the portfolio share declines by 0.01 ppt and 0.05 ppt, respectively, in response to a 1 bps decline in the CCB. The magnitude of these estimates is consistent with the bond-level estimates in panel (A) when adjusting by the average USD portfolio share. The robustness of the estimates across bond and portfolio levels suggests that country-sectors mostly adjust their portfolios at the intensive rather than the extensive margin. This result is not surprising since, due to the level of aggregation of bond holdings, extensive margin adjustments only occur if all individual investors in a country-sector purchase a bond for the first time or sell all holdings of a specific bond. Moreover, we also find differential responses depending on rollover risk, although the results are less significant at this higher level of aggregation.

[18] Specifically, for each investor, we calculate the 25th percentile of the total USD bond investments and exclude investors with the 25% lowest value from the sample.

6.4 Robustness

A remaining possible concern regarding the interpretation of the results is that variations in USD relative to EUR bond holdings could be due to other determinants of bond demand, such as fluctuations in the spot exchange rate. First, it is important to note that FX positions, by construction, do not mechanically respond to spot exchange rates (see Section 1). Thus, fluctuations in the spot rate do not mechanically affect the instrumental variable GFX_t. Second, we revalue current USD-denominated holdings at the previous quarter's spot exchange rate (as described above) to purge the dependent variable from changes in exchange rates. The estimates are almost unchanged by this revaluation, which suggests that the results are driven by investor rebalancing. Finally, in Appendix Table IA.4, we show that our baseline results are robust to including controls for spot rates and rate volatility interacted with the USD indicator. Moreover, we document that the results are also robust to the inclusion of credit rating-by-time and time-to-maturity-by-time fixed effects, which absorb shocks to bonds with different credit and interest rate risks. They are also robust to adjusting the instrument by including size bucket-by-time fixed effects when computing idiosyncratic shocks and adjusting the instrument for heteroskedasticity following Gabaix and Koijen (2024).

6.5 Funds' Hedging Mandates

In our model, USD bond holdings respond to the CCB via investors' desire to hedge currency risk. In this subsection, we provide additional evidence for this mechanism using heterogeneity in FX hedging mandates across EA investment funds from the fund-level holdings data described in Section 1. Whereas funds may want to swiftly reduce their hedging activity in response to a wider (i.e., more negative) CCB, hedging mandates restrict their ability to do so. Thus, we expect funds with hedging mandates to resort more to selling USD bonds to avoid higher hedging costs. To empirically investigate this mechanism, we estimate the CCB elasticity of bond holdings in Equation (2) at fund-by-bond level separately for funds with and without a hedging mandate.

Table 5 reports the estimated coefficients for this analysis. We start by examining the CCB elasticity of an average fund, pooling funds with and without hedging mandates. Both the OLS and IV estimates imply a significant elasticity of close to 0.1 (columns 1 and 4).[19] As hypothesized, we find that this elasticity is larger for funds with an FX hedging mandate. The IV estimates suggest that funds with a mandate are approximately twice

[19]This estimate is lower than the elasticity estimated at country-sector level in Table 4, which may be explained by the different coverage in the two samples and the fact that the regression is run at the fund level, which estimates the elasticity for the average fund rather than the average EUR invested.

as elastic as those without a mandate (columns 5 and 6). These results reinforce our hypothesis that FX hedging demand is a key mechanism through which the CCB affects portfolio allocation.

7 CCB Elasticity of Bond Yields

In the following, we examine the price impact of cross-currency-basis-risk–implied investor rebalancing. Due to the segmentation of bond markets—e.g., by issuers and maturities—investor base characteristics tend to be mirrored in bond prices (Coppola, forthcoming; Kubitza, 2023). With strong enough segmentation, bonds whose investors are exposed to cross-currency basis (CCB) risk are likely to display stronger price sensitivity to fluctuations in the CCB. Since investors substitute USD with EUR bonds in response to a widening of the CCB, we expect this rebalancing to decrease USD bond yields. Below, we provide corresponding empirical evidence and highlight the significant spillovers of frictions in FX derivatives markets to international bond markets.

7.1 US Corporate Bonds

We first focus on corporate bonds, which account for more than 60% of EA USD bond holdings. Because only corporate bonds with significant EA ownership should be affected by fluctuations in the CCB, we restrict our sample to USD bonds issued by US entities with at least 10% EA ownership share on average over our sample. We examine the average bond yield spread between the concurrent and 5 business days following an innovation in the CCB, detrended by the average bond yield spread in the lagged 3 months (ΔYield Spread). The average yield spread change is 7 bps and ranges from -1.25 ppt to 1.77 ppt at the 5th/95th percentiles (see Table 1).

Baseline Result Table 6 reports estimates from regressions of ΔYield Spread at bond level on instrumented CCB changes at daily frequency. All regressions include controls for potential macroeconomic confounders: dollar strength, stock market volatility, and exchange rate volatility. The specifications also include bond fixed effects, which absorb time-invariant heterogeneity in bond characteristics. We find that the yield of an *average* bond does not significantly respond to a wider (negative) CCB (column 1). This result is unsurprising in light of significant heterogeneity in bonds' investor base.

Rollover Risk Previous sections highlighted significant cross-sectional heterogeneity in investors' portfolio response to the CCB based on their exposures to FX rollover risk. With sufficient bond market segmentation, we expect this demand differential to be reflected in bond yields.

To explore this role of investor FX rollover risk, analogously to the previous section, we compute for each country-sector i the share of hedging positions outstanding at the previous month-end that matures in the current month m, denoted by $\%\text{FX mat}_{i,m}$.[20] Then, we aggregate $\%\text{FX mat}_{i,m}$ to bond level by computing the holdings-weighted average across past bond investors:

$$\%\overline{\text{FX mat}}_{b,m} = \sum_i \frac{h_{i,b,q-1}}{\sum_j h_{j,b,q-1}} \times \%\text{FX mat}_{i,m}, \tag{7}$$

where $h_{i,b,q-1}$ is the total nominal value of bond b held by country-sector pair i in the previous quarter $q-1$. Finally, we split bonds into those exposed to high and low rollover risk through their investor base based on the median value of $\%\overline{\text{FX mat}}_{b,m}$.

In column (2), we estimate separate coefficients on ΔCCB_t for bonds depending on their rollover risk exposure. We observe a significantly negative coefficient for bonds exposed to high rollover risk, which implies that the yield on these bonds declines with a more negative CCB. The estimated coefficient implies that yields decrease by 1.82 bps in response to a 1 bps decline (i.e., widening) in the CCB when bond investors are exposed to high rollover risk. Instead, bonds with low rollover risk exposure do not significantly respond to changes in the CCB. It is important to note that the specification includes rollover-risk fixed effects, which absorb any time-invariant differences between bonds associated with the rollover risk of their investor base.

In column (3), we show that the results are also robust to including maturity fixed effects (with thresholds at 2, 5, 10, and 15 years) and credit rating fixed effects (based on dummies for an AAA-AA, A, BBB, BB, B, CCC, below CCC, and missing rating in the prior month), which absorb differences in interest rate and credit risk across bonds.

The difference between bonds with low and high rollover risk is significantly positive at the 1% level (column 4). Also, the rich heterogeneity in rollover risk across bonds within rating and maturity buckets allows us to include granular maturity-by-time and rating-by-time fixed effects in column (5). These fixed effects absorb any aggregate, maturity-specific, and rating-specific shocks that might correlate with the CCB and bond yields, such as aggregate demand for USD assets and term or credit spreads. The resulting estimate implies that the yield spread of bonds with high rollover risk experiences an approximately 1.6 bps increase in response to a 1 bps CCP widening relative to bonds

[20]The high frequency of price data allows us to use monthly instead of quarterly variation in rollover risk.

with low rollover risk. This result is consistent with prior studies on price impact in the US corporate bond market (e.g., Bretscher et al., 2024) and highlights the CCB as an important determinant of bond prices when held by international investors.

7.2 Government Bonds

Furthermore, we explore the price impact on US and EA government bonds. For this purpose, we consider the yields of government bonds with 6 months and 1, 5, 10, and 20 years to maturity. Analogously to the above, for each issuer-maturity pair, we compute the rollover risk of the investor base.[21] We regress bond yields on the interaction of ΔCCB_t and high rollover risk exposure, absorbing aggregate shocks with time fixed effects. Consistent with the prior results, US treasury yields increase in response to a decrease (i.e., widening) in the CCB when held by investors exposed to high rollover risk, relative to other bonds (column 6). Nonetheless, the coefficient is not statistically significant. A possible explanation is the relatively low EA ownership share of US treasuries, which is approximately 3% of the amount outstanding.

We then turn to EA government bonds and hypothesize that CCB-induced rebalancing from USD to EUR bonds by EA investors could decrease EUR bonds' yields. We indeed find a statistically significant impact on bonds with high rollover risk exposure relative to those with low rollover risk exposure (column 7). The coefficient implies that exposed EA government bond yields *decrease* by 0.43 bps in response to a 1 bps decrease in the CCB, relative to unexposed bonds.

8 Conclusion

This article provides evidence that deviations from the covered interest rate parity, as observed since 2008, have significant consequences for international capital markets. Because wider deviations imply higher costs of hedging currency risk, they lead international investors to decrease both their FX positions and their investments in USD assets. This rebalancing drives significant international capital flows and affects capital market prices. Overall, these results have important implications for understanding international capital flows and their interaction with frictions in international financial markets, financial stability, and monetary policy, many of which remain to be explored in future research.

[21] We assign holdings of bonds with a residual time to maturity of up to 6 months to 3-month yields, those between 6 months and 2 years to 1-year yields, those between 3 and 7 years to 5-year yields, those between 8 and 12 years to 10-year yields, and those between 18 and 22 years to 20-year yields.

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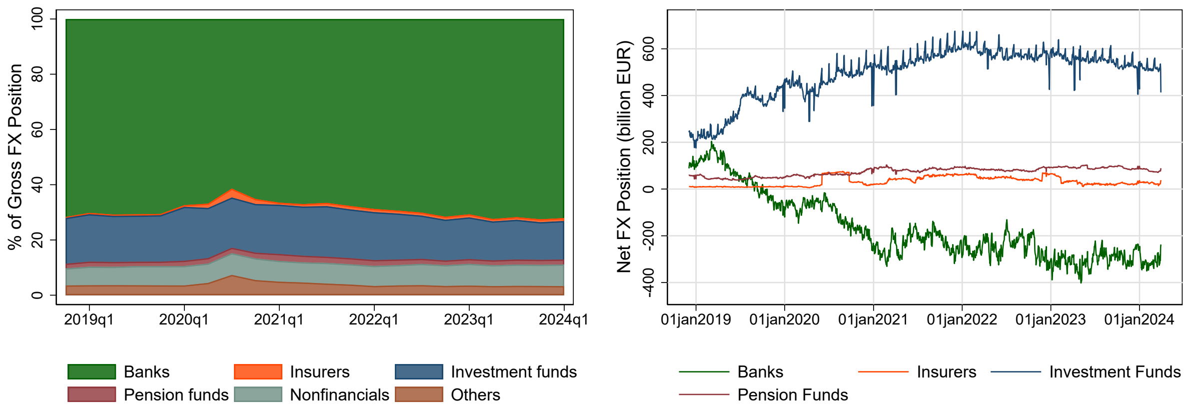
Figures and Tables

Figure 1. FX Forward Positions.
Figure (a) plots the total gross position (in terms of notional in EUR) for EA sectors. "Others" include governments, money-market funds, and central banks. Figure (b) plots the total net position (in terms of notional in EUR) for euro-area financial sectors. Net positions are defined as the difference between buy and sell positions. A buy position is one in which the investor has the obligation to redeem USD in the future against EUR. Such positions can be achieved, for example, by entering a swap in which the investor obtains USD at the spot date and delivers USD at the forward date.



(a) Gross FX Positions

(b) Net FX Positions

Figure 2. USD-EUR Cross-currency Basis.
The figure plots the USD-EUR CCB for 3-month maturity. It is computed from transaction-volume–weighted average spot and forward rates from money market statistical reporting to the ECB and the EURIBOR and USD LIBOR rates. The more negative the CCB, the more expensive it is for euro-area investors to fund USD positions. For confidentiality purposes, the original value of 13 observations is omitted and replaced by an interpolated value.

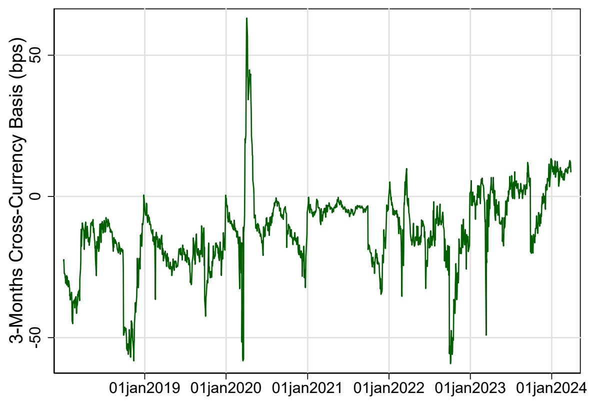
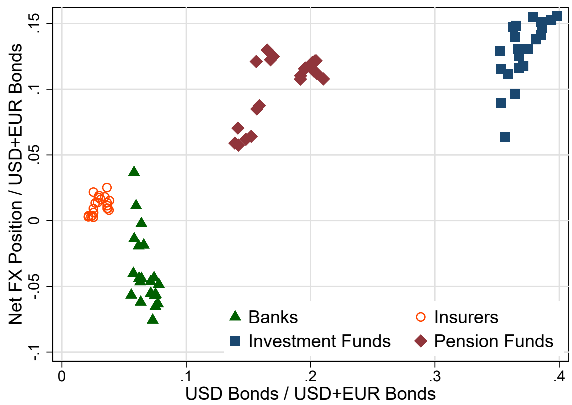
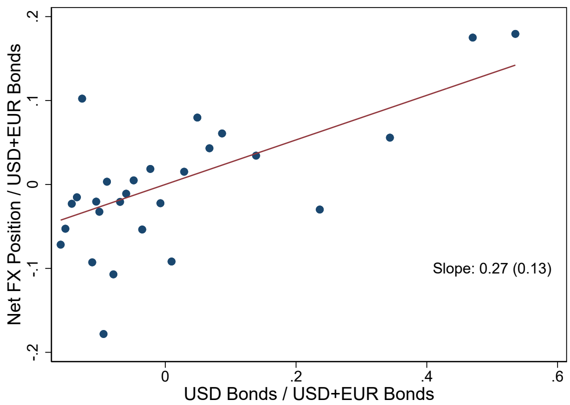


Figure 3. FX Forward Positions and Portfolio Allocation.

Figure (a) plots an investor sector's total net FX forward position (y-axis) and total USD bond holdings (x-axis), both scaled by total USD and EUR bond holdings. Figure (b) is a binned scatter plot of total net FX forward positions (y-axis) and total USD bond holdings (x-axis) of insurers, pension funds, and investment funds at country-sector-by-quarter level, both scaled by total USD and EUR bond holdings, after absorbing time fixed effects. The figure also reports the estimated coefficient and its standard error of a regression of net FX forward positions on USD bond holdings.

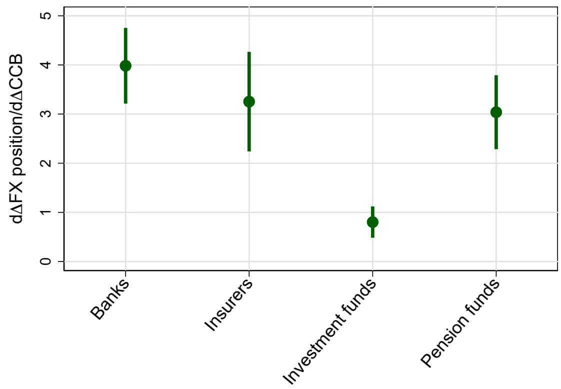


(a) Time Series (sector level)

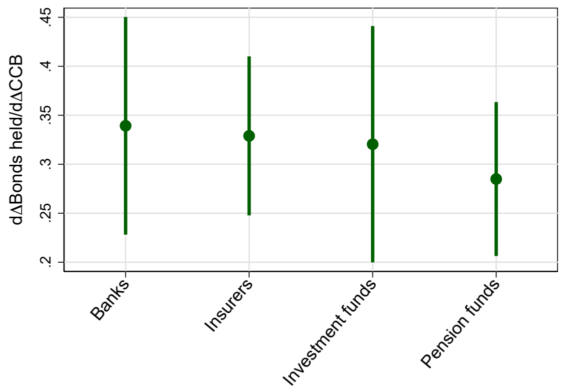


(b) Cross-section of Nonbanks (country-sector level)

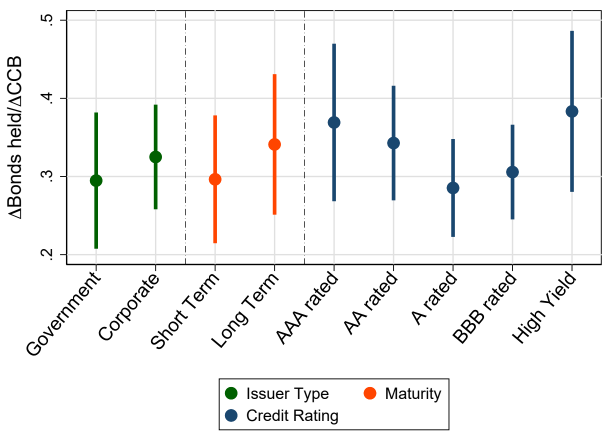
Figure 4. Cross-currency Basis, FX Forward Positions, and Bond Holdings: Heterogeneity. This figure depicts the estimated coefficient on the instrumented change in the cross-currency basis individually for different sectors and types of bonds based on regressions analogously to (a) column (4) in Table 3 and (b,c) column (4) in Table 4, respectively, and the corresponding 90% confidence intervals. Long-term (short-term) bonds are bonds with at least (less than) 5 years remaining time to maturity. High-yield bonds are those with a credit rating worse than BBB.



(a) FX Positions: by Investor Sector



(b) Bonds: by Investor Sector



(c) Bonds: by Issuer Type, Maturity, and Credit Rating

Table 1. Summary Statistics.

The table depicts summary statistics for (1) USD-EUR net and gross FX forward positions as well as their gross volume-weighted average time to maturity at sector-day level, (2) the share of USD bond holdings (relative to USD and EUR bonds), the average time to maturity of USD bond holdings (excluding bonds with more than 50 years to maturity), and the hedge ratio at sector-quarter level, (3) the USD-EUR cross-currency basis (CCB) and size-weighted average of idiosyncratic shocks to typical hedgers' FX positions (GFX) at daily frequency, (4) the share of FX hedging contracts maturing in the current quarter at country-sector-quarter level, and (5) the change in the yield spread and the maturities of USD-denominated US corporate bonds at bond-day level. FX positions and their time to maturity are winsorized at the 1/99 percentiles at investor level before aggregation. The hedge ratio is computed using a sector's average net FX position at the last 3 days of each quarter. To preserve confidentiality, we only report one digit for the CCB, replace one percentile of rollover risk by *, and exclude 22 sector-by-day observations of gross FX positions. Appendix Table IA.1 details variable definitions and sources.

	N	Mean	SD	p5	p50	p95
FX Derivatives Positions (Sector-by-Day Level, Dec 2018 - Mar 2024)						
Net FX Position (bil EUR)	5,560	107.87	257.73	-290.36	59.82	575.46
Gross FX Position (bil EUR)	5,538	1,693.54	2,203.39	31.52	798.67	6,514.67
FX: Time to Maturity (months)	5,560	2.33	0.91	1.03	2.29	3.63
Bond Holdings (Sector-by-Quarter Level, 2019q1 - 2024q1)						
Share of USD Bonds	88	0.17	0.14	0.03	0.11	0.40
Time to Maturity of USD Bonds (ex. > 50 yrs)	88	8.87	1.77	6.18	9.03	12.24
Hedge Ratio (Banks)	21	-0.56	0.42	-1.02	-0.70	0.19
Hedge Ratio (Non-Banks)	63	0.43	0.17	0.16	0.40	0.73
Bond Holdings (Bond-by-Country-Sector-by-Quarter Level, 2019q2 - 2024q1)						
Δlog Bond Holdings	8,568,914	-0.01	0.37	-0.44	0.00	0.39
Time-Series Variables (Daily Frequency, 2019q2 - 2024q1)						
CCB (bps)	1,256	-9.7	13.4	-28.4	-8.7	8.9
ΔCCB (bps)	1,256	0.41	10.69	-16.63	0.75	16.28
GFX	1,256	-0.12	0.19	-0.44	-0.11	0.17
ΔFX position	1,256	0.06	0.12	-0.12	0.05	0.27
Investor Characteristics (Country-Sector-by-Quarter Level, 2019q2 - 2024q1)						
Rollover Risk (quarterly)	1,056	0.79	0.24	0.28	0.87	*
US Bonds (Bond-by-Day Level, Apr 2019 - Mar 2024)						
ΔYield Spread (ppt)	1,132,822	0.07	1.31	-1.25	-0.06	1.77
Time to Maturity (years)	1,132,822	6.30	5.83	1.00	5.00	21.00

Table 2. Summary Statistics by Sector: FX Forward Positions and Bond Holdings.
The table depicts the sector-specific time-series averages of the variables from Table 1.

	Banks	Insurers	Investment Funds	Pension Funds
Net FX Position (bil EUR)	-169.81	32.54	494.57	74.18
Gross FX Position (bil EUR)	5,276.59	82.88	1,246.56	146.23
FX: Time to Maturity (months)	3.35	2.65	1.17	2.14
Share of USD Bonds	0.07	0.03	0.38	0.18
Hedge Ratio	-0.56	0.38	0.35	0.57

Table 3. Cross-currency Basis and FX Forward Positions.
Columns (1) and (2) present estimated coefficients from first-stage specifications analogously to equation (5) at daily frequency, where the dependent variable, ΔCCB_t, is the deviation of the 3-month USD-EUR cross-currency basis from its 3-month trailing average (in ppt). The main explanatory variable, GFX_t, is the size-weighted average of idiosyncratic shocks to typical hedgers' FX positions. Columns (3) to (8) present estimated coefficients from second-stage specifications analogously to equation (6) at daily frequency, where the dependent variable is the % deviation of 3-month net FX position from their 3-month trailing average and the explanatory variable is ΔCCB_t. In columns (4) to (8), ΔCCB_t is instrumented with GFX_t. Columns (1) to (4) are based on the time-series of the respective variables. Columns (5) to (8) are based on an investor-by-day panel of FX positions with 2 and 4 months to maturity which only includes investors with a 3-month trailing positive net FX position. *High Rollover Risk* indicates that at least 50% of an investor's FX hedging positions outstanding at the prior month end are maturing in the current month. Rem. Time to Mat is the notional-weighted average time to maturity of hedgers' outstanding FX positions. Macro controls are the change in the risk-free rate US-EA differential and in the log of the S&P 500, Euro STOXX 50, dollar strength, and US and EU VIX from their respective 3-month trailing averages as well as the 4-week trailing standard deviation of USD-EUR spot rates. Aggregate factors are the first three principal components of the residualized % deviation of all investors' net FX positions. Cal. Month FEs are based on dummies for each calendar month. In columns (1) to (4), heteroskedasticity-robust standard errors and, in columns (5) to (8), standard errors clustered by investor and day are in shown in parentheses. We also report the first-stage Cragg-Donald Wald F statistic. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	ΔCCB		ΔFX Position					
	OLS			IV				
Sample:	Time Series				Hedgers			
					Low Rollover Risk	High Rollover Risk	All	
GFX	-0.13***	-0.13***						
	(0.02)	(0.01)						
ΔCCB			0.09***	1.98***	0.38	3.02**	0.54	
			(0.03)	(0.24)	(0.50)	(1.46)	(0.50)	
ΔCCB × High Rollover Risk							2.11	9.74**
							(1.44)	(4.12)
Rem. Time to Mat		Y	Y	Y	Y	Y	Y	
Macro Controls		Y	Y	Y	Y	Y	Y	
Aggregate Factors		Y	Y	Y	Y	Y	Y	
Investor FEs					Y	Y	Y	
High Rollover Risk FEs	Y	Y						
Time FEs								Y
Investor-Cal. Month FEs								Y
F Statistic (1st)				62.2				
No. of obs.	1,256	1,256	1,256	1,256	466,161	81,261	547,428	547,414
No. of investors					998	516	1,033	1,033

Table 4. Cross-currency Basis and Bond Holdings.
Panel (A) presents estimated coefficients from specifications of the form:

$$\Delta \log \text{Bond Holdings}_{i,b,t} = \alpha \Delta \text{CCB}_t \times \text{USD}_b + \Gamma' C_{i,b,t} + \varepsilon_{i,b,t}$$

at country-sector-bond-quarter level. $\Delta \log \text{Bond Holdings}_{i,b,t}$ is the quarterly change in country-sector i's log holdings of bond b at nominal value. ΔCCB_t is the quarterly average in the deviation of the 3-month USD-EUR cross-currency basis from its 3-month trailing average (in ppt). In columns (4) to (7), ΔCCB_t is instrumented with the size-weighted average of idiosyncratic shocks to typical hedgers' FX positions GFX_t. High (low) Rollover Risk indicates that at least (less) than 99% of a country-sector's FX hedging positions outstanding at the prior quarter's end are maturing in the current quarter. $C_{i,b,t}$ is a vector of fixed effects. Panel (B) presents estimated coefficients from a specification of the form:

$$\Delta \text{USD share}_{i,t} = \beta \Delta \text{CCB}_t + \varepsilon'_{i,t}$$

at country-sector-quarter level, where $\Delta \text{USD share}_{i,t}$ is the portfolio share of USD bonds held by country-sector i and the sample excludes country-sectors with the 25% lowest (time-series 25th percentile of the) amount of USD holdings. Standard errors are shown in parentheses, clustered in panel (A) at bond and country-by-currency-by-time levels and in panel (B) at country-sector and country-by-time levels. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

Panel A: Bond level	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	$\Delta \log$ Bond Holdings						
	OLS			IV			
USD × ΔCCB	0.20***		0.18***	0.32***		0.27***	
	(0.02)		(0.02)	(0.04)		(0.04)	
USD × ΔCCB × Low Rollover Risk		0.18***			0.27***		
		(0.02)			(0.04)		
USD × ΔCCB × High Rollover Risk		0.34***	0.16*		0.66***	0.39*	0.17***
		(0.08)	(0.08)		(0.20)	(0.22)	(0.06)
Country-Sector-Time FEs	Y	Y	Y	Y	Y	Y	Y
Country-Sector-Bond FEs	Y	Y	Y	Y	Y	Y	Y
Issuer Industry-Time FEs	Y	Y	Y	Y	Y	Y	
Bond-Time FEs							Y
No. of obs.	8,568,914	8,568,914	8,568,914	8,568,914	8,568,914	8,568,914	6,816,419
No. of bonds	342,185	342,185	342,185	342,185	342,185	342,185	95,018

Panel B: Portfolio level	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	ΔUSD Share					
	OLS			IV		
ΔCCB	0.01***		0.01**	0.05***		0.04***
	(0.00)		(0.01)	(0.01)		(0.01)
ΔCCB × Low Rollover Risk		0.01**			0.04***	
		(0.01)			(0.01)	
ΔCCB × High Rollover Risk		0.03**	0.02		0.07***	0.02
		(0.01)	(0.01)		(0.02)	(0.02)
High Rollover Risk FEs			Y			Y
Country-Sector FEs	Y	Y	Y	Y	Y	Y
No. of obs.	1,080	1,080	958	1,080	1,080	958
No. of country-sectors	54	54	51	54	54	51

Table 5. Role of Hedging Mandates.
This table presents estimated coefficients from specifications of the form:

$$\Delta \log \text{Holdings}_{i,b,t} = \alpha \text{USD}_b \times \Delta \text{CCB}_t + \Gamma' C_{i,b,t} + \varepsilon_{i,b,t}$$

at fund-bond-quarter level. $\Delta \log \text{Bond Holdings}_{i,b,t}$ is the quarterly change in fund i's log holdings of bond b at market value. ΔCCB_t is the quarterly average in the deviation of the 3-month USD-EUR cross-currency basis from its 3-month trailing average (in ppt). In columns (4) to (6), ΔCCB_t is instrumented with the size-weighted average of idiosyncratic shocks to typical hedgers' FX positions GFX_t. Mandate funds are defined as funds with an FX portfolio hedging mandate for at least 10% of outstanding shares on average. We also report the p-value on the coefficient of the interaction term $\text{Mandate}_i \times \text{USD}_b \times \Delta\text{CCB}_t$ in a pooled specification that also includes $\text{USD}_b \times \Delta\text{CCB}_t$ as a control. Standard errors are in parentheses clustered at bond and fund country-by-currency-by-time levels. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	$\Delta \log$ Bond Holdings					
	OLS			IV		
Investors:	All	Non-Mandate	Mandate	All	Non-Mandate	Mandate
USD × ΔCCB	0.13***	0.12***	0.14***	0.12**	0.11	0.19***
	(0.03)	(0.03)	(0.02)	(0.06)	(0.07)	(0.05)
Investor-Time FEs	Y	Y	Y	Y	Y	Y
Investor-Bond FEs	Y	Y	Y	Y	Y	Y
No. of obs.	4,990,671	4,488,981	501,690	4,990,671	4,488,981	501,690
No. of bonds	54,757	51,144	26,525	54,757	51,144	26,525
p-value for H0: Mandate = Non-Mandate			0.50			0.21

Table 6. Cross-currency Basis and Bond Yields.
This table presents estimated coefficients from specifications of the form:

$$Y_{b,t} = \beta \Delta \text{CCB}_t + \Gamma' C_{b,t} + \varepsilon_{b,t}$$

at bond-day level. In columns (1) to (5), the dependent variable is the change in the yield spread of USD corporate bonds from US issuers, defined as the difference in the average of bond b's yield spread (relative to the US treasury yield with the closest remaining time to maturity) on day t and the following 5 days relative to its 3-month trailing average (in ppt). In columns (6) and (7), the dependent variable is the change in the yield of US and EA government bonds, respectively, which are computed analogously. Government bond yields are at maturity-by-issuer country level, considering 3 months and 1, 5, 10, and 20 years to maturity. ΔCCB_t is the deviation of the 3-month USD-EUR cross-currency basis from its 3-month trailing average (in ppt). It is instrumented with the size-weighted average of idiosyncratic shocks to typical hedgers' FX positions GFX_t. We interact ΔCCB_t with an indicator for high rollover risk of those investors that held bond b in the lagged quarter, which is equal to one if the holdings-weighted average lagged share of hedgers' FX derivatives buy notional outstanding at which matures in the month of day t exceeds its median value. $C_{b,t}$ is a vector of fixed effects and control variables. Macro controls are the dollar strength, and US and EU VIX from their respective 3-month trailing averages as well as the 4-week trailing standard deviation of USD-EUR spot rates. The sample consists of USD-denominated US corporate bonds with at least 10% euro-area ownership share. Rating FEs are based on the prior end-of-month's credit rating (either AAA-AA, A, BBB, BB, B, CCC, below CCC, or unrated). Maturity FEs are based on thresholds at 2, 5, 10, and 15 years. Standard errors are shown in parentheses, clustered at bond and day levels. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	ΔYield Spread					ΔYield	
Sample:	US Corporate					US Gov	EA Gov
	IV						
ΔCCB	-0.74			0.24			
	(0.45)			(0.49)			
ΔCCB × Low Rollover Risk		0.24	0.24				
		(0.49)	(0.49)				
ΔCCB × High Rollover Risk		-1.82***	-1.80***	-2.04***	-1.60***	-1.16	0.43***
		(0.61)	(0.60)	(0.63)	(0.49)	(1.03)	(0.13)
Macro Controls	Y	Y	Y	Y			
Bond FEs	Y	Y	Y	Y	Y	Y	Y
High Rollover Risk FEs		Y	Y	Y	Y	Y	Y
Maturity			Y	Y			
Rating			Y	Y			
Maturity-Time FEs					Y		
Rating-Time FEs					Y		
Time FEs						Y	Y
No. of obs.	1,132,822	1,132,822	1,132,822	1,132,822	1,132,794	5,997	87,488
No. of bonds	2,237	2,237	2,237	2,237	2,237		
No. of issuer-maturity pairs						5	71

Internet Appendix for

The Implications of CIP Deviations for International Capital Flows

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A Relegated Model Derivations

A.1 Optimization Problem

European Investor The European investor maximizes its lifetime logarithmic utility from consumption given as

$$V_t = \max_{\{c_\tau, w^d_\tau, w^a_\tau, \alpha_\tau\}_{\tau=t}^{\infty}} \mathbb{E}\left[\int_t^\infty e^{-\rho(\tau-t)} \log(c_\tau) d\tau\right]$$

subject to the law of motion of wealth:

$$\frac{dn_t}{n_t} = \Big(r^e + w^a_t(r^d + \varsigma_t + \mu^x - r^e) + w^d_t(r^d + \mu^x - r^e) + \alpha_t(\theta_t - \mu^x) - c_t/n_t\Big)\, dt$$
$$+ (w^d_t + w^a_t - \alpha_t)\sigma^x dZ^x_t + w^a_t \sigma^a dZ^a_t + (e^{-\nu|dw^a_t|} - 1)$$

and

$$w^d_t \geq 0,$$

where n_t is the net worth and c_t is the consumption in period t. The European investor invests w^a_t and w^d_t of its wealth into risky and interest rate risk-free USD assets, respectively, and hedges α_t of its wealth. It also faces the transaction cost of ν when adjusting the holding of risky USD assets following d'Avernas et al. (2024).[1]

CIP Arbitrageur The CIP arbitrageur takes advantage of the deviation from CIP (i.e., the CCB) but faces a positive balance sheet cost and is restricted from taking any exchange rate risk by mandate, making it a pure cross-currency basis arbitrageur. By assumption, the CIP arbitrageur is prevented from taking exchange rate risk so that $\alpha^s_t = w^d_t$. It maximizes

$$V^s_t = \max_{\{\alpha^s_\tau\}_{\tau=t}^{\infty}} \mathbb{E}\left[\int_t^\infty e^{-\rho(\tau-t)} \log(c^s_\tau) d\tau\right]$$

[1] To keep our problem tractable, we assume that this transaction cost takes an exponential form in the size of the transaction so that the first-order condition for logarithmic utility agents is linear in the transaction cost.

subject to

$$\frac{dn_t^s}{n_t^s} = (r^e + \alpha_t^s(r^d + \theta_t - r^e) - c_t^s/n_t^s)dt - \frac{\chi}{2}\,(\alpha_t^s)^2\,dt,$$

where n_t^s is the arbitrageur's net worth and χ is a parameter that modulates the strength of the quadratic balance sheet cost. When the CCB is negative, as observed in the data, arbitragers have the incentive to borrow in risk-free USD assets and sell FX contracts (supplying the hedge). This supply fulfills the European investor's hedging demand as well as the residual demand d_t.

Global Outside Investor To close the model and simplify our derivations, we assume the existence of outside-demand investors for risky USD assets whose demand is given by

$$\widetilde{b}_t = \begin{cases} 0 & r^d + \varsigma_t + \mu^x - r^e < \overline{r}_t^a, \\ [0, +\infty) & r^d + \varsigma_t + \mu^x - r^e = \overline{r}_t^a. \end{cases}$$

That is, it is willing to purchase elastically any excess supply of the risky USD assets for a net return of $\overline{r}_t^a$.

A.2 First-order Conditions

We first derive the first-order conditions for the European investor and the global cross-currency basis arbitrageur. As d_t is the only parameter that varies across states, we denote agents' dynamic investing choice as functions of d_t.

European Investor For logarithmic preferences, we can guess and verify the form of the value function as

$$V(n_t, w_t^a; d_t) = \xi(d_t) + \frac{\log(n_t)}{\rho} + \frac{\phi(d_t)w_t^a}{\rho} \tag{IA.1}$$

and write the HJB as follows:

$$\begin{aligned} V(n_{t\text{-}}, w_{t\text{-}}^a; d_t) = \max_{c_t, w_t^a, w_t^d, \alpha_t} \Big\{ &\log(c_t)dt + (1-\rho dt)(1-\lambda(d_t)dt)\mathbb{E}_t\big[V(n_t + dn_t, w_t^a; d_t + d(d_t)|dS_t = 0\big] \\ &+ (1-\rho dt)\lambda(d_t)dt\mathbb{E}_t\big[V(n_t + dn_t, w_t^a; d_t + d(d_t))|dS_t = 1\big]\Big\} \end{aligned}$$

where dS_t denotes the Poisson process for d_t. Using Ito's lemma

$$\begin{aligned}(\rho+\lambda(d_t))V(n_t, w^a(d_t); d_t) =& \log(c(d_t)) + \lambda(d_t)V(n_t e^{-\nu|w^a(d_t+d(d_t))-w^a(d_t)|}, w^a(d_t+d(d_t)); d_t+d(d_t)) \\ &+ \Big[r^e + w^a(d_t)(r^d+\varsigma(d_t)+\mu^x-r^e) + w^d(d_t)(r^d+\mu^x-r^e) \\ &\quad + \alpha(d_t)(\theta(d_t)-\mu^x) - c(d_t)/n_t\Big] n_t V_n(n_t, w^a(d_t); d_t) \\ &+ \Big[(w^d(d_t)+w^a(d_t)-\alpha(d_t))^2(\sigma^x)^2/2 + (w^a(d_t)\sigma^a)^2/2\Big] n_t^2 V_{nn}(n_t, w^a(d_t); d_t) \\ &+ \Lambda^d(d_t)w^d(d_t),\end{aligned}$$

where $\Lambda^d(d_t) \geq 0$ is the Lagrangian parameter for $w^d(d_t) \geq 0$. Substituting V obtains

$$\begin{aligned}(\rho+\lambda(d_t))\phi(d_t)w^a(d_t) =& \rho\log(c(d_t)/n_t) + \lambda(d_t)\left(-\nu|w^a(d_t+d(d_t)) - w^a(d_t)| + \phi(d_t+d(d_t))w^a(d_t+d(d_t))\right) \\ &+ r^e + w^a(d_t)(r^d+\varsigma(d_t)+\mu^x-r^e) + w^d(d_t)(r^d+\mu^x-r^e) \\ &+ \alpha(d_t)(\theta(d_t)-\mu^x) - c(d_t)/n_t - (w^d(d_t)+w^a(d_t)-\alpha(d_t))^2(\sigma^x)^2/2 \\ &- (w^a(d_t)\sigma^a)^2/2 + \rho\Lambda^d(d_t)w^d(d_t) + \rho\left(\lambda(d_t)\xi(d_t+d(d_t)) - (\rho+\lambda(d_t))\xi(d_t)\right).\end{aligned}$$

The first-order conditions for c, w^d, and α are then given by

$$c(d_t)/n_t = \rho \tag{IA.2}$$

$$r^d + \mu^x - r^e - (w^d(d_t)+w^a(d_t)-\alpha(d_t))(\sigma^x)^2 + \rho\Lambda^d(d_t) = 0 \tag{IA.3}$$

$$\theta(d_t) - \mu^x + (w^d(d_t)+w^a(d_t)-\alpha(d_t))(\sigma^x)^2 = 0. \tag{IA.4}$$

When CCB is negative, $r^d + \theta(d_t) - r^e < 0$, we have $\Lambda^d(d_t) > 0$ and $w^d(d_t) = 0$ hold for all d_t.

Following d'Avernas et al. (2024), $\phi(d) = -\phi(d') = \nu$ when $w^a(d') < w^a(d)$, and $-\nu \leq \phi(d), \phi(d') \leq \nu$ when $w^a(d') = w^a(d)$. Hence, we can write the envelope theorem of $w^a(d_t)$ in the same form whether or not the European investor sells risky USD assets in the shock state. It is as follows:

$$\begin{aligned}(\rho+\lambda(d_t))\phi(d_t) =& \lambda(d_t)\phi(d_t+d(d_t)) + r^d + \varsigma(d_t) + \mu^x - r^e \\ &- (w^d(d_t)+w^a(d_t)-\alpha(d_t))(\sigma^x)^2 - w^a(d_t)(\sigma^a)^2.\end{aligned} \tag{IA.5}$$

CIP Arbitrageur Similarly, for logarithmic preferences, we can guess and verify the form of the value function as

$$V^s(n_t^s; d_t) = \xi^s(d_t) + \frac{\log(n_t^s)}{\rho} \tag{IA.6}$$

and use Ito's Lemma to obtain

$$\rho V^s(n_t^s; d_t) = \log(n_t^s) + \left[r^e + \alpha^s(d_t)(r^d + \theta(d_t) - r^e) - \frac{\chi}{2}(\alpha^s(d_t))^2 \right] n_t^s V_{n^s}^s(n_t^s; d_t). \tag{IA.7}$$

The first-order condition for α^s is then given by

$$r^d - r^e + \theta(d_t) = \chi \alpha^s(d_t). \tag{IA.8}$$

When CCB is negative, $r^d + \theta(d_t) - r^e < 0$, it must be that for all d_t,

$$\alpha^s(d_t) = \frac{r^d - r^e + \theta(d_t)}{\chi} < 0. \tag{IA.9}$$

A.3 Solving

We then solve the equilibrium outcomes in both the steady and shock states.

Steady State: $d_t = d$. Equilibrium restriction (iii) implies that $\widetilde{b}(d) = 0$. Then by the market-clearing condition, we immediately get $w^a(d) = b$. From the FX contract market-clearing condition and the first-order condition (IA.4)

$$\alpha(d) = -\alpha^s(d) - d = \frac{r^e - r^d - \theta(d)}{\chi} - d, \tag{IA.10}$$

$$\theta(d) - \mu^x + (w^a(d) - \alpha(d))(\sigma^x)^2 = 0, \tag{IA.11}$$

we can solve for $\alpha(d)$ and $\theta(d)$ as

$$\alpha(d) = \frac{(\sigma^x)^2 b - \chi d}{\chi + (\sigma^x)^2}, \tag{IA.12}$$

$$r^d + \theta(d) - r^e = -\frac{(\sigma^x)^2(b + d)}{1 + \frac{1}{\chi}(\sigma^x)^2}, \tag{IA.13}$$

given the equilibrium restriction that UIP holds, $r^d + \mu^x - r^e = 0$. Then, from the envelope theorem, we obtain

$$\begin{aligned}\varsigma(d) &= (\rho+\lambda)\phi(d) - \lambda\phi(d') + (\sigma^a)^2 b - (r^d + \theta(d) - r^e) \\ &= (\rho+\lambda)\phi(d) - \lambda\phi(d') + (\sigma^a)^2 b + \frac{(\sigma^x)^2(b+d)}{1+\frac{1}{\chi}(\sigma^x)^2}. \end{aligned} \tag{IA.14}$$

Shock State: $d_t = d'$. Equilibrium restriction (iii) implies that $\varsigma(d') = \varsigma(d)$. Then, given that UIP holds, $w^a(d')$, $\alpha(d')$, and $\theta(d')$ can be solved by the following system of equations:

$$\theta(d') - \mu^x + (w^a(d') - \alpha(d'))(\sigma^x)^2 = 0 \tag{IA.15}$$

$$(\rho+\lambda')\phi(d') - \lambda'\phi(d) = \varsigma(d') - (w^a(d') - \alpha(d'))(\sigma^x)^2 - w^a(d')(\sigma^a)^2 \tag{IA.16}$$

$$\alpha(d') = \frac{r^e - r^d - \theta(d')}{\chi} - d' \tag{IA.17}$$

where $\varsigma(d') = \varsigma(d)$ is given by equation (IA.14). The first equation comes from the first-order condition (IA.4), the second from the envelope theorem, and the third from the FX contract market-clearing condition. The solutions are

$$\begin{aligned} r^d + \theta(d') - r^e &= -\frac{-(\rho+\lambda')\phi(d') + \lambda'\phi(d) + \varsigma(d') + (\sigma^a)^2 d'}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} \\ &= -\frac{(\rho+\lambda+\lambda')(\phi(d) - \phi(d')) + (\sigma^a)^2(d'-d)}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} - \frac{(\sigma^x)^2(b+d)}{1+\frac{1}{\chi}(\sigma^x)^2} \end{aligned} \tag{IA.18}$$

$$\begin{aligned} \alpha(d') &= \frac{1}{\chi}\frac{-(\rho+\lambda')\phi(d') + \lambda'\phi(d) + \varsigma(d') - \chi\left(1+\frac{(\sigma^a)^2}{(\sigma^x)^2}\right)d'}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} \\ &= \frac{1}{\chi}\frac{(\rho+\lambda+\lambda')(\phi(d) - \phi(d')) + \chi\left(1+\frac{(\sigma^a)^2}{(\sigma^x)^2}\right)(d-d')}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} + \frac{(\sigma^x)^2 b - \chi d}{\chi + (\sigma^x)^2} \end{aligned} \tag{IA.19}$$

$$\begin{aligned} w^a(d') &= \left(\frac{1}{\chi} + \frac{1}{(\sigma^x)^2}\right)\frac{-(\rho+\lambda')\phi(d') + \lambda'\phi(d) + \varsigma(d')}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} - \frac{d'}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} \\ &= \left(\frac{1}{\chi} + \frac{1}{(\sigma^x)^2}\right)\frac{(\rho+\lambda+\lambda')(\phi(d) - \phi(d'))}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} - \frac{d'-d}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} + b. \end{aligned} \tag{IA.20}$$

Condition of Fire Sale Following d'Avernas et al. (2024), $\phi(d) = -\phi(d') = \nu$ when $w^a(d') < w^a(d)$, and $-\nu \leq \phi(d), \phi(d') \leq \nu$ when $w^a(d') = w^a(d)$. Hence, given $w^a(d) = b$, by equation (IA.20), $w^a(d) > w^a(d')$ holds if and only if

$$d' - d > 2\left(\frac{1}{\chi} + \frac{1}{(\sigma^x)^2}\right)(\rho + \lambda + \lambda')\nu. \tag{IA.21}$$

This is condition (C) in the main text. When the transaction cost ν is positive, $d' - d$ needs to be large enough for the European investor to have the incentive to sell risky USD assets. If the condition is not met, the shock state lies in the inaction region, and the European investor bears the flow of hedging costs to avoid paying a round-trip transaction cost.

A.4 Proof of Propositions

When Condition (C) holds—that is, the European investor sells risky USD assets in the shock state—the equilibrium outcomes in the steady state are characterized by equations (IA.12)-(IA.14) and those in the shock state are characterized by equations (IA.18)-(IA.20) under equilibrium restrictions (i)-(iii), where $\phi(d) = -\phi(d') = \nu$. We then prove Propositions 2 and 3.

Proof of Proposition 2. By the second line of equation (IA.18), we have

$$\theta(d') - \theta(d) = -\frac{2(\rho + \lambda + \lambda')\nu + (\sigma^a)^2(d' - d)}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} < 0 \tag{IA.22}$$

given that $d' > d$. Hence, $r^d + \theta(d) - r^e > r^d + \theta(d') - r^e$.

By the second line of equation (IA.19), we have

$$\begin{aligned}
\alpha(d') - \alpha(d) &= \frac{1}{\chi}\frac{2(\rho + \lambda + \lambda')\nu + \chi\left(1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\right)(d - d')}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} \\
&< \frac{1}{\chi}\frac{2(\rho + \lambda + \lambda')\nu - \chi\left(1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\right)2\left(\frac{1}{\chi} + \frac{1}{(\sigma^x)^2}\right)(\rho + \lambda + \lambda')\nu}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} \\
&= -\frac{2(\rho + \lambda + \lambda')\nu}{(\sigma^x)^2} < 0,
\end{aligned}$$

where the first inequality follows from Condition (C). Hence, $\alpha(d) > \alpha(d')$.

Finally, the sale of risky USD assets $w^a(d) > w^a(d')$ directly follows from Condition (C).

Proof of Proposition 3. By the second line of equation (IA.20), we have

$$w^a(d') - w^a(d) = \left(\frac{1}{\chi} + \frac{1}{(\sigma^x)^2}\right) \frac{2(\rho + \lambda + \lambda')\nu}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} - \frac{d' - d}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)}. \tag{IA.23}$$

Given that $d' - d$ is fixed, we further obtain

$$\frac{\partial(w^a(d) - w^a(d'))}{\partial \lambda'} = -2\nu \frac{\frac{1}{\chi} + \frac{1}{(\sigma^x)^2}}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} < 0. \tag{IA.24}$$

By the second line of equation (IA.18), we have

$$\theta(d') - \theta(d) = -\frac{2(\rho + \lambda + \lambda')\nu + (\sigma^a)^2(d' - d)}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)}. \tag{IA.25}$$

Given that $d' - d$ is fixed, we further obtain

$$\frac{\partial(\theta(d) - \theta(d'))}{\partial \lambda'} = \frac{2\nu}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} > 0. \tag{IA.26}$$

B Details on Sample Construction

Table IA.1: Variable Definitions and Data Sources.

Note: *EMIR* refers to the European Market Infrastructure Regulation, *MMSR* to the Money Market Statistical Reporting, *CSDB* to the Centralised Securities Database, and *SHS-S* to the Securities Holdings Statistics at Sector level, which all are datasets maintained at the European Central Bank.

Variable	**Definition**
Net FX Position	USD-EUR net FX forward position such that a positive position indicates buying EUR and selling USD in the future (*Source: EMIR*)
Gross FX Position	USD-EUR gross FX forward position (*Source: EMIR*)
FX Time to Maturity	Gross volume-weighted average maturity of outstanding FX positions (*Source: EMIR*)
Hedge Ratio	Total net FX forward position divided by total USD-denominated bond holdings (*Sources: EMIR, CSDB, SHS-S*)
USD	Indicator that equals one if a bond is denominated in USD and zero otherwise (*Source: CSDB*)
CCB	3-month USD-EUR cross-currency basis (*Sources: MMSR, Bloomberg*)

Continued on next page

Table IA.1 – *Continued from previous page*

Variable	**Definition**
Δlog Bond Holdings	Quarterly change in a country-sector pair's or fund's log bond holdings (*Sources: SHS-S, Lipper*)
ΔUSD Share	Quarterly change in the portfolio share of USD bonds relative to all USD and EUR bond holdings (*Sources: CSDB, SHS-S*)
Bond Time to Maturity	Remaining time to maturity (*Sources: CSDB, Mergent FISD*)
ΔYield Spread	Difference between an USD-denominated US corporate bond's average yield spread on day t and the following 5 days and its 3-month trailing average (in percentage points), where the yield spread is the difference between the bond's secondary market yield and the treasury yield with the closest time to maturity (*Sources: TRACE, Mergent FISD, FRED*)
ΔYield	Difference between the average yield of US or EA government bonds for a given issuer-maturity pair on day t and the following 5 days and its 3-month trailing average (in percentage points) (*Sources: FRED, Datastream*)
GFX	Granular instrumental variable based on idiosyncratic shocks to euro-area typical hedgers' 3-month FX positions (*Source: EMIR*)
Rollover Risk (quarterly)	Share of investors' hedging (i.e., net buy) positions outstanding at the prior quarter end that are maturing in the current quarter (*Source: EMIR*)
Risk-free rate US-EA differential	3-month LIBOR - EURIBOR (*Source: Bloomberg*)
S&P 500	US stock market index (*Source: Datastream*)
Euro STOXX 50	European stock market index (*Source: Datastream*)
Dollar strength	Trade-weighted USD exchange rate against its major trading partners (*Source: Datastream*)
US VIX	US stock market volatility index (*Source: FRED St. Louis*)
EU VIX	European stock market volatility index (*Source: Datastream*)
$\Delta \log S^{\mathrm{USD/EUR}}$	Log growth in the USD-EUR spot rate (*Source: Datastream*)
FX volatility	30-day-trailing standard deviation of the daily growth rate of the USD-EUR spot rate (*Source: Datastream*)

B.1 FX Positions (EMIR)

Derivatives transactions are reported to the European Central Bank if at least one counterparty is domiciled in the euro area. From these, we select all positions that are classified as USD-EUR FX forwards or FX swaps.[2] To remove duplicate filings of the same transaction, we link filings that belong to the same transaction and, if there are multiple filings, we require them to match in terms of notional, counterparty, and maturity date. We apply several filters to ensure the reliability of reported data:

1. We drop transactions with missing or implausible information about the spot date,

[2]When a *Classification of Financial Instrument* (CFI) is reported, we impose the CFI to start with JF (FX forward) or SF (FX swaps).

maturity date, notional value, or counterparty side. In particular, we drop trades with an implausible notional, namely those with less than EUR 10 thd or more than EUR 200 billion. We also drop intra-group transactions.

2. We leverage that the EMIR regulation requires that each transaction is reported by all European counterparties involved and use for each transaction the information from the most reliable filing. Specifically, we prefer to use the information from filings by banks that are also subject to MMSR reporting because these typically report more accurately. If such filings are not available, we prefer to use information from filings that include information about the forward rate, and otherwise on the spot rate.

3. We separate the two legs of each trade reported as a swap to construct a homogeneous sample of forward contracts. For this purpose, we drop swap contracts without information about both settlement dates.

   When splitting swaps into forwards, the notional of the forward implied by the second leg differs from that of the first leg.[3] To calculate the notional value of the second leg of swap trades, we require information on contract-specific spot and forward rates. For this purpose, first, we drop swap transactions for which either the spot or the forward rate is missing. Second, when the spot is larger than the forward rate (both in USD per EUR), we swap the two rates.[4] Third, we correct rates with a wrong base currency by comparing reported rates with the Bloomberg spot rate on the trade date, allowing for a $+/-5$ bps (i.e., 0.05 USD per EUR) deviation. If Bloomberg rates are not available for the trade date, we consider the reported rate to be in EUR per USD if it is outside the range of USD per EUR spot rates and within the range of EUR per USD spot rates observed during the sample period.[5]

[3] For example, if the spot rate is 1.1 EUR per USD and the forward rate is 1.2 EUR per USD and the notional of the first leg is EUR 110, then, at the end of the first leg (the "spot date"), EUR 110 are exchanged for USD 100. At the end of the second leg, USD 100 are exchanged for EUR 120 ($= 100 \times 1.2$). Thus, the notional of the forward that only includes the second leg is equal to EUR 120.

[4] Forward points, i.e., the forward-spot differential, is strictly positive for our entire sample, on average, for rates expressed in USD per EUR. Reporting agents are supposed to report rates in USD per EUR. We assume that it is more likely that a counterparty accidentally reports a spot as a forward rate (and vice versa) than that it correctly reports a negative forward point.

[5] The observations that remain far from the USD per EUR spot rates (allowing for a $+/-20$ bps

4. Trades reported as forward contracts are subject to the following two cleaning steps: First, if only a spot but no forward rate is reported, we assume that the spot rate is in fact the forward rate. Second, we delete contracts that report a forward rate that differs by more than $+/-500$ bps from the Bloomberg spot rate (i.e., which implies an implausible forward premium).

Except for descriptive statistics on aggregate FX market volumes (e.g., in Figure 1), we drop Austrian, Finnish, French, and Luxembourg pension funds from the analysis. For these country-sector pairs, the data imply a hedge ratio of more than 300% (in absolute terms), which suggests significant measurement error—e.g., stemming from low accuracy in merging EMIR with SHS-S and a small total amount of USD bond holdings.

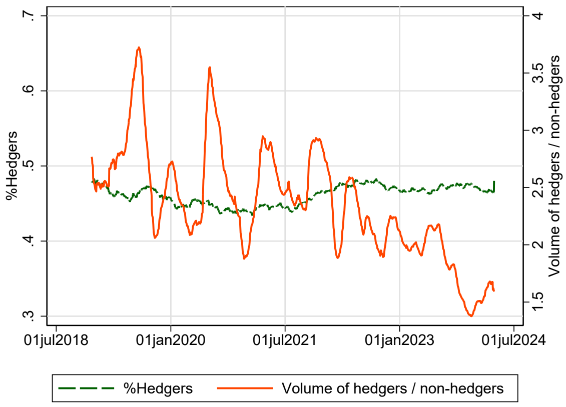
B.2 Spot and Forward Rates (MMSR)

Major euro-area banks are required to report FX swap transactions under the Money Market Statistical Reporting (MMSR) framework (see https://www.ecb.europa.eu/stats/financial_markets_and_interest_rates/money_market/html/index.en.html). This includes information on the spot rate and forward rate as well as the spot and maturity date of contracts. We exclude contracts with a spot date that occurs more than 4 days after the trade date and define 3-month contracts as those with a time to maturity of between 81 and 99 days. On each trading day, we compute the transaction-volume–weighted median spot rate and forward point (the difference between the forward and spot rate) among 3-month contracts. On days on which the market covered by MMSR reporting is relatively illiquid (indicated by a transaction volume below EUR 1 million), we use the forward and spot rates from Bloomberg instead (this only applies to 4 days in our sample).

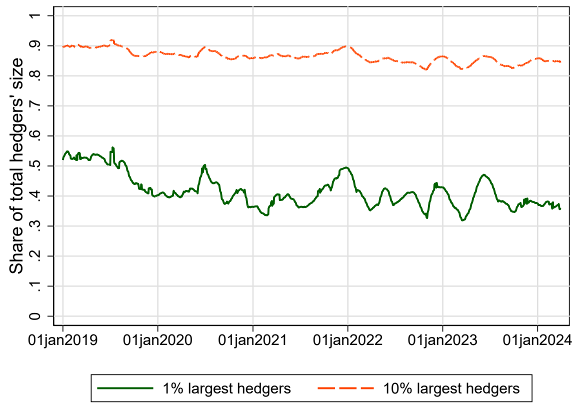
deviation) are deleted. These manipulations implicitly assume that the forward rate is reported with the same base currency as the spot rate.

C Details on GIV Estimation

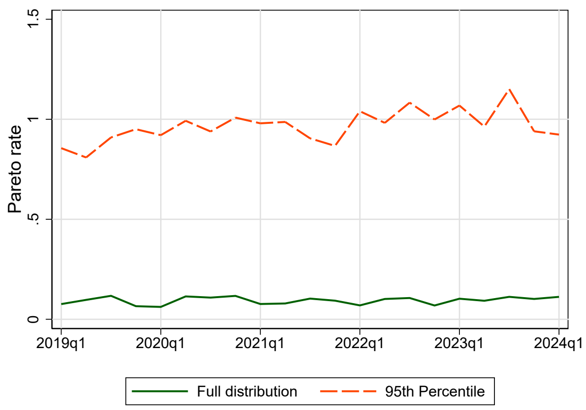
Figure IA.1. FX Market Structure and Granularity in Size Weights.
Hedgers are defined as investors who exhibit a positive 3-month trailing average net FX forward position. Figure (a) plots (i) the number of hedgers relative to the number of investors and (ii) the total net position of hedgers relative to the negative of the total net position of non-hedgers. Figure (b) plots the total size of the 1% and 10% largest hedgers relative to the total size of all hedgers, where size is defined as the 3-month trailing average net FX position. Figure (c) plots the Pareto rate of the cross-sectional distribution of hedger size for each quarter end for (i) all hedgers and (ii) the 5% largest hedgers. The Pareto rate is defined as ξ when sizes are drawn from a power law distribution $\mathbb{P}(S > x) = ax^{-\xi}$. $\xi < 2$ implies that the distribution is fat tailed.



(a) Importance of hedgers

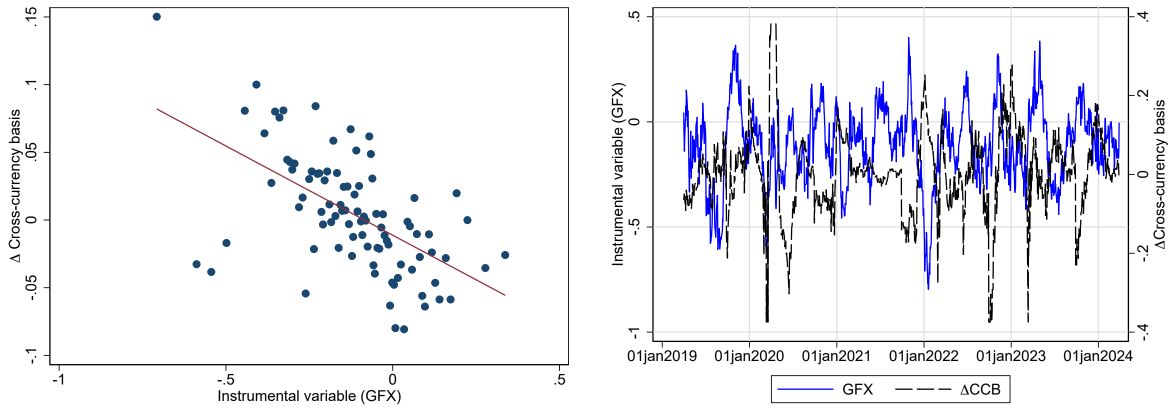


(b) Concentration of hedgers



(c) Pareto rate of hedger size

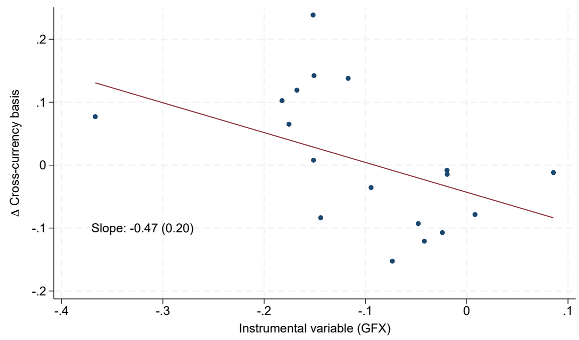
Figure IA.2. Cross-currency Basis and GFX$_t$ at Daily Frequency.
This figure plots the deviation of the 3-month USD-EUR cross-currency basis from its 3-month trailing average, ΔCCB_t, and the size-weighted average of idiosyncratic shocks to typical hedgers' FX positions, GFX_t, (a) as a binned scatter plot and (b) as a time series at daily frequency.



(a) Binscatter plot

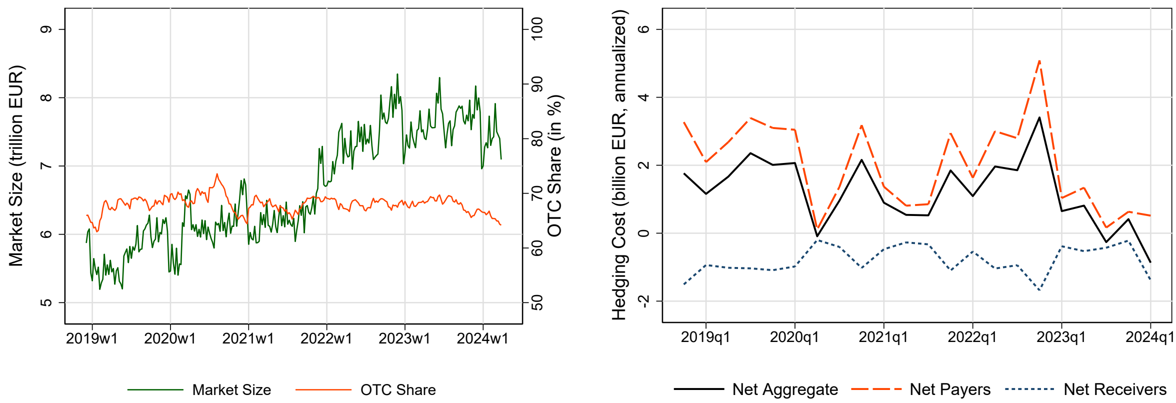
(b) Time series

Figure IA.3. Cross-currency Basis and GFX$_t$ at Quarterly Frequency.
This figure plots the quarterly change in the quarterly average 3-month USD-EUR cross-currency basis, ΔCCB_t, and the size-weighted average of idiosyncratic shocks to typical hedgers' FX positions, GFX_t, as a binned scatter plot at quarterly frequency. We also display the estimated coefficient of the corresponding linear regression and its standard error (in parentheses).



D Additional Figures and Tables

Figure IA.4. Size of and Aggregate Hedging Cost in the European USD-EUR FX Market. Figure (a) depicts on the left vertical axis the gross amount outstanding (in trillion EUR) of all USD-EUR FX contracts outstanding in a given week (averaged across days) reported in EMIR (i.e., with at least one euro-area counterparty) and on the right vertical axis the share of these contracts that is traded over the counter. Figure (b) depicts the annualized net hedging cost paid by (1) the euro area, (2) net payers of hedging costs, (3) net receivers of hedging costs. To calculate the hedging cost, we first compute each investor's quarterly hedging cost defined by $N(e^{-\tau/12\text{CCB}_\tau} - 1)/(\tau/3)$, where N is the quarterly average notional and τ the quarterly average remaining time to maturity in months, and then annualize and aggregate across (1) all investors, (2) investors with positive net hedging cost, and (3) investors with negative net hedging cost.



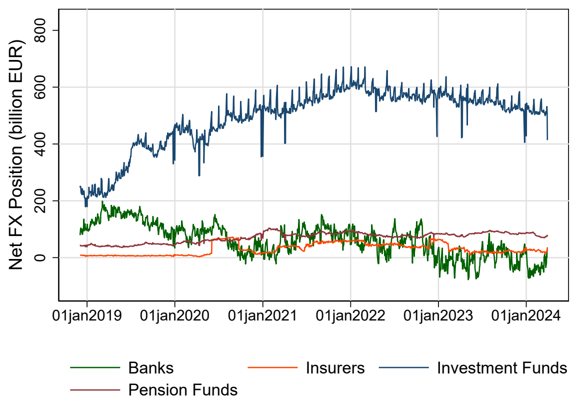
(a) Market Size (b) Hedging Cost

Table IA.2. Additional Summary Statistics. The table depicts summary statistics for the change in yields and maturities of US and euro-area government bonds at issuer-country-by-maturity level at daily frequency. The sample includes bonds with 3 months and 1, 5, 10, and 20 years to maturity.

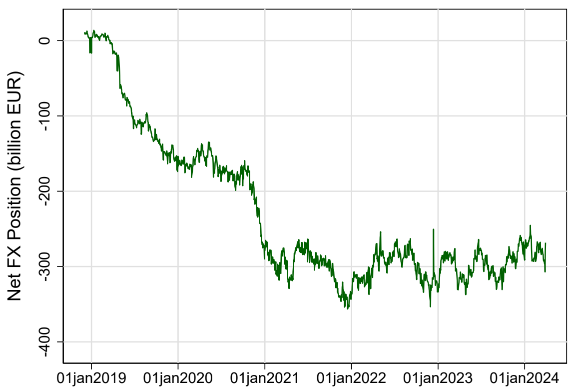
	N	Mean	SD	p5	p50	p95
US Treasuries (Maturity-by-Day Level, Apr 2019 - Mar 2024)						
ΔYield (ppt)	5,997	0.06	0.32	-0.43	0.02	0.67
Time to Maturity (years)	5,997	89.96	87.23	3.00	60.00	240.00
EA Gov Bonds (Maturity-by-Issuer-by-Day Level, Apr 2019 - Mar 2024)						
ΔYield (ppt)	87,488	0.06	0.28	-0.35	0.02	0.61
Time to Maturity (years)	87,488	111.48	82.35	3.00	120.00	240.00

Figure IA.5. FX Forward Positions by Parent Domicile.

The figures depict the net FX forward derivatives positions analogously to Figure 1 (b), splitting the sample into investors whose parent is headquartered in the euro area (Figure (a)) and those whose parent is not headquartered in the euro area (Figure (b)). Because non-banks with international parents have negligible positions, these are excluded to preserve confidentiality in Figure (b).



(a) Euro-Area Parent.



(b) International Parent (Banks).

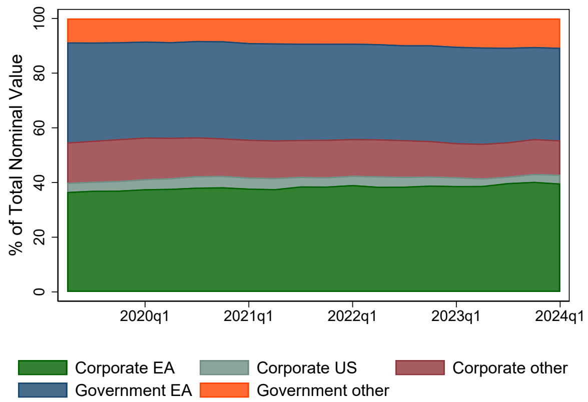
Table IA.3. Bond Holdings and Rollover Risk.

This table tests for differences in portfolio allocation between investors with high and low rollover risk. We regress the portfolio share of (1) USD-denominated, (2) short-term (up to 3 years remaining to maturity), (3) medium-term (between 3 and 13 years), (4) long-term (more than 13 years), (5) investment-grade, (6) high-yield, and (7) unrated bonds on the indicator for investors with high rollover risk at country-sector level at quarterly frequency. Standard errors are shown in parentheses, clustered at country-sector level. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

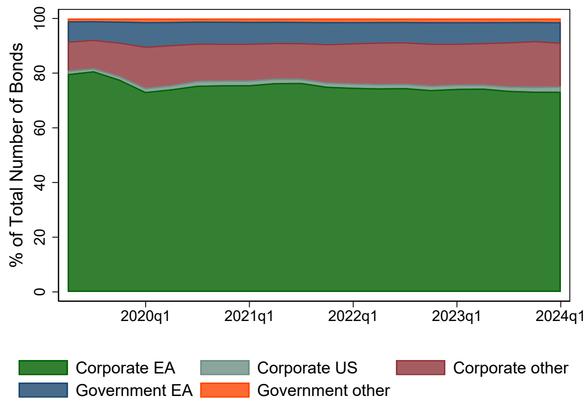
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	Portfolio share of						
	USD	short-term	medium-term	long-term	IG	HY	unrated
High Rollover Risk	0.04	0.02	-0.01	-0.00	-0.03	0.02	0.01
	(0.03)	(0.03)	(0.02)	(0.04)	(0.04)	(0.02)	(0.02)
Time FEs	Y	Y	Y	Y	Y	Y	Y
No. of obs.	1,056	1,056	1,056	1,056	1,056	1,056	1,056

Figure IA.6. Bond Portfolio Composition.

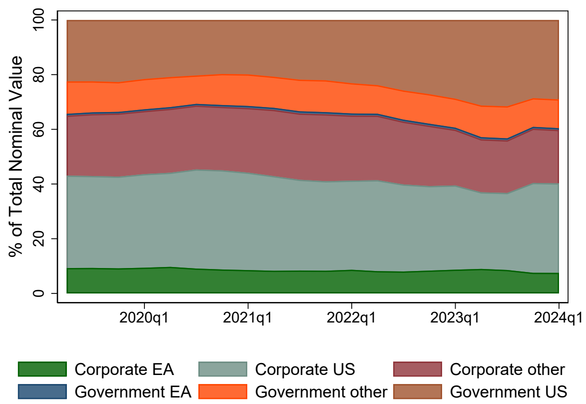
The figures depict the composition of the (a,b) EUR and (c,d) USD bond portfolios of euro-area investors in our main regression sample. We report the composition in terms of (a,c) nominal value held and (b,d) number of bonds.



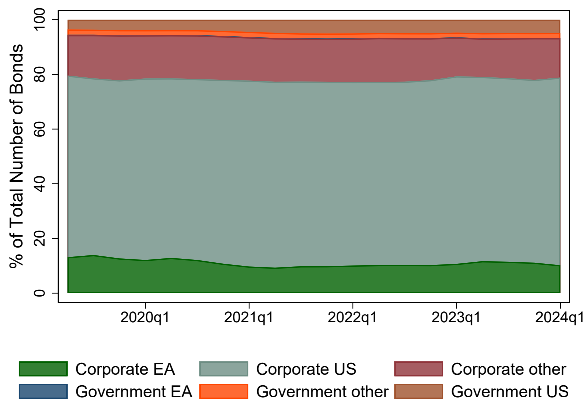
(a) EUR Bonds: Nominal Value.



(b) EUR Bonds: No. of Bonds.



(c) USD Bonds: Nominal Value.



(d) USD Bonds: No. of Bonds.

Table IA.4. Cross-currency Basis and Bond Holdings: Robustness.

This table provides a robustness analysis of the results in column (4) in Panels A and B of Table 4. At security level, column (1) additionally includes credit rating-by-time fixed effects, column (2) maturity bucket-by-time fixed effects, column (3) both types of fixed effects, column (4) includes an interaction of the USD indicator with the quarterly change in the log average USD-EUR spot exchange rate, and column (5) an interaction with the one-quarter–lagged quarterly average 30-day-trailing volatility of the daily change in the log USD-EUR spot rate. Column (6) re-estimates the baseline regression using an alternative instrument that alsoincludes gross-volume-tercile-by-time fixed effects when computing idiosyncratic shocks in equation (3), and column (7) uses an alternative heteroskedasticity-adjusted instrument defined as $\mathrm{GFX}_t^{\mathrm{het}} = \frac{1}{\sum_{i\in\mathcal{L}_t} \bar{Q}_{i,t}} \sum_{i\in\mathcal{L}_t} \bar{Q}_{i,t}\check{q}_{i,t} - \frac{1}{\sum_{i\in\mathcal{L}_t} 1/\sigma_i^2} \sum_{i\in\mathcal{L}_t} \frac{1}{\sigma_i^2}\check{q}_{i,t}$. At portfolio level, column (8) controls for the quarterly change in the log average USD-EUR spot exchange rate and column (9) for the one-quarter–lagged USD-EUR spot rate volatility, defined as above. Standard errors are in parentheses, clustered in columns (1) to (7) at bond and country-by-currency-by-time levels and in columns (8) and (9) at country-sector and country-by-time levels. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Dependent variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\Delta\log$ Bond Holdings							ΔUSD Share	
	IV								
USD × ΔCCB	0.32***	0.31***	0.32***	0.32***	0.31***	0.31***	0.27***		
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)		
USD × $\Delta\log S^{\mathrm{USD/EUR}}$				0.00					
				(0.09)					
USD × FX Volatility					-4.95**				
					(1.99)				
ΔCCB								0.05***	0.04***
								(0.01)	(0.01)
$\Delta\log S^{\mathrm{USD/EUR}}$								0.00	
								(0.01)	
FX Volatility									-0.87***
									(0.27)
Country-Sector-Time FEs	Y	Y	Y	Y	Y	Y	Y		
Country-Sector-Bond FEs	Y	Y	Y	Y	Y	Y	Y		
Issuer Industry-Time FEs	Y	Y	Y	Y	Y	Y	Y		
Rating-Time FEs	Y		Y						
Maturity-Time FEs		Y	Y						
Country-Sector FEs								Y	Y
Instrument	GFX_t					$\mathrm{GFX}_t^{-\mathrm{size}}$	$\mathrm{GFX}_t^{\mathrm{het}}$	GFX_t	
No. of obs.	8,568,914	8,568,914	8,568,914	8,568,914	8,568,914	8,568,914	8,568,914	1,080	1,080
No. of bonds /country-sectors	342,185	342,185	342,185	342,185	342,185	342,185	342,185	54	54