Dollar Asset Holdings and Hedging Around the Globe*

Wenxin Du† Amy W. Huber‡

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Abstract

We collect and analyze detailed filings from global institutional investors to estimate foreign investors' U.S. dollar (USD) security holdings and currency hedging practices. Over two decades, foreign USD holdings grew sixfold, with hedge ratios of mutual funds, insurance companies, and pensions rising by 15 percentage points since the 2008–09 financial crisis, reaching $2 trillion by 2019. We find significant variation in hedging demand across currency areas and banking systems. Our analysis demonstrates that expected FX returns are a key driver of hedging decisions beyond variance minimization. Finally, we uncover a strong correlation between hedging activity and cross-currency CIP deviations.

JEL Classifications: F21, F31, G11, G15, G22, G23
Keywords: dollar holdings, FX hedging, CIP deviations, institutional investors, portfolio allocation

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†Harvard Business School and NBER. Email: wdu@hbs.edu.
‡The Wharton School of the University of Pennsylvania. Email: amyhuber@wharton.upenn.edu.

1 Introduction

The U.S. dollar (USD) is the predominant currency in cross-border securities holdings, and foreign investments in USD-denominated securities have been steadily increasing. However, holdings of USD-denominated assets do not necessarily imply full exposure to USD currency risk, as foreign investors can hedge their USD currency exposure using foreign exchange (FX) derivatives. In this paper, we analyze a comprehensive set of industry- and company-level filings from global institutional investors, providing the first detailed estimates of foreign investors' USD securities holdings and their currency hedging practices. Our analysis distinguishes between the demand for USD-denominated assets and the demand for USD currency exposure, shedding light on the economic drivers of currency risk management.

According to the Bank for International Settlements' (BIS) triennial FX derivatives survey, average daily turnover in FX derivatives reached $5.4 trillion in 2022, with 88% of this volume involving USD-linked currency pairs. If foreign investors wish to hedge their currency risk in USD investments, they can access a vast and liquid FX derivatives market. However, little is known about the actual FX hedging practices of foreign institutional investors. In the absence of clear empirical evidence, the existing international finance literature either assumes that foreign asset demand is fully unhedged (e.g., Koijen and Yogo (2020)) or fully hedged for bonds but unhedged for equities (e.g., Camanho, Hau, and Rey (2022)). Models on the demand for safe assets typically do not separate the demand for USD exposure from the demand for underlying assets (e.g., Jiang, Krishnamurthy, and Lustig (2021, 2023)).

Our first contribution is to collect and analyze data to create the first systematic picture of foreign holdings of USD securities and their associated FX hedging practices. Our estimates of foreign investors' USD securities holdings differ from those available through centralized reporting systems like Treasury International Capital (TIC). While centralized reporting focuses on *aggregated U.S.* cross-border liabilities, we adopt a bottom-up approach, tracking holdings of USD assets by sector and relative to investor portfolios.[1] We focus on foreign holdings of USD assets across seven major sectors: the official sector, banks, insurance companies, pension funds, mutual funds, the non-financial sector, and hedge funds. In 2020, foreign holdings in these seven sectors amounted to 75% of TIC's estimate of foreign-held U.S. assets and around 60% of our estimated total foreign-held USD securities.

Moreover, we construct a novel dataset on how foreign investors manage their USD currency exposure from securities holdings. Standardized data on FX hedging activities across countries and sectors are unavailable, so we analyzed company filings and industry statistics to generate the first sector- and country-level estimates of USD currency hedging demand for mutual funds, insurance companies, and pension funds. Our findings reveal approximately $2 trillion in outstanding USD FX hedging positions across these three sectors by the end of 2019. We complement our estimated FX hedging demand with an estimate of the hedging supply, particularly the short-term dollar funding provided by global banks. This effort uncovers new facts about foreign investors' hedging of USD securities, offering fresh insights into the role of the dollar in international portfolio allocation.

Our second contribution is to investigate the drivers and implications of FX hedging using our unique data. Building on the existing literature, we begin with the optimal portfolio choice problem of a mean-variance investor. However, unlike Campbell, de Medeiros, and Viceira (2010), we emphasize not only the covariance between asset returns but also the expected FX return arising from deviations from uncovered interest parity (UIP) and covered

[1] The IMF's Coordinated Portfolio Investment Survey (CPIS) reports cross-border holdings by country, but its data are insufficient for our analysis for several reasons. First, overall USD holdings are understated due to voluntary reporting and the absence of country-level breakdowns. Second, many countries do not categorize U.S. investments by holder sector. Third, CPIS does not include data on allocation or hedging.

interest parity (CIP). We empirically confirm that, in both the cross-section and time-series, expectations of currency returns influence investors' USD exposures beyond considerations of variance-covariance. Moreover, investors' aggregate FX hedging demand could influence the equilibrium price of FX derivatives, particularly when intermediated by constrained financial institutions. We derive and validate the prediction that variations in FX hedging activities are correlated with cross-country differences in CIP deviations. These findings provide novel empirical evidence on the limited risk-bearing capacity of financial intermediaries.

We start the paper by describing our data sources and methodology. We then present four stylized facts about foreign investors' USD holdings and hedging practices. First, we find that foreign investors have significantly tilted their portfolios toward USD assets over the past two decades. The size of foreign USD securities holdings increased six-fold, from \$5.5 trillion in 2002 to approximately \$33.4 trillion in 2021. This increase is not solely due to larger foreign wealth: post-GFC, mutual funds, insurance companies, and pension funds raised the share of USD securities in their overall portfolios by 7.7 percentage points and increased the share of USD securities in their non-domestic investments by 6.6 percentage points.

Second, the large increase in USD securities holdings does not fully translate into higher USD currency exposure. Foreign investors in actively managed industries hedge a substantial amount of their USD currency risk post-GFC. The USD hedge ratios for insurance companies, pension funds, and mutual funds were 44%, 35%, and 21%, respectively, in 2020. These sectors alone generated nearly \$2 trillion in annual hedging demand. On average, hedge ratios in these industries increased by 14.7 percentage points post-GFC compared to pre-GFC levels. Elevated and fluctuating deviations from CIP post-GFC increased the cost of hedging: we estimate that the cost of hedging for the insurance and pension sectors due to short-term CIP deviations averaged \$2.7 billion per annum between 2017 and 2020.

Third, we document significant heterogeneity in foreign investors' hedging practices across currency areas. We find suggestive evidence that investors hedge USD bonds at higher ratios than they hedge equities, as predicted by Campbell, de Medeiros, and Viceira (2010). But even within the same sector, where portfolios follow more similar allocations between bonds and equities, USD hedge ratios vary considerably in the cross-section.

Finally, we examine how the substantial USD FX hedging activity by global pensions, mutual funds, and insurance companies is accommodated within global financial markets. The direct counterparties for foreign institutional investors hedging their currency risk are FX forward and swap dealers, who are typically affiliated with large global banks. These global banks meet hedging demand either by matching institutional investors with counterparties that have offsetting FX derivative needs, or by directly supplying hedges — effectively providing temporary dollar funding through their own balance sheets. Using banking data from the Bank for International Settlements (BIS), we find significant cross-country differences in banks' dollar funding business models: whereas some banks are net suppliers of USD FX hedges, others are net demanders, relying on FX hedges to fund their own USD operations.

Having documented key facts about foreign investors' USD hedging practices, we next investigate the drivers of USD hedging demand and its impact on FX derivatives pricing. We model both sides of the FX derivatives market in turn. The demand for FX hedging arises from the mean-variance foreign investor's optimal currency exposure, conditional on their portfolio allocation between USD and domestic securities.[2] In our model, the investor

[2]We do not solve for the mean-variance optimal portfolio allocation between USD and domestic securities, as the literature extensively documents the role of home-bias and other frictions (e.g., French and Poterba (1991)). However, such frictions do not necessarily influence the optimal currency exposure decision.

considers not only the variance of portfolio return, as in Campbell, de Medeiros, and Viceira (2010), but also the expected level of portfolio return, which can be influenced by expected currency returns due to UIP violations or FX hedging costs from CIP deviations. The model offers predictions on the effects of UIP and CIP deviations on the hedging decision, beyond variance-minimization motive as in Campbell, de Medeiros, and Viceira (2010). The data support our model's predictions: investors' observed FX exposures are substantially better rationalized when expected FX returns are considered in addition to return variances and covariances.

After presenting the demand for FX hedging from mean-variance investors, we introduce the supply of hedging services by intermediaries. These intermediaries, constrained by balance sheet size, require CIP deviations as compensation for supplying the short-term USD funding needed to meet FX hedging demands. Consistent with Ivashina, Scharfstein, and Stein (2015), we show that CIP deviation must rise in the amount of hedging provided by intermediaries. In a world where intermediaries' balance sheets are segmented across currencies, shocks to local hedging demand explain the cross-sectional variation in CIP deviations. We find that the cross-sectional R-squared between hedging volume (normalized by GDP) and CIP deviations is 0.73.

Our paper contributes to the literature on institutional investors' portfolio allocation. Whereas previous studies focus primarily on variance-covariance as the motive in currency hedging (e.g., Campbell and Viceira (2002) and Campbell, de Medeiros, and Viceira (2010)), our model emphasizes the additional influence of deviations from UIP and CIP. We then exploit our unique data to establish the empirical relevance of mean-variance drivers in FX hedging. By documenting the USD asset holdings and hedging practices of various non-U.S. investor types, our work is related to several strands of research examining portfolio allocation in international investments.[3] In particular, two related papers focus on the use of FX derivatives by U.S. fixed-income and equity mutual funds who invest outside of the U.S. (Sialm and Zhu (2022), Opie and Riddiough (2023)). By contrast, our paper investigates the currency management of a broad cross section of non-U.S. investors and characterizes the drivers behind their optimal FX exposure.

Our work expands the active literature on CIP deviations. The presence and variations of CIP deviations point to the importance of intermediaries' regulatory constraints in driving asset prices (Du, Tepper, and Verdelhan (2018), Du, Hébert, and Huber (2022)). This paper illuminates two outstanding questions. First, we demonstrate that although CIP deviations are small in magnitude, they impose substantial financial costs on investors due to the enormity of hedging demand.[4] Second, we show that investors' hedging demand offers an explanation for the puzzling cross-sectional variations in the CIP basis.[5] Similar to Borio et al. (2016), we link CIP deviations to global banks' USD funding shortages or surpluses. However, we approximate banks' provision of hedging services in specific currencies directly from institutional investors' hedging demand, as opposed to estimating this provision from banks' balance sheet currency mismatch. Our approach allows banks to intermediate transactions denominated in currencies other than their home jurisdiction. Empirically, our data explain the cross-section of CIP deviations in a wide range of currencies, including those of

[3]Examplines of portfolio allocation in international investments include public investment funds (e.g., Mitchell, Piggott, and Kumru (2008), Lucas and Zeldes (2005)), mutual funds (e.g., Maggiori, Neiman, and Schreger (2020)), European investors (e.g., Faia, Salomao, and Veghazy (2022)), and in sovereign debt (e.g., Fang, Hardy, and Lewis (2022)).

[4]Davila, Graves, and Parlatore (2022) explore the social welfare implications of arbitrage violations, including CIP deviations.

[5]In a fully arbitrageable world, cross-sectional differences in CIP deviations would be eliminated by intermediaries. Our paper advances the understanding of these deviations by introducing the concept of hedging supply from intermediaries with segmented balance sheets. Diamond and Van Tassel (2021) similarly explain the cross-section of CIP deviations using market-specific option-implied box rates, implying market segmentation.

emerging economies.

Last but not the least, this paper is directly connected to the growing body of research that estimates the impact of asset demand on exchange rates. Using either hedging data from one single country or proxies of hedging demand, several recent studies explore the connection between hedging demand and exchange rate.[6] Relative to these studies, we offer the first direct measure of hedging demand across currency areas, which allows us to investigate the economic drivers behind the pronounced cross-sectional heterogeneity in hedging practices. Our findings can improve models of asset demand that equate the demand for currency with the demand for the underlying asset, implicitly assuming no FX hedging (e.g., Koijen and Yogo (2020), Jiang, Krishnamurthy, and Lustig (2021)). More broadly, in showing that FX hedging demand affects prices, we highlight intermediaries' limited risk-bearing capacity, which connects asset demand to asset prices in the FX market and beyond (An and Huber (2024)).

The remainder of this paper is structured as follows. Section 2 describes our data sources and estimation methodology. Section 3 discusses four stylized facts about foreign investors' USD holdings and hedging practices. Section 4 rationalizes these patterns with a model of mean-variance hedging demand and constrained intermediary hedging supply, and tests model predictions in the data. Section 5 concludes.

2 Methodology and Data Construction

In this section, we describe the methodology used to construct the data analyzed in this paper. First, we outline our approach to estimating foreign holdings and hedging of USD

[6] Ben Zeev and Nathan (2022b) study Israeli institutional investors' hedging. Liao and Zhang (2020) approximate hedge demand with countries' net U.S. dollar foreign debt holdings. Bräuer and Hau (2022) impute hedging demand from observed currency trading.

securities, with detailed procedures available in Appendix A. Next, we define the cross-currency basis, which serves as our measure for deviations from covered interest-rate parity (CIP). Finally, we summarize additional data used and outline the currency areas included in the sample for our analysis of portfolio allocations and hedging.

2.1 Estimating Foreign Holdings and Hedging of USD Securities

We estimate foreign holdings and hedging of USD securities from two complementary perspectives. On the one hand, we leverage TIC and BIS statistics to provide the first systematic estimate of all USD securities held by foreign investors. On the other hand, through a bottom-up data collection effort, we estimate foreign USD securities holdings across seven major sectors and use portfolio-level data to assess FX hedging in three actively managed industries.

2.1.1 Overall Foreign Holdings of USD Securities

We begin with the total foreign holdings of securities issued by U.S. *residents*, available from TIC, and make several adjustments to derive the total foreign holdings of U.S. *dollar*-denominated securities. First, we subtract foreign holdings of securities issued by U.S. residents that are not denominated in USD. Second, we augment this estimate by including foreign-held USD securities issued by non-U.S. residents. In particular, we use BIS international debt securities statistics to understand cross-border USD issuance and subtract securities held by U.S. residents.[7] Detailed estimation procedures are provided in Appendix

[7] We adjust for debt securities only because equities are generally denominated based on their place of issuance.

A.1. In summary, our estimation is as follows:

Total Foreign Holding of USD Securities

= Foreign USD Holding of U.S. Issuers + Foreign USD Holding of Non-U.S. Issuers

= (TIC Foreign Holding of U.S. Securities − TIC Foreign Holdings of Non-USD Securities)

+ (USD Securities Outstanding Outside the U.S. − U.S. Investors' Cross-border USD Holdings).

2.1.2 Sector-Specific USD Securities Holdings and Hedging

We identify seven sectors with significant investments in USD securities and collect country- and sector-specific portfolio allocations for USD bonds and equities. The sectors we focus on are insurance, pensions, mutual funds, banks, hedge funds, non-financial corporations and households, and the official sector. Our sector-specific data account for 60% of our estimated aggregate foreign holdings in 2020 (see Figure 4). The remaining 40% in part reflects the imperfect coverage of the 7 sectors that we study, as we do not extrapolate from the observed; in part suggests other potentially significant sources that we do not capture, such as USD holdings in separately managed accounts of institutional investors and high-net-worth individuals.[8]

Among the seven sectors, we focus our analysis of USD hedging on three that employ active hedging strategies: insurance companies, pension funds, and mutual funds. FX risk management considerations outside these three sectors may not be comparable. For example, banks typically engage in nearly full FX hedging due to the high regulatory capital charges

[8] High-net-worth individuals command a substantial amount of wealth. Forbes estimates that non-U.S. billionaires held $8 trillion in wealth in 2022, although much of this wealth is tied to their own company stocks.

associated with unhedged FX positions.[9] Moreover, the official sector generally conducts minimal FX hedging, as one key objective of FX reserve management is to maintain sufficient foreign currency liquidity for balance of payment needs and potential FX interventions.[10] In contrast, FX hedging by insurance companies, pension funds, and mutual funds reflects investor preferences for FX risk exposure. Mutual funds, for instance, are not required to maintain specific FX exposure but design hedging strategies to attract investors with varying degrees of FX risk tolerance. While pension funds and insurance companies may face foreign investment limits, few countries impose binding limits on USD securities; see Table A1.

Table 1 summarizes the currency areas and sectors included in our analysis, along with the main data sources. Full estimation details are in Appendix A.2. Below, we briefly outline our approach, beginning with the insurance sector. In regions such as Japan and Taiwan, insurers are significant holders of investment securities due to their role in retirement savings. For Japan, we manually collect statutory filings from all active insurers since 2004. In Taiwan, we gather physical copies of the Central Bank of the Republic of China's monthly life insurance reports and complement these with data from the annual reports of the six largest Taiwanese life insurers. We source data on Danish and Swedish insurers from their central banks and obtain aggregate data on European Economic Area insurers from the European Insurance and Occupational Pensions Authority (EIOPA). For Israeli insurers, we use monthly statistics from the Bank of Israel. For each region, we collect information on overall portfolio sizes and USD securities holdings, and where possible, we estimate the USD hedge ratio, defined as the share of USD investments with hedged FX risk. Appendix A.2.1

[9] Although FX hedging by banks may not purely reflect preference for currency exposure from securities holdings, banks could nonetheless demand or supply meaningful amounts of FX hedges. We estimate and discuss banks' FX hedging in Section 3.

[10] The official sector's holdings may also include sovereign wealth funds. While little is known about their currency hedging practices, it is documented that the world's largest sovereign wealth fund, the Norwegian Sovereign Wealth Fund, does not hedge FX risk on its foreign investments (Du and Viceira (2024)).

contains estimation details.

For the pension sector, we focus on countries with the largest pension assets (OECD (2020)) and classify them by industry structure. Japan, the Netherlands, and Canada have highly concentrated pension markets, so we analyze filings from their largest pension funds. In contrast, Australia, Switzerland, and the U.K. have more fragmented pension industries, so we rely on industry-level data from national authorities. Additional countries studied include Denmark, Sweden, Israel, and Chile, as well as nine Latin American countries that are FIAP members.[11] For each country, we collect information on total pension assets and USD investments, and we estimate the USD hedge ratio for all but the U.K. and the nine non-Chile Latin American countries. See Appendix A.2.2 for further details.

For mutual funds, we use data from Morningstar, which covers open-ended and exchange-traded funds (ETFs) domiciled in 64 non-U.S. countries. This dataset provides security-level holdings data similar to that used in Maggiori, Neiman, and Schreger (2020) and Coppola et al. (2021). We estimate USD bond holdings by aggregating USD-denominated bonds and calculate USD equity holdings from each fund's U.S. equity allocations. Hedge ratios are estimated at the share-class level using a combination of disclosure data (e.g., "fully hedged") and benchmark choice (e.g., "U.S. Corporate Bond EUR Hedged"). See Appendix A.2.3 for discussion of the limitations of this estimation.

Lastly, we estimate foreign USD holdings for banks, hedge funds, non-financial corporations, and the official sector. For banks, we use BIS Locational Banking Statistics (LBS) and focus on debt holdings: banks do not hold much positions in equity because the associated capital requirement is much higher. We estimate foreign banks' USD debt holdings as

[11] FIAP (Federación Internacional de Administradoras de Fondos de Pensiones) members include Argentina, Bolivia, Colombia, Costa Rica, Chile, El Salvador, Mexico, Peru, the Dominican Republic, and Uruguay.

proportional to the difference between total USD assets and USD loans. For hedge funds' U.S. equity investments, we utilize 13F reporting, which requires institutional investment managers with at least $100 million AUM to disclose their equity holdings quarterly. For non-financials, we conservatively estimate their USD holdings from holdings of U.S. securities, as reported to IMF's Coordinated Portfolio Investment Survey (CPIS) data. Of the 81 countries reported as having investments in U.S. securities, 56 provide non-financial sector breakdowns. Finally, we estimate the official sector's USD securities holdings from its U.S. securities holdings reported in TIC. Full details are provided in Appendix A.2.4.

2.2 Deviations from Covered Interest-Rate Parity

We measure deviations from CIP using the cross-currency basis. Following Du, Tepper, and Verdelhan (2018), we define the τ-month cross-currency basis of foreign currency c vis-à-vis the USD as:

$$X_{t,\tau}^{c,\$} = \frac{R_{t,\tau}^{\$}}{R_{t,\tau}^{c}} \left(\frac{F_{t,\tau}}{S_t} \right)^{\frac{12}{\tau}} - 1,$$

and the log version as:

$$x_{t,\tau}^{c,\$} = \ln{(1 + X_{t,\tau}^{c,\$})}. \tag{1}$$

Here, $R_{t,\tau}^{c}$ denotes the annualized spot gross τ-month risk-free interest rate in foreign currency c at time t, and $R_{t,\tau}^{\$}$ represents the corresponding USD interest rate. Exchange rates are expressed in units of foreign currency per USD, so an increase in the spot exchange rate S_t reflects a depreciation of the foreign currency and an appreciation of the USD. The forward exchange rate at time t for a τ-month tenor is denoted $F_{t,\tau}$.

If CIP held, $x_{t,\tau}^{c,\$} = X_{t,\tau}^{c,\$} = 0$, meaning that the forward exchange rate is priced based solely on the interest rate differential. A more negative cross-currency basis indicates higher costs for non-U.S. investors to hedge USD exposure: when the cross-currency basis $x_{t,\tau}^{c,\$}$ is negative, the forward exchange rate is priced too low relative to the prevailing interest rates, reducing the proceeds from selling USD forward.

We measure R using IBOR rates from different countries, focusing on the three-month tenor as the prevailing hedging practice is to continuously roll over short-term hedges. We obtain daily IBOR rates, as well as spot and forward FX rates, from Bloomberg using London closing rates.

2.3 Other Data and Sample Currencies

We supplement our analysis of foreign USD holdings and hedging with several additional data series. From the BIS, we obtain the Triennial Central Bank Survey on Foreign Exchange and Derivatives Market Activities (2001–2022), the Debt Securities Statistics, and the Locational Banking Statistics. From the World Bank, we gather data on public equity market capitalization. From Preqin, we acquire AUM data for U.S. and global private equity funds. SIFMA provides data on outstanding U.S. debt securities, compiled from Bloomberg, the Federal Reserve, U.S. Agencies, and the U.S. Treasury.

We also obtain from Bloomberg the historical yield for 10-year government bonds and major equity indices in the U.S. and 12 other currency areas. These data are used to study the empirical correlations between asset and currency returns. The 12 currency areas included in our analysis are Australia (AUD), Canada (CAD), Switzerland (CHF), Denmark (DKK), Germany (EUR), the United Kingdom (GBP), Japan (JPY), Norway (NOK), Sweden (SEK), Chile (CLP), Israel (ILS), and Taiwan (TWD). These areas form the core of our sample, as we can obtain mutual fund hedging data and at least one of insurance or pension hedging data for each. Our sample includes nine advanced economies and three emerging economies.

3 Stylized Facts on Foreign USD Holdings and Hedging

In this section, we present four stylized facts regarding foreign investors' aggregate USD holdings and currency hedging patterns.

Fact 1: Foreign investors increasingly tilt their portfolios toward USD securities.

Figure 1 shows that foreign holdings of USD securities reached $33.4 trillion by mid-2021. Our estimate surpasses the comparable figure from TIC due to the inclusion of substantial amounts of USD debt issued by non-U.S. residents. It is also nearly double the estimate from CPIS, which relies on reporting countries to break down their cross-border holdings either by country or by currency. We estimate that overall foreign holdings of USD securities have grown six-fold since 2002 (from $5.5 trillion). This remarkable increase occurred during a period when global GDP (excluding the U.S.) grew by less than three-folds.

The increase in foreign holdings of USD securities is broad-based across both bonds and equities. In aggregate, foreign investors hold approximately two-thirds of their USD securities in bonds and one-third in equities (Figure 2, Panel (a)). In fact, foreign holdings represent a larger share of total USD bonds outstanding compared to U.S. equities (Panel (b)).[12] Importantly, the share of foreign holdings has been rising in both asset classes.

In Figure 3, we illustrate the evolution of portfolio allocations to USD securities across three industries: insurers (Panel (a)), pensions (Panel (b)), and mutual funds (Panel (c)).

[12] We estimate total outstanding USD debt as the sum of U.S. fixed-income securities and USD-denominated cross-border debt issued by non-U.S. residents. Total outstanding equities are estimated as the market capitalization of U.S.-listed stocks and AUM of U.S. private equity funds.

The portfolio allocation to USD assets, defined as the ratio of USD bonds and equities to total assets (hereafter, "USD asset allocation"), has been steadily increasing. For many investors, their USD asset allocation has nearly doubled over the sample period.[13]

To determine whether this rise in USD allocation reflects a broader increase in foreign investors' non-domestic investments or a shift within non-domestic portfolios towards USD assets, we examine the portfolio allocations of foreign insurers, pensions, and mutual funds in Table 2. Columns (1) and (2) show that, post-GFC, investors in our 12 sample currency areas (9 advanced economies and 3 emerging economies, see Section 2.3) increased their USD asset allocation by an average of 7.7 percentage points (Column (1)). This growth follows a linear trend of 0.23 percentage points per quarter (Column (2)). Additionally, foreign investors increased the share of USD securities in their non-domestic investments by about 6.6 percentage points post-GFC (Column (3)).[14] The robust but slightly smaller growth trend of USD securities' share in non-domestic investments (Column (4)) shows that the rise in USD asset allocation is driven by both a greater allocation to non-domestic investments and a more active rebalancing within those non-domestic investments toward USD-denominated assets.

Fact 2: Substantial hedging in actively managed industries post-GFC despite rising hedging costs.

Although foreign investors have large and growing holdings of USD securities, they do not retain all the associated USD currency exposures. As of June 2020, we estimate that the

[13]Our USD asset allocation focuses on investments in USD securities and excludes investments in real estate and infrastructure. Anecdotal evidence suggests that the share of USD real estate and infrastructure has also been rising, contributing to an even higher overall portfolio exposure to USD assets.

[14]Appendix Figure A1 shows the share of USD bonds in the global bond market and the share of U.S. equities in the global equities market. Neither share increased significantly post-GFC, suggesting that the relative supply of USD securities does not fully explain the rise in USD allocation.

USD hedge ratios — the proportion of USD securities hedged against FX risk — were 44%, 35%, and 21%, for insurance companies, pension funds, and mutual funds, respectively. Collectively, hedging demand from these three sectors exceeded $2 trillion by 2019. Figure 4 provides a snapshot of hedging practices.

Table 3 uses our microdata to examine time-series trends in USD hedging and currency exposure. Columns (1) and (2) show that USD hedge ratios increased post-GFC. Controlling for industry-by-currency fixed effects, post-GFC hedge ratios are on average 14.7 percentage points higher. The increase in hedging activities is corroborated by aggregate data on FX derivatives trading. FX hedging is primarily conducted through FX forward or swaps.[15] Appendix Figure A2 shows that daily average turnover in FX forward and swap markets, as reported in the BIS Triennial Central Bank Surveys, increased between 2001 and 2022, outpacing growth in spot FX transactions. This trend holds for institutional investors such as insurance companies, pension funds, and mutual funds.[16]

Despite rising hedge ratios, foreign investors' total portfolio exposure to unhedged USD currency risk has continued to increase due to the rising USD asset allocation, which outpaced the increase in hedge ratios. Columns (3) and (4) of Table 3 show that post-GFC, investors' (unhedged) USD currency exposure increased by 5.8 percentage points overall, and by 6.7 percentage points, on average, for a given investor type in a specific currency area.

The rise in hedge ratios and the increase in USD asset allocations have resulted in a surge in the *volume* of USD hedging post-GFC. Yet the CIP condition, which should govern the pricing of FX forward and swaps used in hedging, has exhibited large and fluctuating

[15] Appendix Figure A4 shows that non-forward and non-swap FX derivatives constitute a small and stable-to-declining share of the FX derivatives market since the GFC.

[16] BIS defines "institutional investors" as including mutual funds, pension funds, insurance and reinsurance companies, and endowments. They typically engage in FX trading for hedging, investing, and risk management purposes. BIS refers to this group as "real money investors" BIS (2022).

deviations since the GFC. In fact, for many currencies, the cross-currency basis has been persistently negative, meaning that hedging USD exposure is costly for foreign investors (see also Section 2.2). Consequently, total hedging costs, which we estimate as the product of hedging volume and the negative of the cross-currency basis, reached approximately \$2.1-\$4 billion per annum between 2017 and 2020 for the pensions and insurers in our sample.[17] The average annual hedging cost over these four years was \$2.7 billion, or about 0.1% of all USD securities held by these two sectors. We note that our estimates may underestimate the true cost of FX hedging, as the cross-currency basis implied in Bloomberg rates reflects inter-dealer quotes, and investors could pay more due to dealers' market power (Hau et al. (2021)).

Fact 3: Hedging behavior exhibits heterogeneity across currencies.

Although most countries and sectors have increased their USD FX hedging, there is substantial variation in USD hedge ratios across currencies.

Table 4 presents a snapshot of USD securities holdings and hedging at the end of 2019. The average USD hedge ratio across mutual funds, pension funds, and insurance companies ranges from 10% in Canada to 57% in Denmark (Column "Hedge Ratio"). Figure 5 illustrates the time series of USD hedge ratios across industries. Even within the same industry, hedge ratios span a wide range across currencies. This cross-country heterogeneity is particularly pronounced among pensions (Panel (b)), with hedge ratios as low as 5% in Japan and as high as 80% in Denmark in 2020. Mutual funds (Panel (c)) display the smallest range, but

[17] Specifically, we use a quarterly snapshot of hedging volumes and the quarterly average of daily 3-month cross-currency basis. We assume investors use short-term forwards and continuously roll over these short-term hedges, consistent with industry practices. For the purpose of estimating total hedging cost, we assume that countries covered by EIOPA (other than Denmark and Sweden) have the industry average hedge ratio. For U.K. pensions, we estimate their hedging costs using the 2016Q1-2020Q4 average hedge ratio from Czech et al. (2022).

in 2020, hedge ratios still varied from near 0% to almost 30%.

One possible explanation for the variation in hedge ratios is that investors adopt distinct hedging strategies based on the composition of their portfolios. Campbell, de Medeiros, and Viceira (2010) suggest that investors in advanced economies should hedge bonds more than equities. We find suggestive evidence supporting this prediction from the few investors in our sample who report hedge ratios for bonds and equities separately. In Figure 6, fixed-income mutual funds hedge at significantly higher ratios than equity mutual funds (Panel (a)), while Australian and Dutch pensions also hedge bonds at higher ratios (Panel (b)). However, even comparing within bonds or within equities, pensions in these two countries display different levels of USD hedging and follow distinct time-series patterns. In Section 4, we explore drivers of the cross-sectional variation in hedging behavior.

Fact 4: Global banks employ varied business models for providing USD FX Hedges.

In this subsection, we examine how foreign institutional investors' demand for USD FX hedges is accommodated within global financial markets. This demand essentially represents a need for short-term USD funding. Global banks play a central role in intermediating FX forwards and swaps used in hedging by matching FX hedge demand from some customers (e.g., institutional investors) with the USD funding supplied by others (e.g., non-financial corporations, hedge funds). When customer-supplied FX hedges are insufficient, banks step in to clear the market by providing USD funding through deposits or wholesale borrowings. Conversely, banks may also act as demanders of FX hedges, obtaining synthetic dollar funding to support their USD-denominated assets.

Since FX derivatives are predominantly traded over-the-counter, comprehensive data on global banks' FX hedging activities are not readily available. Following the methodologies of Borio et al. (2016) and Borio et al. (2018), we construct the "dollar funding gap" as an empirical proxy for USD FX hedges supplied or demanded by banks across various currency areas. This gap is defined as the difference between on-balance-sheet USD assets and liabilities. Under the assumption that banks use FX derivatives to cover their dollar funding gap,, a positive dollar funding gap indicates net borrowing of USD through FX swaps, while a negative gap reflects net lending. We estimate the dollar funding gap using data from BIS Locational Banking Statistics (LBS).[18]

U.S. banks have a distinct advantage in providing USD funding due to their extensive access to USD deposits. For U.S. banks, we infer net dollar lending as the difference between foreign-currency assets and liabilities, assuming that any open on-balance-sheet FX positions are hedged off-balance-sheet using FX derivatives. A limitation of this approach is that U.S. BIS statistics capture only cross-border loans and liabilities. As a result, if U.S. banks hold significant foreign-currency *securities* but minimal local-currency liabilities in their foreign branches, our methodology may underestimate their FX hedging supply.

Table 4 presents the net supply of USD FX hedges from various banking systems, measured by their "dollar funding gaps." A negative (positive) value in the "Bank Hedging" column indicates that banks are net suppliers (demanders) of USD FX hedges. The data reveal considerable heterogeneity in banks' funding models across jurisdictions. For instance, Japanese banks exhibit a strong positive net demand for USD hedging and funding, totally $305 billion. In contrast, banks in Australia, the euro area, the U.K., and the U.S. collectively

[18] Where consolidated statistics are available, we use aggregated positions of all bank branches headquartered in a given country. Consolidated data are available for Canada, Japan, Sweden, Switzerland, the United Kingdom, and six EU countries (Belgium, France, Germany, Italy, Netherlands, and Spain). For countries without consolidated data, we approximate the dollar funding gap using aggregate positions of all bank branches located in the respective country.

supply approximately $410 billion in net USD hedging and funding. It is important to note that our estimates capture the total USD funding supplied or demanded by different global banks. As we discuss in Section 4.4, these estimates may be too coarse to reflect the specific currencies in which FX hedges are provided. Instead, we rely on institutional investors' FX demand to approximate banks' provision of FX hedges across different currencies.

A key caveat of our analysis is that the net supply of USD hedges by banks in our sample currency areas, as estimated from the BIS "dollar funding gap," totalled only $333 billion as of December 2019. This figure falls short of the $2 trillion USD hedging demand from mutual funds, pensions, and insurance companies in the same period. The discrepancy likely arises from the limitations of relying on BIS cross-border banking statistics to infer global banks' FX derivatives positions. Recent research by Hacıoglu-Hoke et al. (2024), which uses granular FX derivatives data for U.K.-based entities, suggests that dealer banks domiciled in the U.K. (including U.K. branches and subsidiaries of U.S. banks) provide the majority of USD hedges demanded by other sectors.

4 FX Hedging: Theory and Practice

On the whole, foreign investors meaningfully hedge the FX exposure associated with their USD securities holdings. But there is substantial heterogeneity in hedging practices. In this section, we explore two related questions. First, what drives foreign investors' demand for FX hedging? Second, what are the implications for FX derivative pricing when investors' hedging demand is met by possibly constrained intermediaries? We examine the two questions in turn. For each, we first present our theoretical framework and then test the model predictions against our data.

4.1 Definitions and Hedged Portfolio Return

We adopt the perspective of what has thus far been referred to as the "foreign", or non-US, investor. The investor has access to investment opportunities at home and in n other countries, each using a different currency. We define the spot and forward exchange rates, S_t and F_t, as units of home currency per foreign currency. An increase in S_t or F_t corresponds to an appreciation of the foreign currency.[19] For simplicity, we assume that only one asset exists in each country. Follow notations in Viceira and Shen (2023), we let $\boldsymbol{\omega}_t$ denote a $(n+1)\times 1$ vector of portfolio asset weights, where ω_c is the portfolio share of asset in country (currency) c, with $c = 1$ representing the home country (currency). Moreover, let $\boldsymbol{\psi_t}$ denote a $(n+1)\times 1$ vector of foreign currency exposure expressed in portfolio shares, with $\psi_1 = 0$. Therefore, $\boldsymbol{\theta_t} = \boldsymbol{\omega_t} - \boldsymbol{\psi_t}$ is a $(n+1)\times 1$ vector of FX hedging, also expressed in portfolio shares.

We assume that the investor does not have direct access to foreign short-term rates, so currency hedging must be done via the FX derivatives market, namely FX forward and swaps. We allow for a wedge in the CIP condition between the home currency and foreign currency c,

$$F^c_{t+1} = S^c_t \frac{1+i^1_t}{1+i^c_t}(1+X^c_t),$$

where i^1_t and i^c_t denote one-period domestic and foreign money market rates, F^c_{t+1} is the one-period forward exchange rate known at time t, and X^c_t is the cross-currency basis. In log form, the CIP deviation is given by:

$$x^c_t = (i^c_t - i^1_t) + (f^c_{t+1} - s^c_t),$$

[19]This definition is consistent with Section 2.2, where S_t and F_t were defined as units of foreign (non-USD) currencies per USD. In this section, USD is one potential foreign currency for the investor.

where $f^c_{t+1} = \log(F^c_{t+1})$, $s^c_t = \log(S^c_t)$, and $x^c_t = \log(1 + X^c_t)$. In other words, investors can synthetically access the foreign short-term rate by swapping the local short-term rate $i^c_t - x^c_t = i^1_t - (f^c_{t+1} - s^c_t)$.

Finally, we measure the violation of uncovered interest parity (UIP) with the expected return of going long in foreign currency c:

$$\xi^c_t = (i^c_t - i^1_t) + \mathbb{E}_t \Delta s^c_{t+1},$$

where $\mathbb{E}_t \Delta s^c_{t+1}$ is the expected foreign currency appreciation. If UIP holds, the expected appreciation of the foreign currency should exactly offset the interest rate differential. However, on average, high-interest-rate currencies do not depreciate enough against low-interest-rate currencies relative to their interest rate differentials (e.g., Lustig and Verdelhan (2007); Lustig, Roussanov, and Verdelhan (2011); Hassan and Mano (2019)). Therefore, on average, there are positive excess returns from going long in high-interest-rate currencies and shorting low-interest-rate currencies.

With these definitions, we define the hedged portfolio return as:

$$R_{h,t+1} = \boldsymbol{\omega_t'} \boldsymbol{R_{t+1}} (\boldsymbol{S_{t+1}} \div \boldsymbol{S_t}) - \boldsymbol{\theta_t'} (\boldsymbol{S_{t+1}} \div \boldsymbol{S_t}) + \boldsymbol{\theta_t'} (\boldsymbol{F_t} \div \boldsymbol{S_t}),$$

where $\div$ represents element-wise division of vectors. Following Campbell, de Medeiros, and Viceira (2010), we log-linearize the hedged return over the local risk-free rate as follows (details in Appendix B):

$$r_{h,t+1} - i^1_t = \underbrace{\boldsymbol{\omega_t'} (\boldsymbol{r_{t+1}} - \boldsymbol{i_t} + \boldsymbol{x_t})}_{\text{portfolio asset return}} + \underbrace{\boldsymbol{\psi_t'} (\boldsymbol{\Delta s_{t+1}} - i^1_t \mathbf{1} + \boldsymbol{i_t} - \boldsymbol{x_t})}_{\text{portfolio currency return}} + \frac{1}{2} \Sigma_{h,t+1}. \tag{2}$$

Here and throughout, we use boldface to indicate an $(n + 1) \times 1$ vector where the first element corresponds to home country (currency). The cross-currency basis for the home country (currency), x_t^1, is zero, as $f_t^1 = s_t^1 = 1$.

The first term represents the "portfolio asset return," which is the sum of each portfolio asset's excess return in its local currency. The cross-currency basis x_t adjusts for the effective foreign currency short rate accessible to the investor. The second term captures the "portfolio currency return," which is the excess return from foreign currency exposure. The third term is Jensen's inequality, with $\Sigma_{h,t+1}$ denoting the variance of the log excess return.

4.2 Mean-Variance Investor Problem for Optimal Currency Exposure

We derive the mean-variance investor's optimal foreign currency exposure, $\boldsymbol{\psi_t}$, conditional on the portfolio asset share $\boldsymbol{\omega_t}$:

$$\max_{\boldsymbol{\psi_t}} \mathbb{E}_t(r_{h,t+1} - i_t^1) - \frac{\gamma}{2}\mathbb{V}(r_{h,t+1} - i_t^1),$$

where γ is the risk aversion coefficient. Biases and frictions, such as home bias, investor mandates, and information frictions, are known to cause portfolio asset allocations to deviate from a global mean-variance benchmark (e.g., French and Poterba (1991)). We therefore abstract from asset allocation and focus on optimal currency exposure for a given $\boldsymbol{\omega_t}$.

Substituting the hedged return in Equation 2 and solving the optimization problem, we derive the optimal currency exposure as:

$$\begin{aligned}\boldsymbol{\psi}_t^* &= \frac{\boldsymbol{\xi}_t - \boldsymbol{x}_t}{\gamma \mathbb{V}(\boldsymbol{\Delta s}_{t+1} - i_t^1 \mathbf{1} + \boldsymbol{i}_t - \boldsymbol{x}_t)} \\ &\quad - \frac{\mathbb{C}\left[\boldsymbol{\omega}_t'(\boldsymbol{r}_{t+1} - \boldsymbol{i}_t + \boldsymbol{x}_t), (\boldsymbol{\Delta s}_{t+1} - i_t^1 \mathbf{1} + \boldsymbol{i}_t - \boldsymbol{x}_t)\right]}{\mathbb{V}(\boldsymbol{\Delta s}_{t+1} - i_t^1 \mathbf{1} + \boldsymbol{i}_t - \boldsymbol{x}_t)} \\ &= \underbrace{\frac{\boldsymbol{\xi}_t - \boldsymbol{x}_t}{\gamma \mathbb{V}(\boldsymbol{\Delta s}_{t+1} - i_t^1 \mathbf{1} + \boldsymbol{i}_t - \boldsymbol{x}_t)}}_{\text{var-adjusted FX return}} - \underbrace{\boldsymbol{\beta}}_{\text{var-adj cov(FX, portfolio assets)}}, \end{aligned} \tag{3}$$

where $\boldsymbol{\beta}$ is the regression coefficient of portfolio asset returns on currency excess returns adjusted for CIP deviations:

$$\boldsymbol{\omega}_t'(\boldsymbol{r}_{t+1} - \boldsymbol{i}_t + \boldsymbol{x}_t) = \alpha + \boldsymbol{\beta}'(\boldsymbol{\Delta s}_{t+1} - i_t^1 \mathbf{1} + \boldsymbol{i}_t - \boldsymbol{x}_t) + \boldsymbol{\epsilon}_t.$$

The term $\boldsymbol{\beta}$ captures the effect of portfolio return volatility on the optimal FX exposure, as emphasized in Campbell, de Medeiros, and Viceira (2010) and Viceira and Shen (2023). The optimal foreign currency exposure decreases in the covariance between foreign currency excess returns and the portfolio asset return. If a foreign currency return is highly correlated with the portfolio asset return, adding exposure to that foreign currency amplifies the overall portfolio return's volatility, which a risk-averse mean-variance investor seeks to avoid. Conversely, if a foreign currency return is negatively correlated with the portfolio asset return, currency risk offers a good hedge for the overall portfolio, and the mean-variance investor would take on some exposure to that foreign currency.

In addition to $\boldsymbol{\beta}$, we analyze the effect of currency return on optimal FX exposure, as captured by the first term in Equation 3. The term $\boldsymbol{\xi}_t$ is the expected excess return of investing in foreign currencies, which could be non-zero due to UIP violations. The higher the expected foreign currency excess return, the greater the demand for foreign currency exposure by a mean-variance investor. The term $-\boldsymbol{x_t}$ represents the cost of foreign currency hedging arising from CIP deviations: the more negative $\boldsymbol{x_t}$ is, the higher the cost of foreign currency hedging, and the greater the incentive to leave foreign currency exposure unhedged. The overall effect of UIP and CIP deviations $\boldsymbol{\xi_t} - \boldsymbol{x_t}$ decreases in the degree of investor risk aversion and FX return volatility, as the mean-variance investor balances utility from expected return with disutility from portfolio return variance.

We note that the overall effect of foreign currency volatility on optimal foreign currency exposure is negative only when the covariance between foreign currency return and the portfolio asset return is sufficiently high relative to expected currency returns:

$$\frac{\partial \boldsymbol{\psi}^*}{\partial \mathbb{V}(\boldsymbol{\Delta s_{t+1}} - i_t^1 \mathbf{1} + \boldsymbol{i_t} - \boldsymbol{x_t})} < 0 \Leftrightarrow \mathbb{C}\left[\boldsymbol{\omega_t'}(\boldsymbol{r_{t+1}} - \boldsymbol{i_t} + \boldsymbol{x_t}), (\boldsymbol{\Delta s_{t+1}} - i_t^1 \mathbf{1} + \boldsymbol{i_t} + \boldsymbol{x_t})\right] > \frac{\boldsymbol{\xi_t} - \boldsymbol{x_t}}{\gamma}. \tag{4}$$

This contrasts with Campbell, de Medeiros, and Viceira (2010), where FX exposure always decreases in FX return volatility. In our model, the investor also cares about the expected currency return and may thus tolerate some amount of volatility if compensated by high returns.

The following proposition summarizes the key drivers of optimal FX exposure for a mean-variance investor:

Proposition 1. *Fixing asset allocations, ψ_c, the optimal foreign currency exposure of a mean-variance investor to currency c,*

1. *increases with the expected excess return of holding foreign currency, ξ_c;*

2. *decreases with the cross-currency basis between the foreign and home currency, x_c;*

3. decreases with the covariance between foreign currency return and portfolio asset return.

4. when the covariance between foreign currency return and overall portfolio return is sufficiently high relative to expected currency returns, decreases with foreign currency return volatility.

4.3 Testing Mean-Variance Predictions

We now test the predictions for optimal currency exposure (Proposition 1) in both the cross-section and time-series. Continue adopting the perspective of non-US investors, we assume that non-US investors' investments in USD-denominated securities expose them to FX risk. As non-US investors' non-domestic investments predominantly consist of USD securities, we simplify by assuming their investment portfolios consist only of assets denominated in either their local currency or USD.

We first estimate the empirical covariance between FX returns and portfolio asset returns. We construct each investor's portfolio asset return from USD bond, USD equity, local-currency bond, and local-currency equity returns, weighted by the investor's observed, time-varying portfolio weights. To approximate bond returns, we use 10-year government bonds, and for equity, we use major local stock market indices.[20] Focusing on annualized one-month holding period excess returns, and adjusting for the cross-currency basis x_t (as in Equation

[20]For Europe, we use the 10Y German bund to estimate bond returns and STOXX Europe 600 to estimate equity returns.

2), we estimate the following:

$$
\begin{aligned}
rx_{t+1}^{bond,adj} &= 12(p_{9\frac{11}{12}Y,t+1M} - p_{10Y,t}) - i_{1M,t} + x_t, \\
&\approx y_{10Y,t} - i_{1M,t} - 119(\Delta y_{10Y,t+1}) + x_t, \\
rx_{t+1}^{equity,adj} &= 12(\Delta p_{t+1}) - i_{1M,t} + x_t, \\
rx_{t+1}^{FX,adj} &= 12(\Delta s_{t+1}) - i_{1M,t} + i_{1M,t}^{\$} - x_t.
\end{aligned}
$$

Our estimation period spans June 2002 to September 2020, inclusive of the GFC and COVID-19.[21] We use month-end non-overlapping returns, and proxy $i_{1M,t}$ with 1M IBOR in the respective currency.

Implicit in our estimation is the assumption that the covariance structure is fairly stable over time. We thus take the covariance between FX returns and the investor's portfolio asset returns as a salient property of the cross-section, and hold this covariance constant in our cross-sectional analysis. Moreover, to test Proposition 1 in the time series, we use option-implied FX volatility from 3-month at-the-money contracts to capture potentially high-frequency variations in the time series. Finally, investors' expected FX return from holding USD exposure could vary in both the cross-section and the time-series. We appeal to the persistent violation of UIP and use interest rate differentials to approximate expected FX returns.

Before conducting regression analysis, we explore the data visually. Figure 7 presents cross-currency scatter plots of observed currency exposure in the post-GFC period against various mean-variance drivers. We construct the currency-level representative investor's portfolio as the weighted average of portfolios held by insurance companies, pension funds,

[21] This estimation period ends slightly before our sample period concludes in June 2021, as September 2020 is the latest point when we have a complete panel of holdings and hedging data.

and mutual funds in a particular currency area.[22] Panel (a) shows the correlation between the observed unhedged USD exposure (ψ) and $-\beta$, the negative covariance between investor's currency excess return and their portfolio asset return (adjusted for currency return volatility). This $-\beta$ has been the main driver of foreign currency exposure in the literature. We find that there indeed is a positive correlation between unhedged USD exposure and $-\beta$. Yet, the correlation of 0.42 is far from perfect, suggesting that covariance between currency and portfolio asset returns may not be the only driver of currency exposure.

Panel (b) explores the role of expected currency return on currency exposure. The vertical axis measures the unexplained portion of unhedged exposure after accounting for the covariance term, $\psi - (-\beta)$ or $\psi + \beta$. The horizontal axis measures the 3M IBOR differential between the US and the foreign investor's home country, which is our proxy for UIP violations.[23] Consistent with mean-variance predictions, there is a strong positive correlation of 0.86. Low-interest-rate countries, such as Japan, Denmark, and Switzerland, tend to have high unhedged USD exposure after accounting for the covariance between portfolio asset returns and USD currency returns. Conversely, high-interest-rate countries, such as Chile, Australia, Canada, and Norway, have low unhedged USD exposure after adjusting for the covariance term. Panels (c) and (d) further illustrate the correlation between covariance-adjusted unhedged exposure ($\psi + \beta$) and the 3M CIP deviations between USD and home currency. Taiwan presents as a large outlier for CIP deviations in Panel (c). Panel (d) excludes Taiwan and shows a negative correlation of -0.55. Overall, in addition to return covariance, UIP and CIP deviations are strongly correlated with observed USD exposure in the cross-section, consistent with mean-variance predictions in Proposition 1.

[22] We focus on the representative investor as opposed to sector-specific investors to minimize sector-specific frictions that distort the portfolio away from the mean-variance optimum.

[23] As with the portfolio covariance in Panel (a), UIP deviation in Panel (b) and CIP deviation in Panels (c) and (d) are divided by FX return variance, per Equation 3.

We now investigate the mean-variance drivers of optimal FX exposure using panel regressions. Table 5 reports the results. The outcome variable is currency-level representative investor's observed unhedged USD exposure, stated as a share of the portfolio. Columns (1)-(4) study the cross-section of currency areas, where we include time fixed effects. The explanatory variables directly follow the mean-variance investor's optimal FX exposure (Equation 3).[24] The results confirm observations from the cross-country scatter plots in Figure 7. Return covariance, interest rate differentials (a proxy for violations of UIP), and CIP deviations all enter significantly, with signs consistent with Proposition 1. These relationships hold in both the full sample (Columns (1) and (2)) and the post-GFC sample (Columns (3) and (4)). The joint explanatory power of these drivers increased post-GFC, as reflected in the rise of the "Within Adjusted R^2" (adjusted R^2 excluding fixed effects) from 0.23 in Column (2) to 0.3 in Column (4). More importantly, comparing the "Within Adjusted R^2" of 0.09 and 0.1 in Columns (1) and (3), where return covariance is the sole explanatory variable, with 0.23 and 0.3 of Columns (2) and (4), we see that cross-sectional variation in FX exposures is better explained when UIP and CIP deviations are included.

Mean-variance drivers of FX exposure could also affect investor portfolios over time. Columns (5)-(8) focus on the time series, where we include currency fixed effects. Looking at Columns (6) and (8), in both the full-sample and the post-GFC period, the interest rate differential (a proxy for UIP deviation) enters positively and significantly, consistent with Proposition 1. Moreover, similar to the cross-section, the joint explanatory power of mean-variance drivers increases substantially when UIP and CIP deviations are included. The increase in "Within Adjusted R^2" is 0.11 in the whole sample (Column (5) vs. Column (6)) and 0.22 in the post-GFC period (Column (7) vs. Column (8)).

[24]As in Equation 3, each explanatory variable is divided by FX return variance.

We also note that FX return volatility enters negatively in the full sample but loses significance post-GFC. This may be due to improved expected FX returns of going long in USD: from Equation 4, the optimal FX exposure decreases in FX volatility only when expected FX returns are low relative to the covariance between currency returns and portfolio asset returns. Post-GFC, interest rates in most countries approached or fell below zero, and in many high-interest-rate countries, the formerly negative US-local interest rate spread narrowed or turned positive. If the covariance structure is constant, then a higher level of USD currency return may no longer satisfy the inequality in Equation 4.[25]

In summary, the mean-variance drivers of optimal currency exposure, as outlined in Proposition 1, align well with observed investor portfolios. In particular, we find strong support for UIP-driven expected currency returns as a factor, over and above considerations of portfolio variance.

4.4 Intermediary's Supply of FX Hedging and Equilibrium Pricing

To hedge their USD exposure, investors enter into FX forward or FX swap contracts with a financial intermediary. So far, we have focused on the drivers of investors' hedging decisions. Next, we consider the aggregate implications of hedging. Specifically, we model the supply of FX hedges by a representative financial intermediary to determine the effect of hedging on the equilibrium pricing of FX derivatives.

We have a competitive and risk-neutral intermediary. As discussed in Fact 4 of Section 3, the intermediary may "supply" some of the FX hedges demanded by investors by sourcing USD funding in the cash market, which expands its balance sheet. This balance-sheet

[25] In unreported tests, FX volatility continues to enter negatively post-GFC when restricted to low-interest-rate currency areas (e.g., CHF, EUR, JPY), whose currency return due to UIP violations did not meaningfully increase.

expansion has become costly post-GFC, as non-risk-weighted leverage ratio under Basel III assesses capital charges based on the total size of bank's balance sheet. Thus, the intermediary requires compensation for providing FX hedges to offset the cost of balance-sheet expansion.

We assume that the competitive intermediary takes prices as given and faces a total leverage constraint. In the short term, the size of the intermediary's balance sheet, consisting of H, the net notional amount of FX derivatives, and I, the amount of other investments, must not exceed a fixed balance sheet size W.[26] Furthermore, we assume that the intermediary operates with a segmented balance sheet across currency areas c:

$$
\begin{aligned}
H_c \cdot \text{sign}(H_c) + I_c &= W_c, \\
H_c &= \sum_{i \in c} (\boldsymbol{\omega_i'} - \boldsymbol{\psi_i'}) A_i \mathbf{1}, \\
\sum_c W_c &= W.
\end{aligned}
$$

Here, A_i represents the portfolio size of investor i (in currency area c), $\boldsymbol{\omega_i}$ is the vector of investor's portfolio asset weight, and $\boldsymbol{\psi_i}$ is the vector of investor's foreign currency (USD) exposure from each asset, expressed in portfolio shares. Hence, $(\boldsymbol{\omega_i'} - \boldsymbol{\psi_i'}) A_i \mathbf{1}$ is the amount of FX hedging sought by investor i. If the aggregating FX hedging demand over all investors in a currency area is not zero, then the intermediary clears the market by providing $H_c \neq 0$.[27]

The assumption of a segmented intermediary balance sheet reflects frictions within large banking organizations that prevent investment opportunities from being equalized at the

[26] The intermediary's balance sheet size is fixed in the short term due to capital market frictions that prevent it from quickly and cheaply raising outside equity.

[27] The investors here include all customers of the intermediary, including both the institutional investors we studied and modeled as having demand for FX hedges, as well as other customers with FX hedging needs that may offset those of institutional investors

margin (Siriwardane, Sundaram, and Wallen (2022)). For instance, trading desks in different countries may be allocated different balance sheet capacities, depending on market size and investment opportunities, and this allocation may not adjust flexibly.

Taking as given the compensation for supplying FX hedges (x_c), the intermediary chooses its supply of FX hedges to maximize its risk-adjusted total return subject to its balance sheet constraint:

$$\max_{H_c} x_c H_c \cdot \text{sign}(H_c) + f(I_c),$$
$$\text{s.t. } H_c \cdot \text{sign}(H_c) + I_c = W_c.$$

Here, $f(I)$ denotes the risk-adjusted expected excess return on the intermediary's other investments.[28] At the optimum, the intermediary chooses H_c such that $x \cdot \text{sign}(H^*) = f'(I^*)$. This x corresponds to the cross-currency basis in practice and follows the same sign as the intermediary's net FX derivative position, H.[29] Note that this optimization arises because post-GFC regulations constrain banks' balance sheet size. If there were no such regulations, the intermediary doesn't require compensation for balance sheet expansion and $x = 0$, the pricing of FX derivatives would then be governed by CIP and the supply of H is perfectly elastic.

Following Ivashina, Scharfstein, and Stein (2015), we adopt the simple case of $f(I) = \delta \log(I) - I$. This functional form reflects diminishing marginal returns from investments

[28]For simplicity, we abstract away from modeling other regulatory constraints, e.g., risk-weighted capital requirement, by interpreting $f(I)$ to be net of the cost arising from all other non-balance-sheet-size constraints.

[29]For instance, if the intermediary uses USD as the reference currency and non-US investors demand to buy USD today and sell USD tomorrow to hedge, the intermediary takes the opposite position, resulting in a negative net derivative position H_c today. In this case, the intermediary would demand $x_c < 0$ as compensation.

and limited profitable opportunities. This results in:

$$x_c \cdot \text{sign}(H_c^*) = \frac{\delta}{W_c - H_c^* \cdot \text{sign}(H_c^*)} - 1.$$

Because x represents compensation for using the balance sheet, x should be zero when there is no net demand for FX derivatives. This implies $\delta = W$. Thus, we have:

$$x_c = \frac{H_c^*}{W_c - H_c^* \cdot \text{sign}(H^*)_c} = \frac{H_c^*}{I_c^*}. \tag{5}$$

From Equation 5, we see that the cross-currency basis must become more negative to induce the intermediary to supply more FX hedges in a currency. Moreover, Equation 5 highlights that what matters to the intermediary is not the absolute amount of FX derivatives it supplies, but how much it supplies relative to the size of the balance sheet available for currency area c. Given a fixed balance sheet, supplying FX hedges comes at the cost of reducing other investments. This trade-off underpins the intermediary's optimization and leads to a prediction that quantitatively links FX hedging with cross-currency basis in the cross-section:

Proposition 2. *Cross-currency basis is not uniform in the cross-section. The more FX derivatives the intermediary supplies relative to its balance sheet allocated to a currency area, the larger the cross-currency basis is in absolute terms.*

Using our data on USD FX hedging, we empirically test the relationship between the cross-section of cross-currency basis and hedging in Proposition 2. We make two assumptions to bridge the model with data. First, we assume that the intermediary segments its balance sheet in proportion to GDP, as GDP is often correlated with the depth of financial markets and the availability of investment opportunities. We collect trading assets by geography for two large global banks, Citi and JP Morgan, and verify in Appendix Table A2 that there is a strong positive correlation between GDP and banks' trading asset allocation.

Second, because institutional investors' liabilities are mostly domestic, the USD FX hedges they demand should convert USD back into their local currency, not into other currencies. Therefore, we assume that the intermediary-supplied USD FX hedges in a particular currency are proportional to the total amount of hedges demanded by institutional investors in that currency area. Our approach differs from using the on-balance-sheet USD mismatch of banks headquartered in a currency area to approximate hedges between USD and that currency (e.g., Borio et al. (2016), Borio et al. (2018)). Underlying this alternative approach is the assumption that the net supply of FX hedges in a currency comes only from banks headquartered in that currency area. In contrast, our approach assumes that segmentation arises from hedging demand and does not take a stance on which bank meets that demand.

Consistent with Proposition 2, Figure 8 demonstrates a striking linear relationship between the time series average of currency-specific CIP 3M basis and GDP-normalized total hedging volume of insurance companies, pension funds, and mutual funds in a currency area. In the cross-section, the linear correlation between cross-currency basis and normalized hedging volume has an R^2 of 0.73.[30] Importantly, this relationship holds across both advanced and developing economies.

[30] In Appendix Figure A5, we illustrate the cross-sectional relationship between cross-currency basis and hedging volume approximated with bank' on-balance-sheet USD mismatch.

5 Conclusion

In this study, we collect and analyze a vast array of industry statistics and company filings to examine foreign investors' USD-denominated securities holdings and hedging strategies. Our findings reveal a six-fold increase in foreign investors' USD holdings, driven largely by a growing portfolio allocations to USD assets. We also demonstrate that, in the post-GFC period, investors hedge a significant portion of their USD exposure despite large CIP deviations,incurring substantial financial costs. We further uncover considerable cross-currency heterogeneity in the hedging practices of foreign institutional investors, as well as differences in the business models of global banks across countries in providing USD FX hedging.

Employing a mean-variance framework, we derive the relationship between the optimal hedge ratio and key drivers: the volatility of USD FX returns, the covariance between USD FX and U.S. asset returns, and the FX returns driven by deviations from UIP and CIP. Our results underscore the empirical importance of expected FX returns in shaping investors' hedging decisions. Finally, we document a strong correlation between the cross-section of hedging demand and the cross-currency basis, highlighting the role of constrained financial intermediaries in currency hedging markets.

Our findings provide the first comprehensive empirical investigation into foreign investors' USD asset holdings and hedging practices. The rising hedge ratios among foreign investors emphasize the distinction between demand for U.S. assets and demand for the U.S. dollar itself. This shift in perspective offers new opportunities for research into the drivers of international investment flows and the strategic management of currency risks.

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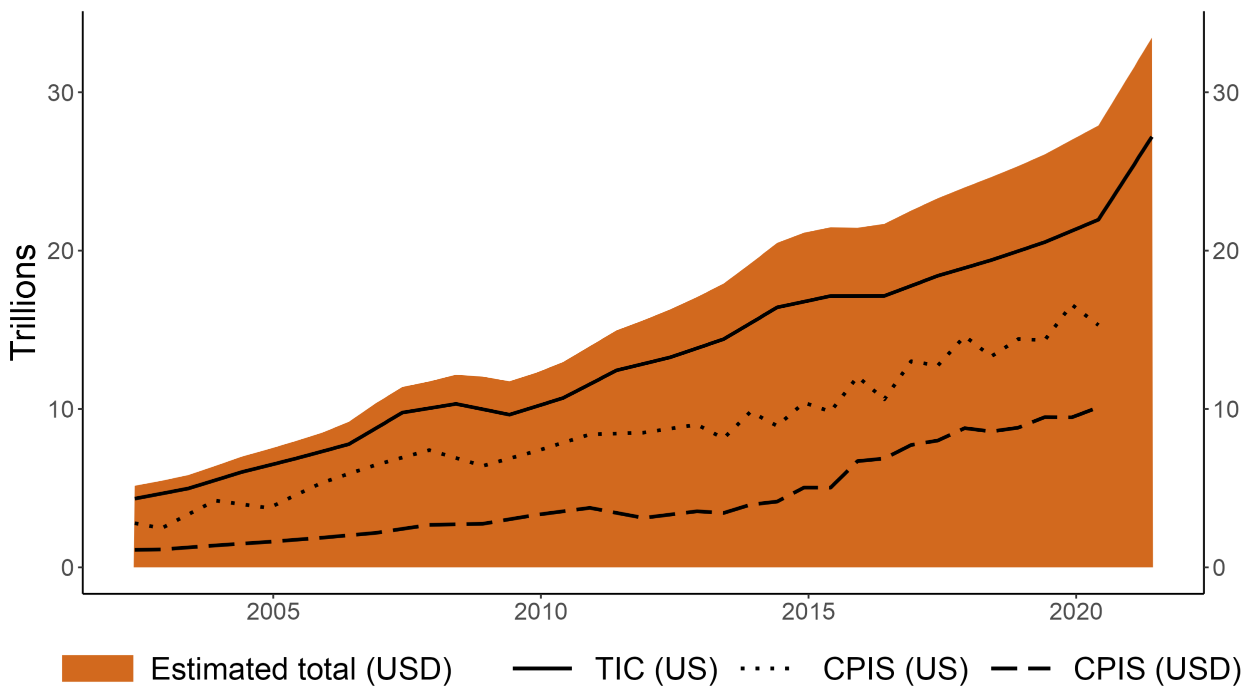
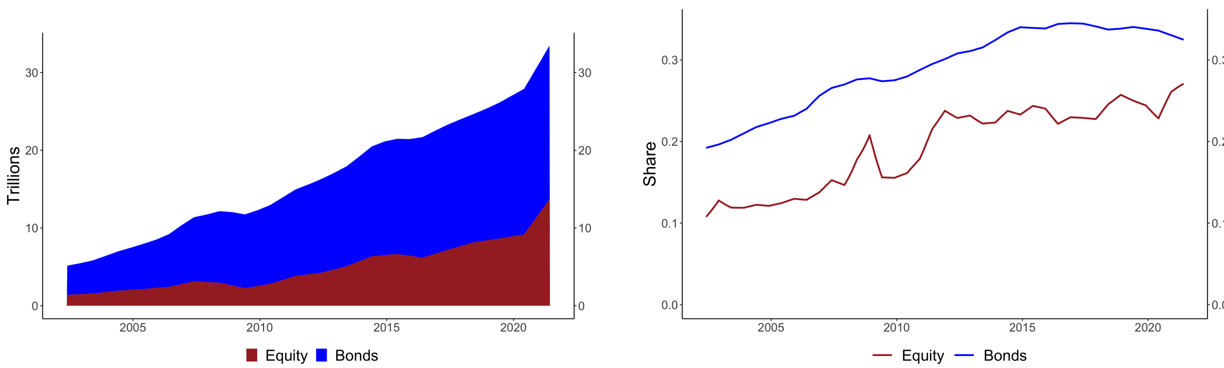
Figures and Tables

Figure 1: **Foreign holdings of US or USD securities**



Notes: This figure plots different estimates of foreign holdings of US or USD securities. Plotted in orange shade is our estimate of total USD holdings, which builds on the TIC estimate but adjusts for foreign-issued USD securities and US-issued non-USD securities. The solid line is the TIC estimate of foreign holdings of securities issued by US-residents. The dotted line is the CPIS estimate of foreign holdings of securities issued by US-residents. The dashed line is the CPIS estimate of foreign holdings of USD securities. The sample period is June 2002 to June 2021.

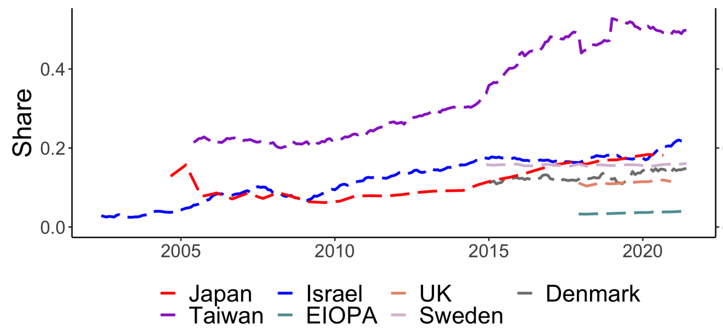
Figure 2: **Foreign USD holdings by security type**



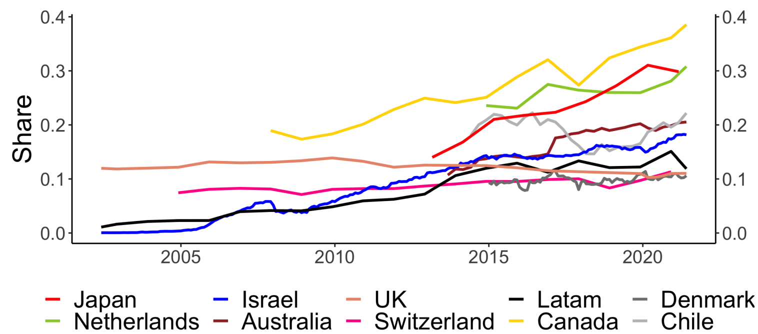
(a) **Volume** (b) **Share of total outstanding**

Notes: This figure plots estimated foreign-held USD securities by type. Panel (a) is volume of securities. Panel (b) is the share of total USD bonds and USD equity held by foreign investors. Total USD bond holdings are estimated as outstanding US fixed income securities adjusted for foreign-issued USD bonds. Total USD equity is estimated as the sum of US public market capitalization and AUM of US private equity funds. The sample period is June 2002 to June 2021.

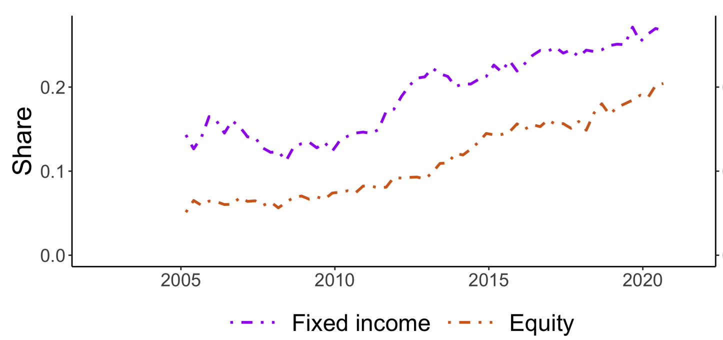
Figure 3: **Portfolio allocation to USD securities across industries**



(a) **Insurance**



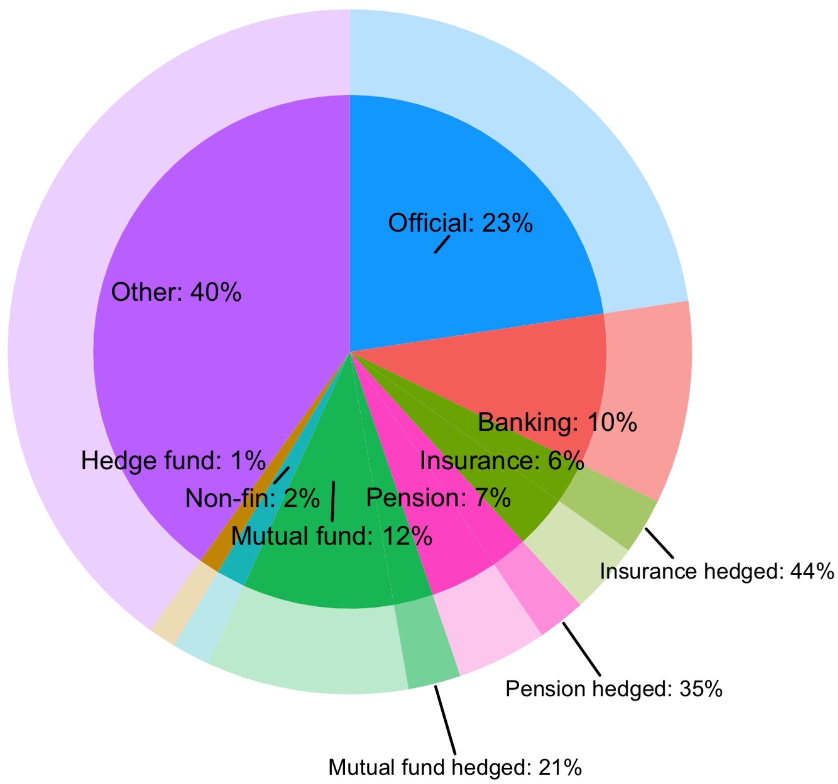
(b) **Pensions**



(c) **Mutual funds**

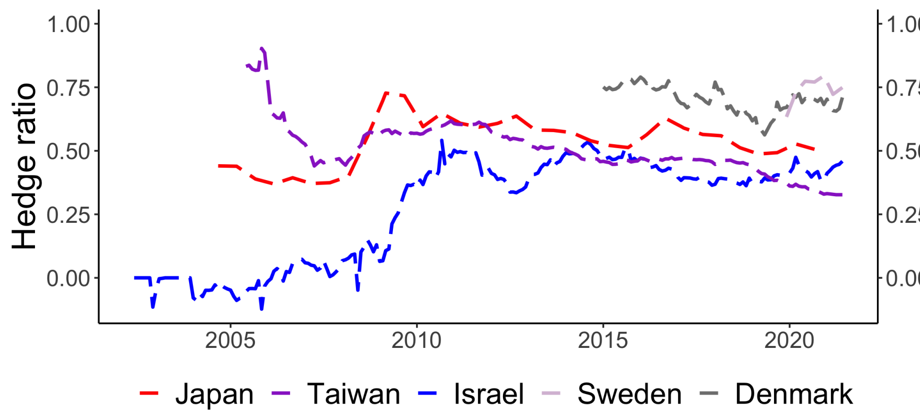
Notes: This figure plots foreign investors' portfolio allocation to USD securities. Allocation is estimated as the ratio of USD securities to total assets. See Table 1 for sample period coverage of different series. This figure is best viewed in color. Each country is plotted in the same color across different panels. See Section 2.1.2 and Appendix Section A.1 for estimation methodologies.

Figure 4: **Foreign holdings of USD securities by industry and hedging status, June 2020**

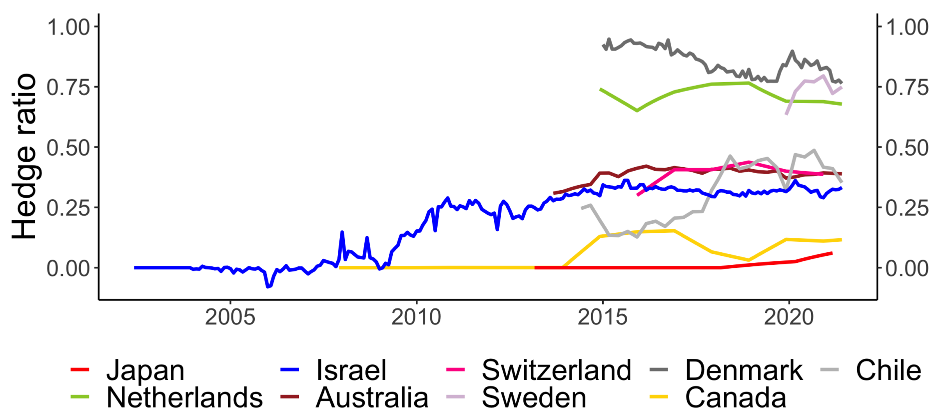


Notes: This figure illustrates foreign investors' USD holdings and hedging, by industry, as of June 2020. Each slice of the inner pie corresponds to industry holdings as a percentage of the total amount of USD securities held by foreign investors. Different shading on the outer ring corresponds to hedging status, with a darker shade indicating the percentage hedged and the lighter shade indicating the complement.

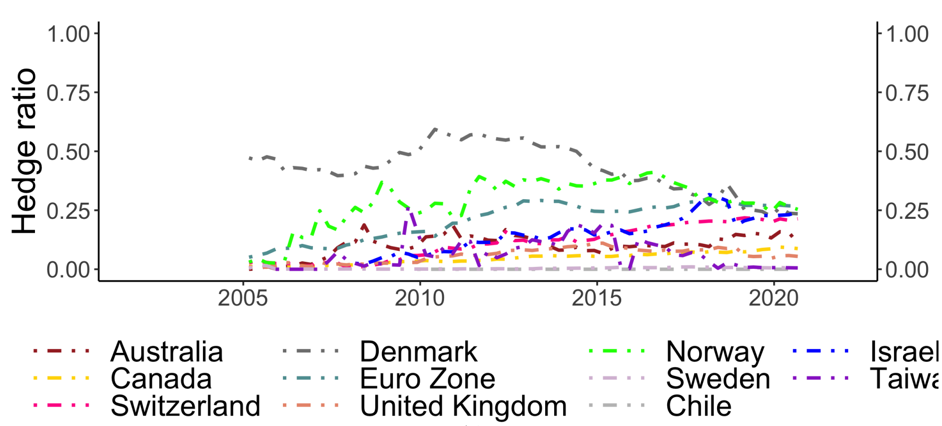
Figure 5: **USD hedging across industries**



(a) **Insurance**



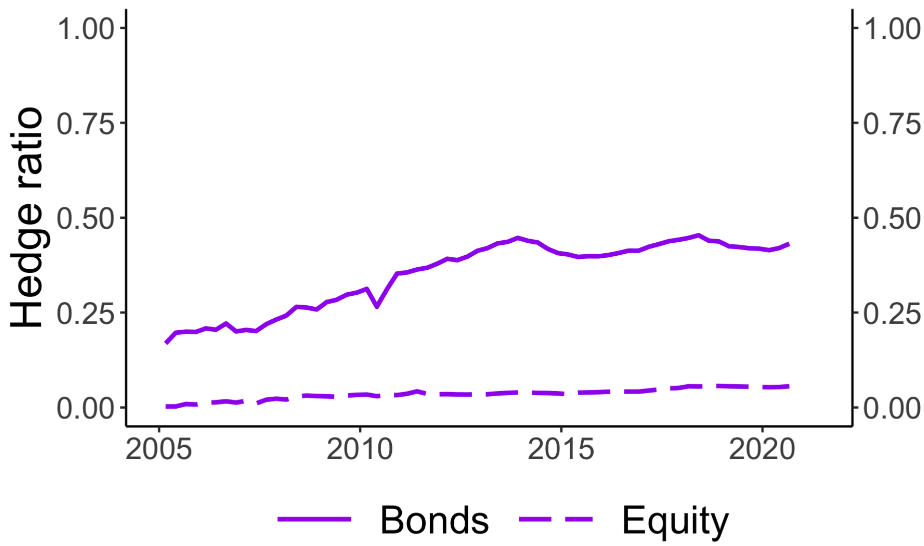
(b) **Pension**



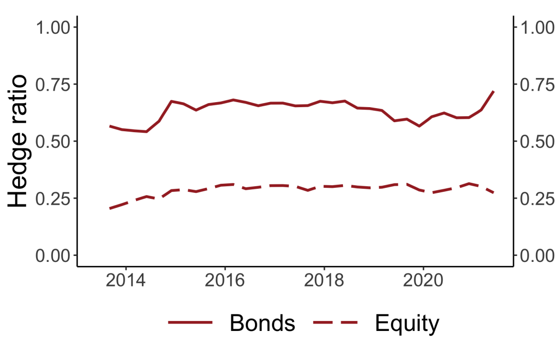
(c) **Mutual funds**

Notes: This figure plots the USD hedge ratio of different countries in the insurance, pension, and mutual fund industry. This figure is best viewed in color. Each country is plotted in the same color across different panels. See Section 2.1.2 and Appendix Section A.1 for estimation methodologies.

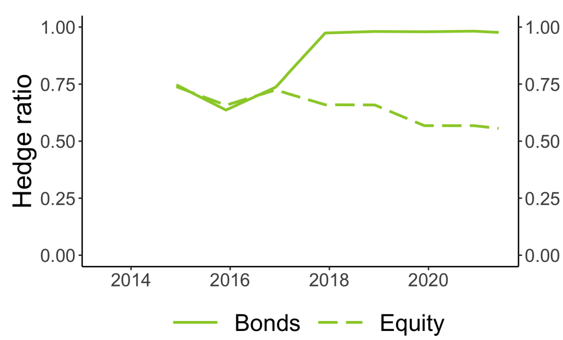
Figure 6: **USD hedging in bonds vs. equities**



(a) **Mutual funds**



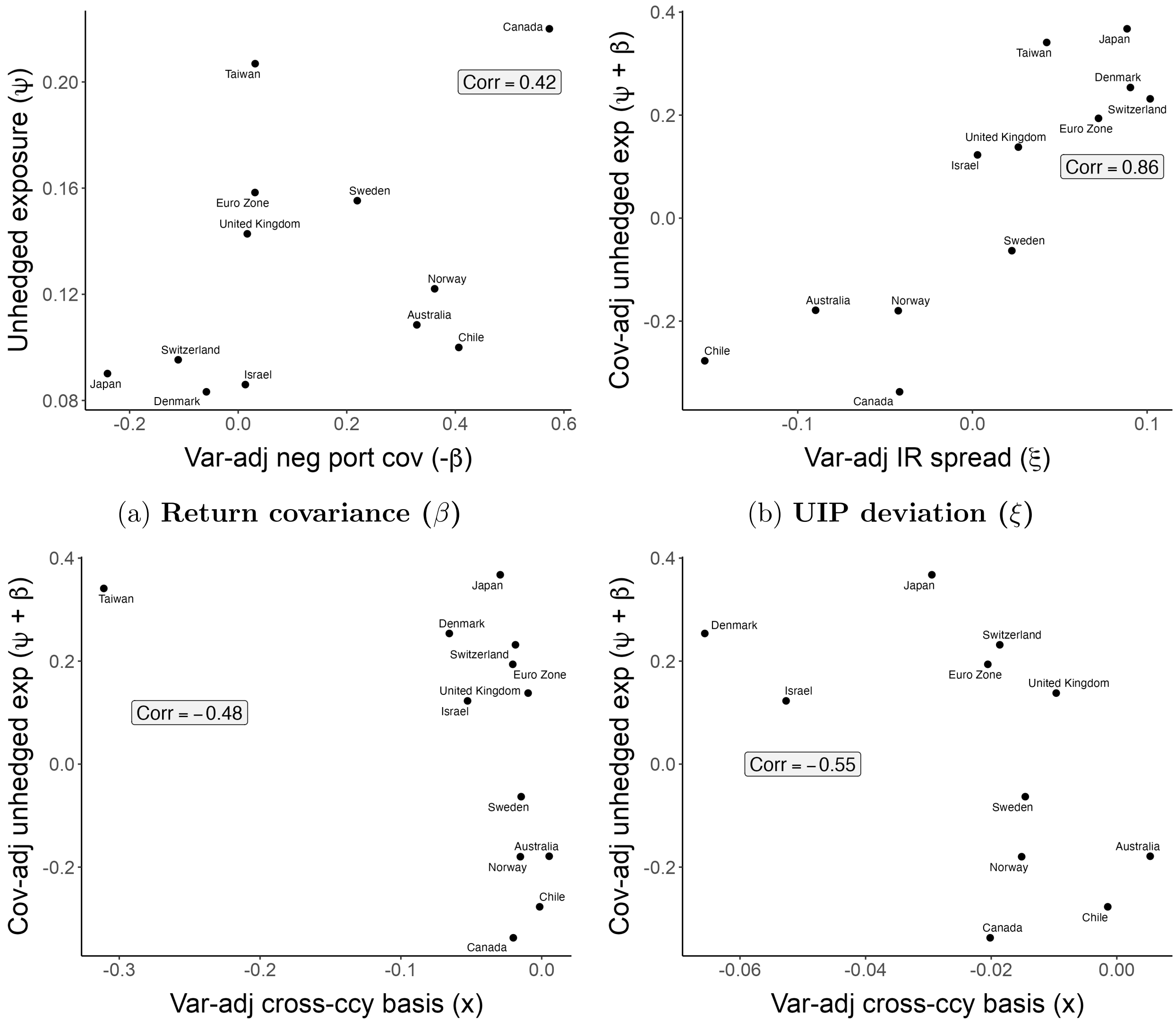
(b) **Australian pensions**



(c) **Dutch pensions**

Notes: This figure plots hedge ratios for USD bonds vs. equities in mutual funds, Australian pensions, and Dutch pensions. See Section 2.1.2 and Appendix Section A.1 for estimation methodologies.

Figure 7: **Mean-variance drivers of USD exposure**



(a) **Return covariance** (β)

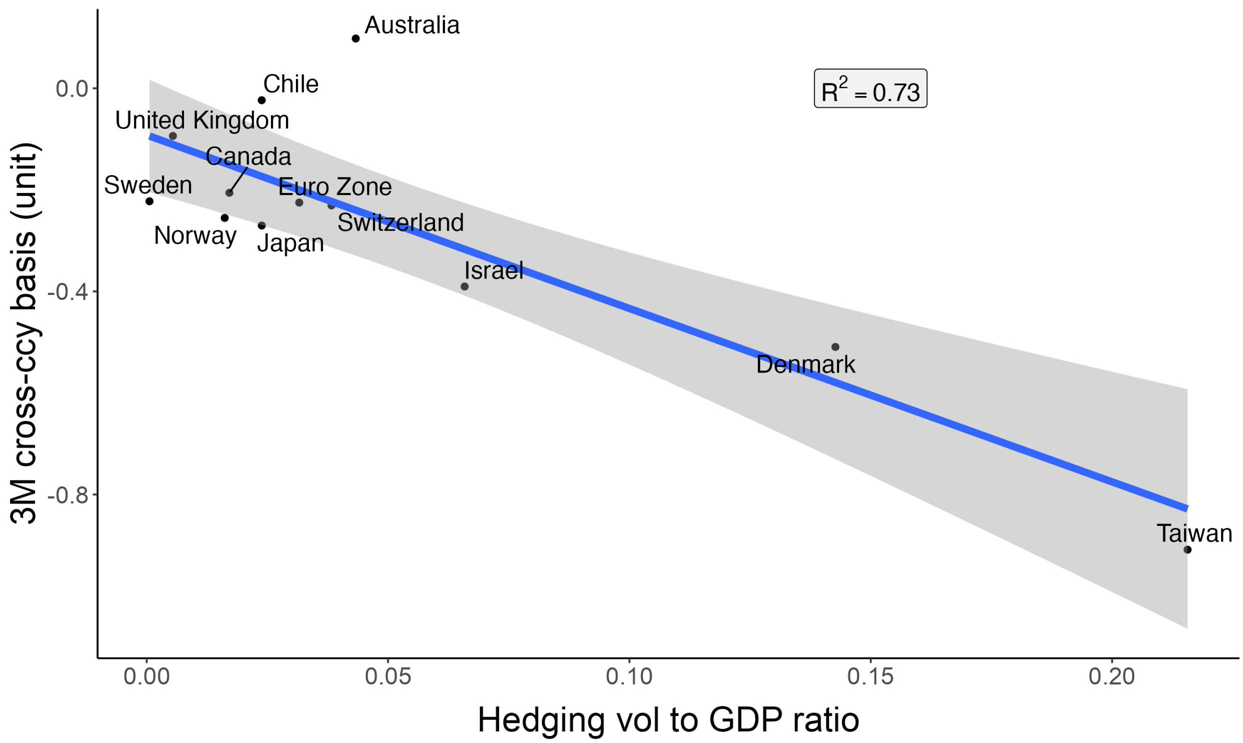
(b) **UIP deviation** (ξ)

(c) **CIP deviation** (x)

(d) **CIP dev.** (x) **no TWD**

Notes: This figure plots the unhedged USD exposure, measured as shares of the portfolio, against three mean-variance drivers of the optimal FX exposure. Each observation reflects the post-GFC time-series average. The portfolio for a currency area is constructed as the weighted-average portfolio of insurance, pensions, and mutual funds in that currency area. "Var-adj neg port cov" is the negative covariance between FX return and portfolio asset return, divided by the variance of FX return. "Var-adj IR spread" is the US-local 3M IBOR spread, divided by the variance of FX return. "Var-adj cross-ccy basis" is the US-local 3M IBOR cross-currency basis, divided by the variance of FX return. Estimation period is 2010 September through 2020 September.

Figure 8: **Cross-section of hedging and cross-currency basis**



Notes: This figure plots each currency's time-series average of 3M IBOR cross-currency basis against their time-series average of hedging volume to GDP ratio. Hedging volume is the estimated from USD FX hedging of insurance, pensions, and mutual funds. Sample period is 2010 July to 2020 September.

Table 1: **Summary of coverage and sources**

Industry	Region / Country	Firm filings	Industry or national statistics providers	Start	End	Hedging info start
Insurance	Asia: Japan	11		2004	2020	2004
	Asia: Taiwan	6	Central Bank of the Republic of China	2005	2021	2005
	Europe: Denmark		Danmarks Nationalbank	2015	2021	2015
	Europe: Sweden		Sveriges Riksbank	2014	2021	2019
	Europe: UK		EIOPA	2017	2020	2017
	Europe: 19 Euro countries		EIOPA	2017	2021	–
			SHS	2013	2017	–
	Europe: 9 other EU countries		EIOPA	2017	2021	–
	ROW: Israel		Bank of Israel	2002	2021	2002
Pensions	Asia: Japan	1		2013	2021	2013
	Asia: Australia		APRA, Australian Bureau of Statistics	2004	2021	2013
	Europe: Netherlands	2		2014	2021	2014
	Europe: Denmark		Danmarks Nationalbank	2015	2021	2015
	Europe: Sweden		Sveriges Riksbank	2014	2021	2019
	Europe: Switzerland		Federal Statistical Office	2004	2020	2015
	Europe: UK		Office for National Statistics	2002	2021	–
	NA: Canada	2		2007	2021	2010
	ROW: Israel		Bank of Israel	2002	2021	2002
	ROW: Chile		Superintendencia de Pensiones	2014	2023	2014
	ROW: 9 Latam countries		FIAP	2002	2021	–
Mutual funds	64 countries		Morningstar	2002	2021	2002
Banking	48 countries		BIS Locational Banking Statistics	2002	2021	–
Hedge funds	53 countries		13F, Factset	2002	2021	–
Non-financial	56 countries		CPIS	2002	2020	–
Official sector	237 countries and jurisdictions		TIC	2002	2021	–

Notes: This table reports the data sources used to construct industry-specific USD holdings and hedging. "Company filings" records the number of companies from whom filings are obtained. Within "Industry or national statistics providers", EIOPA is the European Insurance and Occupational Pensions Authority, APRA is the Australian Prudential Regulation Authority, and FIAP is Federación Internacional de Administradoras de Fondos de Pensiones. "Start" and "End" refer to the first and the last year of availability for each source. "Hedging info start" is the start year of hedging information.

Table 2: **USD asset allocations in the time-series**

	Share: USD in Overall		Share: USD in Foreign	
	(1)	(2)	(3)	(4)
Indicator: Crisis	0.69**		2.8*	
	(0.31)		(1.4)	
Indicator: Post-Crisis	7.7***		6.6***	
	(0.85)		(1.1)	
Counter by Quarter		0.23***		0.18***
		(0.01)		(0.02)
Currency X Industry	Yes	Yes	Yes	Yes
Observations	1,449	1,449	1,082	1,082
R^2	0.78	0.84	0.70	0.71
Within Adjusted R^2	0.34	0.53	0.03	0.06

Notes: This table examines time-series patterns in portfolio allocation to USD securities. "Share: USD in Overall" is the share of USD securities in investors' overall portfolio, stated in percentage points. "Share: USD in Foreign" is the share of USD securities in investors' foreign portfolio, stated in percentage points. Foreign portfolio comprises all non-local investments. "Counter by Quarter" is a counter that increases linearly for each passing quarter. Estimation period is 2002 June through 2020 September, and observations are industry-currency-quarter, where the industries include insurance, pensions, and mutual funds. Standard errors are calculated using Driscoll and Kraay (1998), and *, **, *** denotes significance at the 10%, 5%, and 1% level, respectively.

Table 3: **USD hedging and currency exposure in the time-series**

	USD hedge ratio		USD ccy exposure	
	(1)	(2)	(3)	(4)
Indicator: Crisis	5.2***	7.9***	1.2**	0.72**
	(1.6)	(2.3)	(0.51)	(0.28)
Indicator: Post-Crisis	15.7***	14.7***	5.8***	6.7***
	(1.5)	(1.7)	(0.78)	(0.94)
Currency X Industry	No	Yes	No	Yes
Observations	1,209	1,209	1,209	1,209
R^2	0.07	0.86	0.10	0.68
Within Adjusted R^2		0.23		0.28

Notes: This table examines time-series patterns in hedging. "USD hedge ratio" is the ratio of the amount of USD securities with currency exposure hedged to the amount of all USD security holdings. "USD ccy exposure" is the share of the portfolio invested in USD securities and not hedged. Estimation period is 2002 June through 2020 September, and observations are industry-currency-quarter, where the industries include insurance, pensions, and mutual funds. Standard errors are calculated using Driscoll and Kraay (1998), and *, **, *** denotes significance at the 10%, 5%, and 1% level, respectively.

Table 4: **Foreign holdings and hedging of USD securities, Dec 2019**

Currency Area	Active Industries Holdings	Active Industries Hedging	USD Hedge Ratio	Bank Hedging	Total Hedging
Australia	368	114	31%	-183	-68.88
Canada	670	65	10%	143	207.75
Switzerland	197	60	30%	31	90.48
Chile	38	11	30%	-5	6.37
Denmark	157	90	57%	-20	69.31
Euro Zone	2734	911	33%	-147	764.36
United Kingdom	979	241	25%	-166	74.88
Israel	97	35	36%	–	35.14
Japan	724	172	24%	305	477.49
Norway	35	9	24%	-19	-10.36
Sweden	217	85	39%	32	116.75
Taiwan	539	178	33%	-60	118.57
United States	–	–	–	-244	-243.60
Total	6755	1971	29%	-333	1638.25

Notes: This table reports foreign holdings and hedging of USD securities by country as of December 2019. "Active Industries Holdings" and "Active Industries Hedging" are our estimates of holdings and hedging of USD securities by insurance, pensions, and mutual funds. "USD Hedge Ratio" is the share of "Active Industry Holdings" that is FX hedged. "Bank Hedging" is the implied hedging demand (supply, if negative) by banks headquartered in Canada, Switzerland, Euro Zone, the U.K., and the U.S., and by banks located in each of the other currency areas. "Total Hedging" is the sum of "Active Industries Hedging" and "Bank Hedging".

Table 5: **Mean-variance drivers of USD exposure**

	Unhedged USD allocation							
	Cross-section				Time-series			
	Sample		Post-GFC		Sample		Post-GFC	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Var-adj neg port covariance ($-\beta$)	0.06***	0.10***	0.07***	0.13***				
	(0.003)	(0.007)	(0.004)	(0.006)				
Var-adj US-local 3M IBOR spread (ξ)		0.07***		0.17***				
		(0.01)		(0.02)				
Var-adj cross-ccy basis (x)		-0.19***		-0.22***				
		(0.02)		(0.02)				
Option-implied FX vol					-0.003***	-0.003***	-0.004**	0.0010
					(0.0010)	(0.0007)	(0.002)	(0.001)
US-local 3M IBOR spread						0.006**		0.01***
						(0.002)		(0.002)
3M cross-ccy basis						0.01		0.04***
						(0.01)		(0.01)
Time FE	Yes	Yes	Yes	Yes	No	No	No	No
Currency FE	No	No	No	No	Yes	Yes	Yes	Yes
Observations	749	649	492	492	749	649	492	492
R^2	0.40	0.46	0.29	0.45	0.47	0.54	0.60	0.70
Within Adjusted R^2	0.09	0.23	0.10	0.30	0.05	0.14	0.04	0.26

Notes: This table examines the mean-variance drivers of the optimal FX exposure in the cross-section and in the time-series. Observations are by currency and quarter. "Var-adj neg port cov" is the negative covariance between FX return and portfolio asset return, divided by the variance of FX return. "Var-adj IR spread" is the US-local 3M IBOR spread, divided by the variance of FX return. "Var-adj cross-ccy basis" is the US-local 3M IBOR cross-currency basis, divided by the variance of FX return. "Option-implied FX vol" is from 3M at-the-money options. "US-local 3M IBOR spread" is calculated as US 3M IBOR less local 3M IBOR. "3M cross-ccy basis" is calculated using IBOR in the log version of Equation 2.2. Estimation period is July 2010 through September 2020. Standard errors are calculated using Driscoll and Kraay (1998), and *, **, *** denotes significance at the 10%, 5%, and 1% level, respectively.

A Details of Data Construction

A.1 Overall Foreign Holdings of USD Securities

We first estimate foreign holdings of USD securities issued by U.S. entities. We obtain data on "TIC Foreign Holding of U.S. Securities" directly from the TIC system, specifically from annual reports on *Foreign Residents' Portfolio Holdings of U.S. Securities*, beginning in June 2002 and ending in June 2021. These reports detail non-U.S. residents' holdings of securities issued by U.S. entities, separately reported for equities and bonds. Because U.S. residents may issue non-USD-denominated securities, we estimate "TIC Foreign Holdings of Non-USD Securities" using TIC's reporting on non-USD debt held by foreign investors.

Next, we estimate foreign holdings of USD securities issued by non-U.S. residents. To do so, we first calculate "USD Securities Outstanding Outside the U.S." from the international debt securities statistics published by the Bank for International Settlements (BIS). We then subtract the amount of foreign-issued USD assets held by U.S. residents, referred to as "U.S. Investors' Cross-border USD Holdings." TIC's *U.S. Residents' Portfolio Holdings of Foreign Securities* provides the currency breakdown of U.S. residents' foreign holdings by country, with annual data starting in 2007. From this, we find that U.S. residents primarily hold USD-denominated debt abroad, with country-level averages fluctuating between 72% and 79%. For the period from 2002 to 2007, we estimate the share of U.S.-held foreign-issued USD debt as the average between 2007 and 2021.

A.2 Sector-specific USD Securities Holdings and Hedging

A.2.1 Foreign Insurance Companies' Holdings and Hedging

In Japan, we hand-collect quarterly filings since 2004 from all 25 active domestic companies and 12 foreign-controlled companies. The largest 11 Japanese insurance companies break out their portfolio holdings by currency. For these companies, we record total assets, investments in USD and other foreign currencies, and investments in foreign equity and foreign debt. We use the equity-to-debt split in foreign investments to infer Japanese insurers' risk-return preferences, and we estimate the amount of USD equity and debt by multiply the share of USD in their foreign investment portfolios with total foreign equity or total foreign debt. Japanese insurers' hedging practices are estimated directly from company-level filings on FX derivatives positions, available semi-annually. Because we are interested in managing long USD positions, we estimate the total USD hedge as the sum of net forward USD sales positions and USD swaps.[31] The net forward position is calculated as the notional difference between USD forward sold and USD forward bought, excluding small positions in FX options.

[31] This contrasts with Liao and Zhang (2020), who estimate USD hedging based on all FX derivatives and total foreign investments.

In Taiwan, the Central Bank of the Republic of China publishes the *Financial Statistics Monthly*, which details life insurers' total assets and foreign investments. We locate physical copies of these reports dating back to 2005 to form a monthly series of aggregate investments. To further understand the share of USD in foreign investments and the debt-to-equity split, we hand-collect detailed information from the annual reports of six of the largest Taiwanese life insurers. The Central Bank's monthly reports also provide information on the aggregate FX hedging undertaken by life insurers in the footnotes to Appendix Table 8.

We leverage quarterly filings made by all insurers to the European Insurance and Occupational Pensions Authority (EIOPA) to study portfolio allocations in the European Economic Area (EEA). The sample includes 31 countries, covering 19 in the eurozone, 11 others in the EEA, and the U.K. We estimate European insurers' USD holdings as investments in bonds and equities issued by U.S. entities. Our estimates of European insurers' USD bond holdings may be conservative due to USD bonds issued by non-U.S. residents. EIOPA data collection started in 2017. For the period between 3Q2013 and 4Q2017, we use ECB's Securities Holdings Statistics (SHS) to estimate holdings by insurers in the 19 eurozone countries. As with EIOPA data, our estimates from SHS are conservatively based on investments in U.S. issuers' securities. SHS includes reporting from both insurers and pensions; we subtract pensions' holdings from our SHS estimates to focus on insurers' holdings in the eurozone (e.g., the Netherlands).

In Denmark, instead of EIOPA, we use the monthly reporting by Danmarks Nationalbank, which tracks Danish insurers' investments by currency and security type. These reports also outline total FX exposure and hedging by currency. For Swedish insurers, we use the Sveriges Riksbank's semi-annual Financial Stability Report, which provides historical quarterly investment data for insurance companies. Life insurers have the longest series, from 2009 through 2022, while non-life and unit-linked insurance products have data through 2019. Using the ratio of life to non-life insurers before 2019, we impute the size of non-life insurers after 2019. The series starts in 2014 due to adjustments made by Sveriges Riksbank in 2022. We use the debt-to-equity split in the overall portfolio to infer the security type split of the foreign portfolio. Hedging information for Swedish life insurers is available starting in 2019.

For Israel, we use data from the Bank of Israel's *Institutional Investors' Exposure to Foreign Exchange*, which provides monthly statistics from 2002 onward, covering foreign investments made by Israeli insurers and pension funds. We estimate Israeli insurers' USD investments based on their total foreign investment portfolios and the typical share of USD in Israeli institutional investors' FX market activities.[32] We estimate the breakdown between USD equity and bonds using asset allocations in Israeli insurers' overall portfolios, which are available from the Bank of Israel's *Assets Portfolio of the Institutional Investors by Securities*.

[32] Ben Zeev and Nathan (2022a) find that 85.9% of Israeli institutional investors' FX swap flow volume and 87.8% of FX spot volume is in dollars. Institutional investors include insurers and pension funds.

The *Institutional Investors' Foreign Exchange Exposure* publication shows insurers' portfolio FX exposure before and after hedging. We use this data to estimate Israeli insurers' hedge ratios.

A.2.2 Foreign Pension Funds' Holdings and Hedging

We study the Japanese Government Pension Investment Fund (GPIF), which manages 72% of Japan's public pensions and whose size is equivalent of 76% of private retirement assets (ICI (2021)). GPIF is almost exclusively invested through external managers targeting specific benchmarks. For instance, in the fiscal year ending March 2021, GPIF invested in Fund VI, managed by BlackRock Japan Co., to track the FTSE U.S. Government Bond Index (USGOV). We analyze GPIF's investments manager by manager and estimate GPIF's USD investments based on allocations to U.S. bond or equity benchmarks. Similarly, we estimate GPIF's FX hedging activities by tracking allocations to hedged benchmarks, such as "FTSE US Government Bond Index (JPY hedged/JPY basis)," versus non-hedged benchmarks, such as "FTSE US Government Bond Index (no hedge/JPY basis)."

The pension industry in the Netherlands is highly concentrated, with the two largest funds, ABP and PFZW, managing assets equivalent to 1.5 times those of the next 15 largest funds combined.[33] Together, the two funds have 50% of total assets across all Dutch pension funds.[34] From ABP's and PFZW's annual reports, we gather data on total assets, USD investments, and the split between USD equities and USD bonds. Both funds disclose their unhedged (or net) USD exposure after factoring in FX derivatives. We estimate their hedging activity as the difference between total and unhedged USD exposure, separately for bonds and equities.

Canada's two largest pension funds, the Canada Pension Plan Investment Board (CPP) and Caisse de dépôt et placement du Québec (CDPQ), account for 45% of the assets under management (AUM) of the top eight public pension funds in Canada, which together represent two-thirds of the country's total pension assets.[35] For CPP, we collect data from its annual reports on total assets, U.S. investments, and portfolio allocations. Since 2015, CPP has ceased investing in foreign bonds, so its U.S. exposure is entirely through equity. We also analyze CPP's discussions of hedging strategy. CPP conducted no currency hedging between 2004 and 2007, and after 2015. Between 2008 and 2014, it hedged only bond investments. For CDPQ, we collect data from its annual reports on total assets, foreign portfolios, and the split between debt and equity, along with USD exposure. In recent years, CDPQ has stopped reporting USD exposure, instead reporting only its U.S. exposure, which we use as a conservative estimate of USD exposure. Since 2013, CDPQ has reported its unhedged (or net) USD exposure. We estimate CDPQ's hedging as the difference between total USD

[33] https://www.investmentoffice.com/Pension_Funds/Netherlands/

[34] https://www.pensioenfederatie.nl/website/the-dutch-pension-system-highlights-and-characteristics

[35] https://www.bankofcanada.ca/wp-content/uploads/2016/06/fsr-june2016-bedard-page.pdf

exposure and unhedged USD exposure.

To be conservative, we do not extrapolate holdings and hedging of the pensions we study in Japan, Canada, and Australia to the entire pension sectors in these countries.

In Australia, the Australian Prudential Regulation Authority (APRA) publishes the *Quarterly Superannuation Performance*, which provides data on all regulated pensions (those with more than four members) dating back to 2004. These reports include detailed information on total assets, foreign investments, and FX hedging activities. Foreign investments and hedging are reported separately for equities and bonds. To estimate USD bond and equity holdings, we supplement APRA statistics with data from the Australian Bureau of Statistics' (ABS) *Foreign Currency Exposure, Australia*, a triennial survey of Australian enterprises with foreign currency exposure. From this, we analyze non-bank financial institutions' (including pension funds, insurance companies, and other financial intermediaries) currency holdings in foreign equity and bond portfolios, which we use to estimate pensions' USD exposure.

The Swiss Federal Statistical Office provides annual data similar to APRA's, detailing pension funds' foreign investments, though without a currency breakdown. To address this gap, we use Credit Suisse's Swiss Pension Fund Index 2020, which estimates the currency allocation of Swiss pension funds' investment portfolios between 2018 and 2020. Like APRA, the Swiss data does not differentiate between domestic and foreign private equity investments, so we conservatively exclude private equity from our estimates of USD equity holdings. We estimate hedging activities for Swiss pensions using the industry-wide hedge ratio from the Swiss Pension Fund Study 2021 (Swisscanto Pensions (2021)).

For U.K. pension funds, we rely on data from the Office for National Statistics (ONS). Since 2019Q4, the ONS has released quarterly reports on U.K. pension funds' overseas assets, broken down by country and security type. We conservatively estimate U.K. pension funds' USD bond and equity holdings as those issued by U.S. entities. Prior to 2019, the ONS released annual statistics on foreign bond and equity investments by pension funds; we use the post-2019 average share to impute the share of USD in earlier years' foreign equity and foreign bond portfolios.

Chile's Superintendencia de Pensiones publishes quarterly reports on the country's pension sector beginning in 2014. These reports provide detailed information, including total assets, foreign investments, and net FX exposure after hedging, broken down by currency and by bond versus equity holdings.

Finally, we analyze pension funds in Denmark, Sweden, Israel, and nine other Latin American countries. Data for Danish, Swedish, and Israeli pension funds come from the same sources as insurers in these countries, as previously described. For the nine Latin American countries, we use data from Federación Internacional de Administradoras de Fondos de Pensiones (FIAP), which has published annual series on pension funds' foreign investments in Argentina, Bolivia, Colombia, Costa Rica, El Salvador, Mexico, Peru, the Dominican

Republic, and Uruguay.[36]

A.2.3 Foreign Mutual Funds' Holdings and Hedging

We analyze foreign mutual funds' allocations to USD using a dataset of holdings from open-ended funds and exchange-traded funds (ETFs) domiciled in 64 non-U.S. countries. This dataset includes security-level holdings from Morningstar for bond funds, mixed bond-equity funds (referred to as "allocation funds" by Morningstar), and equity funds, similar to the data used by Maggiori, Neiman, and Schreger (2020) and Coppola et al. (2021). We estimate foreign bond holdings by aggregating bond securities denominated in USD, excluding bank loans, alternative investments, and all derivatives (including bond futures and CDS). We estimate foreign equity holdings by obtaining each fund's share of U.S. equity investments from the Morningstar Direct platform.

We assess mutual funds' hedging strategies at the share-class level. Each Morningstar share class reports its hedging status as fully hedged, partially hedged, or unhedged. In addition to the self-reported hedging status, we identify additional hedged share classes by their currency-hedged benchmarks (e.g., "U.S. Corporate Bond EUR Hedged"). We aggregate the assets under management (AUM) of all share classes that are fully or partially hedged. While partially hedged share classes are rare, we acknowledge that we do not observe the exact hedge ratios for mutual fund investments.

A.2.4 Holdings of Foreign Banks, Hedge Funds, Non-Financials, and the Official Sector

Foreign Banks' Holdings

We estimate the holdings of USD securities by non-U.S. banks using the BIS Locational Banking Statistics (LBS), which provide quarterly data on the outstanding claims and liabilities of internationally active banks in reporting countries. Our focus is on banks' holdings of debt securities, as it is more capital-intensive for banks to hold equity securities. However, non-U.S. banks' cross-border holdings of USD debt securities are a confidential time series, available only to central banks.[37] To estimate USD debt securities holdings, we apply an adjustment factor to the difference between foreign banks' USD holdings and USD loans, yielding an estimate of debt securities holdings. Our estimated series has a 0.98 correlation with LBS' confidential series.

[36] FIAP also reports sparse data from Russia, Poland, Romania, and Kazakhstan, though these reports stopped after 2013. For Chile, we use information directly from the Superintendencia de Pensiones instead of FIAP's aggregate data.

[37] This information cannot be deduced from U.S. reporting to the BIS, as the U.S. reports only U.S. banks' loan and deposit positions, excluding debt securities.

Foreign Hedge Funds' Holdings

We estimate non-U.S. hedge funds' investments in U.S. equities by utilizing 13F reporting requirements, whereby institutional investment managers with at least $100 million in assets under management must disclose their equity holdings quarterly. The 13F filings specify whether the reporting entity is a hedge fund. We merge this data with Factset to determine each fund's domicile.

Foreign Non-Financial Sector's Holdings

We estimate the USD holdings of foreign non-financial companies and households using data from the IMF's Coordinated Portfolio Investment Survey (CPIS), which reports bilateral investment portfolios. In some cases, CPIS data is broken out by currency and sector. Since few countries report cross-border investments by currency, our estimates are based on investments in the U.S. by the non-financial sector in reporting countries. Of the 81 countries reporting U.S. asset holdings, 56 report investments separately for the non-financial sector. Our estimates are therefore conservative: some countries may own U.S. assets but choose not to report, and some investments by the non-financial sector may not be reported separately.

Foreign Official Sector's Holdings

We estimate the foreign official sector's holdings of U.S. securities using TIC data. Since 2007, TIC has reported official sector holdings in 237 countries and jurisdictions, broken down by debt and equity. For years prior to 2007, we estimate the total as the sum of the official sector's holdings of long-term debt and equity, as reported by Bertaut and Judson (2014), and short-term Treasury securities, as released by the Treasury Department. We assume the official sector — central banks, sovereign wealth funds, and other public financial agencies — does not acquire significant USD assets from non-U.S. entities.

B Additional Derivations

In this section, we show derivations of the log-linearized version of the hedged portfolio return. The hedged portfolio return is given by

$$\begin{aligned}
R_{h,t+1} &= \boldsymbol{\omega}_t'\boldsymbol{R}_{t+1}\cdot(\boldsymbol{S}_{t+1} \div \boldsymbol{S}_t) - \boldsymbol{\theta}_t'(\boldsymbol{S}_{t+1} \div \boldsymbol{S}_t) + \boldsymbol{\theta}_t'(\boldsymbol{F}_t \div \boldsymbol{S}_t) \\
&= \boldsymbol{\omega}_t'\boldsymbol{R}_{t+1}(\boldsymbol{S}_{t+1} \div \boldsymbol{S}_t) - \boldsymbol{\theta}_t'(\boldsymbol{S}_{t+1} \div \boldsymbol{S}_t) + \boldsymbol{\theta}_t'[(1 + i_t^1\mathbf{1}) * (1 + \boldsymbol{X}_t) \div (1 + \boldsymbol{i}_t)] \\
&= \boldsymbol{\omega}_t'\boldsymbol{R}_{t+1}(\boldsymbol{S}_{t+1} \div \boldsymbol{S}_t) - (\boldsymbol{\omega}_t' - \boldsymbol{\psi}_t')(\boldsymbol{S}_{t+1} \div \boldsymbol{S}_t) + (\boldsymbol{\omega}_t' - \boldsymbol{\psi}_t')[(1 + i_t^1\mathbf{1}) * (1 + \boldsymbol{X}_t) \div (1 + \boldsymbol{i}_t)] \\
&= \boldsymbol{\omega}_t'\boldsymbol{R}_{t+1}(\boldsymbol{S}_{t+1} \div \boldsymbol{S}_t) - \boldsymbol{\omega}_t'[(\boldsymbol{S}_{t+1} \div \boldsymbol{S}_t) - (1 + i_t^1\mathbf{1}) * (1 + \boldsymbol{X}_t) \div (1 + \boldsymbol{i}_t)] \\
&\quad + \boldsymbol{\psi}_t'[(\boldsymbol{S}_{t+1} \div \boldsymbol{S}_t) - (1 + i_t^1\mathbf{1}) * (1 + \boldsymbol{X}_t) \div (1 + \boldsymbol{i}_t)]
\end{aligned}$$

We now want to log-linearize the hedged portfolio return:

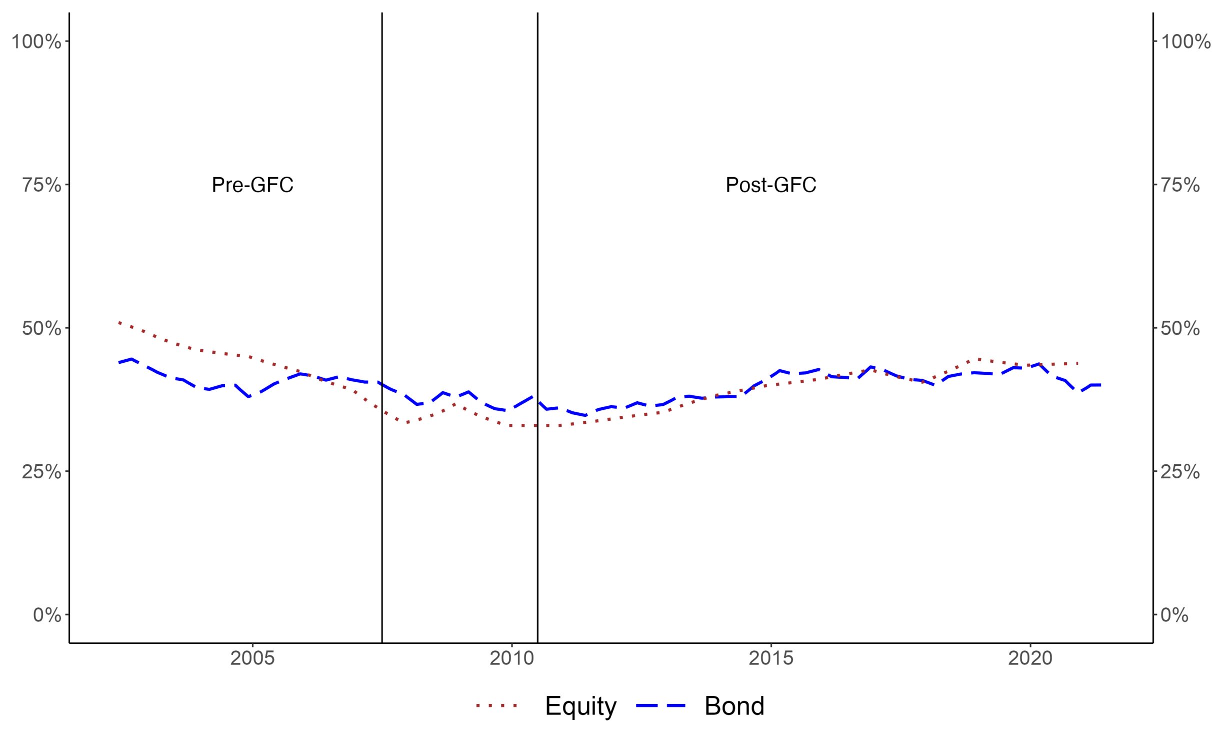
$$\begin{aligned} r_{h,t+1} &= \boldsymbol{\omega_t'}(\boldsymbol{r_{t+1}} + \boldsymbol{\Delta s_{t+1}}) - \boldsymbol{\omega_t'}(\boldsymbol{\Delta s_{t+1}} - i_t^1\mathbf{1} - \boldsymbol{x_t} + \boldsymbol{i_t}) + \boldsymbol{\psi_t'}(\boldsymbol{\Delta s_{t+1}} - i_t^1\mathbf{1} - \boldsymbol{x_t} + \boldsymbol{i_t}) + \frac{1}{2}\Sigma_{h,t+1} \\ &= \boldsymbol{\omega_t'}(\boldsymbol{r_{t+1}} - \boldsymbol{i_t} + \boldsymbol{x_t} + i_t^1\mathbf{1}) + \boldsymbol{\psi_t'}(\boldsymbol{\Delta s_{t+1}} - i_t^1\mathbf{1} - \boldsymbol{x_t} + \boldsymbol{i_t}) + \frac{1}{2}\Sigma_{h,t+1} \end{aligned}$$

Since $\boldsymbol{\omega_t'} i_t^1\mathbf{1} = i_t^1$, the hedged excess return is given by

$$r_{h,t+1} - i_t^1 = \boldsymbol{\omega_t'}(\boldsymbol{r_{t+1}} - \boldsymbol{i_t}^1 + \boldsymbol{x_t}) + \boldsymbol{\psi_t'}(\boldsymbol{\Delta s_{t+1}} - i_t^1\mathbf{1} + \boldsymbol{i_t} - \boldsymbol{x_t}) + \frac{1}{2}\Sigma_{h,t+1}.$$

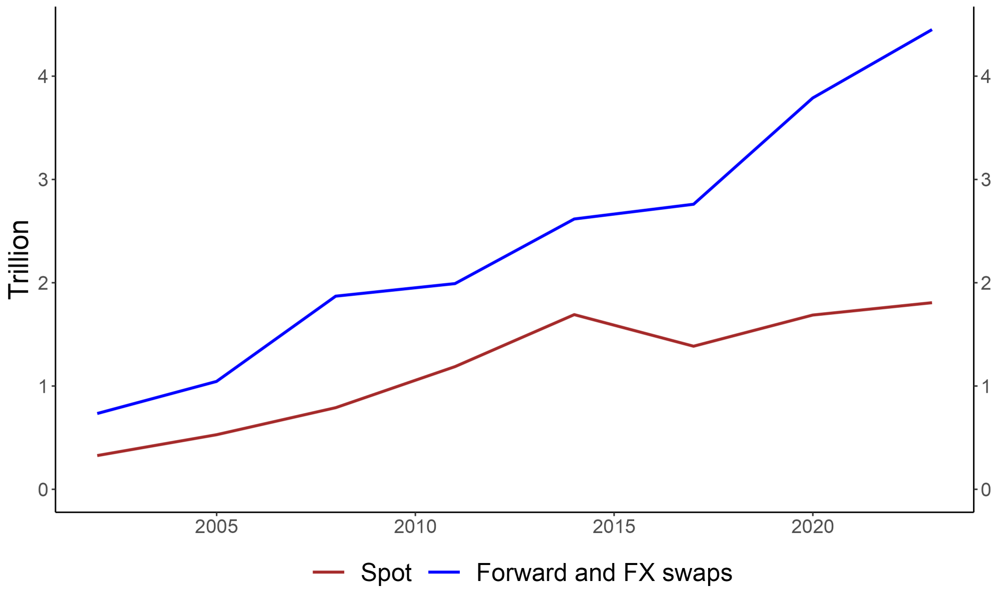
C Additional Figures and Tables

Figure A1: **Share of USD bonds and equities in global markets**

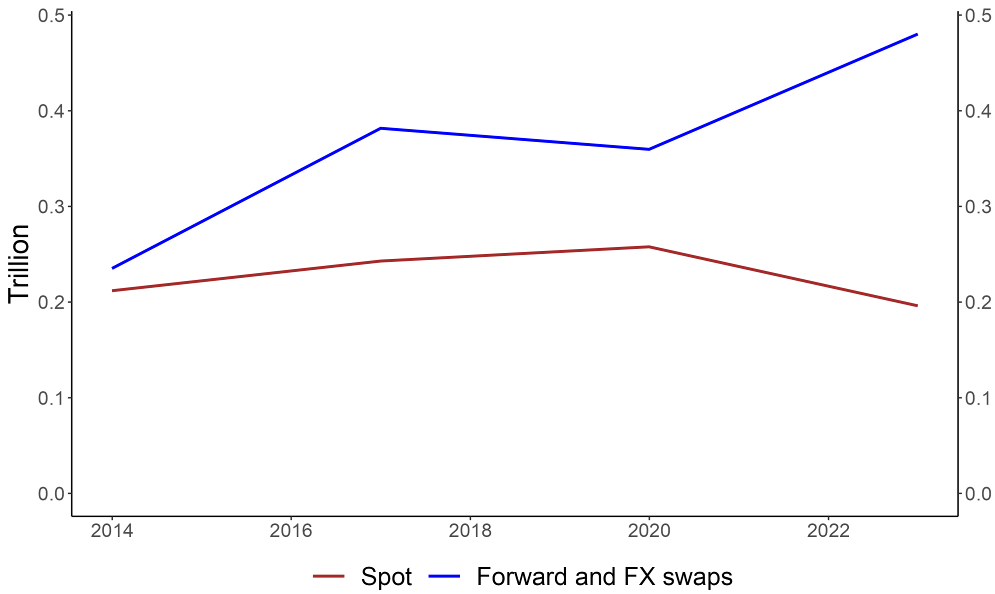


Notes: This figure plots the share of USD bonds and equities in their respective global markets. Global bond market size is calculated from BIS' debt securities statistics, inclusive of all issue markets. Global equity market is the sum of global public market cap and global private equity AUM. Global public market cap is compiled by World Bank in conjunction with World Federation of Exchanges. Global private equity AUM is sourced from Preqin.

Figure A2: **FX daily turnover against USD**



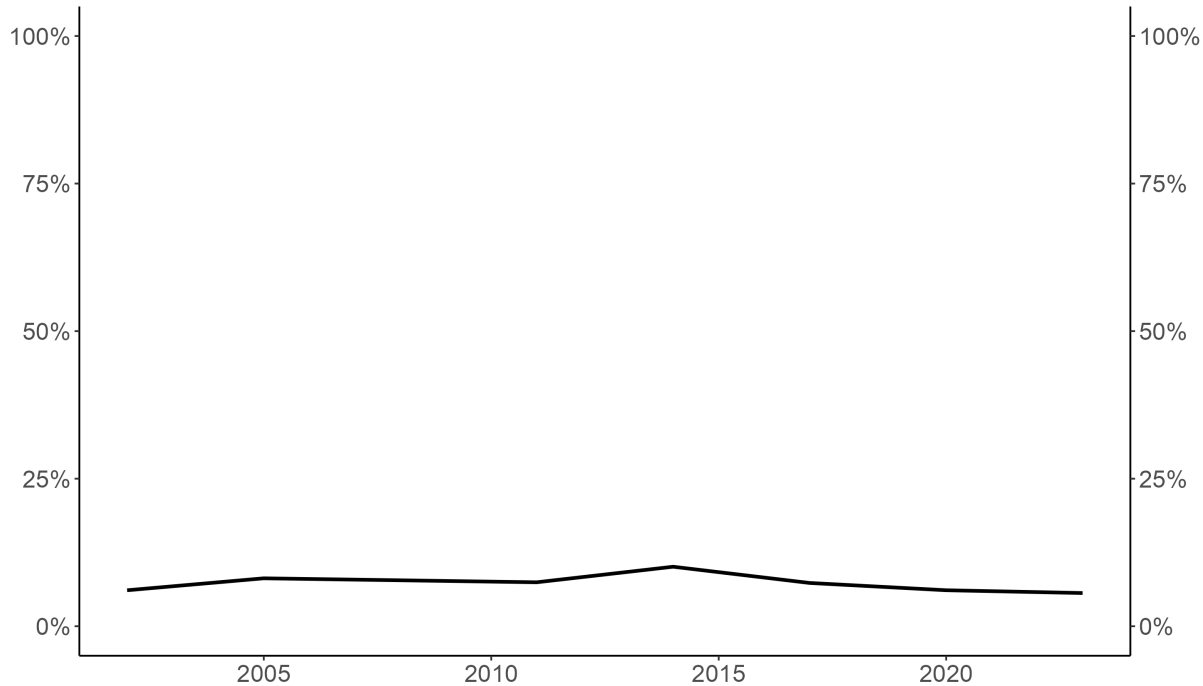
(a) **All volumes**



(b) **Institutional investors**

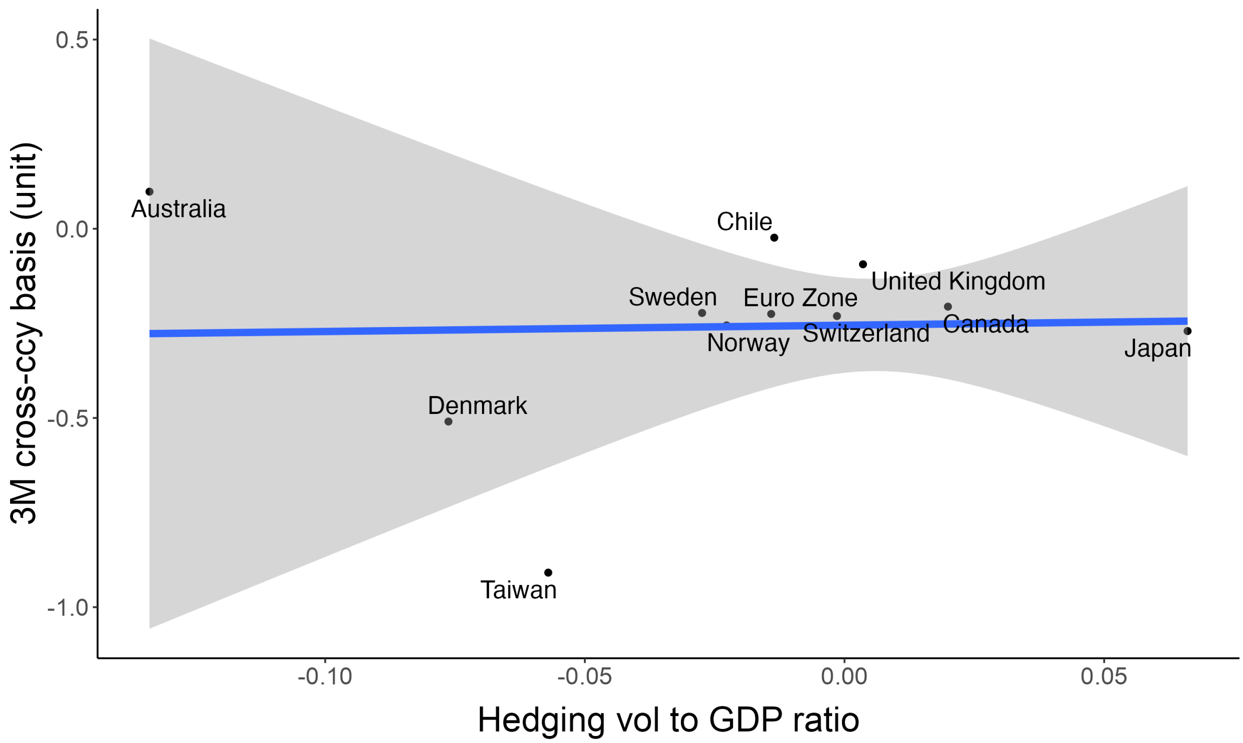
Notes: This figure plots the global daily volume of foreign exchange spot vs. forward and FX swaps transactions involving USD. Panel (a) shows the total market volume, and panel (b) shows the volume from transactions involving institutional investors. Daily volume is calculated as the average of all trading days in April of the survey year. The survey is conducted triennially from 2001 to 2022 by BIS.

Figure A4: **Share of non-forward, non-swap FX derivatives**



Notes: This figure plots the share of non-forward and non-swap derivatives in all FX derivatives. FX derivatives include in FX forward, FX swaps, FX options, FX futures, and other instruments. Daily volume is calculated as the average of all trading days in April of the survey year. The survey is conducted triennially from 2001 to 2022 by BIS.

Figure A5: **Cross-section of bank USD mismatch and cross-currency basis**



Notes: This figure plots each currency's time-series average of 3M IBOR cross-currency basis against the time-series average of on-balance sheet USD mismatch in banks with headquarter in the corresponding currency area. Sample period is 2010 July to 2020 September.

Table A1: **Summary of investment limits**

Industry	Region / Country	Limit on foreign investment (excluding real estate)
Insurance	Asia: Japan	None post-2012, 30% pre-2012
	Asia: Taiwan	65%
	Europe: Denmark	EIOPA risk weights
	Europe: Sweden	EIOPA risk weights
	ROW: Israel	None for countries rated A and above
Pensions	Asia: Japan	None
	Asia: Australia	None
	NA: Canada	None
	Europe: Denmark	None
	Europe: Netherlands	None
	Europe: Switzerland	30%
	ROW: Israel	None for OECD or countries rated at least BBB-
	ROW: Chile	80%

Notes: This table summarizes foreign investments limits on pensions and insurances in countries from which we obtain hedging information. Investment limits for pensions are obtained from OECD's Annual Survey of Investment Regulation of Pension Funds and Other Pension Providers (2021). Investment limits for insurances are extracted from laws and regulations governing insurers in Taiwan and Japan and from OECD's Review of the Insurance System (2011, Israel).

Table A2: **Correlation between GDP and banks' cross-country trading assets**

	Trading Assets			
	(1)	(2)	(3)	(4)
	Citi All	Citi Ex China	JPM All	JPM Ex China
GDP	0.073***	0.764***	0.419**	1.29***
	(0.013)	(0.110)	(0.091)	(0.230)
Year	Yes	Yes	Yes	Yes
Observations	120	115	100	95
R^2	0.03	0.27	0.20	0.28

Notes: This table reports the correlation between GDP and Citi's and JPM's (JP Morgan's) trading assets in reported geographies. Trading assets are measured in billions of USD and GDP is measured in trillions of USD. Sample period is 2018 to 2022, and measurement frequency is annual. Standard errors are calculated using Driscoll and Kraay (1998). *, **, *** denotes significance at the 10%, 5%, and 1% level, respectively.