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). The average elasticity is driven by investors who need to roll over existing positions, and it is robust to instrumenting the CCB. These CCB-driven shifts in bond demand significantly affect government bond prices. Our findings shed new light on the determinants of international capital flows and have important consequences for financial stability.

Keywords: Institutional Investors, Currency Hedging, FX Swap, Derivatives, Covered Interest Rate Parity, Foreign Exchange.

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An important no-arbitrage pricing condition in foreign exchange (FX) markets has been the Covered Interest Rate Parity (CIP).[1] Yet, since the Great Financial Crisis and during episodes of financial turmoil in particular, FX markets exhibit significant deviations from CIP, referred to as *cross-currency basis* (CCB) (Du et al., 2018). A first-order concern for financial stability is that foreign investors withdraw from US dollar capital markets during such episodes. For instance, this has prompted the Fed to intervene 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, 2024).[2] Whereas the prior literature has mostly focused on the sources of deviations from CIP, little is known of their consequences for international capital markets.

In this paper, we aim to fill this gap. To do so, we combine two regulatory datasets that jointly cover the universe of FX derivatives and securities holdings in the euro area (EA). We document three important facts. First, EA investors hold a total of more than EUR 2 trillion in USD-denominated bonds, stressing the significance of the euro area for US dollar capital markets. Second, EA non-bank financial institutions hedge the currency risk of a significant proportion, approximately 40%, of these assets using FX derivatives. Third, FX derivatives exhibit a substantially shorter maturity (2.3 months) than the hedged assets (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. This incentivizes risk-averse EA investors to rebalance their portfolio away from USD-denominated assets. In line with these predictions, we document that euro-area investors significantly rebalance from USD- to EUR-denominated bond holdings in response to a wider CCB, especially when faced with greater FX rollover risk. This rebalancing significantly affects EUR-denominated government bond prices, which appreciate in response. These results are robust to instrumenting the cross-currency basis with a granular instrumental variable, which we construct using transaction-level data on FX positions to construct a novel. Taken together, our findings suggest a causal impact of FX derivatives market frictions on international capital markets.

[1] 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 on the spot market to earn the risk-free euro rate while simultaneously entering into a forward contract fixing the future exchange rate, which, as a bundle, is called "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).

To guide our empirical investigation, we first develop a stylized dynamic model of international portfolio allocation with FX derivatives markets and limited arbitrage. In the model, EA investors allocate their portfolios between long-term assets denominated in EUR and US dollar and trade short-term cross-currency derivatives. Because EA investors cannot borrow in dollars, FX derivative markets are essential to hedge currency risk. Instead, currency arbitrageurs have the ability to directly borrow in dollars but face convex balance sheet costs, which generate an upward-sloping supply curve for forward contracts (Du et al., 2018). This friction accounts for the existence of frictions to currency dealer intermediation (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 larger hedging costs, to which investors respond by reducing FX hedging positions and USD asset holdings. Moreover, the model implies that more persistent CCB shocks result in stronger portfolio rebalancing despite a weaker impact on the level of CCB because they correspond to increased investors' willingness to bear fixed portfolio adjustment costs.

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 as well as bond holdings at the security level, merging several data sources available at the European Central Bank (ECB). We document several novel facts about currency risk hedging: (i) the USD-EUR FX derivatives market has grown steadily to a size of EUR 8 trillion in 2023, roughly equivalent to the size of the European repo market; (ii) FX positions typically have much shorter maturity than bond holdings, with the average time to maturity of FX positions being 2.3 months and 8.9 years for USD-denominated bond holdings; (iii) hedge ratios, computed as the ratio of FX positions to USD-denominated bond holdings, are heterogeneous across investors, with insurance companies hedging on average 38%, investment funds hedging 35%, and pension funds hedging 57% while banks supply more hedging than they demand (-56%). Hedging supply by banks is driven by global banks, which have access to international money market markets.

In our main analysis, we study the relationship between investor behavior and the USD-EUR cross-currency basis. We document a significant reduction in euro-area investors' holdings of USD-denominated bonds relative to EUR-denominated ones in response to a widening (i.e., more negative) cross-currency basis. Exploiting the granularity of our dataset, we rule out that this correlation is driven by aggregate or investor-specific fluctuations in macroeconomic conditions. However, the possible presence of currency-specific omitted variables and simultaneous supply and demand shocks could still bias our estimates. For example, an increase in the interest rate differential between the US and the euro area increases the demand for USD bonds, thereby widening the cross-currency basis and biasing our OLS estimate toward zero.

We overcome this identification challenge by leveraging the granular nature of our data. First, motivated by the predictions of our model, we explore heterogeneity across investors in their exposure to the CCB driven by rollover risk. We use the investor-level share of FX hedging positions from the last quarter that mature in the current quarter as a measure of FX rollover risk. We find that the average response in bond holdings is driven by investors with high rollover risk, consistent with these investors being more exposed to increased FX hedging costs. The sensitivity of high-rollover-risk investors is significantly larger than that of investors with low rollover risk. This finding suggests that the response of bond holdings to the CCB is driven by investor currency hedging in the FX derivatives market rather than omitted macroeconomic conditions that differently affect EUR- and USD-denominated bonds.

Second, to improve the identification at the aggregate level, we construct a granular instrumental variable for the CCB by isolating idiosyncratic shifts in FX positions. Specifically, we purge daily changes in investor-level FX positions from sector-by-country-wide shocks, which removes potentially confounding variation stemming from shocks at the aggregate, sector, country level, and any combination of these. Due to the high concentration of agents in the FX derivatives market, the remaining idiosyncratic shocks do not wash out in the aggregate (Gabaix, 2011). We use their size-weighted average to identify aggregate shocks to the cross-currency basis (Gabaix and Koijen, 2023). These isolated demand shifts significantly move the CCB, validating the instrument's relevance. A close to 10% increase in currency risk hedgers' net FX positions (approximately EUR 8.5 billion) is associated with a 1 bps widening in the CCB, consistent with significant limits to arbitrage in the supply of currency risk hedging.

First, the instrumental variable approach allows us to estimate the FX elasticity of demand. Instrumented changes in the CCB significantly affect FX positions. We estimate that a 1 bps widening of the CCB (7.5% of its standard deviation), reduces FX derivatives positions by

2.4% on average. This finding aligns with the model predictions and also helps to alleviate endogeneity concerns: It is unlikely that an omitted variable would be related to both lower hedging demand and higher hedging cost. The estimated coefficient suggests that FX demand is relatively inelastic, consistent with the presence of strong hedging motives (Liao and Zhang, 2020). FX demand elasticity is significantly larger for investors with high rollover risk, especially when these maintain net USD hedging positions in longer-term derivatives.

We then revisit our main analysis using the instrumented cross-currency basis. The 2SLS estimate for the USD bond demand elasticity to CCB remains highly significant and is slightly increased compared to the OLS estimate, as would be expected when removing simultaneity bias. We estimate that a 1 bps widening of the cross-currency basis reduces EA investors' holding of an average USD-denominated bond by 0.32% relative to EUR-denominated bonds. Adjusting this estimate by the distribution of bond holdings implies a decline in euro-area USD bond demand by 0.29% for the average EUR invested in USD bonds. This magnitude is consistent with existing estimates for the price elasticity of bonds and suggests that EA investors view currency-hedged USD bonds and EUR-denominated as close substitutes. It implies significant international flows from large movement in the CCB as expected in periods of crisis: We estimate that the 95th largest percentile change in the CCB implies a decline of close to EUR 100 billion in USD bond holdings by euro-area investors.

Using the instrumented CCB, we also confirm the significantly larger response of investors with higher rollover risk. The difference to investors with low rollover risk is also significant after including security-by-time fixed effects, which absorb any bond-specific (and, thus, currency-specific) shocks. Whereas the baseline analysis is performed at the security 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 and additionally absorbing shocks to investors with different size (measured by gross FX positions).

Finally, we explore the implications of CCB-driven investor rebalancing on asset prices. Our results on bond holdings imply an increase in demand for EUR-denominated bonds following a widening (i.e., decrease) in the CCB. Therefore, we expect EUR bond yields to decrease in response. We test this hypothesis by focusing on euro-area government bonds, which exhibit significant euro-area ownership (50% of outstanding amounts on average in our sample).

Whereas the average bond's yield is not significantly correlated with the CCB, we uncover significant differences across bonds whose investors have heterogeneous rollover risk. We compute for each bond (aggregated to the issuer-maturity level) the average rollover risk of its investor base, defined as the share of maturing FX hedging contracts. The yields of bonds with high rollover risk exposure display a significantly negative correlation with the CCB: as a more negative CCB reduces their investors' demand for USD relative to EUR bonds, these bonds appreciate in price, consistent with the hypothesis. Instead, the response is significantly lower for bonds with low rollover risk exposure, emphasizing FX derivatives pricing as the main underlying driver.

These results are robust to controlling for potential macroeconomic confounders such as financial market uncertainty or exchange rate volatility. They are also robust to using the instrumental variable strategy. Our second-stage estimate implies that the yield of rollover-risk–exposed bonds declines by approximately 1 bps in response to a 1 bps widening in the CCB. This magnitude is consistent with investors trading off the cost of larger hedging costs on USD-denominated bonds with a lower yield on EUR-denominated bonds.

Related Literature This paper builds on recent studies documenting persistent deviations from CIP since the Great Financial Crisis, driven by new regulations limiting intermediary 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 investors demand for US dollar funding and hedging having been shown to be a significant driver of the CCB (Aldunate et al., 2022; Kloks et al., 2024), emphasizing the global importance of the USD (Coppola et al., 2024). Dávila et al. (2023) estimate the social cost of those CIP deviations based on price elasticity in the FX futures market. We complement this literature by investigating the consequences of this opening of the cross-currency basis for capital markets rather than its causes, focusing on institutional investors' currency hedging, portfolio allocations, and bond yields. Closely related, Liao (2020) studies the consequences of CIP deviations for corporations' currency choice in bond issuances, whereas we study its consequences for investors' currency portfolio allocations. Ahmed et al.

(2023) finds evidence that EA investors rebalance to riskier USD-denominated corporate bonds following US monetary policy shocks, which reduce currency-hedged returns. We focus instead on the currency portfolio allocation 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 substantial home bias among international investors (Coeurdacier and Rey, 2013). Maggiori et al. (2020) attribute home bias among investment funds to currency preferences. Faia et al. (2022) examine the effects of investor currency preferences on international yield differentials. Our finding that portfolio choice is affected by cross-currency basis suggests that frictions in FX derivatives markets may contribute to such 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 cross-currency basis.

The availability of empirical data on investor currency hedging remains notably limited in the existing literature. Du and Huber (2023) estimate hedge ratios based on hand-collected industry-level publications. Sialm and Zhu (2021) and Opie and Riddiough (2024) explore the currency hedging by U.S. fixed-income and equity funds, respectively, based on manually collected data from SEC filings. Alfaro et al. (2021) use a granular regulatory dataset on Chilean FX derivatives to study the currency hedging of non-financial firms. We extend these studies by exploiting detailed regulatory filings covering the entire euro area.

International macro-finance models also highlight the importance of currency risk in portfolio allocation (Campbell and Viceira, 2002; Campbell et al., 2010; Coeurdacier and Gourinchas, 2016). Existing models typically study optimal portfolios under the assumption that currency risk is either fully hedged or unhedged. We contribute to this literature by jointly modeling the currency portfolio allocation and hedging decision in a model in which hedging is subject to cross-currency basis risk due to the maturity mismatch between the hedging and foreign asset positions.

1 Data

We create a novel data set that provides a complete picture of euro-area investors' bond investments and their FX derivatives positions by combining detailed filings to European regulatory authorities. Appendix Table IA.1 provides an overview of variable definitions and sources. We describe the main data sources and variables in the following.

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 at 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. To homogenize information on swaps and forwards, we convert each FX swap into two forward contracts. Investors are identified by their Legal Entity Identifier (LEI), which we use to obtain information about their domicile and sector following Lenoci and Letizia (2021). We apply several filters to clean the data, which we describe in Appendix B. We focus on the most important financial sectors in the FX market, which are banks (including dealers), investment funds, insurance companies, and pension funds. These collectively account for nearly 90% of total gross positions in the euro area.

Throughout the paper, we define as a *buy* position one which requires 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 where the investor that buys USD at the spot date commits to sell back the USD against EUR at the maturity date. 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 are not mechanically resulting from exchange rate fluctuations.

Securities Holdings The Securities Holdings Statistics by Sector (SHS-S) at the ECB 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 positions in EUR- and USD-denominated bonds of euro-area sectors at a quarterly frequency from 2013Q1 to 2024Q1 at both nominal and market value. Securities are identified by their International Security Identification Number (ISIN). We use the ISIN 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).

Bond Yields We retrieve information on euro-area government bond yields at daily frequency by country and maturity from Thomson Reuters Datastream. To focus on the most liquid segments of the market, we consider 3 months and 1, 5, 10, and 20 years remaining to maturity. The sample includes government bonds issued by Austria, Belgium, Cyprus, Germany, Spain, Finland, France, Greece, Ireland, Italy, Lithuania, Latvia, Netherlands, Portugal, Slovenia, and Slovakia.

Cross-Currency Basis We use the Money Market Statistical Reporting (MMSR) to the ECB to extract information on the spot and forward rates in the euro-area FX market. MMSR provides confidential information on all USD-EUR swap transactions by major euro-area 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 is the USD-EUR spot exchange rate, and $F_{t,\tau}$ is the τ-months USD-EUR forward rate.[3] 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 $\mathrm{CCB}_{t,\tau}$, the larger the cost for euro-area investors (with EUR funding) to hedge their USD investments.

2 Stylized Facts

We first make use of our novel dataset to document a series of salient facts about FX derivatives markets. Overall, we find that the USD-EUR market is large and entails significant costs for euro-area investors stemming from CIP deviations.

USD-EUR Derivatives Market We compute the market size of the USD-EUR FX derivatives market as the total notional amount outstanding of all USD-EUR FX contracts with at least one euro-area counterparty. The market has steadily 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), and, thus, highlights the significance of the USD-EUR FX derivatives market.

Leveraging the exhaustive coverage of the EMIR dataset, we further document that approximately 70% of the USD-EUR FX market volume is traded over the counter (OTC) (see Appendix Figure IA.4). The OTC share is very stable over the sample horizon, suggesting that the increase in market volumes is not driven by changes in market structure. The OTC nature of derivatives markets gives rise to significant financial frictions (Duffie et al., 2005) and

[3] Due to the cessation of LIBOR, it has been 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.

strengthens the importance of (global) dealers in managing liquidity.

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

We further report each financial sector's net position in Figure 1 (b).[4] In comparison to gross positions, net positions are dominated by the investment fund sector, with a positive net buy position of approximately EUR 600 billion (gaining in case of a future depreciation of the USD). The pension fund sector has the second-largest net buy 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 EUR 200 billion.

To hedge their USD hedging positions, some global banks access direct USD funding through their US parent or subsidiary. We document evidence for this behavior by splitting the sample into international investors and domestic investors based on the location of their parents. Consistently, we find that banks with international parents are net suppliers of USD hedging in the euro area, displaying a net FX sell position of EUR 300 billion. In contrast, banks with domestic (euro-area) parents exhibit a total net FX position of close to zero. Note that this pattern is mostly driven by banks, as the presence of investment funds, insurers, and pension funds with international parents is negligible.

Lastly, we make use of our comprehensive dataset to quantify the contribution of CIP deviations to EA investors' hedging costs. The cross-currency basis at the 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.[5] The net hedging cost peaked in 2022Q4 at EUR 3.4 billion. Whereas the majority of

[4]Monthly spikes in net FX positions, especially of investment funds, are due to the fact that EMIR reporting does not include very short-term derivatives contracts.

[5]More specifically, we first compute each investor's quarterly hedging cost paid defined by $\mathcal{C}_{i,t} = N_{i,t}(\exp(-\tau/12\mathrm{CCB}_{t,\tau}) - 1)/(\tau/3)$, where $N_{i,t}$ is the quarterly average net notional of investor i and τ the

euro-area investors pay the cross-currency basis, some are receivers as they sell future EUR. Net payers paid more than EUR 5 billion in 2022 in hedging costs.

FX Derivatives Positions and USD Investments By combining two holistic datasets, we can compute the portion of USD-denominated bonds that is currency-hedged for the entire euro area. On average, we find that euro-area non-bank investors hedge 43% of their USD bond holdings, whereas banks exhibit a negative hedge ratio of -56% (see Table 1). We further document a striking maturity mismatch between the average maturity of USD bond holdings of 8.9 years and that of FX derivatives positions of 2.3 months. These findings imply that investors face rollover risk in their FX contracts and are, therefore, exposed to shocks to the CCB. We also find that 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%).

Figure 3 provides additional insight into the hedging activity of European investors. We first plot net FX positions against the volume of USD bonds holdings at the 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 forward position than others (insurers and banks). Moreover, all non-bank sectors display a strong and positive relationship between net FX positions and USD bond share across time. These patterns are consistent with foreign currency assets hedging as a key driver of FX positions. Instead, the banking sector's FX position is not correlated with its USD bond share in aggregate. This suggests that banks' FX activity is not primarily driven by demand for hedging USD bond investments, consistent with banks being the main suppliers of currency risk protection through direct access to USD funding.

Figure 3 (b) compares net FX positions and USD investments in the cross-section of non-banks. To generate this figure, we disaggregate sectors and plot country-by-sector-by-quarter net FX positions against the volume of USD-denominated bond holdings, both scaled by total bond holdings and purged of aggregate shocks using time fixed effects. The strong and positive correlation between the two variables implies that country-sectors with a larger USD bond share

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.

exhibit larger net FX hedging positions.[6]

3 Stylized Model

This section proposes a simple dynamic asset pricing model to study how investors' exposure to basis risk affects their asset currency decisions. In the model, home (European) investors invest in foreign-denominated assets (USD) 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 cross-currency basis due to convex balance sheet costs of arbitrageurs. We make use of this framework below to guide our empirical investigations.

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 (iii) an outside US investor, standing ready to purchase the risky USD assets for a low enough price.

Exchange Rate 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 is the drift of the process and σ^x is the loading of the process to the adapted Brownian process dZ_t^x.[7]

Capital Markets From the perspective of a representative European investor, the return processes for investing in both interest rate risk-free and risky USD-denominated assets, respec-

[6]The corresponding estimated regression coefficient shows that a 1 ppt increase in the share of USD investments is accompanied by a 0.27 ppt increase in net FX positions relative to total investments. The relationship between FX positions and USD investments is not mechanically affected by changes in 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).

[7]We make this assumption for parsimony and to focus on the financial implications of the cross-currency basis. Such an exchange rate process could be endogenized following Gabaix and Maggiori (2015) by adding a market clearing condition for non-tradable goods and a second arbitrageur absorbing international imbalances in the demand for financial assets.

tively, 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. From the perspective of the European investor, the return process for the interest rate 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; (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 representing USD market risk and requiring an endogenous 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.

Derivatives Market The European investor also accesses a derivatives market, in which he can purchase a FX forward (or, equivalently, a swap) contract to hedge currency risk. When entering into a 1 USD nominal forward contract at a price $\exp(f_{t,\tau})$, investors agree at time t to buy $\exp(f_{t,\tau})$ EUR for 1 USD at date τ at date τ. In doing so, the investor reduces its exposure to currency risk at the cost of reducing their expected return by a factor $\mathbb{E}\left[\exp(x_\tau - f_{t,\tau})\right]$. To capture the observed maturity mismatch between forwards and underlying assets, we restrict the derivatives contractual space to instantaneous forward contracts ($\lim \tau \to t$) and denote by $\theta_t = (f_t - x_t)$ the contract's instantaneous forward premium. The return process for buying FX contracts is given by: $dR_t^f = d\left[f_t - x_{t+dt}\right] = (\theta_t - \mu^x)\, dt - \sigma^x dZ_t^x$. That is, when purchasing a forward contract, an investor gains from the forward premium $\theta_t dt$ and loses from USD appreciation $dx_t = \mu^x dt + \sigma^x dZ_t^x$. As the European investor needs to sell USD forward (buy EUR forward) to hedge a currency exposure derived from holding USD assets, the instantaneous gross cost of hedging is $-(\theta_t - \mu^x)$ while 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 to the subset of assets they have access to. For the European Investor: portfolio weight in the USD risky asset w_t^a, the USD risk-free asset $w_t^d > 0$, the EUR risk-free asset w_t^e, and the derivatives contract position α_t. For the CCB arbitrageur: its derivative contract position α_t^s, implying a corresponding position in USD risk-free. The global outside investor is assumed to purchase elastically any excess risky USD bond supply with an expected return above $\overline{r}_t^a$. Those programs are relegated in the Appendix.

Shock We further assume that the residual demand of the FX contracts d_t is subject to a Poisson shock shifting across two states, to which we refer as the *steady state* and the *shock state*, respectively. 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'. Note that the variable d_t may be negative, so the shock may equally correspond to a contraction of outside FX contracts supply without loss of generality.

Financial Frictions The model features three financial frictions. First, the European investor cannot borrow in USD and, thereby, needs to use FX derivatives to reduce the currency mismatch on its balance sheet (i.e., hedge currency risk). This assumption corresponds to existing institutional settings, which prevent European financial institutions from directly accessing the USD repo market but rather have to rely on intermediation of USD funding, typically through FX swaps (Correa et al., 2020). This friction is captured by a nonnegativity constraint on the USD risk-free allocation $w^d \geq 0$. Second, liquidity in the FX market highly depends on intermediation by global dealers, which are subject to severe frictions, e.g., stemming from leverage regulation (Andersen et al., 2019; Huang et al., 2024). To capture these frictions, we assume that CIP arbitrageurs, which, in our model, borrow directly in USD and supply it in the FX market, are facing a quadratic cost on the size of their balance sheet with modulating parameter χ. Third, we assume that trading USD assets is subject to a transaction cost ν per transacted value. This assumption corresponds to the existence of non-trivial transaction costs for trading securities as captured by bid-ask spreads and fire-sale discounts incurred when selling securities in the middle of an adverse event, as was observed in March 2020, for instance. These three assumptions combined make the European investor's optimization problem dynamic. When choosing how much to invest in USD assets, it takes into account that the cost of hedging may go up in the shock state and that adjusting its portfolio by selling USD assets will incur a transaction cost.

3.2 Analysis and Predictions

In Appendix A, we solve for the above model in closed form and derive the equilibrium prices and allocations. We now characterize how these are affected by a shock to the residual FX demand under the following set of equilibrium restrictions.

Equilibrium Restrictions To keep our stylized model tractable and focused, we restrict the set of parameters corresponding to equilibria in which (i) uncovered interest rate parity (UIP) holds: $r^d + \mu^x - r^e = 0$; (ii) CIP deviates negatively, i.e., the cross-currency basis is negative: $r^d + \theta_t - r^e < 0$; and (iii) the global outside investor only enters the market in the shock state.[8] Hence, $\widetilde{b}(d) = 0$ and $\widetilde{b}(d') \geq 0$. Due to the market-clearing condition for the risky USD asset, it is $w^a(d) \geq w^a(d')$. Moreover, those conditions also ensure that the European investor will choose not to hold any USD risk-free asset.

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

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

We assume that condition (C) holds. The longer the shock is expected to last (as implied by a lower λ'), the lower the threshold on the right-hand side for USD asset liquidations. This result has an intuitive interpretation. The European investor compares the equilibrium hedging cost flow per period, captured by $(d' - d)/(1/\chi + 1/(\sigma^x)^2)$, to a linear function of the transaction cost ν.

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 two propositions, analyzing the effect of the FX derivatives' residual demand shock on FX and risky USD asset markets, which we use to

[8] The last restriction can be achieved simply by adding a small variation into $\overline{r}^a_t$: $\overline{r}^a(d) - \varepsilon = \overline{r}^a(d') = \varsigma(d)$, where $\varepsilon > 0$ is an infinitesimally small amount.

guide our empirical investigation below.

Proposition 1. *Following a (Poisson arrival) transition to the shock state and assuming a set of parameters such that Condition (C) and equilibrium restrictions (i), (ii), (iii), and (iv) hold, adjustments to equilibrium allocation and prices are such that*

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

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

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

According to Proposition 1, the European investor reacts to an upward shock to FX derivatives residual demand by fire-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. Upon the arrival of the Poisson shock, the investor trades off maintaining his hedging position at a higher cost by selling USD assets to reduce exposure to currency risk according to his risk aversion. 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.[9] The combination of instantaneous FX contracts, transaction costs, shocks to residual FX demand, and inelastic FX supply due to convex balance sheet costs of the arbitrageur implies that European investors are facing cross-currency basis risk. When the Poisson shock hits, they adjust their portfolio by selling assets, paying a higher hedging cost (through a larger CCB), and reducing their hedging ratios. All these options result in a net loss of utility in those states of the world. Proposition pred:riskyholding stresses the interdependence of asset and derivatives market in general equilibrium. In the model, some inelasticity of the USD risky asset market—which we capture through the transaction cost ν—is key for the hedging cost to react to an FX derivative supply shock.

The following proposition shows how the combination of these adjustments crucially depends on expectations about shock dynamics.

[9] The presence of this elastic outside investor is assumed for expositional and tractability reasons. This assumption could easily be relaxed by assuming some interior elasticity for the outside investor without affecting the results qualitatively.

Proposition 2. *Assuming a set of parameters such that Condition (C) and equilibrium restrictions (i), (ii), (iii), and (iv) 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 2 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 d'Avernas et al. (2024) for the repo market, here applied to the CCB with similar intuition. When the shock is expected to be short-lived, European investors are willing to pay a higher hedging cost for a short period of time to avoid paying the liquidation cost. Conversely, when the shock is expected to be long-lived, European investors are willing to liquidate their positions at a lower threshold in condition (C). As a consequence, 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 studying the implications of FX market shocks to capital market flows. Because the cross-elasticity of capital market allocations to the CCB is decreasing as a function of the shock expected duration, highly transitory shocks such as quarter-end or year-end spikes are likely to be associated with a large reaction in CCB but only weak, if any, reactions 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 on identifying the impact of a widening of the cross-currency basis (CCB) on euro-area investors' USD asset holdings.

4.1 Empirical Specification

In our main analysis, we aim to estimate the elasticity of security holdings to changes in the cross-currency basis. The baseline specification is at the country-by-sector-by-security-by-quarter level and regresses quarterly changes in bond holdings on the cross-currency basis interacted with an indicator for US dollar denomination:

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

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 change in the quarterly average USD-EUR cross-currency basis (in bps). The sample includes all EUR- and USD-dominated bond holdings by euro-area insurers, pension funds, banks, and investment funds and runs from 2019q2 to 2024q1, which is determined by data limitations on FX derivatives. Guided by 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-denominated holdings as $\Delta \log \text{Held}_{i,b,t} = \log \frac{S_{t-1}}{S_t} \text{Held}_{i,b,t} - \log \text{Held}_{i,b,t}$, where S_t is the quarterly average EUR-USD 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 the security and country-by-currency-by-time levels, ensuring convergence of standard error estimators. These account for correlated errors due to the autocorrelation of security holdings as well as due to common shocks at the currency denomination-country level.

By estimating the semi-elasticity α in regressions at the security level, we rule out a large number of 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-security 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' (time-invariant) investment preferences. Issuer industry-by-time fixed effects ($w_{\text{industry}(b),t}$) absorb shocks that differently affect bond issuers depending on their industry. Thus, the estimate compares bonds issued by firms within the same industry at the same point in time but with different currency denominations. This alleviates the concern that demand for bonds in more internationally diversified industries differs from those in other industries. In addition to the evidence at the security level, we find consistent estimates for α at the portfolio level, which supports our focus on changes in bond holdings at the intensive margin in Equation (2).

Despite the detailed fixed effects, the main coefficient may still be biased by the presence of currency-specific omitted variables or simultaneous supply and demand shocks. For example, in our model, the CCB responds to fluctuations in USD asset demand. To address this identification challenge, first, we construct a measure for investors' exposure to changes in the CCB, namely their FX derivatives rollover risk. Specifically, we consider the share of investors' maturing FX hedging contracts. For each country-sector pair, we consider the set of hedgers, i.e., investors that maintained an average net buy position in the previous three months. Among these hedgers' hedging positions (that swap USD for EUR in the future) outstanding at the lagged quarter's 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 $\%\text{FX mat}_{i,t}$, the larger is the rollover risk of hedgers in country-sector i and, therefore, their exposure to changes in the cross-currency basis.

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, approximately corresponding to 75th percentile of $\%\text{FX mat}_{i,t}$. We use a triple-interaction term in Equation (2), which interacts $\text{USD}_b \times \Delta\text{CCB}_t$ with $\text{High Rollover Risk}_{i,t}$ to test for a differential response of USD bond holdings to CCB changes.

As a second means to address identification concerns, we use a granular instrumental variable for the cross-currency basis, described below.

4.2 An Instrumental Variable for the Cross-Currency Basis

We consider the total net outstanding USD-EUR forward position EUR $Q_{i,t}$ of investor i on day t in FX derivatives contracts with a remaining time to maturity of between 2 to 4 months.[10] $Q_{i,t}$ includes both the forward legs of swap transactions and pure forwards, as described in Section

[10]Euro-area investors hedge USD currency risk with an average time to maturity of 3 months.

1. At contract maturity, investor i receives EUR $Q_{i,t}$ and pays USD $Q_{i,t} \times 1/F_{t,\tau}$, where $F_{t,\tau}$ is the τ-months USD-EUR forward rate on day t expressed in EUR per USD.

Preliminaries We start with the set of all euro-area investors classified as banks, insurers, pension funds, investment funds, or nonfinancial companies, and aggregate at the parent level using their LEIs. We exclude groups not located in the euro area. We focus on investors that regularly access the FX market by excluding those with nonzero positions for less than one month, that have an absolute net FX position of less than EUR 250,000 on average or more than one third of the time, and those with the standard deviation of their net position exceeding two times their average gross position. The final sample includes 7,170 investors. We de-trend net positions $Q_{i,t}$ by their 3-months trailing average $\bar{Q}_{i,t} = \sum_{\tau=t-84}^{t-1} Q_{i,\tau}$, defining the percentage deviation of positions as $\Delta Q_{i,t} = (Q_{i,t} - \bar{Q}_{i,t})/|\bar{Q}_{i,t}|$. To ensure a high data quality, we consider the sample of $\Delta Q_{i,t}$ starting in 2019q2.

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 that are *typical hedgers* of USD currency risk, defined as those having maintained a long position in future EUR against USD on average in the past three months: $\mathcal{L}_t = \{i \geq 1 : \bar{Q}_{i,t} > 0\}$, in which $\mathcal{L}_t$ reflects the demand side of the market. In the following, we will 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 (2023). 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:

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

where $\log(\text{mat}_{i,t})$ is the log average remaining time to maturity of investor i's FX positions (within the 2 to 4 months bucket). Investor fixed effects (u_i) absorb time-invariant heterogeneity, e.g., stemming from differences in risk aversion. Sector-by-country-by-time fixed effects ($v_{s,c,t}$) absorb shocks that similarly affect all investors of a given sector s domiciled in a given country

c. For example, it absorbs 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 hedgers:

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

The construction of GFX_t is motivated by Gabaix (2011)'s finding that idiosyncratic shocks do not wash out in the aggregate in concentrated markets. With slight abuse of notation, in regressions at daily frequency, we define by $\Delta\mathrm{CCB}_t$ 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 $\Delta\mathrm{CCB}_t$ on GFX_t:

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

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 cross-currency basis, i.e., make 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 cross-currency basis.

Relevance The instrument is relevant if typical hedgers are sufficiently impactful in the FX market and idiosyncratic shocks to their positions do not wash out in the aggregate. This is confirmed in first-stage regressions below. 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, indicating the significance of hedgers in the euro-area FX market (see Appendix Figure IA.1). Banks account for 40% of the total size of hedgers, followed by investment funds (24%), pension funds (19%), and non-financial companies (13%). In particular, the relevance of the granular instrument 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 44% (87%) 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. Any estimate below two implies that idiosyncratic shocks to large hedgers have the potential to generate nontrivial market-wide shocks. This observation directly speaks to the relevance of an instrument based on idiosyncratic shocks (Gabaix, 2011): an instrument that weights these shocks by hedgers' size is a relevant instrument because the market is very concentrated.

Exclusion Restriction Under regularity assumptions, the exclusion restriction holds if $\check{q}_{i,t}$ are truly idiosyncratic shocks (Gabaix and Koijen, 2023).[11] Instead, if the exclusion restriction was 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 bias the estimate of μ in Equation (5) toward zero, i.e., make the results more conservative.

Jointly analyzing prices and quantities provides suggestive evidence that a potential bias is contained: a sufficiently large bias would imply that GFX_t captures the effect of a more negative cross-currency basis *reducing* FX positions, i.e., $\mu > 0$. Instead, we find a significantly negative estimate for μ (see Table 3). 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. We also use the principal components of residuals $\check{q}_{i,t}$ to control for aggregate factors, following Gabaix and Koijen (2022).[12]

[11]Alternatively, identification may also come from the weights $\bar{Q}_{i,t}/(\sum_{i\in\mathcal{L}_t}\bar{Q}_{i,t}) - |\mathcal{L}_t|^{-1}$ being orthogonal to hedgers' exposure to aggregate shocks. However, it seems likely that investor size correlates with investor characteristics that affect demand elasticity.

[12]Investors with different volatilities of $\check{q}_{i,t}$ are likely to have different exposures to the factors. Therefore,

The identification is threatened by aggregate shocks that differently affect small and large investors and, at the same time, are not absorbed in Equation (3). For example, less sophisticated investors pay higher markups in FX markets (Hau et al., 2021). Time-invariant differences in markups are absorbed by the investor fixed effect u_i in Equation (3). Moreover, the 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 remaining confounding variation is restricted to differential shocks to markups *within* a country-sector, which is concerning only if it correlates with investor weights (otherwise, it is averaged out in the construction of GFX_t). To address this identification concern, we exploit that GFX_t is constructed from *net* volume weights whereas markups and other potential confounders typically depend on investor sophistication, which can be proxied by *gross* volume. We sort investors based on terciles of average 3-months 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, used in robustness analyses.

One regularity assumption is that idiosyncratic shocks are homoskedastic, i.e., with the same volatility across investors. For heteroskedastic shocks, (Gabaix and Koijen, 2023) suggest to use weights inversely proportional to their variance:

$$\mathrm{GFX}_t^{\mathrm{het}} = \frac{1}{\sum_{i \in \mathcal{L}_t} \bar{Q}_{i,t}} \sum_{i \in \mathcal{L}_t} \bar{Q}_{i,t} \check{q}_{i,t} - \frac{1}{\sum_{i \in \mathcal{L}_t} 1/\sigma_i^2} \sum_{i \in \mathcal{L}_t} \frac{1}{\sigma_i^2} \check{q}_{i,t}. \tag{6}$$

We document the robustness our results to this alternative construction of the instrument, estimating σ_i^2 as the investor-specific variance of residuals $\check{q}_{i,t}$.

5 Empirical Results

This section exposes the main results of our paper and estimates the reaction of hedging and dollar asset allocations to changes in the cross-currency basis.

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 FX Derivatives Positions

First Stage Results We test the first prediction of Proposition 1 that the cross-currency basis (CCB) becomes more negative (i.e., widens) upon idiosyncratic FX demand shocks. Columns (1) and (2) in Table 3 report the estimated coefficients for Equation (5), in which we regress changes in the CCB on the instrument GFX_t. The coefficient is significantly negative, which is consistent with GFX_t capturing the impact of FX demand shifts: Increasing idiosyncratic demand widens the (negative) cross-currency basis in the presence of inelastic FX supply. The point estimate implies that a 8.3% increase in the net position of typical hedgers is associated with a 1 bps lower CCB. Relative to the average net position of typical hedgers, this suggests that a EUR 8.5 billion increase in net positions is associated with a 1 bps wider cross-currency basis. The magnitude of the effect emphasizes FX hedging supply constraints (Du et al., 2018). The more constrained the supply side (e.g., dealers), the larger is the response of the CCB to demand shifts. The estimate implies that relatively small demand shifts are sufficient to generate meaningful changes in the CCB (which has 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, 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 aggregate financial market conditions and USD demand as well as unobserved aggregate shocks. The result is highly robust in terms of magnitude as well as statistical significance. This suggests that the variation in GFX_t is orthogonal to these potential macroeconomic confounders, which supports the empirical strategy. Appendix Figure IA.2 further shows that the correlation between ΔCCB_t and GFX_t is not driven by outliers but, instead, visible throughout the full sample distribution.

FX Demand Elasticity Instrumenting the CCB with GFX_t, we test the second prediction of Proposition 1 that euro area investors reduce their FX hedging positions in response to a more negative CCB. Columns (3) to (4) in Table 3 report the estimated demand (semi-)elasticity ϕ of FX positions from the following regression at daily frequency, using GFX_t as an instrument for ΔCCB_t:

$$\overline{\Delta Q}_t = \phi \Delta \text{CCB}_t + \Gamma' M_t + \varepsilon_t. \tag{7}$$

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

We first report the OLS estimate in column (3), which does not use the instrumental variable. The estimated coefficient is significantly positive and implies that investors reduce their FX positions by 0.11% 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 an opposite effect on the CCB.

Column (4) reports our baseline estimate, which results from instrumenting the CCB with GFX_t. The estimate implies that investors reduce their FX positions by 2.39% in response to a 1 bps decrease (i.e., widening) in the CCB. The coefficient is statistically significant at the 1% level. The magnitude is also economically significant. It implies that, for example, a 17 bps decrease in the cross-currency basis (corresponding to the 5th percentile of ΔCCB) reduces net FX positions by 41% ($= 0.17 \times 2.39$). The estimated elasticity is approximately 20 times larger when instrumenting the CCB compared to the OLS estimate. This suggests that the latter suffers from substantial simultaneity bias, which is reduced by using the instrumental variable.

We investigate differences across sectors in Figure 4 (a) by estimating Equation (7) separately for different sectors. The sensitivity of FX positions to the CCB is the highest for insurers and banks (close to 4) and only slightly lower for pension funds (close to 3.5). In contrast, investment funds display a substantially lower elasticity (close to 1). This finding is consistent with the low elasticity of investment funds to quarter-end spikes in the CCB documented by Wallen (2022). The result suggests that investment funds reduce their hedging activity by much less than other investors in response to higher currency hedging costs. A likely explanation is the substantial heterogeneity in regulatory frameworks across sectors. Bank, insurer, and pension fund regulation is 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 reduce their sensitivity to changes in hedging costs.

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 the investor-by-day level. We measure rollover risk by the share of an investor's FX hedging contracts outstanding at the prior month's end that matures in the current month. In regressions analogously to Equation (7), we interact the cross-currency basis with an indicator variable for high (low) rollover risk, which equals 1 if more than two thirds (two thirds or less) of outstanding contracts mature.

The estimate in column (5) implies that FX demand elasticity is approximately 37% larger for investors with high rollover risk. Intuitively, these investors are forced to decide on the extent to which they roll over previous contracts and, therefore, are more sensitive to changes in the CCB than other investors. While FX demand elasticity is significantly positive for both low- and high-rollover-risk investors, the cross-sectional difference is not precisely estimated (column 6).

In columns (7) and (8), we focus on the sample of long-term hedgers, defined as investors with a positive 3-months trailing net position in 3 months to 1 year contracts. We hypothesize that these investors are more sensitive to rollover risk as a long FX derivatives maturity indicates that they seek to hedge longer-term exposure to currency risk. Consistent with this hypothesis, the FX demand elasticity differs significantly between long-term hedgers with high and low rollover risk (column 7). Low-rollover–risk hedgers display an elasticity close to and not significantly different from zero. Instead, the elasticity is significantly larger for those with high rollover risk. The estimates suggest an elasticity of 7.81 ($= 0.35 + 7.46$) for hedgers with high rollover risk. The differential response between hedgers with low and high rollover risk is also robust to including time fixed effects (column 8), which absorb aggregate shocks that simultaneously affect FX positions and rollover risk.

5.2 Bond Holdings

We now turn to test the third prediction of Proposition 1 that investors react to residual demand shocks by reducing their dollar asset holdings.

OLS Estimates In Panel (A) of Table 4, we report the semi-elasticity of euro-area bond holdings to fluctuations in the cross-currency basis (CCB), estimated using Equation (2). In column (1), we report the OLS estimate from regressing bond holdings on the not-instrumented CCB interacted with an indicator for US dollar denomination. The estimated coefficient is significantly positive and implies that USD bond holdings decrease by 0.21% relative to EUR bonds in response to a 1 bps decrease (i.e., widening) in the CCB. The significantly positive coefficient suggests that the empirical specification isolates plausibly exogenous variation in the CCB.

In columns (2) and (3), we examine differences across investors depending on their FX derivatives rollover risk. Because bond holdings are at the 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 the the CCB elasticity of bond holdings is more than twice as large for investors with high rollover risk compared to 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 emphasize 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.

2SLS Estimates We further strengthen the identification by instrumenting the CCB with the quarterly average of GFX_t in columns (4) to (7).[13] As a result, the estimated CCB elasticity of bond holdings increases to 0.32, implying 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 affecting both bond demand and CCB.

We find that the impact of rollover risk on the CCB elasticity is robust to instrumenting the CCB (columns 5 and 6). In addition, in column (7), we show that the different elasticity across

[13] In Internet Appendix C, we show that, in the time series, GFX_t also correlates significantly with the cross-currency basis at this lower frequency.

investors with high and low rollover risk remains significantly positive after including security-by-time fixed effects, which absorb any bond-specific shocks (such as variation in USD $\times$ CCB).[14] 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.

The baseline estimate reports the elasticity for the average bond weighted by the number of observations. To grasp the implications for flows, we also compute the estimate weighted by the lagged nominal value of bond holdings. The holdings-weighted estimate corresponding to column (4) is 0.29, implying 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 translates into a decline by approximately 0.24% in the euro-area's *total* USD bond holdings.[15] 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. As euro-area banks, insurers, and investment and pension funds jointly hold EUR 2.3 trillion of USD-denominated bonds in 2024Q1, this corresponds to approximately EUR 92 billion of USD bonds being disposed.

We note that the estimated CCB elasticity is close to the estimates for the price elasticity of euro-area bond markets that have been documented in previous literature.[16] Because EUR-denominated bonds are close substitutes for currency-hedged USD-denominated bonds, the demand elasticity to changes in the CCB is in the upper range of estimates for price elasticities.[17] Consistently, we document that our baseline estimate is largely unaffected by the

[14] 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.

[15] Due to the fixed effects holding portfolio size constant, Equation (2) provides an estimate for the differential change in the 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%.

[16] Jansen (2023) estimates a price elasticity of 4.31 and Koijen et al. (2021) of 3.21 for euro-area investors' demand for euro-area government bonds, which translates into a semi-elasticity with respect to yields of 0.36 and 0.27, respectively, for bonds with 8.3 years duration (the average time to maturity of USD bond holdings).

[17] Chaudhary et al. (2023) document that bond demand elasticities are larger when close substitutes are available.

inclusion of rating-by-time or time to maturity-by-time fixed effects (see Appendix Table IA.2), suggesting that investors substitute between bonds with different currency denomination 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). 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.

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 shy away relatively more from bonds that also carry higher interest rate and credit risk. On the other hand, anecdotal evidence suggests that investors mostly hedge the currency risk of less risky bonds, given that their cash flows are easier to hedge and investors with less risky portfolios may exhibit higher risk aversion.

In Figure 4 (c), we document that CCB elasticity does not substantially differ depending on bonds' time to maturity. Long-term bond holdings (with at least 5 years remaining time to maturity) display a slightly larger elasticity than short-term bond holdings, consistent with investors trading off interest rate and currency risk.

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 is consistent with anecdotal evidence and currency risk hedging being correlated with investor risk aversion. At the same time, high-yield bonds display a similar elasticity as AAA-rated bonds, suggesting that investors trade off the (substantial) credit risk of these bonds with currency risk and that this channel dominates other explanations due to large differences in credit risk.

Portfolio level Our baseline estimates reflect portfolio adjustments at the intensive margin because they condition on a country-sector holding a security in the previous period. 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-denominated bonds (relative to all USD- and EUR-denominated bonds). We focus on investors with a non-negligible preference to invest in USD.[18] Both the OLS and 2SLS estimates for the CCB elasticity of the USD portfolio share are significantly positive (columns 1 and 4), implying that the portfolio share declines by 0.02 ppt and 0.05 ppt, respectively, in response to a 1 bps decline in CCB. The magnitude of these estimates is consistent with the security-level estimates in panel (A) when adjusting by the average USD portfolio share. The robustness of the estimates across security and portfolio level suggests that country-sectors mostly adjust their portfolios at the intensive rather than the extensive margin. This result is not surprising as, due to the level of aggregation of bond holdings, extensive margin adjustments only occur if all individual investors in a country-sector purchase a security for the first time or sell all holdings of a specific security. Moreover, we also find differential responses depending on rollover risk, although the results are less significant at this higher level of aggregation.

Robustness A possible concern regarding the interpretation of the results is that variation in USD- relative to EUR-denominated 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 completely unchanged by this revaluation, emphasizing that the results are driven by investor rebalancing. Finally, in Appendix Table IA.2, we show that our baseline

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

results are robust to including controls for spot rates and spot rate volatility interacted with the USD indicator. Moreover, we document that the results are robust to including credit rating-by-time and time to maturity-by-time fixed effects, which absorb shocks to bonds with different credit and interest rate risk. They are also robust to adjusting the instrument by including size bucket-by-time fixed effects when computing idiosyncratic shocks and by adjusting the instrument to heteroskedasticity as in Equation (6).

5.3 Price Impact

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 as documented by Bretscher et al. (2023), Coppola (2022), and Kubitza (2023). If this segmentation is sufficiently strong, our theory would predict that bonds whose investors are (more) exposed to cross-currency basis risk will respond (more) to variations in the CCB. As investors substitute EUR for USD bonds in response to a decrease (i.e., widening) in the cross-currency basis (CCB), we expect this rebalancing to increase euro-area bond prices and, thus, reduce yields.

To test this hypothesis, we use daily data on euro-area government bond yields across issuer countries and time to maturity, focusing on bond yields for 3 months and 1, 5, 10, and 20 years to maturity. Euro-area investors hold approximately 50% of these bonds' outstanding amount on average. Because it may take time for bond yields to respond to CCB changes, we examine the average bond yield in the current and 5 business days following CCB fluctuations, de-trended by the average bond yield in the lagged 3 months (ΔBond Yield). The average yield change is 10 bps and it ranges from -30 bps to 70 bps at the 5th/95th percentiles (see Table 1). In Table 5, we report estimates from regressions of ΔBond Yield on CCB changes (ΔCCB) at daily frequency, controlling for bond fixed effects to absorb time-invariant heterogeneity. We also include controls for potential macroeconomic confounders, namely dollar strength, stock market volatility, and exchange rate volatility. We find that the yield of the *average* euro-area government bond does not significantly respond to a wider (negative) CCB, neither based on the OLS (column 1) nor IV estimate (column 5). This result is not surprising in light of significant differences in bonds' investor base. Instead, we expect that bonds held by investors that are (more) exposed to the

CCB show a significant response.

Rollover Risk We examine heterogeneity in euro-area investors' FX derivatives rollover risk at the bond level. Analogously to the previous section, we compute for each country-sector i the share of hedging positions outstanding at the previous month's end that mature in the current month m (exploiting the higher frequency of bond yield data), denoted by $\%\text{FX mat}_{i,m}$. Then, we aggregate $\%\text{FX mat}_{i,m}$ to the bond level by computing the holdings-weighted average across bond investors:

$$\%\overline{\text{FX mat}}_{s,m} = \sum_i \frac{h_{i,s,q-1}}{\sum_j h_{j,s,q-1}} \times \%\text{FX mat}_{i,m}, \tag{8}$$

where $h_{i,s,q-1}$ is the total market value of bond s 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 based on the 66th percentile of $\%\overline{\text{FX mat}}_{s,m}$.

In column (2), we estimate separate coefficient on the CCB for bonds depending on their investors' rollover risk exposure, without instrument the CCB. We observe a significantly positive coefficient for bonds with high rollover risk, implying that the yield on these bonds declines with a more negative CCB. The estimated coefficient implies that yields decrease by 0.28 bps in response to a 1 bps decline in the CCB when bonds are exposed to high rollover risk. The difference between bonds with low and high rollover risk is significantly positive at the 1% level (column 3). It is robust to including maturity-by-time fixed effects (column 4). These fixed effects absorb any aggregate and maturity-specific shocks that might correlate with the cross-currency basis and bond prices, such as aggregate demand for long-term USD assets. They also absorb investor segmentation across maturities as a determinant of heterogeneity in rollover risk, which likely explains the drop in the coefficient upon including the fixed effects.

We confirm the robustness of these results by instrumenting the CCB with GFX_t in columns (6) to (8). The estimated coefficient in column (6) implies that yields decrease by approximately 1 bps in response to a 1 bps decline in the CCB when bonds are exposed to high rollover risk. The magnitude is consistent with investors trading off paying 1 bps more in hedging costs with receiving a 1 bps lower investment yield. The IV estimate is substantially larger than the OLS estimate in column (2), suggesting that the empirical strategy removes variation in the cross-currency basis driven by bond market outcomes. These findings emphasize the spillovers from FX derivatives markets to the bond market, suggesting that frictions in USD funding markets significantly affect asset prices.

6 Conclusion

In this article, we study how frictions to currency risk hedging through FX derivatives markets affect international capital allocation. For this purpose, we build on a novel, granular dataset that covers the entire euro area and combines both investors' USD-EUR FX derivative positions as well as their securities holdings. We find converging evidence that an increase in the cost of currency hedging leads investors to decrease both their FX positions and their investments in foreign assets. This rebalancing significantly affects capital market prices, emphasizing the importance of CIP deviations for asset pricing. 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.

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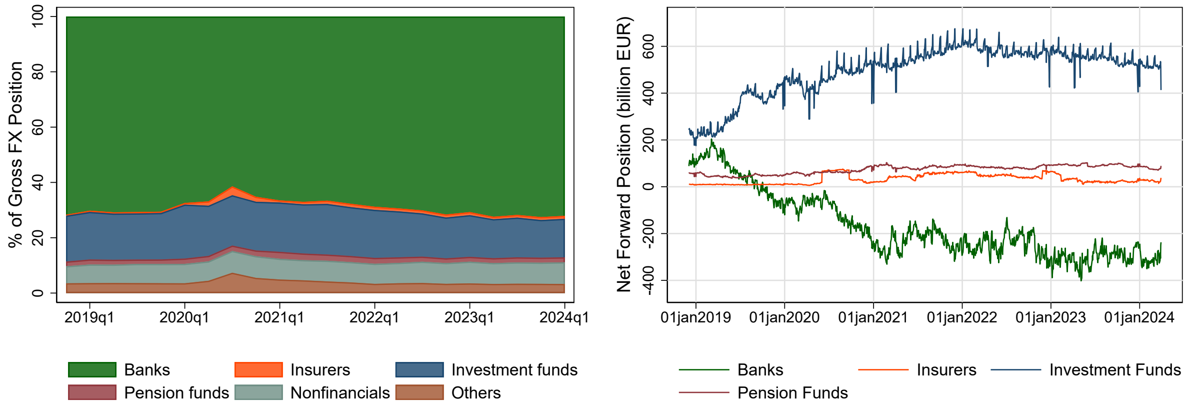
Figures and Tables

Figure 1. FX Forward Positions. Figure (a) plots the total gross position (in terms of notional in EUR) for euro-area 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 investor sectors. Net positions are defined as the difference between buy and sell positions. A buy position is one where the investor has the obligation to redeem USD in the future against EUR. Such positions can be achieved, for example, by entering a swap where the investor obtains USD at the spot date and delivers USD at the forward date. Source: EMIR.



(a) Gross FX Positions

(b) Net FX Positions

Figure 2. USD-EUR Cross-Currency Basis. The figure plots the USD-EUR cross-currency basis for 3-months 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 cross-currency basis, 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. Source: MMSR, Bloomberg.

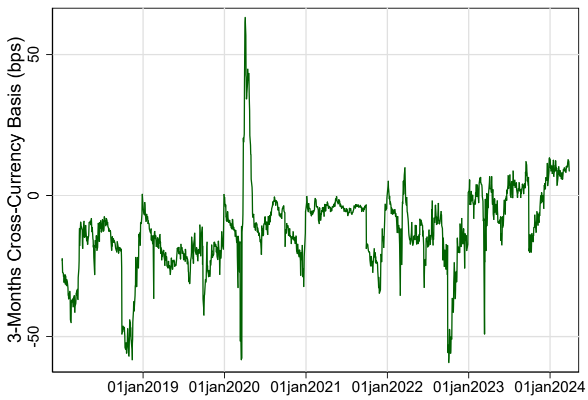
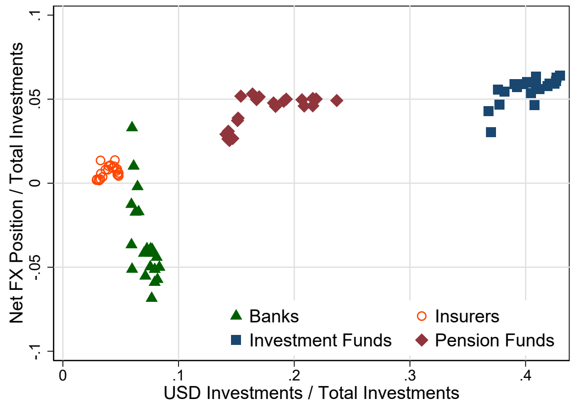
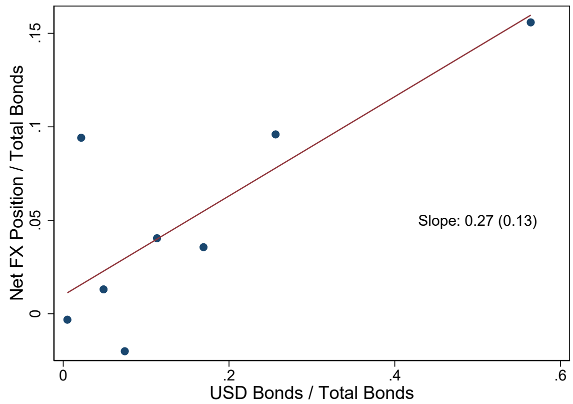


Figure 3. FX Forward Positions and Portfolio Allocation. Figure (a) plots an investor sector's total net forward position (y-axis) and total USD investments (x-axis), both scaled by total investments. Figure (b) is a binscatter plot of total net forward positions (y-axis) and total USD investments (x-axis) of insurers, pension funds, and investment funds at the country-sector-by-quarter level, both scaled by total investments, after absorbing time fixed effects. The figure also reports the corresponding estimated coefficient and its standard error of a regression of net forward positions on total USD investments. Sources: EMIR and SHS-S.

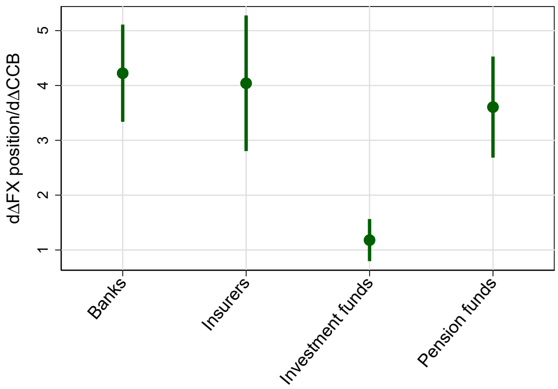


(a) Time Series (sector level)

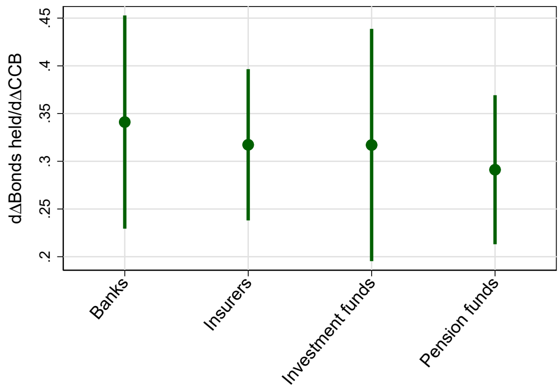


(b) Cross-Section of Nonbanks (sector-country level)

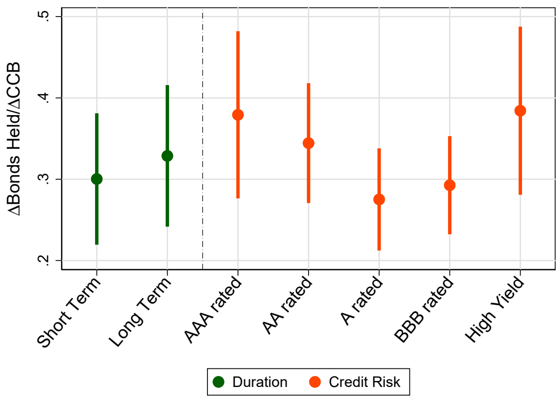
Figure 4. Cross-Currency Basis, FX Forward Positions, and Bond Holdings: Heterogeneity. This figure depicts the estimated coefficient on the instrumented change in the cross-currency basis individually for different sectors and types of bonds based on regressions analogously to (a) column (4) in Table 3 and (b,c) column (2) in Table 4, respectively, and the corresponding 90% confidence interval. 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 Sector



(b) Bonds: by Sector



(c) Bonds: by Risk

Table 1. Summary Statistics.

The table depicts summary statistics for (1) USD-EUR FX net and gross forward positions as well as their gross volume-weighted average time to maturity at the sector-day level, (2) the share of USD-denominated bond holdings (relative to USD and EUR-denominated bonds) and the hedge ratio at the sector-quarter level, (3) the USD-EUR cross-currency basis (CCB), size-weighted average of idiosyncratic shocks to typical hedgers' FX positions (GFX), and (changes) in the German-US government bond rate differential at the daily level, (4) the share of FX hedging contracts maturing in the following month or quarter at the country-sector-quarter level, and (5) the change in yield and bond characteristics of euro-area government bonds at the bond-day level. FX positions and their time to maturity are winsorized at the 1/99 percentiles at the investor level before aggregation. The hedge ratio is computed using a sector's average net FX position at each quarter's last three days. To preserve confidentiality, we only report one digit for the CCB, replace some percentiles of rollover risk by *, and exclude 22 sector-by-day observations of gross FX positions. Data sources: EMIR, SHS-S, MMSR, Bloomberg, Thomson Reuters Eikon.

	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
Securities Holdings (Sector-by-Quarter Level, 2019q1 - 2024q1)						
Share of USD Bonds	84	0.17	0.14	0.03	0.11	0.40
USD Bonds: Time to Maturity (ex. $>$ 50 yrs)	84	8.85	1.75	6.18	9.03	12.21
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
Time-Series Variables (Daily Frequency, 2019q2 - 2024q1)						
CCB (bps)	1,212	-9.6	13.4	-28.4	-8.7	9.0
ΔCCB (bps)	1,212	0.39	10.69	-16.63	0.75	16.28
GFX	1,212	-0.12	0.19	-0.44	-0.11	0.18
ΔFX position	1,212	0.06	0.12	-0.13	0.05	0.27
Investor Characteristics (Country-by-Sector-by-Quarter Level, 2019q2 - 2024q1)						
Rollover Risk (quarterly)	810	0.79	0.24	0.32	0.86	*
Euro-Area Bonds (Bond-by-Day Level, Dec 2018 - Mar 2024)						
ΔYield (ppt)	52,646	0.10	0.29	-0.30	0.06	0.70
Time to Maturity (months)	52,646	117.46	79.27	3.00	120.00	240.00

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 a specification of the form:

$$\Delta\text{CCB}_t = \alpha\ \text{GFX}_t + \Gamma' C_t + \varepsilon_t$$

at daily frequency. ΔCCB_t is the deviation of the 3-months USD-EUR cross-currency basis from its 3-months trailing average (in ppt). GFX_t is the size-weighted average of idiosyncratic shocks to typical hedgers' FX positions. Columns (3) to (8) present estimated coefficients from a specification of the form:

$$\Delta\text{FX Position} = \phi\ \Delta\text{CCB} + \Gamma' C + \varepsilon'$$

at daily frequency. Columns (1) to (4) are based on the time-series of the respective variables and columns (5) to (8) on an investor-by-day panel of FX positions. The dependent variable is the % deviation of the average investor's 3-months net FX position from its 3-months trailing average. In columns (4) to (8), ΔCCB_t is instrumented with GFX_t. *High Rollover Risk* indicates that more than 66% of an investor's FX hedging positions outstanding at the prior month's end are maturing in the current month. The sample in columns (7) and (8) only include investors with a 3-months trailing positive net position in long-term (3 months to 1 year) contracts. C_t is a vector of control variables. Rem. Time to Mat is the notional-weighted average time to maturity of typical buyers' outstanding FX positions. Macro controls are the change in the risk-free rate US-euro area differential and in the log of the S&P 500, Euro STOXX 50, dollar strength, US and EU VIX from their respective 3-months trailing averages as well as the 4-weeks trailing standard deviation of USD-EUR spot rates. Aggregate factors are the first three principal components of the residualized % deviation of all investors' net 3-months FX positions. 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 first-stage coefficients, their standard errors, and the Cragg-Donald Wald F statistic. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample:	Time Series				All Investors		Long-Term Hedgers	
Dependent variable:	ΔCCB		ΔFX Position					
	OLS			IV				
GFX	-0.12***	-0.11***						
	(0.02)	(0.01)						
ΔCCB			0.12***	2.44***		2.49***	0.43	
			(0.02)	(0.32)		(0.62)	(0.67)	
ΔCCB × Low Rollover Risk					2.49***			
					(0.62)			
ΔCCB × High Rollover Risk					3.28***	0.79	7.28**	7.45**
					(1.26)	(1.24)	(2.97)	(2.96)
High Rollover Risk					0.11*	0.11*	-0.09	-0.09
					(0.06)	(0.06)	(0.10)	(0.10)
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	
Time FEs								Y
F Statistic (1st)				44.0				
No. of obs.	1,256	1,212	1,212	1,212	684,118	684,118	315,803	327,267
No. of investors					1,127	1,127	909	909

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

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

at the 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-months USD-EUR cross-currency basis from its 3-months trailing average (in ppt). In columns (4)-(8), 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 the country-sector-quarter level, where $\Delta\text{USD share}_{i,t}$ is the portfolio share of USD bonds held by country-sector i. Panel (B) 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 the bond and country-by-currency-by-time levels and in panel (B) at the country-sector and country-by-time levels. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Panel A: Bond level	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	$\Delta \log$ Bond Holdings						
	OLS			IV			
USD × ΔCCB	0.21***		0.19***	0.32***		0.27***	
	(0.02)		(0.02)	(0.04)		(0.04)	
USD × ΔCCB × Low Rollover Risk		0.15***			0.08**		
		(0.03)			(0.04)		
USD × ΔCCB × High Rollover Risk		0.39***	0.19		0.72**	0.49*	0.15**
		(0.14)	(0.14)		(0.28)	(0.29)	(0.07)
Country-Sector-Time FEs	Y	Y	Y	Y	Y	Y	Y
Country-Sector-Security FEs	Y	Y	Y	Y	Y	Y	Y
Issuer Industry-Time FEs	Y	Y	Y	Y	Y	Y	
Security-Time FEs							Y
No. of obs.	8,567,136	8,567,136	8,567,136	8,567,136	8,567,136	8,567,136	6,814,127
No. of securities	342,243	342,243	342,243	342,243	342,243	342,243	95,024

Panel B: Portfolio level	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	ΔUSD Share					
	OLS			IV		
ΔCCB	0.02***		0.01	0.05***		0.03***
	(0.00)		(0.01)	(0.01)		(0.01)
ΔCCB × Low Rollover Risk		0.01			0.03***	
		(0.01)			(0.01)	
ΔCCB × High Rollover Risk		0.02*	0.01		0.06***	0.02
		(0.01)	(0.02)		(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	721	1,080	1,080	721
No. of country-sectors	54	54	50	54	54	50

Table 5. Cross-Currency Basis and Government Bond Yields.
This table presents estimated coefficients from a specification of the form:

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

at the bond-day level based on a sample of euro-area government bonds. Bonds are aggregated to the maturity-by-issuer-country level for maturities 3 months and 1, 5 10, and 20 years. $\Delta \text{Yield}_{b,t}$ is the difference in the average of bond b's yield on day t and the following 5 days relative to its 3-months trailing average (in percentage points). ΔCCB_t is the deviation of the 3-months USD-EUR cross-currency basis from its 3-months trailing average (in ppt). In columns (5) to (8), it is instrumented with the size-weighted average of idiosyncratic shocks to typical hedgers' FX positions GFX_t. ΔCCB_t is interacted with an indicator for high rollover risk of those investors that held bond b in the prior quarter, which is equal to one if the holdings-weighted average share of hedgers' buy-side FX derivatives notional outstanding at the prior quarter's end which matures in the month of day t exceeds its 66th percentile. $C_{b,t}$ is a vector of fixed effects and control variables. Macro controls are the dollar strength, US and EU VIX from their respective 3-months trailing averages as well as the 4-weeks trailing standard deviation of USD-EUR spot rates. Standard errors are shown in parentheses, clustered at the bond and day levels. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	ΔBond Yield							
	OLS				IV			
ΔCCB	-0.11		-0.28***		0.26		-0.16	
	(0.07)		(0.07)		(0.20)		(0.25)	
ΔCCB × Low Rollover Risk		-0.28***				-0.16		
		(0.07)				(0.25)		
ΔCCB × High Rollover Risk		0.28***	0.56***	0.18**		0.95***	1.11***	0.35**
		(0.10)	(0.11)	(0.08)		(0.27)	(0.34)	(0.16)
Macro Controls	Y	Y	Y		Y	Y	Y	
Bond FEs	Y	Y	Y	Y	Y	Y	Y	Y
High Rollover Risk FEs		Y	Y	Y		Y	Y	Y
Maturity-Time FEs				Y				Y
No. of obs.	52,646	52,646	52,646	52,462	52,646	52,646	52,646	52,462
No. of bonds	71	71	71	71	71	71	71	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:

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

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 the 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]

Global Cross-Currency Basis (CCB) Arbitrageur The 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. It maximizes:

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

subject to

$$\frac{dn^s_t}{n^s_t} = (r^e + \alpha^s_t(r^d + \theta_t - r^e))dt - \frac{\chi}{2}\left(-\min\{\alpha^s_t, 0\} - \min\{1-\alpha^s_t, 0\}\right)^2 dt,$$

[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.

where n_t^s is the arbitrageur's net worth and χ is a parameter modulating the strength of the quadratic balance sheet cost. When the CCB is negative, as observed in 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 $\overline{r}_t^a$.

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

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 varying 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

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

Global Cross-Currency Basis 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

$$\begin{aligned}\rho V^s(n_t^s; d_t) = & \log(n_t^s) + \Big[r^e + \alpha^s(d_t)(r^d + \theta(d_t) - r^e) \\ & - \frac{\chi}{2}\left(-\min\{\alpha^s(d_t), 0\} - \min\{1 - \alpha^s(d_t), 0\}\right)^2\Big] n_t^s V_{n^s}^s(n_t^s; d_t).\end{aligned} \tag{IA.7}$$

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

$$r^d - r^e + \theta(d_t) = \chi\left(\min\{\alpha^s(d_t), 0\} - \min\{1 - \alpha^s(d_t), 0\}\right) \tag{IA.8}$$

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 (iv) implies that $\widetilde{b}(d) = 0$. Then by 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 (iv) 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 first-order condition (IA.4), the second equation comes from the envelope theorem, and the third equation comes 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 Recall that following d'Avernas et al. (2024), $\phi(d) = -\phi(d') = \nu$ when $w^a(d') < w^a(d)$, and $-\nu \le \phi(d), \phi(d') \le \nu$ 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)-(iv), where $\phi(d) = -\phi(d') = \nu$. We then prove Propositions 1 and 2.

Proof of Proposition 1. 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 2. 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* refers 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 FX net forward position such that a positive position indicates buying EUR and selling USD in the future (*Source: EMIR*)
Gross FX Position	USD-EUR FX gross forward position (*Source: EMIR*)
FX Time to Maturity	Volume-weighted average maturity of outstanding FX positions (*Source: EMIR*)
Hedge Ratio	Total net FX position divided by total USD-denominated debt and equity holdings (*Source: EMIR, CSDB, SHS-S*)
USD	Indicator that equals one if a bond is denominated in USD and zero otherwise (*Source: CSDB*)
CCB	3-months USD-EUR Cross-Currency Basis (*Source: MMSR, Bloomberg*)
Δlog Bond Holdings	Quarterly change in country-sector i's log holdings of bond b at nominal value (*Source: SHS-S*)
ΔUSD Share	Quarterly change in the portfolio share of USD bonds held by country-sector i relative to all USD and EUR bond holdings (*Source: CSDB, SHS-S*)

Continued on next page

Table IA.1 – *Continued from previous page*

Variable	**Definition**
Bond Time to Maturity	Remaining time to maturity (*Source: CSDB*)
EA Share	Share of a bond's outstanding amount held by euro-area investors (*Source: CSDB, SHS-S*)
ΔBond Yield	Difference in a bond's average of yield in the 3 weeks starting on day t relative to its 3-months trailing average (in percentage points) (*Source: Datastream*)
GFX	Granular instrumental variable based on idiosyncratic shocks to euro-area typical hedgers' 3-months FX positions (*Source: EMIR*)
Rollover Risk (quarterly)	Share of investors' hedging (net buy) positions outstanding at the prior quarter's end that are maturing in the current quarter (*Source: EMIR*)
Risk-free rate US-euro area differential	3-months LIBOR - EURIBOR (*Source: Bloomberg*)
S&P 500	U.S. 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	U.S. stock market volatility index (*Source: FRED St. Louis*)
EU VIX	European stock market volatility index (*Source: Datastream*)
$\Delta \log S^{\text{USD/EUR}}$	Log growth in the USD-EUR spot rate (*Source: Datastream*)
FX volatility	30-day-trailing standard deviation of the daily USD-EUR spot rate growth rate (*Source: Datastream*)

B.1 FX Positions (EMIR)

From the set of all derivatives transactions reported to the European Central Bank, we select all positions that are classified by EMIR as FX forwards or FX swaps.[2] We drop intra-group transactions and transactions with a notional below EUR 10,000 or above EUR 10 billion. We link observations that belong to the same transaction and, if there are multiple observations, we require them to match in terms of notional, counterparty, and maturity date. To ensure the reliability of reported data, we apply several filters:

1. We drop transactions with missing or implausible information on the spot date, maturity date, notional value or counterparty side. In particular, we drop trades with implausible notional: a notional of less than EUR 10 thd or more than EUR 200 billion.
2. We leverage that the EMIR regulation requires all European counterparties to report a given transaction, and use for each transaction the information from the more reliable filing. Specifically, we preferably use the information from filings by systematically important banks, which typically report more accurately information (likely due to various additional reporting obligations). If such filings are not available, we use information from those filings that report the forward rate and, otherwise, filings that report the spot rate.

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

3. We separate the two legs of each swap trade to yield a homogeneous sample of forward contracts. For this purpose, we drop swap contracts without information on both settlement dates. When splitting swaps, the notional of the forward implied by the second leg is different from that of the first leg.[3]

   To calculate the notional value of the second leg of the swap trades, reliable information on spot and forward rates are necessary. For this purpose, first, we drop the swap transactions on which both spot and forward rate are not reported. Second, we correct rates with a wrong base currency (e.g., EUR/USD instead of USD/EUR) by comparing the reported rates to the Bloomberg spot rate on the trade date, allowing for a $+/-10\%$ deviation. If Bloomberg rates are not available for the trade date, we consider the reported rate to be in EUR/USD if it is outside the range of USD/EUR spot rates and within the range of EUR/USD spot rates observed during the sample period, allowing for a $+/-10\%$ margin of error. Then, we assume that forward rate is reported with the same base currency as the spot rate.

   To account for inconsistencies in reporting of rates, we apply the following manipulations. First, we assume that it is more likely that a counterparty accidentally reports a spot as a forward rate and the forward rate as a spot rate than that the forward point is negative. Second, we drop all the remaining transactions for which the reported spot and forward rates are outside the range of EUR/USD spot rates observed in the sample period, or the spot rate is strictly larger than the forward rate.

Except for reporting aggregate FX market volumes (e.g., in Figure 1), we drop Austrian, Finnish, French, and Luxembourg pension funds, for which the data implies a hedge ratio of more than 300% (in absolute terms), suggesting significant measurement error, e.g., stemming from merging EMIR with SHS-S.

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 and forward rate as well as the spot and maturity date of contracts. We exclude

[3] For example, if the spot rate is 1.1 USD/EUR and the forward rate is 1.2 USD/EUR and the notional of the first leg is EUR 100, at the end of the first leg, EUR 100 are exchanged for 110 USD. At the end of the second leg, USD 110 are exchanged for EUR 91.67 (=110/1.2).

contracts with a spot date that occurs more than 4 days after the trade date and define 3-months 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 forward and spot rate) among 3-months contracts. On days on which the market covered by MMSR reporting is relatively illiquid (indicated by a transaction volume below EUR 1 mil), we use the forward and spot rate from Bloomberg instead (this only applies to four days in our sample).

C Details on GIV Estimation

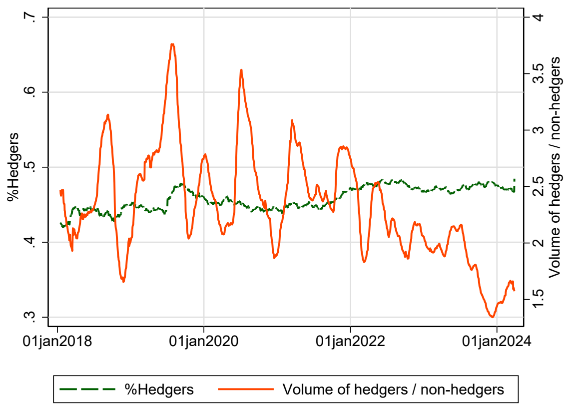
We use the following macroeconomic control variables in the regressions of Table 3:

- 3-months LIBOR and EURIBOR
- log of the S&P 500, Euro STOXX 50, dollar strength, US and EU VIX.

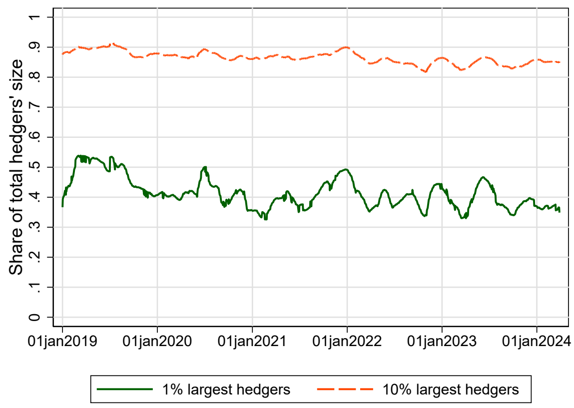
All variables are de-trended by computing the change relative to their 3-months trailing average. Following Avdjiev et al. (2019), we control for dollar strength using the trade-weighted US dollar exchange rate against its major trading partners (retrieved from FRED St. Louis).

Figure IA.1. FX Market Structure and Granularity in Size Weights.

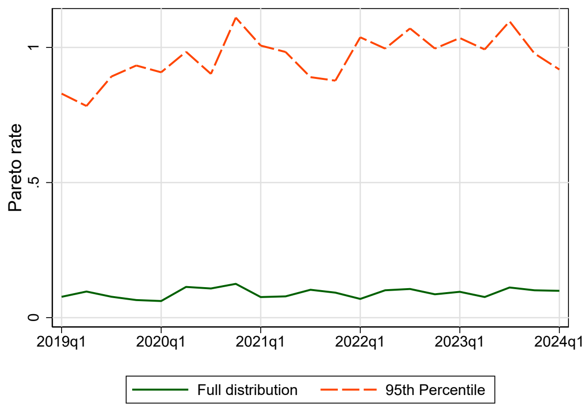
Hedgers are defined as investors that exhibit a positive 3-months trailing average FX position. Figure (a) plots (i) the number of hedgers relative to the number of investors and (ii) the total net position of hedgers relative to negative of the total net position of non-hedgers. Figure (b) plots the total size of the 1% and 10% largest hedgers relative to the total size of all hedgers, where size is defined as the 3-months trailing average 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



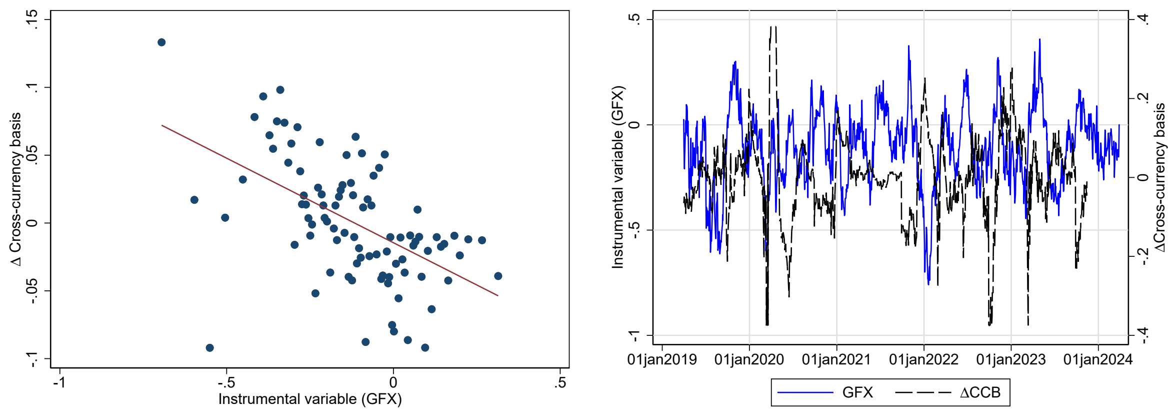
(b) Concentration of hedgers



(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-months cross-currency basis from its 3-months 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.

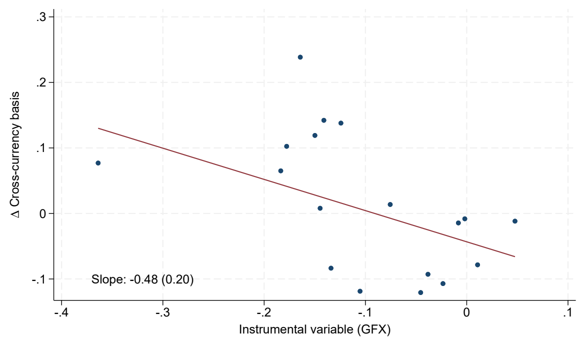


(a) Binscatter plot.

(b) Time series.

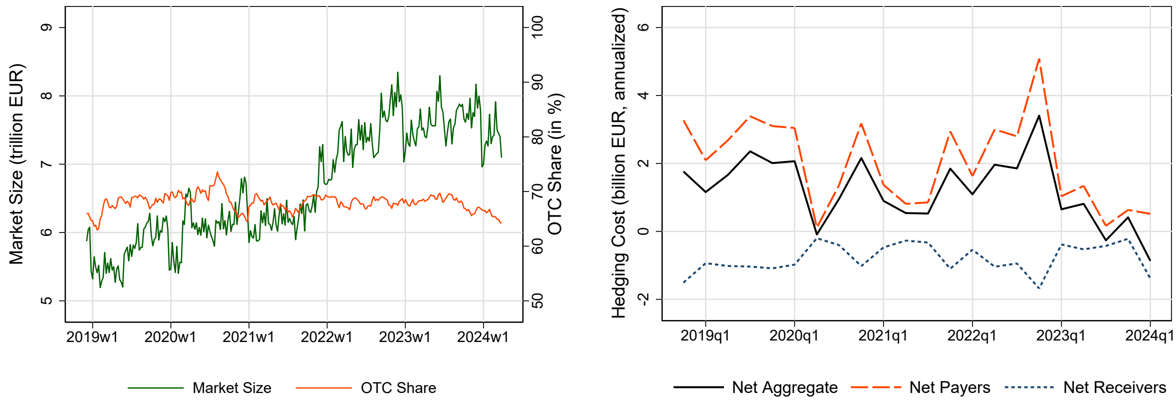
Figure IA.3. Cross-Currency Basis and GFX$_t$ at Quarterly Frequency.

This figure plots the deviation of the 3-months cross-currency basis from its 3-months trailing average 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).



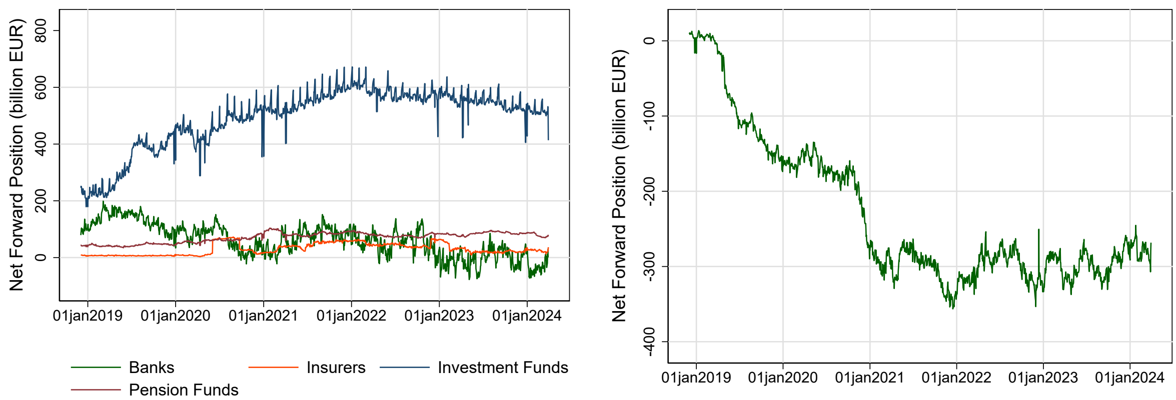
D Additional Figures and Tables

Figure IA.4. Size of and Aggregate Hedging Cost in the European USD-EUR FX Market.
Figure (a) depicts on the x-axis the 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 y-axis the share of these contracts traded over the counter. Figure (b) depicts the annualized hedging cost paid by (1) net payers of hedging cost, (2) net receivers, and (3) the euro area (in net terms). To calculate hedging cost, we first compute each investor's quarterly hedging cost defined by $N(e^{-\tau/12\mathrm{CCB}_\tau} - 1)/(\tau/3)$, where N is the quarterly average notional and τ the quarterly average remaining time to maturity in month, and, then, aggregate across (1) investors with positive net hedging cost, (2) investors with negative net hedging cost, and (3) all investors.



(a) Market Size. (b) Hedging Cost.

Figure IA.5. Net FX Positions by Parent Type.
The figures depict the net FX derivatives positions analogously to Figure 1 (b) but splits 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 volume, these are excluded to preserve confidentiality in Figure (b).



(a) Euro-area Parent. (b) International Parent (Banks).

Table IA.2. Cross-Currency Basis and Bond Holdings: Robustness.

This table provides a robustness analysis of the results in columns (2) and (7) from Table 4. At the security level, column (1) additionally includes credit rating-by-time fixed effects, column (2) time to 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 which additionally includes gross-volume-tercile-by-time fixed effects when computing idiosyncratic shocks in Equation (3), and column (7) uses the alternative heteroskedasticity-adjusted instrument from Equation (6). At the 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. Standard errors are shown in parentheses, clustered in columns (1)-(7) at the bond and country-by-currency-by-time levels and in columns (8) and (9) at the country-sector and country-by-time levels. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable:	$\Delta \log$ Bond Holdings							ΔUSD Share	
	IV								
USD × ΔCCB	0.32***	0.31***	0.31***	0.32***	0.30***	0.30***	0.25***		
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)		
USD × $\Delta \log S^{\mathrm{USD/EUR}}$				0.01					
				(0.08)					
USD × FX Volatility					-4.89**				
					(1.98)				
ΔCCB								0.05***	0.04***
								(0.01)	(0.01)
$\Delta \log S^{\mathrm{USD/EUR}}$								0.01	
								(0.01)	
FX Volatility									-0.86***
									(0.27)
Country-Sector-Time FEs	Y	Y	Y	Y	Y	Y	Y		
Country-Sector-Security 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.	8,567,136	8,567,136	8,567,136	8,567,136	8,567,136	8,567,136	8,567,136	1,080	1,080
No. of securities /country-sectors	342,243	342,243	342,243	342,243	342,243	342,243	342,243	54	54