The Implications of CIP Deviations for International Capital Flows*

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This version: June 14, 2024.

Abstract

We study the implications of deviations from covered interest rate parity (CIP) for international capital flows using a novel dataset covering the universe of derivatives and securities holdings in the euro area. We document that euro-area investors' holdings of USD bonds decrease following a widening in CIP deviations. Consistent with a simple dynamic model of currency risk hedging, we find that investors are significantly more responsive to CIP deviations when they need to roll over existing currency derivatives. CIP-driven shifts in bond demand significantly affect government bond prices and modulate the strength of monetary policy transmission to term premia.

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

*We thank Pierre Collin-Dufresne, Giancarlo Corsetti, Wenxin Du, Harald Hau, Peter Hoffmann, Ralph Koijen, Steven Ongena, Daniel Paravisini, Federica Romei, Steven Riddiough, Bo Sun, Silvana Tenreyro and seminar participants at the Rotman School of Management, Rome Junior Finance Conference, and European Central Bank for their comments and suggestions. We also thank Philippe Peroumal, Andrea Ricciardi, Joonas Remes, Baiyang Han, and Bowen Dong for their excellent research assistance. The views expressed in this paper are the authors' and do not necessarily reflect those of the European Central Bank or the Eurosystem. Quentin Vandeweyer acknowledges and thanks the Fama-Miller Research Center for its gracious financial support.

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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 especially during episodes of financial turmoil, 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 studied 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). EA investors hold a total of EUR 2.3 trillion in USD-denominated debt securities, stressing the importance of the EA for USD markets. They hedge the currency risk of a significant proportion of these assets using FX derivatives with shorter maturity than the hedged assets. In a simple dynamic model, we show that this maturity mismatch implies that risk-averse international investors are exposed to cross-currency basis risk: When the CCB widens, the net cost of rolling over hedging positions increases, which incentivizes investors to rebalance their portfolio away from foreign-currency-denominated assets. Consistent with these predictions, we then document that euro-area investors significantly reduce their USD bond holdings relative to their EUR bond holdings in response to a wider CCB, and that they are more responsive when faced with greater FX rollover risk. As a result, prices of EUR-denominated government bonds increase when they are held by investors with large rollover risk. 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, these findings suggest a causal impact of FX derivatives market frictions on international capital markets.

To guide our empirical investigation, we develop a stylized dynamic model of international portfolio allocation with FX derivatives markets and limited arbitrage. In the model, EA in-

[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 tn. globally (Eren et al., 2020; Borio et al., 2022; Shin, 2023).

vestors allocate their portfolios between long-term assets denominated in euro and 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 they face convex balance sheet costs, which generate an upward-sloping supply curve for forward contracts (Du et al., 2018). Following d'Avernas et al. (2024), we solve for a fixed point in which portfolio allocation depends on anticipation of shocks and conversely. 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 shocks result in stronger portfolio rebalancing despite weaker CCB widening, as investors are more willing 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. We document several novel facts about currency risk hedging: (i) the USD-EUR FX derivatives market has grown steadily to a size of EUR 7 trillion in 2023, roughly equivalent to the size of the European repo market; (ii) forward positions typically have much shorter maturity than bond holdings, with the median time to maturity of forward contracts being 2.8 months and 8.3 years for USD-denominated bond holdings; (iii) ratios of FX positions to USD-denominated investment are highly heterogeneous across investors, with insurance companies hedging on average 7%, mutual funds hedging 13%, and pension funds hedging 31% while banks supply more hedging than they demand (-13%).

In our main analysis, 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 relative demand for USD bonds, thereby widening the cross-currency basis and biasing the OLS coefficient toward zero.

We address this identification challenge by leveraging the granular nature of our data. First, motivated by the model, we explore heterogeneity in investors' responses to variations in the CCB. For this purpose, we use the investor-level share of FX hedging contracts that mature in the following 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, even after absorbing bond-specific shocks by including security-by-time fixed effects. This finding suggests that the response of bond holdings to the CCB is driven by investor currency hedging in the FX 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, exploiting the richness of our data, 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 to construct a granular instrumental variable (Gabaix and Koijen, 2023). These isolated demand shifts significantly move the CCB, validating the instrument's relevance: A 10% increase in currency risk hedgers' net FX positions (approximately EUR 11 billion) is associated with a 1 bps widening in the CCB, consistent with significant limits to arbitrage in the supply of currency risk hedging.

The instrumental variable approach allows us to first elicit the FX elasticity of demand. Instrumented changes in the CCB significantly affect FX positions. We estimate that a 1 bps widening of the CCB (increasing hedging costs) reduces FX derivatives positions by 1.62% for the average EA investor. This finding aligns with the model predictions and also helps 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).

We then revisit our main analysis using the instrumented CCB. The 2SLS estimate for the USD bond demand elasticity to CCB remains highly significantly different and is slightly increased compared to the OLS estimate, consistent with 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 0.66% relative to EUR-denominated bonds. Adjusting this estimate by the distribution of bond holdings implies an aggregate decline in euro-area USD bond demand by 0.28%. The magnitude is similar to existing estimates for the price elasticity of bonds and suggests that EA investors view currency-hedged USD bonds and EUR-denominated as close substitutes.

Finally, we find important implications for monetary policy. High-frequency policy surprises by the European Central Bank (ECB) have a stronger effect on long-maturity EUR bond yields in the presence of a large CCB than otherwise. Our main results offer an explanation for this finding. Higher euro-area policy rates increase investor demand for EUR relative to USD bonds (Hanson and Stein, 2015) and, therefore, reduce pressure on the CCB, which dampens USD hedging costs. The lower hedging cost feeds back into demand for USD bonds, which reduces demand for EUR bonds and, hence, supports higher EUR bond yields. Supporting this mechanism, we find that surprise hikes from the ECB attenuate the CCB significantly more when the lagged CCB is already large, indicating the presence of strong FX derivatives market frictions. In response, FX hedging demand declines significantly less in the presence of a large CCB, whereas 10-year bond yields increase significantly more. In contrast, the transmission to 1-year bond yields does not depend on the initial level of the CCB, consistent with the central bank controlling the short end of the yield curve. Thus, the effect of the CCB on monetary policy transmission works through term premia. The results suggest that derivatives market frictions partly temper the "trilemma" of monetary policy in international finance by creating a feedback loop between asset demand and hedging cost (Rey, 2018).

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.

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 cross-currency basis affects portfolio choice 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.

FX Derivatives The European Market Infrastructure Regulation (EMIR) adopted in 2012 requires that all investors report the characteristics of 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 September 2023. To homogenize information on swaps and forwards, we convert each FX swap into two forward contracts based on the two legs of the swap. 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 85% of the aggregate gross position of the euro area.

Throughout the paper, we define as a *buy* position one where the investor has the obligation to *buy* EURs against USDs in the future. With a buy position, the investor stands to gain from a future weakening of the USD against the EUR. Hence, a buy position hedges the currency risk of an asset yielding a USD-denominated cash flow. 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 EURs 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 due to active trading by investors or contract maturity but 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 2023Q3. 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., issuance and maturity dates) and their issuers (e.g., their domicile and credit rating) from the ECB's Centralised Securities Database (CSDB).

Bond Yields We retrieve information on US and euro-area bond 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 The Money Market Statistical Reporting (MMSR) provides information on the spot and forward rates of FX swap transactions in the euro area. MMSR provides confidential information on all USD-EUR swap transactions by major euro-area banks to the European Central Bank. 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 (CIP) as the cross-currency basis (CCB). Following convention (Du et al., 2018), the τ-months cross-currency basis of EUR vis-à-vis the US dollar at time t, denoted by $\text{CCB}_{t,\tau}$, 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:

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

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 EUR-USD spot exchange rate, and $F_{t,\tau}$ is the τ-months EUR-USD 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 (2018-2023) and based on the rates paid by European 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 been steadily expanding from around EUR 5 trillion in 2019 to EUR 7 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 importance of the USD-EUR FX derivatives market.

Figure 1 plots the time series of net positions in USD-EUR FX contracts across sectors. With

[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.

a net position of approximately EUR 540 billion, the investment fund sector has the largest net buying position as of 2023, gaining in case of a future depreciation of the USD. The pension fund sector has the second-largest net buying position of close to EUR 100 billion. Since 2018, 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 180 billion. Thus, banks are the primary suppliers of USD currency risk hedging, whereas foreign investors are residual suppliers.

A more negative cross-currency basis translates into a higher cost of funding (i.e., hedging) USD investments by euro-area investors. 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.[4] The net hedging cost peaked in 2022Q4 at EUR 3.3 billion. Whereas the majority of euro-area investors pay the cross-currency basis, some are receivers as they sell future EUR. Net payers paid close to EUR 5 billion in 2022 in hedging costs.

FX Derivatives Positions and USD Investments Thanks to the holistic coverage of our datasets, we can compute the portion of USD assets that is currency-hedged for the entire euro area. On average, we find that euro-area investors hedge 8% of their USD investments. Amongst those hedged positions, we further document a striking maturity mismatch between the average maturity of the security of 8.3 years and the maturity of the average FX derivatives of 2.8 months (see Table 1). These findings imply that investors face basis risk from rolling over FX contracts and are thereby exposed to a widening of the CCB. We also find that there is significant heterogeneity across sectors (see Table 2). Pension funds display the largest hedge ratio (25%), followed by insurers (15%) and investment funds (13%). Instead, banks' hedge ratio is negative (-0.33%), owing to their negative net position in FX derivatives.

Figure 3 provides additional insight into the hedging activity of European investors. We first plot net FX positions against the volume of USD investments at the sector-by-quarter

[4] 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 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.

level. Both are scaled by total investments to account for differences in sector size. We observe that the two sectors with the largest share of USD investments (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 investments 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 investments in aggregate. This suggests that banks' FX activity is not primarily driven by demand for hedging USD equity and bond investments. Instead, banks provide intermediation in derivatives markets, consistent with them being the main suppliers of currency risk protection in the euro area, often through direct access USD funding and, thereby, arbitrage the cross-currency basis.

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 investments, both scaled by total investments and purged of aggregate shocks using time fixed effects. The strong and positive correlation between the two variables implies that country-sectors that invest more in USD-denominated assets exhibit larger net FX hedging positions.[5]

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.

[5]The corresponding estimated regression coefficient shows that a 1 ppt increase in the share of USD investments is accompanied by a 0.18 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).

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 agents populate the economy: (i) A representative European investor that invests its wealth into a risky USD asset, a risk-free USD asset, and a risk-free EUR asset while trading FX futures contracts but cannot borrow directly in USD; (ii) A CIP arbitrageur with convex balance sheet costs, borrowing in USD to invest in EUR while supplying futures contracts to the European investor; (iii) An outside-option US investor, standing ready to purchase the risky USD assets for a low enough price.

Exchange Rate Process For parsimony and to focus on the financial implications of the cross-currency basis, 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.[6]

Return Process From the perspective of a representative European investor, the return processes for investing in both interest rate risk-free and risky USD-denominated assets, respectively, are given by:

$$dR_t^d = (r^d + \mu^x)dt + \sigma^x dZ_t^x, \qquad dR_t^a = (r^d + \mu^x + \varsigma_t)dt + \sigma^a dZ_t^a + \sigma^x dZ_t^x,$$

where r^d is the risk-free interest rate for the US investors. Note that 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 exchange rate risk through the currency risk factor dZ_t^x; (ii) its drift incorporates the exchange rate drift μ^x. In

[6] 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.

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 return drifts for interest rate risk-free and risky assets are $r^d + \mu^x$ and $r^d + \mu^x + \varsigma_t$ respectively, while parameter σ^a is the volatility loading on the US market risk factor. In addition, the investor earns the EA 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 forward (or, equivalently, a swap) exchange rate contract to hedge currency risk. When entering into a 1 dollar nominal forward contract at a price $\exp(f_{t,\tau})$, investors agree at time t to exchange 1 dollar to EUR $\exp(f_{t,\tau})$ at date τ. In doing so, the investor reduces its exposure to exchange rate 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:

$$dR_t^f = d\left[f_t - x_{t+dt}\right] = \left(\theta_t - \mu^x\right) dt - \sigma^x dZ_t^x.$$

That is, when purchasing a forward contract, an investor gains from the forward premium $\theta_t dt$ and loses from dollar 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 $\sigma^x dZ_t^x$.

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). Second, to capture the maturity mismatch between forwards and underlying assets documented earlier, we assume that the derivatives contracts have an instantaneous maturity so that the European investor has to roll over its hedging position. Third, we assume that trading capital market USD assets is subject to a transaction cost. 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. As we show below, these combined assumptions will imply that the European investor is subject to cross-currency basis risk.

3.2 Optimization Problem

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

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

subject to the law of motion of wealth:

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

and

$$w_t^d \geq 0,$$

where n_t is the net worth and c_t is the consumption in period t. The European investor invests w_t^a and w_t^d 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).[7]

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:

$$V_t^s = \max_{\{\alpha_\tau^s\}_{\tau=t}^\infty} \mathbb{E}\left[\int_t^\infty e^{-\rho(\tau-t)} \log(n_\tau^s) d\tau\right]$$

subject to

$$\frac{dn_t^s}{n_t^s} = (r^e + \alpha_t^s(r^d + \theta_t - r^e))dt - \frac{\chi}{2}\left(-\min\{\alpha_t^s, 0\} - \min\{1-\alpha_t^s, 0\}\right)^2 dt,$$

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

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

[7] 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.

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.

3.3 Analysis and Predictions

We derive the equilibrium prices and allocations and study how they vary following shocks to residual demand between the steady and shock states.

Equilibrium Restrictions To focus on the relevant case for our analysis, we restrict the set of parameters corresponding to equilibria in which (i) the net worth of the European investor and the global arbitrageur is at a constant unit level: $n_t = n_t^s = 1$; (ii) UIP holds: $r^d + \mu^x - r^e = 0$; (iii) CIP deviates negatively: $r^d+\theta_t-r^e < 0$; and (iv) the global investors only enters the market in the shock state. The last restriction can be achieved simply by adding a small variation into $\overline{r}_t^a$: $\overline{r}^a(d) - \varepsilon = \overline{r}^a(d') = \varsigma(d)$, where $\varepsilon > 0$ is an infinitely small amount. Hence, $\widetilde{b}(d) = 0$ and $\widetilde{b}(d') \geq 0$. Due to the market-clearing condition for the risky USD asset, it is $w^a(d) \geq w^a(d')$.

Inaction Region In the Online Appendix, we derive the explicit solution to the above optimization problem and impose market clearing conditions. In particular, we 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. We derive the threshold of this inaction region at which the investor starts selling USD assets as:

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

As follows from condition (C), 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 to be optimal. This result has an intuitive interpretation. The European investor compares an equilibrium hedging cost flow per period, captured by $(d'-d)/(1/\chi+1/(\sigma^x)^2)$, to a fixed cost of selling those assets. It is, therefore, willing to bear a larger flow of hedging costs for a shorter period of time to avoid paying a round-trip transaction cost.

Model Predictions We now assume a set of parameters such that Condition (C) holds. 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 guide our empirical investigation below.

Proposition 1. *Assuming a set of parameters such that Condition (C) and equilibrium restrictions (i), (ii), (iii), and (iv) hold, adjustments to equilibrium allocation and prices following Poisson arrival are such that*

(a) the CCB becomes more negative (widens) in 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 due to the mismatch between the liquidity of the USD asset and the instantaneous FX contract. Upon the arrival of the Poisson shock, the investor trades off maintaining its hedging position at a higher cost by selling USD assets to reduce exposure to currency risk according to its 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.[8] The combination of instantaneous FX contracts, transaction costs, shocks to residual FX demand, and inelastic FX

[8]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 this outside investor without affecting the results qualitatively.

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 either selling assets, paying a higher hedging cost (through a larger CCB), or reducing their hedging ratios. All these options result in a net loss of utility in those states of the world. The following proposition shows how the combination of these adjustments crucially depends on expectations about shock dynamics.

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 prices to the Poisson shock is such that for a given shock size* $(d' - d)$ *it holds that*

(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 increase in the magnitude 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 for a high hedging cost for a short period of time to avoid paying the liquidation fixed cost. Conversely, when the shock is expected to be long-lived, European investors are willing to liquidate their position at a lower threshold in condition (C). Therefore, in this scenario, the CCB does not widen as much. 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 ends or year ends are likely to be associated with a large reaction in CCB but only low, if any, reaction in capital markets as observed by Du et al. (2018) and Wallen (2022). It is, therefore, crucial to assess those elasticities to be able to identify longer-lasting shocks. In the next section, we develop our empirical strategy.

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 instrumented cross-currency basis interacted with an indicator for US dollar denomination:

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

where Bond Holdings$_{i,b,t}$ is the nominal amount of bond b held by a country-sector pair i at quarter t. The sample includes all EUR- and US dollar-dominated bond holdings. 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 unit of EUR per USD. Bond holdings are measured in nominal values to remove variation due to price changes. To ensure convergence of standard error estimators, we use two-way-clustered standard errors at the security and country-by-currency-by-time levels. 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 omitted shocks to security characteristics, issuers, or investors. Investor (country-sector)-by-time fixed effects ($u_{i,t}$) absorb shocks that differently affect investors and investor (country-sector)-by-security fixed effects ($v_{i,b}$) absorb variation from time-invariant investor preferences. Thus, the regression effectively holds an investor's 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 growth rates in more internationally diversified industries differ from those in other industries. In addition to the evidence at the security level, we also find consistent estimates for α at the portfolio level, which supports our focus on changes in bond holdings at the intensive margin.

Despite these granular fixed effects, the main coefficient may still be biased by the presence of currency-specific omitted variables or simultaneous supply and demand shocks. 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 as a measure for rollover risk. For each country-sector pair, we consider the set of investors that maintained an average net buy position in 3-month to 1-year contracts in the previous three months, i.e., investors seeking long-term protection against USD currency (and, thus, CCB basis) risk. Among these investors' hedging positions (that swap USD for EUR in the future) outstanding at the lagged quarter's end with a time to maturity of at least 4 days, we compute the share of notional that matures in the current quarter, denoted by %FX mat. The larger %FX mat, the larger is the rollover risk faced by investors due to currency risk hedging and, therefore, their exposure to changes in the cross-currency basis.

We then use a triple-interaction term in Regression (2), which interacts $\text{USD}_b \times \Delta\text{CCB}_t$ with %FX mat, to estimate the impact of exposure to the CCB on the differential response of USD bond holdings to CCB changes. This allows us to also include security-by-time fixed effects, which absorb any shocks at the security (and, thus, currency) level, leveraging the cross-sectional differences in CCB exposure.

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.[9] $Q_{i,t}$ includes both the forward legs of swap transactions and pure forwards, as described in Section 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

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

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 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 $\Delta Q_{i,t} = (Q_{i,t} - \bar{Q}_{i,t})/|\bar{Q}_{i,t}|$.

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:

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

where $\mathrm{mat}_{i,t}$ is the average remaining time to maturity of investor i's FX positions (within the 2 to 4 months bucket), which we set to zero in the absence of outstanding FX positions. Investor fixed effects (u_i) absorb time-invariant heterogeneity, e.g., stemming from differences in risk aversion. Sector-by-country-by-time fixed effects ($v_{\mathrm{s(i),c(i)},t}$) absorb shocks that similarly affect all investors of a given sector $s(i)$ domiciled in a given country $c(i)$. For example, it absorbs the (sector-specific) effects of changes in a country's regulatory environment, trade surplus, or financial market conditions. 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. Consistent with the definition of $\Delta Q_{i,t}$, we also define by $\Delta\mathrm{CCB}_t$ the change in the cross-currency basis relative to its 3-month trailing average in percentage points. 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. In second-stage regressions, we use GFX_t as an instrument for the cross-currency basis. 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:

$$\frac{1}{\sum_{i \in \mathcal{L}_t} \bar{Q}_{i,t}} \sum_{i \in \mathcal{L}_t} \bar{Q}_{i,t} \Delta Q_{i,t} = \frac{\sum_{i \in \mathcal{L}_t} Q_{i,t} - \sum_{i \in \mathcal{L}_t} \bar{Q}_{i,t}}{\sum_{i \in \mathcal{L}_t} \bar{Q}_{i,t}}. \tag{6}$$

Thus, μ is the price impact of a 1% idiosyncratic shock to typical hedgers' aggregate net position. We next discuss the relevance condition and exclusion restriction for the GFX to be a valid instrument.

Relevance Condition 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. 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 The exclusion restriction holds if the weights $\bar{Q}_{i,t}/(\sum_{i\in\mathcal{L}_t}\bar{Q}_{i,t}) - |\mathcal{L}_t|^{-1}$ are orthogonal to hedgers' exposure to aggregate shocks (Gabaix and Koijen, 2023). If, instead, this orthogonality assumption was not satisfied, 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 evidence that a potential bias is contained. If the bias was large, then GFX_t would mostly reflect supply instead of demand shifts, and, therefore, the estimate for μ would be positive, as a more negative cross-currency basis would correlate with lower FX positions. Instead, we find the estimate to be significantly negative (see Table 3). It is also largely unaffected by the inclusion of a variety of macroeconomic control variables that are potential confounders, such as government bond rates or financial market volatility. Moreover, (equal-weighted) average FX positions are negatively correlated with our instrument, which is consistent with GFX_t capturing variation in hedging cost driven by the idiosyncratic demand shifts of large investors.

In addition, we use the principal components of residuals $\check{q}_{i,t}$ to control for aggregate factors, following Gabaix and Koijen (2022). Investors with different volatilities of $\check{q}_{i,t}$ are likely to have different exposures to the factors. Therefore, in each quarter, we sort investors into 20 groups based on the respective time-series standard deviation of their residuals $\check{q}_{i,t}$ and compute the group-by-day-level average residual. Principal components are then based on the panel of 20 groups. Including the first three components (which account for 39% of the variation) as control variables has little effect on the estimate for μ, which provides further support for the validity of the empirical approach.

5 Empirical Results

This section exposes the main results of our paper and estimates the reaction of hedging and dollar asset allocations to a change in the cross-currency basis as instrumented by the GFX.

5.1 FX Derivatives Positions

We first test the second prediction of Proposition 1 that euro area investors reduce their hedging positions following an increase in the CCB generated by idiosyncratic residual demand shocks. Columns (1) and (2) in Table 3 report the estimated coefficients for the first-stage regression (5), in which we regress changes in the cross-currency basis 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 cross-currency basis. Relative to the average net position of typical hedgers (EUR 111 billion), this suggests that a EUR 9.2 billion increase in net positions is associated with a 1 bps wider cross-currency basis. The magnitude of the effect emphasizes the inelastic FX hedging supply (Du et al., 2018). The more constrained the supply side (e.g., dealers), the less elastic is the supply of currency hedging and, thus, the larger is the response of the cross-currency basis to demand shifts. The estimate implies that relatively small demand shifts are sufficient to generate meaningful changes in the cross-currency basis (which has a mean value of -11 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., 2017) as well as the first three principal components of investors' idiosyncratic shocks. Controlling for these variables removes the potential impact of monetary policy, financial market conditions, 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.

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:

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

ϕ is the (semi-)elasticity of Y_t to an increase in the cross-currency basis. The outcome variable Y_t is either the equal-weighted average of de-trended investor-level FX positions across euro-area banks, investment funds, insurers, and pension funds ($\overline{\Delta Q_t}$) or de-trended bond yields (ΔYield). We first report the OLS estimate in column (3), which does not use the instrumental variable. The estimated coefficient is not significantly different from zero. This finding is not surprising because the OLS estimate suffers from a standard simultaneity bias: It conflates demand and supply shocks, which have an opposite effect on prices, i.e., the CCB. Column (4) reports our baseline estimate, which results from instrumenting the cross-currency basis with GFX_t. The estimate implies that a 1 bps decrease (i.e., widening) in the cross-currency basis reduces average FX positions by 1.62%. The coefficient is statistically significant at the 1% level (t-statistic: 7.17), which is consistent with our empirical approach to successfully identifying investors' demand elasticity. 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 28%.

Whereas we pool across all investors in Table 3, we report sector-specific estimates in Figure 4 (a). The sensitivity of FX positions to the cross-currency basis is the highest for insurers and pension funds (4 and 3.5, respectively) and only slightly lower for banks (close to 3). In contrast, investment funds display a substantially lower elasticity (close to 0.5). This finding is consistent with the low elasticity of investment funds to quarter-end spikes in CCB documented by Wallen (2022). The results suggest that investment funds reduce their hedging activity by much less than other investors in response to higher currency hedging costs. In this regard, an important difference across investors is their regulatory framework. 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, although investment fund risk-taking is not regulated, many funds face strict mandates to hedge currency risk, which constrain their ability to adjust hedging activity to hedging costs.

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.

Cross-Elasticity In 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 0.45% relative to EUR bonds in response to a 1 bps decrease (i.e., widening) in the CCB. The significantly positive coefficient suggests that the security-level specification is useful to isolate meaningful variation in the CCB that is orthogonal to aggregate bond demand. We instrument the CCB with GFX_t in column (2). As a result, the estimated elasticity is larger than in column (1), implying that USD bond holdings decrease by 0.66% 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 remains biased by shocks affecting both bond demand and CCB.

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

The baseline estimate reports the elasticity for the average bond weighted by the number of observations. To grasp the implications for *aggregate* capital flows, we also compute the estimate weighted by the lagged nominal value of bond holdings. The holdings-weighted estimate corresponding to column (2) is 0.32, implying that (for the average EUR invested) USD-denominated bond holdings decline by 0.32% *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 0.28% in the euro-area's *total* USD bond holdings.[10] This aggregate elasticity is economically significant. It implies that the 5% largest declines in CCB are associated with a 4.5% (-0.16×0.28) 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 2023Q3, this corresponds to approximately EUR 104 billion of USD bonds being disposed.

We also 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.[11] Because EUR-denominated bonds that are close substitutes for currency-hedged USD-denominated bonds are readily available, the demand elasticity to changes in the CCB is in the upper range of estimates for price elasticities.[12] Consistently, we document that our baseline estimate is largely unaffected by the inclusion of rating-by-time or time to maturity-by-time fixed effects (see Appendix Table IA.1), suggesting that investors substitute between bonds with different currency denomination but similar credit and interest rate risk.

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

[10] 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 13.9%.

[11] 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).

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

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, investment funds keep their hedge ratio almost constant, consistent with either particularly strong or particularly weak hedging mandates.

Rollover Risk To further study the role of investors' FX derivatives market activity as a mechanism through which cross-currency basis risk affects bond demand, we examine the share of investors' maturing FX hedging contracts as a measure for rollover risk.

We find that the CCB elasticity of bond holdings is driven by rollover-risk-exposed investors. In column (3), we group country-sector-quarter observations depending on the 50 % largest (and smallest) realizations of %FX mat and, then, estimate separate elasticities for both groups. We find that the CCB elasticity of those with large rollover risk is nearly twice as large as that of other investors. It is also statistically more significant. The result is not driven by time-invariant differences between these types of investors (e.g., due to their investment preferences), which we absorb by including high-rollover-risk fixed effects.

The difference between investors with more and less rollover risk is statistically significant, as we show in column (4). Here, we additionally control for security-by-time fixed effects, which absorb any bond-specific shocks (such as variation in USD $\times$ CCB).[13] Thus, the coefficient identifies differences in bond demand within a particular bond and period, driven entirely by differences in investors' FX derivatives rollover risk.

Heterogeneity We also use the baseline specification to uncover heterogeneity across bond characteristics, which reflects differences in currency hedging motives. In Figure 4 (c), we report that long-term bond holdings (with at least 5 years remaining time to maturity) are more elastic than short-term bond holdings, with an elasticity of approximately 0.75 and 0.4, respectively. This suggests that investors trade off currency and interest rate risk: when hedging currency risk becomes more expensive, investors shy away relatively more from bonds that also carry

[13]These granular 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 significantly reduces the overall sample size.

higher interest rate risk. A similar pattern emerges when considering the credit risk of bond issuers. AAA-rated bonds exhibit the lowest elasticity (below 0.5). In contrast, all other rating classes display an elasticity of around or above 0.5, with the largest elasticity (among rated bonds) for high-yield bonds. Thus, investors trade off currency and credit risk. An additional reason is that, when the cross-currency basis is negative (as most of the time in our sample), USD-denominated risk-free assets are relatively unattractive for euro-area investors. Instead, only when the risk premium on risky USD-denominated assets is sufficiently large, euro-area investors have a strong motive to invest in USD *risky* assets.

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), 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.[14] The OLS estimate for the CCB elasticity of the USD portfolio share is significantly positive (column 5), consistent with the security-level result in column (1). In column (6), we compute the CCB elasticity implied by instrumenting the CCB with GFX_t. It implies that the portfolio share declines by 0.07 ppt in response to a 1 bps decline in CCB. This estimate is consistent with the security-level estimate in column (2) when adjusting by the average USD portfolio share. The robustness of the result 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, 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. Finally, column (7) reports separate coefficient for country-sectors with different FX rollover risk. Consistent with the security-level results, investors with larger rollover risk are more elastic to changes in the CCB, although with a lower level of statistical significance.

[14] 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.

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 investor rebalancing or 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.1, we show that our baseline results are robust not only 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 but also to control for changes in spot rates and spot rate volatility.

5.3 Price Impact

In the following, we examine the price impact of cross-currency-basis-risk–implied investor rebalancing. For this purpose, we use daily data on euro-area government bond yields across issuer countries and time to maturity. Because it may take several days for bond yields to respond to cross-currency basis (CCB) changes, we focus on the average bond yield in the 3 weeks following CCB fluctuations, de-trended by the average bond yield in the lagged 3 months (ΔBond Yield). The average yield change is 8 bps and it ranges from -30 bps to 69 bps at the 5th/95th percentiles (see Table 1). In Table 5, we report estimates from regressions of ΔBond Yield on instrumented CCB changes (ΔCCB) at daily frequency, controlling for bond fixed effects. Whereas yields of the *average* bond do not significantly respond to CCB shifts (column 1), the yield response differs substantially in the cross-section of bonds.

EA Holding Shares 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 strong enough, our theory would predict that bonds whose investors are (more) exposed to cross-currency basis risk will respond (more) to variations in the CCB. To test this prediction, we first examine cross-sectional heterogeneity in the one-quarter-lagged share of a bond's outstanding amount held by euro-area investors (EA share). There is wide variation in the EA share, ranging from 15% to 70% at the 5th/95th percentiles. Because euro-area investors are more exposed to EUR-USD hedging costs than the average foreign investor, we expect bonds with a larger EA share to have a stronger response to CCB shocks.[15]

In column (2), we estimate separate coefficients for bonds with a large (above median) and small (below median) EA share. Whereas the coefficient on ΔCCB remains small and insignificant for small-EA-share bonds, it is large and significantly positive for large-EA-share bonds (column 2). This finding is consistent with our hypothesis. The point estimate implies that the yields of large-EA-share bonds decrease by 0.99 bps in response to a 1 bps decline in the CCB. The larger response of bonds with a larger EA share is also significantly positive, as we show in column (3). In this specification, we also include issuer-by-time fixed effects, which absorb aggregate shocks as well as differential trends across issuer countries. The coefficient is then estimated from differences in the investor base across bonds issued by the same country.[16]

Rollover Risk Second, we examine heterogeneity in euro-area investors' FX derivatives rollover risk. With sufficient segmentation, our theory would predict that bonds held by investors subject to stronger rollover risk should see a stronger reaction in yields. 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 (exploiting the higher frequency of bond yield data), denoted by $\%\text{FX mat}_{i,m(t)}$. Then, we aggregate %FX mat to the bond level by computing the holdings-weighted average across country-sectors:

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

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

[15] Our data does not allow to differentiate between different non-euro-area investors. US investors' demand for hedging EUR currency risk is likely affected by changes in the EUR-USD cross-currency basis, as well. This potentially biases estimated differences across bonds with different EA shares toward zero.

[16] Note that these granular fixed effects reduce the sample size because they require at least two different bonds in the sample at the same time from the same issuer.

In column (4), we estimate separate coefficients for bonds depending on their investors' rollover risk exposure. We observe that only bonds with high rollover risk exposure respond significantly to CCB changes (at the 10% level), whereas the coefficient for bonds with low rollover risk is smaller and not significantly different from zero. As hypothesized, euro-area investors' rollover risk is only relevant if those investors hold a sufficiently large share of a bond. Therefore, in columns (5) and (6), we consider the sample of bonds with a large EA share and estimate separate coefficients for bonds depending on their rollover risk exposure. Whereas both types of bonds exhibit a significantly positive coefficient, those with high rollover-risk exposure respond substantially more CCB changes. The estimated coefficient implies that these bonds' yields decrease by 1.56 bps in response to a 1 bps decline in the CCB, whereas bonds with a low rollover risk exposure exhibit an elasticity of only 0.89. The difference between these types of bonds is significantly different from zero, as we show in column (6). Again, we include granular issuer-by-time fixed effects, absorbing potentially confounding variation due to country-specific shocks. Overall, these results are consistent with a larger demand for euro-area assets in response to a wider (more negative) USD-EUR cross-currency basis, driven by investors with a particularly large exposure to the USD-EUR FX market.

5.4 Monetary Policy Transmission

So far, we have examined variation in the cross-currency basis resulting from idiosyncratic demand shifts in the FX derivatives market. Yet, according to our theory, any variable affecting the demand for USD assets should also impact the FX derivatives market through hedging demand. An important determinant of international capital flows is monetary policy. For instance, tighter euro-area monetary policy should increase bond yields in the euro-area relative to the US. In turn, this effect reduces the demand for USD assets and, therefore, USD currency hedging by euro-area investors, easing global arbitrageurs' constraints and, thus, reducing the (negative of the) level of the cross-currency basis (CCB). In this section, we study how this currency risk hedging channel interacts with the transmission of monetary policy to risky assets. We find that in times with severe FX derivatives market constraints, contractionary euro-area monetary policy surprises significantly dampen the CCB and, thereby, reduce demand for EUR relative to USD assets, which strengthens monetary policy transmission by increasing euro-area yields.

FX Derivatives First, we study the effect of monetary policy on euro-area USD-EUR FX derivatives positions. To remove the potential effects of macroeconomic confounders, we focus on plausibly exogenous variation in monetary policy and follow the prior literature by considering euro-area monetary policy surprises in 3-month overnight index swap rates in a narrow time window around European Central Bank (ECB) monetary policy events based on data collected by Altavilla et al. (2019).[17] We compute the change in the total net position of euro-area institutional investors (banks, investment funds, insurers, and pension funds) around monetary policy events as the difference between the average total net position in the month following the event and the average total net position in the week before (the results are robust to using other time horizons).

Column (1) in Table 6 displays estimates for the impact of monetary policy on euro-area FX positions for all monetary policy events from December 2018 to September 2023. We interact monetary policy surprises with an indicator for the 50% lowest (most negative) observations of the two-day lagged CCB. The results show that euro-area investors significantly reduce FX positions after monetary policy hikes when the lagged CCB is close to zero. This finding is consistent with lower demand for USD assets and, thus, USD currency risk hedging due to higher euro-area yields. However, the response is significantly weaker when the CCB is large and negative. In fact, monetary policy does not significantly affect FX positions in times of large and negative CCB. This result is consistent with the existence of convexity in intermediaries' balance sheet costs. A monetary policy hike relaxes the constraints in FX derivatives supply more significantly when those constraints are large ex-ante. This dampens the negative impact on USD hedging demand.

Second, in column (2), we provide further evidence consistent with this mechanism by regressing changes in the cross-currency basis on monetary policy surprises. To ensure that the result is not restricted to the most recent years (the ones for which we have data on derivatives positions), we also expand the sample to start in 2013 (excluding the impact of the great financial crisis and the European sovereign debt crisis in earlier years). The coefficient on monetary

[17] We purge monetary policy surprises of information shocks, where the ECB mostly conveys surprising information to markets, using poor man's sign restrictions (Jarocinski and Karadi, 2020).

policy surprises is not significantly different from zero when the lagged CCB is close to zero. Instead, only when the lagged CCB is large and negative, monetary policy hikes significantly shrink the CCB (in absolute terms). This result is consistent with significant non-linearities in FX derivatives supply: if constraints are very tight (as reflected in a large and negative lagged CCB), monetary policy has a strong effect on FX forward prices by shifting FX hedging demand.

Bond Yields Third, we examine the impact of monetary policy on bond yields. Motivated by our previous results that variation in the CCB shifts asset demand, we hypothesize that the transmission of monetary policy surprises to risky bond yields depends on the initial level of FX derivatives market frictions, as reflected by the lagged CCB. Because short-term rates are tightly controlled by the central bank, we expect the effects of investor demand to operate through risk premia. In column (3), we regress changes in the yields of 10-year euro-area government bonds on monetary policy surprises without additional interactions.[18] The coefficient is significantly positive at the 5% level, consistent with monetary policy affecting not only short-term but also long-term rates. Column (4) shows that this effect is entirely driven by times when FX derivatives markets are constrained. Whereas monetary policy surprises are not significantly related to bond yield changes in times with small frictions, transmission is significantly stronger when the CCB is large and negative. In such times, a 25 bps monetary policy surprise raises 10-year yields by approximately 0.47 bps. Thus, monetary policy transmission is amplified by relaxing FX derivatives market constraints.

In contrast and consistent with the hypothesis, monetary policy transmission to shorter-term yields does not depend on the level of the initial CCB (column 5). Thus, CCB affects monetary policy transmission to term premia. We directly test the impact of monetary policy on the difference between long-term (with a maturity of at least 5 years) and short-term bonds in column (6), using a maturity-by-issuer-level panel. The coefficient on the interaction between monetary policy surprises, an indicator large and negative lagged CCB, and an indicator for long-term bonds is significantly positive. Hence, monetary policy affects term premia significantly more when FX derivatives market frictions are large. This result is not driven by differential shocks to bond issuers (e.g., some countries being more exposed to FX derivatives market frictions),

[18] The dependent variable is the difference between the average yield in the 7 days following a monetary policy event (including the event) and the yield before the event.

as we show in column (7) by including issuer-by-time fixed effects. Instead, the findings are consistent with FX derivatives market conditions affecting monetary policy transmission through the impact of investor demand on term premia.

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' EUR-USD FX derivative positions as well as their securities holdings. We find that an increase in the cost of currency hedging leads investors to decrease both their FX positions and their investments in foreign assets. FX positions are more elastic, especially for pension funds and insurers, which implies that investors reduce their currency risk hedge ratio. Bonds are more elastic to hedging costs than equity, suggesting that investors mostly hedge bond investments, consistent with the predictions of optimal portfolio models in prior studies. Finally, we show that large hedging costs intensify the transmission of domestic monetary policy to domestic financial markets and, at the same time, dampen the exposure to foreign monetary policy. Overall, our results have important implications for understanding international capital flows, 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. This figure 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.

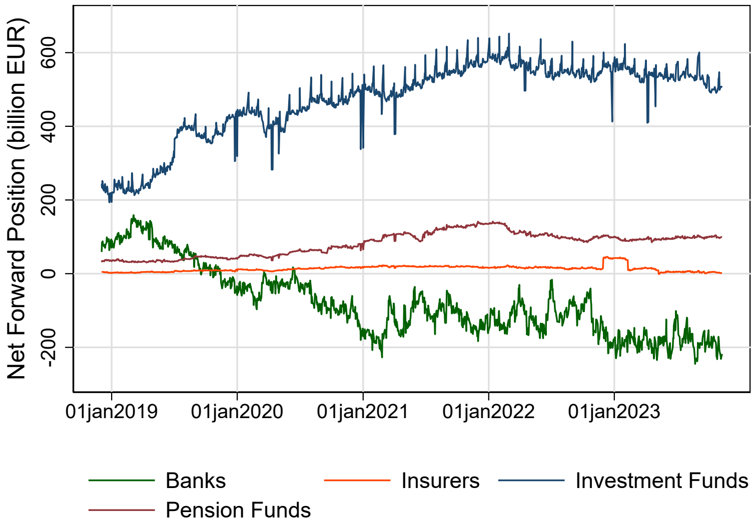


Figure 2. USD-EUR Cross-Currency Basis. The figure plots the USD-EUR cross-currency basis for 3-months maturity. It is computed from transaction-volume–weighted average spot and forward rates from money market statistical reporting to the ECB and the EURIBOR and USD LIBOR rates. The more negative the cross-currency basis, the more expensive it is for euro-area investors to fund USD positions. For confidentiality purposes, the original value of 11 observations is omitted and replaced by an interpolated value. Source: MMSR, Bloomberg.

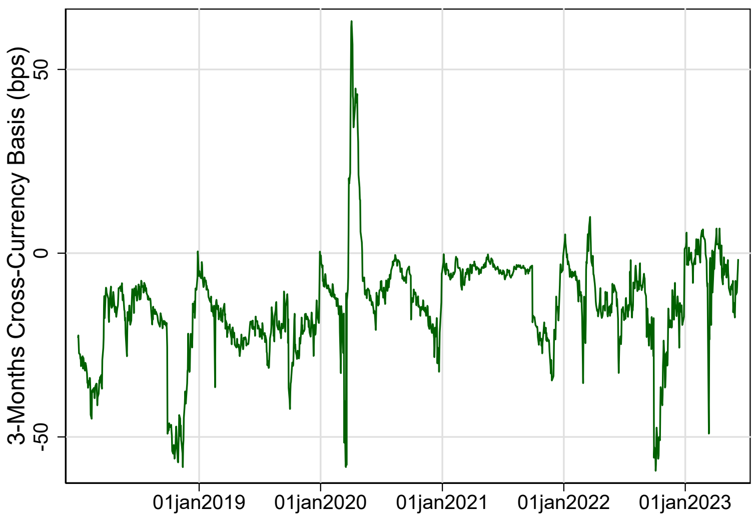
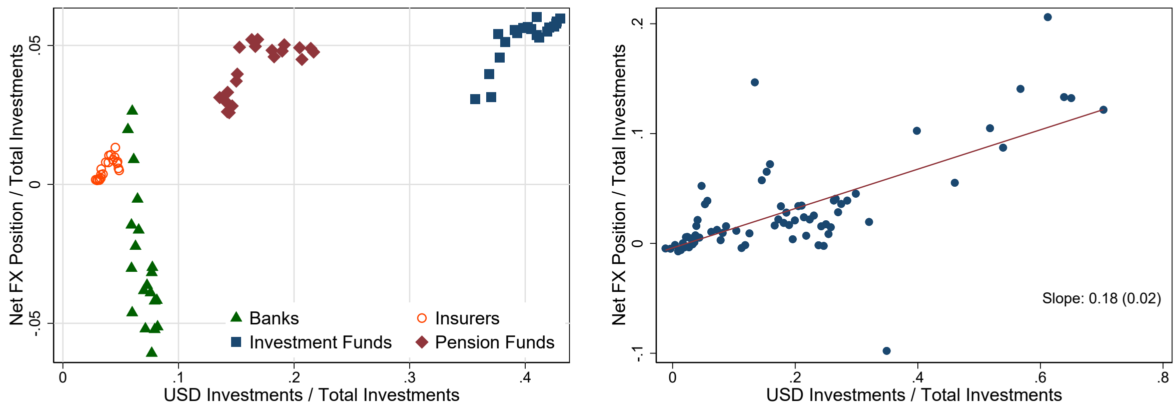


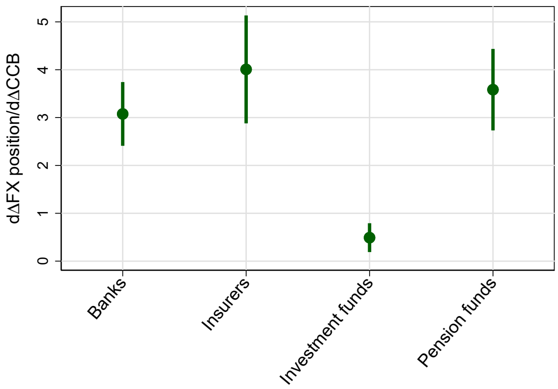
Figure 3. FX Forward Positions and Portfolio Allocation. Figure (a) plots an investor sector's total net forward position (y-axis) and total USD investments (x-axis), both scaled by total investments. Figure (b) is a binscatter plot of total net forward positions (y-axis) and total USD investments (x-axis) 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.



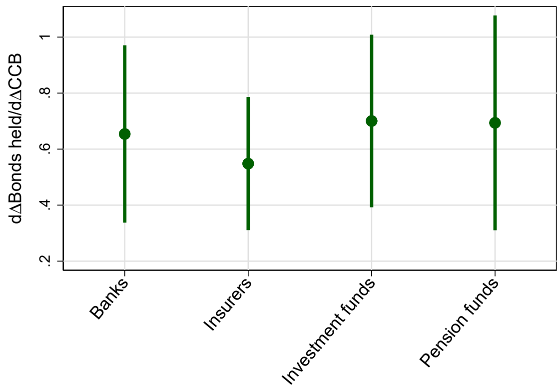
(a) Time Series (sector level)

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

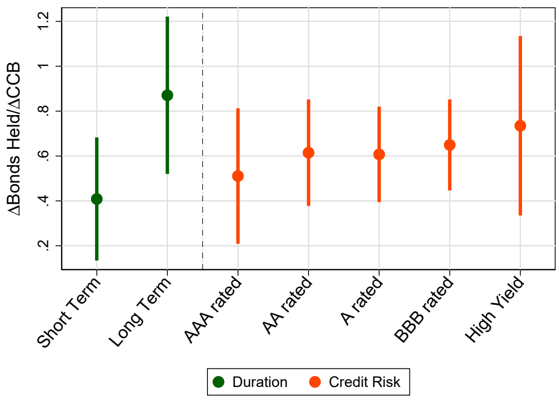
Figure 4. Cross-Currency Basis, FX Forward Positions, and Bond Holdings: Heterogeneity. This figure depicts the estimated coefficient on the instrumented change in the cross-currency basis individually for different sectors and types of bonds based on regressions analogously to (a) column (4) in Table 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 forward positions 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 and replace some percentiles of rollover risk by *. 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 - Sep 2023)						
Net FX Position (bil EUR)	5,040	105.02	241.83	-254.04	49.60	553.83
Gross FX Position (bil EUR)	5,040	1,472.48	1,942.47	28.14	399.04	5,801.27
FX: Time to Maturity (months)	5,040	2.28	0.91	1.05	2.10	3.60
Securities Holdings (Sector-by-Quarter Level, 2018q4 - 2023q3)						
Share of USD Bonds	80	0.17	0.14	0.03	0.11	0.40
USD Bonds: Time to Maturity (ex. > 50 yrs)	80	8.72	1.71	5.95	8.99	11.92
Hedge Ratio	80	0.04	0.30	-0.64	0.14	0.31
Time-Series Variables (Daily Frequency, Dec 2018 - Sep 2023)						
CCB (bps)	1,200	-11.1	12.8	-29.1	-10.3	4.6
ΔCCB (bps)	1,200	0.79	11.33	-16.46	0.66	19.32
GFX	1,200	-0.12	0.21	-0.48	-0.11	0.23
ΔFX position	1,200	0.07	0.11	-0.11	0.06	0.27
Investor Characteristics (Country-by-Sector-by-Quarter Level, 2018q4 - 2023q2)						
Rollover Risk (monthly)	958	0.25	0.22	*	0.24	0.65
Rollover Risk (quarterly)	958	0.73	0.27	0.02	0.82	*
Euro-Area Bonds (Bond-by-Day Level, Dec 2018 - Sep 2023)						
ΔYield (ppt)	71,694	0.08	0.29	-0.30	0.01	0.69
Time to Maturity (months)	71,694	90.67	80.37	3.00	60.00	240.00
EA Share	71,694	0.44	0.17	0.15	0.46	0.70

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)	-148.36	29.93	474.48	64.02
Gross FX Position (bil EUR)	4,600.93	61.11	1,136.62	91.27
FX: Time to Maturity (months)	3.28	2.81	1.16	1.86
Share of USD Bonds	0.07	0.03	0.39	0.18
Hedge Ratio	-0.37	0.15	0.13	0.25

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)-(4) present estimated coefficients from a specification of the form:

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

at daily frequency. The dependent variable is the % deviation of the average investor's 3-months net FX position from its 3-months trailing average. In column (4), ΔCCB_t is instrumented with GFX_t. 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. t-statistics are shown in brackets and based on heteroscedasticity-robust standard errors. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

	(1)	(2)	(3)	(4)
Dependent variable:	ΔCCB		ΔFX Position	
	OLS			IV
GFX	-0.12***	-0.11***		
	[-8.17]	[-8.68]		
ΔCCB			0.02	1.73***
			[0.92]	[7.43]
Rem. Time to Mat		Y	Y	Y
Macro Controls		Y	Y	Y
Aggregate Factors		Y	Y	Y
F Statistic (1st)				47.8
No. of obs.	1,200	1,200	1,200	1,200

Table 4. Cross-Currency Basis and Bond Holdings.
Columns (1) to (4) present 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 (2)-(4), (6), and (7), ΔCCB_t is instrumented with the size-weighted average of idiosyncratic shocks to typical hedgers' FX positions GFX_t. Large Rollover Risk indicates that more than 66% 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. Columns (5) to (7) present estimated coefficients from a specification of the form:

$$\Delta \text{USD share}_{i,t} = \alpha \Delta \text{CCB}_t + \varepsilon_{i,t}$$

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. The sample in these columns excludes country-sectors with the 25% lowest (time-series 25th percentile of the) amount of USD holdings. t-statistics are shown in brackets and based on standard errors clustered in columns (1)-(4) at the bond and country-by-currency-by-time levels and in columns (5)-(7) at the country-sector and country-by-time levels. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Dependent variable:	Δ log Bond Holdings				ΔUSD Share		
	OLS	IV			OLS	IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
USD × ΔCCB	0.45***	0.66***					
	[10.24]	[4.97]					
USD × ΔCCB × Low Rollover Risk			0.41**				
			[2.30]				
USD × ΔCCB × High Rollover Risk			0.86***	0.41**			
			[4.64]	[2.53]			
ΔCCB					0.03***	0.07***	
					[2.98]	[2.86]	
ΔCCB × Low Rollover Risk							0.03
							[0.74]
ΔCCB × High Rollover Risk							0.05*
							[1.95]
Country-Sector-Time FEs	Y	Y	Y	Y			
Country-Sector-Security FEs	Y	Y	Y	Y			
Issuer Industry-Time FEs	Y	Y	Y				
High Rollover Risk FEs			Y	Y			Y
Security-Time FEs				Y			
Country-Sector FEs					Y	Y	Y
No. of obs.	8,890,984	8,890,984	8,087,520	6,371,383	1,080	1,080	749
No. of securities/country-sectors	351,484	351,484	337,205	92,215	54	54	46

Table 5. Cross-Currency Basis and 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. 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 in the 3 weeks starting on day t 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). It is instrumented with the size-weighted average of idiosyncratic shocks to typical hedgers' FX positions GFX_t. ΔCCB_t is interacted with characteristics of the investors that held bond b in the prior quarter, namely a large share held by euro-area investors (more than its median) and high rollover risk, defined as a large (more than its median) share of hedgers' buy-side FX derivatives notional outstanding at the prior quarter's end which matures in the month of day t. $C_{b,t}$ is a vector of fixed effects. In columns (5) and (6), the sample is reduced to bond-day observations with a large share of euro-area investors. t-statistics are shown in brackets and based on standard errors clustered at the bond and day levels. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	ΔBond Yield					
	IV					
Sample:	All				Large EA Share	
ΔCCB	0.30					
	[1.24]					
ΔCCB × Small EA Share		-0.43				
		[-1.13]				
ΔCCB × Large EA Share		0.99***	-0.40*			
		[3.79]	[-1.86]			
ΔCCB × Low Rollover Risk				0.16	0.89**	
				[0.49]	[2.45]	
ΔCCB × High Rollover Risk				0.42*	1.56***	1.06**
				[1.78]	[3.93]	[2.02]
Bond FEs	Y	Y	Y	Y	Y	Y
Large EA Share FEs		Y	Y			
High Rollover Risk FEs				Y	Y	Y
Issuer-Time FEs			Y			Y
No. of obs.	71,694	71,694	70,936	71,694	27,902	23,646
No. of bonds	63	63	63	63	48	46

Table 6. Cross-Currency Basis and Monetary Policy Transmission.
This table reports estimated coefficients from specifications of the form:

$$Y_{b,t} = \beta \text{MoPo}_t + \varepsilon_{b,t}.$$

Each day t in the sample corresponds to an ECB monetary policy event. In columns (1) and (2), the dependent variable is (1) the difference in the average USD-EUR cross-currency basis during the 4 weeks starting on day t compared to its average in the prior week (starting in 2013) and (2) the relative difference in euro-area investors' average net FX derivatives position (starting in Dec 2018). In columns (3) to (7), the dependent variable is the difference in euro-area government bond yields during the week starting on day t compared to day $t-1$. The sample in columns (6) and (7) includes bonds with time to maturity of 3 months, and 1, 5, 10, and 20 years. MoPo_t is the monetary policy surprise in 3-months OIS rates in a narrow time window around monetary policy events. Large $(-\text{CCB}_{t-2})$ indicates the 50% most negative realizations of the cross-currency basis on day $t-2$. *Long TtM* indicates bonds with at least 5 years remaining time to maturity. The sample runs from (1,3-7) March 2013 to October 2023 and (2) December 2018 to October 2023. t-statistics are shown in brackets and based on standard errors clustered at the issuer country-maturity and day levels in columns (3) to (7). ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	ΔCCB	ΔFX Position			ΔYield		
Bond maturity:			10Y		1Y	All	
MoPo × Large $(-\text{CCB}_{t-2})$	3.03***	0.02***		1.56***	-0.62*	-0.68	
	[3.17]	[3.90]		[3.13]	[-2.24]	[-1.54]	
MoPo	-0.88	-0.01***	1.23**	0.33	1.34***	1.35***	
	[-1.17]	[-5.07]	[2.82]	[0.90]	[4.96]	[3.07]	
Large $(-\text{CCB}_{t-2})$	0.04*	-0.05*		-0.01	0.00	-0.01	
	[1.90]	[-1.89]		[-0.75]	[0.58]	[-0.82]	
MoPo × Large $(-\text{CCB}_{t-2})$ × Long TtM						2.13***	2.25***
						[5.35]	[4.95]
Large $(-\text{CCB}_{t-2})$ × Long TtM						-0.00	-0.01
						[-0.30]	[-0.50]
MoPo × Long TtM						-0.96***	-1.00***
						[-3.31]	[-2.70]
Bond FE			Y	Y	Y	Y	Y
Time-Issuer FE							Y
No. of obs.	47	39	722	722	470	2,812	2,812

Internet Appendix for
International Capital Allocation and Currency Risk Hedging

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This version: June 14, 2024.

*ECB and Chicago Booth. The views expressed in this paper are the authors' and do not necessarily reflect those of the European Central Bank or the Eurosystem.

A Relegated Model Derivations

A.1 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

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

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.2 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

$$\begin{aligned}
r^d + \theta(d') - r^e &= -\frac{-(\rho+\lambda')\phi(d') + \lambda'\phi(d) + \varsigma(d') + (\sigma^a)^2 d'}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} \\
&= -\frac{(\rho+\lambda+\lambda')(\phi(d) - \phi(d')) + (\sigma^a)^2(d'-d)}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} - \frac{(\sigma^x)^2(b+d)}{1 + \frac{1}{\chi}(\sigma^x)^2} && \text{(IA.18)} \\
\alpha(d') &= \frac{1}{\chi}\frac{-(\rho+\lambda')\phi(d') + \lambda'\phi(d) + \varsigma(d') - \chi\left(1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\right) d'}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} \\
&= \frac{1}{\chi}\frac{(\rho+\lambda+\lambda')(\phi(d) - \phi(d')) + \chi\left(1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\right)(d-d')}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} + \frac{(\sigma^x)^2 b - \chi d}{\chi + (\sigma^x)^2} && \text{(IA.19)} \\
w^a(d') &= \left(\frac{1}{\chi} + \frac{1}{(\sigma^x)^2}\right)\frac{-(\rho+\lambda')\phi(d') + \lambda'\phi(d) + \varsigma(d')}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} - \frac{d'}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} \\
&= \left(\frac{1}{\chi} + \frac{1}{(\sigma^x)^2}\right)\frac{(\rho+\lambda+\lambda')(\phi(d) - \phi(d'))}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} - \frac{d'-d}{1 + \frac{(\sigma^a)^2}{(\sigma^x)^2}\left(1 + \frac{(\sigma^x)^2}{\chi}\right)} + b && \text{(IA.20)}
\end{aligned}$$

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 $-\nu \leq \phi(d), \phi(d') \leq \nu$ when $w^a(d') = w^a(d)$. Hence, given $w^a(d) = b$, by equation (IA.20), $w^a(d) > w^a(d')$ holds if and only if

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

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

A.3 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

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.[1] 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.
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.[2]

   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

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

[2] 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).

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 three nonbank country-sectors, for which the data implies a hedge ratio of more than 300% (in absolute terms), indicating inconsistent matching across databases leading to substantial measurement error. These are Finnish, French, and Luxembourg pension funds.

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 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).

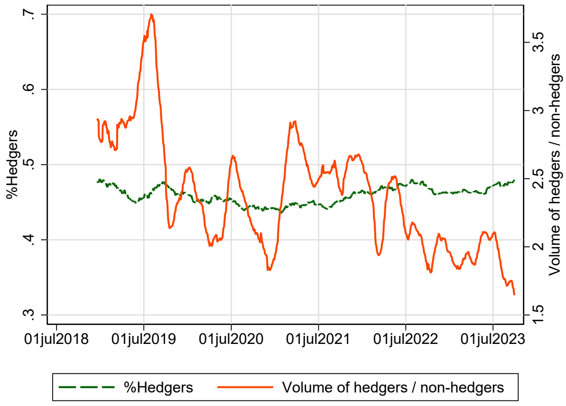
C Details on GIV Estimation

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

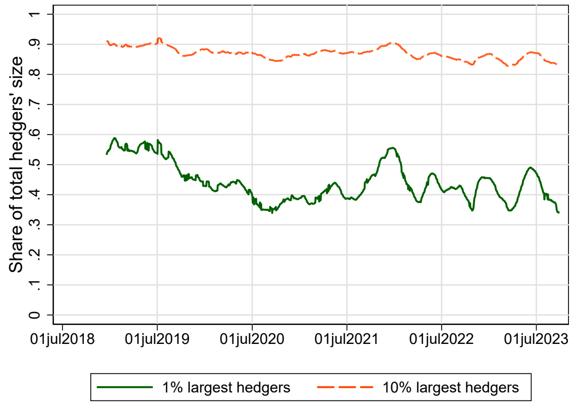
- 3-months LIBOR and EURIBOR
- log of the S&P 500, Euro STOXX 50, dollar strength, US and EU VIX.

All variables are de-trended by computing the change relative to their 3-months trailing average. Following Avdjiev et al. (2017), we control for dollar strength using the trade-weighted US dollar exchange rate against its major trading partners (retrieved from FRED St. Louis).

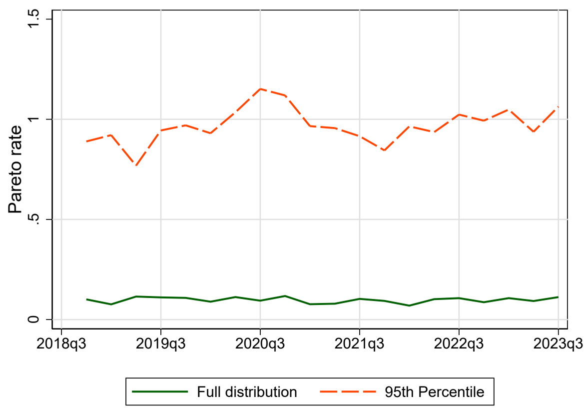
Figure IA.1. FX Market Structure and Granularity in Size Weights.
Hedgers are defined as investors that exhibit a positive 3-months trailing average FX position. Figure (a) plots (i) the number of hedgers relative to the number of investors and (ii) the total net position of hedgers relative to negative 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



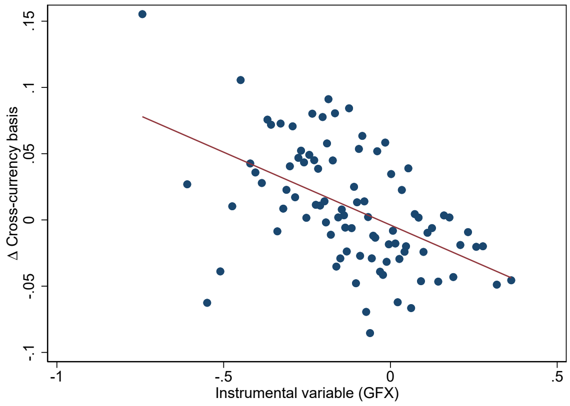
(b) Concentration of hedgers



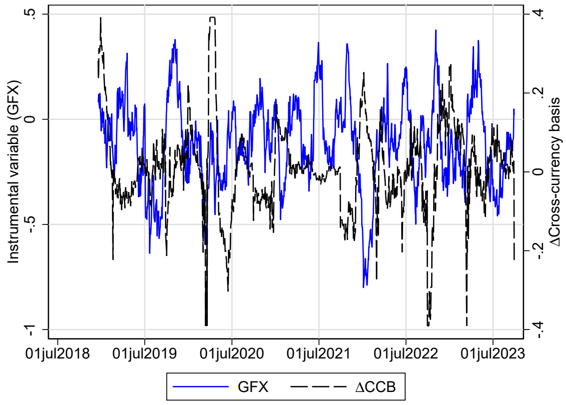
(c) Pareto rate of hedger size

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.



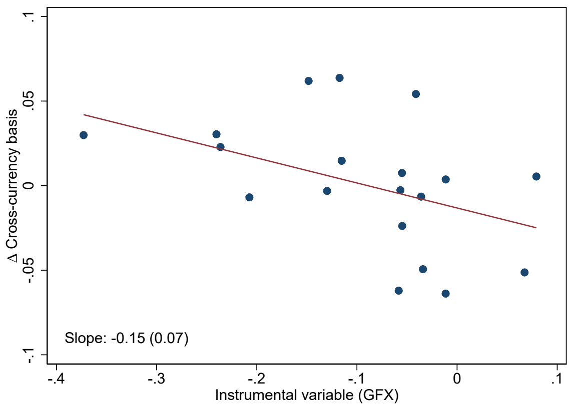
(a) Binscatter plot.



(b) Time series.

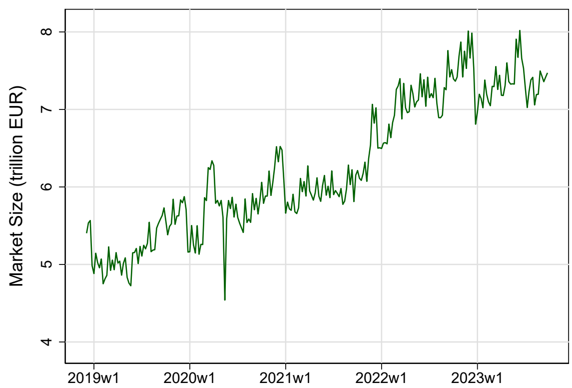
Figure IA.3. Cross-Currency Basis and GFX$_t$ at Quarterly Frequency.

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).

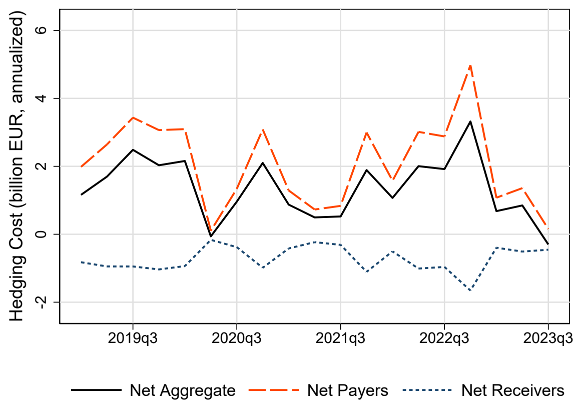


D Additional Figures and Tables

Figure IA.4. Size of and Aggregate Hedging Cost in the European USD-EUR FX Market.
Figure (a) depicts 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). 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 $N(e^{-\tau/12\text{CCB}_\tau} - 1)/(\tau/3)$, 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.

Table IA.1. 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 USD-EUR spot rate volatility. At the portfolio level, column (6) controls for the quarterly change in the log average USD-EUR spot exchange rate and column (7) for the one-quarter lagged USD-EUR spot rate volatility. t-statistics are shown in brackets and based on standard errors clustered in columns (1)-(5) at the bond and country-by-currency-by-time levels and in columns (6)-(7) at the country-sector and country-by-time levels. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Dependent variable:	$\Delta \log$ Bond Holdings					ΔUSD Share	
	IV						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
USD × ΔCCB	0.66***	0.62***	0.62***	0.66***	0.60***		
	[5.27]	[5.17]	[5.32]	[4.96]	[5.48]		
USD × $\Delta \log S^{\mathrm{USD/EUR}}$				-0.12			
				[-1.20]			
USD × FX Volatility					-4.18*		
					[-1.95]		
ΔCCB						0.07***	0.06***
						[2.86]	[2.84]
$\Delta \log S^{\mathrm{USD/EUR}}$						-0.01	
						[-0.57]	
FX Volatility							-0.57*
							[-2.00]
Country-Sector-Time FEs	Y	Y	Y	Y	Y		
Country-Sector-Security FEs	Y	Y	Y	Y	Y		
Issuer Industry-Time FEs	Y	Y	Y	Y	Y		
Rating-Time FEs	Y		Y				
Maturity-Time FEs		Y	Y				
Country-Sector FEs						Y	Y
No. of obs.	8,890,984	8,890,984	8,890,984	8,890,984	8,890,984	1,080	1,080
No. of securities/country-sectors	351,484	351,484	351,484	351,484	351,484	54	54