NBER WORKING PAPER SERIES

DOLLAR ASSET HOLDINGS AND HEDGING AROUND THE GLOBE

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Working Paper 32453
http://www.nber.org/papers/w32453

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
May 2024

We thank William Diamond, Leonardo Elias (discussant) Narayana Kocherlakota, Ralph Koijen, Arvind Krishnamurthy, Karen Lewis, Olivia Mitchell, Robert Richmond (discussant), Nick Roussanov, Tom Sargent, Giorgia Simion (discussant), Emil Siriwardane (discussant), Adrien Verdelhan, Moto Yogo (discussant) and Tony Zhang (discussant) for helpful comments. We also thank seminar and conference participants at Baylor University, the Federal Reserve Board, George Washington University, MIT, Wharton, Bank of Canada Annual Economic Conference, Chicago Booth Asset Pricing Conference, the Fed Dollar Conference, NBER Insurance Spring Meeting, NBER Summer Institute IAP, OFR-Johns Hopkin Carey Finance Conference, and the Vienna FX Conference for helpful comments. We thank Zhiyu Fu, Srikkur Kanuparthy, Bailey Kraus, Simone Ricci, Laurenz De Rosa, Judy Yue, and Amy Zhang for outstanding research assistance. This research was funded in part by the Fama-Miller Center for Research in Finance at the University of Chicago Booth School of Business. All remaining errors are our own. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 32453
May 2024
JEL No. F3,G11,G20

ABSTRACT

We analyze a large number of industry- and company-level filings of global institutional investors to provide the first comprehensive estimate of foreign investors' U.S. dollar (USD) security holdings and currency hedging practices. We document four stylized facts. First, driven by increasing portfolio allocations, foreign investors expanded their USD security holdings six-fold over the past two decades. Second, following the 2007-09 financial crisis, foreign mutual funds, insurers, and pensions raised their USD hedge ratio by an average of 15 percentage points, despite higher hedging costs implied by large and persistent deviations from covered interest-rate parity. The total FX hedging demand from these sector reached $2 trillion in 2019. Third, there is considerable heterogeneity in hedging practice across countries and sectors. Fourth, the global banking sector provides limited dollar hedging on net, underscoring the important role non-banks play in fulfilling the hedging demand of foreign institutional investors. We employ a mean-variance framework to benchmark investors' demand for USD assets and currency hedging practice, emphasizing the influence of expected returns on optimal portfolio construction and the apparent divergence between model predictions and observed hedging behaviors. We show a strong correlation between hedging demand and the cross-section of CIP deviations.

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1 Introduction

The U.S. dollar is the predominant currency in cross-border security holdings, and foreign holdings of U.S. dollar (USD)-denominated securities have been steadily increasing. However, holdings of USD-denominated assets do not necessarily correspond to USD currency exposure because foreign investors can choose to hedge their USD-currency risk using foreign exchange (FX) derivatives. In this paper, we take a deep dive into a large number of industry- and company-level filings of global institutional investors to provide the first comprehensive estimates of foreign investors' USD security holdings and currency hedging practices. Our analysis distinguishes between the demand for USD-denominated assets and the demand for USD currency exposure, and sheds light on the economic drivers of currency risk management.

According to the triennial FX derivatives survey published by the Bank for International Settlements (BIS), the average daily turnover of FX derivatives reached $5.4 trillion in 2022, of which 88% of the total volume involved USD-linked currency pairs. If foreign investors want to hedge the currency risk in their USD investments, they have access to a large and liquid FX derivatives market. Yet very little is known about the actual FX hedging practice 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 (for example, Koijen and Yogo (2020)) or fully hedged for bonds but fully unhedged for equities (Camanho, Hau, and Rey (2022)). Models on the demand for safe assets generally do not separate the demand for USD exposure from the demand for the underlying assets (Jiang, Krishnamurthy, and Lustig (2021, 2023)).

One contribution of this paper is to collect data to paint the first systematic picture of

foreign holdings of USD securities and the associated FX hedging activities. Our estimation of foreign investors' USD securities holdings contrasts with what is available from centralized reporting systems such as Treasury International Capital (TIC). Whereas centralized reporting data typically focus on aggregated cross-border liabilities of the United States, we take a bottom-up approach to track holdings of USD assets by sector and relative to investors' portfolios.[1] In particular, 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. The combined foreign holdings across the seven major sectors that we cover amount to 75% of foreign holdings of U.S. assets from TIC, and about 60% of total foreign holdings of USD securities. We moreover construct a new dataset on foreign investors' FX hedging practice. There are no standard data sources on FX hedging activities across countries or sectors. We comb through company filings and industry statistics to generate the first by-sector and by-country account of foreign dollar holdings for mutual funds, insurance companies, and pension funds. We uncover about $2 trillion USD FX hedging positions outstanding from these three sectors by the end 2019. To complement our estimate of USD FX hedging demand, we furthermore estimate the supply of USD FX derivatives by banks from the BIS locational banking statistics. Our effort uncovers novel facts about foreign investors' holding and hedging of USD securities, providing new insights into the role of the dollar in international portfolio allocation.

Another contribution of this paper is to examine the drivers and implications of hedging using our unique data. Our starting point is the optimal portfolio choice of a mean-variance

[1]IMF's Coordinated Portfolio Investment Survey (CPIS) reports cross-border holdings of assets by country and offers industry breakdown in some instances. However, CPIS data are not ideal for our analysis for at least three reasons. First, CPIS' overall USD holdings are understated, because not all countries reporting to CPIS break out their cross-border portfolio holding by country, and because USD holdings need not be restricted to assets in the U.S. Second, many countries do not break out their U.S. investments by sector of holders. Third, there are no data on allocation or hedging.

investor, where we emphasize expected return as an important theoretical driver of hedging, in additional to the more commonly considered portfolio variance. We benchmark investors' hedging patterns against theoretical predictions and highlight notable deviations in the cross-section. We postulate that the substantial variation in hedging is an explanation for the cross-country difference in deviations from covered interest-rate parity (CIP). More broadly, by documenting correlations between the magnitude of CIP deviations and changes in hedging demand in the time-series and in the cross-section, we offer novel empirical evidence of financial intermediaries' limited risk-taking capacity.

After describing our data sources and methodology, we provide four stylized facts on USD holdings and hedging practices by foreign investors. First, we find that foreign investors significantly increased their preference for dollar assets over the past two decades. The size of foreign holdings of USD securities increased by six-fold from $5.5 billion in 2002 to about $33.4 billion in 2021. This is not simply a reflection of larger foreign wealth. Rather, foreign investors are tilting their portfolios toward USD securities. Compared to pre-GFC, mutual funds, insurance, and pensions increased the share of USD securities in their overall portfolios by 7.7 percentage points post-GFC, and increased the share of USD securities in their non-domestic investments by 6.6 percentage points.

Second, the large increase in USD security holdings does not fully translate into a rise in the USD currency exposure. Foreign investors, especially those in actively managed industries, hedge a substantial amount of their USD currency risk post-GFC. The hedge ratios for insurance companies, pension funds, and mutual funds were 44%, 35%, and 21%, respectively, as of 2020. The total hedging demand from these three sectors alone amounted to almost $2 trillion per annum. These investors' hedge ratios were on average 14.7 percentage points higher post-GFC than pre-GFC. This new hedging regime developed despite elevated

and fluctuating deviations from CIP, which increased the cost of hedging. In fact, the amount of foreign investors' hedging activities tends to be higher when deviations from CIP are also wider. We calculate that the cost of hedging due to short-term CIP deviation averaged $2.7 billion per annum between 2017 and 2020 for the insurance and pension industries.

Third, we document that hedge ratios exhibit considerable heterogeneity. This heterogeneity manifests across geographies and between security types. The level of hedge ratio spans a wide range even within the same sector. More systematically, investors tend to hedge USD bonds at higher ratios than they hedge equity, consistent with the predictions of Campbell, de Medeiros, and Viceira (2010) based on an analysis of minimizing portfolio volatility.

Fourth, there is also considerable cross-country heterogeneity in banks' supply of FX hedges. On net, the banking sector supplies only a small fraction of the total dollar hedging position demanded by foreign institutional investors, which implies that other non-banks must play an important role in meeting the demand of dollar hedging by foreign mutual funds, pensions, and insurance companies. In other words, although banks are the direct counterparty to institutional investors who demand FX hedging, banks may not be the ultimate bearer of the FX risk.

To investigate the drivers of foreign USD holdings and hedging, and the implications of hedging on FX derivatives pricing, we model the two sides of the FX derivatives market. In the model, the demand for FX hedging comes from mean-variance foreign investors' optimal portfolio allocation. The investor's problem can be thought of allocating a portfolio over the local-currency risk-free asset, a risky USD asset, and the short-term FX forward to hedge USD currency risk. We show that under general conditions, the optimal hedge ratio increases with respect to the volatility of FX risk, the covariance between FX risk, and the level of U.S.

asset return. Furthermore, the optimal hedge ratio is affected by deviations from uncovered interest rate parity (UIP) and CIP. In particular, the optimal hedge ratio decreases in the expected return on the FX trade of going long USD and short the local currency, or the UIP deviation, and decreases in the additional cost of hedging USD back to the local currency beyond the interest rate differential, or the CIP deviation. Finally, the model also implies that USD holding and the optimal hedge ratio both increase in the excess return on the U.S. asset over the U.S. risk-free rate, all else being equal.

After deriving the drivers of optimal hedging in the canonical mean-variance model, we compare predictions of these drivers with the data. In the time series, the rise in the hedge ratio is consistent with a rising expected return on the U.S. asset and rising USD allocation. However, in the cross section, using a panel regression with industry fixed effects, we see that the regression coefficients of hedge ratios on the expected FX returns, the covariance between FX and U.S. asset returns, and the cross-currency basis all bear the opposite sign from mean-variance predictions. The divergence between theory and data suggests the limitation of the mean-variance model in explaining the cross-sectional variations in FX hedging demand, especially under the assumption of common risk aversion across countries. We discuss possible additional drivers for hedging demand, including liquidity preferences, which has potential to reconcile the cross-country pattern in FX hedging.

On the supply of FX hedging, we model an intermediary sector that provides FX hedging services subject to balance sheet constraint. Due to the balance sheet constraint, the intermediary charges the CIP deviations as the cost of providing hedging services, and such cost rises as more hedging services are provided, similar to Ivashina, Scharfstein, and Stein (2015). This model of constrained intermediary delivers the prediction that the hedging cost rises in the hedging demand. Moreover, because the intermediary's balance sheet is seg-

mented across currencies in the spirit of Siriwardane, Sundaram, and Wallen (2022), shocks to local hedging demand explain the cross-sectional variations in the CIP basis. Consistent with this prediction, we show for each of our sample currencies that, its aggregate hedging demand, normalized by GDP, is strongly and negatively correlated with its average 3-month CIP basis. The cross-sectional R-squared of the relationship is equal to 0.77.

Our paper augments the broad literature that studies institutional investors' portfolio allocation. Compared to previous works that consider variance-covariance hedging motives in currency hedging, for example, Campbell and Viceira (2002) and Campbell, de Medeiros, and Viceira (2010), our model highlights the additional impact of UIP and CIP deviations on the FX hedging decision. Moreover, we are able to use data to highlight where investors' behavior align versus diverge from theoretical predictions. By studying different types of non-US investors' preferences for USD assets, we complement existing studies that consider portfolio allocation by public investment funds (e.g., Mitchell, Piggott, and Kumru (2008), Lucas and Zeldes (2005)), that study the currency composition of mutual funds' portfolios (e.g., Maggiori, Neiman, and Schreger (2020)), that look at portfolio allocation of institutional investors in Europe (e.g., Faia, Salomao, and Veghazy (2022), that examine global investors' preferences for sovereign debt (e.g., Fang, Hardy, and Lewis (2022)), that investigate US investors' currency hedging of non-USD exposures (e.g., Sialm and Zhu (2022)), and that documents investors' home bias when deciding to invest abroad (e.g., French and Poterba (1991))

In addition, our paper complements the active literature on CIP deviations. CIP deviations have drawn much academic attention because their presence and magnitude indicate that intermediaries' regulatory constraints affect asset prices (Du, Tepper, and Verdelhan (2018), Du, Hébert, and Huber (2022)). This paper illuminates two important outstanding

questions. First, we show that CIP deviations impose significant direct financial cost to investors seeking to hedge their USD assets.[2] Second, we show that investors' hedging demand offers an explanation for the cross-sectional variations in the CIP basis. The cross-sectional difference in CIP deviations is puzzling in a world where intermediaries arbitrage across markets. We make progress by introducing hedging supply from an intermediary with segmented balance sheets, which reconciles the positive correlation between hedging activities and magnitude of the CIP deviations.[3] In considering hedging demand as a driver for the cross-section of CIP deviations, we build on Borio et al. (2016), which argues that the hedging demand from banking sector helps explain variations in CIP deviations in eight advanced economies. By enriching the estimate of hedging demand with data from mutual funds, insurance, and pensions, we account for the cross-section of CIP deviations in a much wider set of countries, including emerging economies. Our results highlight that hedging demand does not originate solely from banks but can arise from institutional investors. Shocks to this hedging demand can move FX prices, underscoring intermediaries' limited risk-taking capacity, which in turn has implications for asset prices beyond the FX market (An and Huber (2024)).

Our paper is directly connected to the growing literature that attempts to estimate the impact of asset demand on exchange rates. Recent work by Liao and Zhang (2020), Bräuer and Hau (2022), and Ben Zeev and Nathan (2022b) present evidence that hedging demand affects exchange rate determination and CIP deviations. Our empirical estimates of currency hedge ratios can help improve the estimates of the FX exposure and hedging demand

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

[3]Diamond and Van Tassel (2021) resolves the cross-section of CIP basis using market-specific option-implied box-rate. Their results similarly imply market segmentation. Our results posit hedging as a reason why intermediaries within each market become differentially constrained.

associated with foreign asset demands. Furthermore, the heterogeneity in asset demand across different sectors across foreign investors can improve estimations of the demand-system based asset pricing models where foreign investors are often treated as a homogeneous group (for example, Koijen and Yogo (2020)).

Finally, our paper contributes to the large literature on dollar safe assets (for example, Caballero, Farhi, and Gourinchas (2017); Gourinchas, Rey, and Sauzet (2019); Jiang, Krishnamurthy, and Lustig (2021); Eren and Malamud (2022)). Theories have examined how a deep and liquid U.S. Treasury and corporate bond market contributes to dollar's sustained dominance (He, Krishnamurthy, and Milbradt (2016); Coppola, Krishnamurthy, and Xu (2023)). The rise in the currency-hedged USD allocation suggests that the characteristics of the USD currency returns is not the sole driver of foreign demand for USD assets. Instead, we underscore that a higher expected return on the USD assets beyond the expected return on currency as a more fundamental driver of foreign investors' ever-higher allocation to USD securities.

Our paper is organized as follows. Section 2 describe our data sources and estimation methodology. Section 3 discusses four stylized facts on foreign USD holdings and hedging practices. Section 4 rationalizes the observed patterns using a mean-variance optimizing agent's portfolio allocation when facing a constrained intermediary. Section 5 concludes.

2 Methodology and Data Construction

We now describe our methodology in constructing the three types of data used in our analysis. We first outline how we estimate foreign holdings and hedging of USD securities, and we refer the reader to Appendix A for details. We then define deviations from covered interest-rate parity (CIP). Finally, we discuss how we use data from the BIS to infer the dollar funding

gap.

2.1 Estimating Foreign Holdings and Hedging of USD Securities

We estimate foreign holdings and hedging of USD securities from two complementary angles. On the one hand, we leverage TIC and BIS statistics to obtain 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 in seven large sectors and use portfolio-level data to estimate the FX hedging done in three actively managed industries.

2.1.1 Overall Foreign Holdings of USD Securities

We start with available estimates of holdings of U.S. securities and make several adjustments to arrive at USD securities holdings. First, securities issued by U.S. residents could be denominated in currencies other than USD. We therefore subtract off the non-USD issuance by U.S. residents from foreign investors' U.S. holdings. Second, focusing on U.S. issuers misses the potentially substantial amount of USD securities issued by issuers domiciled outside of the U.S. This is particularly relevant for debt securities, as all U.S. equities are denominated in dollars, and equities listed in foreign countries are largely denominated in foreign currencies. We therefore augment our estimate with foreign holdings of USD debt from non-U.S. issuers.

More specifically, our estimation is equal to:

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).

We use the annual reporting from the TIC system to inform foreign holdings of U.S. securities, and we use the international debt securities statistics published by the Bank for International Settlements (BIS) to estimate non-US issuance of USD securities. Details of the estimation procedure are in Appendix Section A.1.

2.1.2 Sector-Specific USD Security Holdings and Hedging

We identify seven sectors with significant investments in USD securities, and we exploit a large collection of sources to estimate country-sector-specific portfolio allocations to 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. One potentially significant source that we do not capture is separately managed accounts of institutional investors and high-net-worth individuals.[4]

Among the seven sectors we study for USD security holdings, we focus the analysis of hedging activities on three sectors that employ active hedging strategies: insurances, pensions, and mutual funds. We assume full FX hedging for the banking sector because unhedged

[4]High-net-worth individuals command a staggering amount of wealth. Forbes estimates that the total amount of wealth owned by non-US billionaires is $8T in 2022. However, much of their wealth is typically tied to the stocks of their own companies.

FX positions are associated with hefty regulatory capital charge. We also no hedging by the official sector, as one important objective of FX reserve management is to keep enough foreign currency liquidity for balance of payment needs and potential FX interventions.[5] In contrast to approximately full FX hedging by banks and approximately no FX hedging by the official sector, currency hedging by insurances, pensions, and mutual funds likely reveals investor preferences for FX risk exposure. Mutual funds are not mandated to maintain a certain amount of FX exposure but they choose hedging strategies to attract investors with specific degrees of FX risk tolerance. Pensions and insurances generally have long-dated liabilities in local currency, which can drive additional FX hedging demand beyond the usual risk and return trade-offs.[6]

In Table 1, we summarize the currency areas and sectors included in our analysis and the main data sources. Details of our estimation are in Appendix Section A.2. Below, we briefly outline our approach, starting with the insurance industry. In currency areas such as Japan and Taiwan, insurance is a major holder of investment securities because insurance products can be purchased as retirement savings vehicles. For Japan, we hand-collect statutory filings since 2004 from all active insurers. For Taiwan, we locate physical copies of the Central Bank of Republic of China's monthly publication on life insurers, and we complement these aggregate statistics with information from the annual reports of the 6 largest Taiwanese life insurers. Northern European insurers also have outsized importance relative to the local economy. We source statistics on Danish and Swedish

[5]The official sector's holdings can also include holdings by sovereign wealth funds. Scant information is available on the currency hedging practice of the sovereign wealth fund. However, we know that the largest sovereign wealth fund in the world, the Norwegian Sovereign Wealth Fund, does not hedge FX risk on its foreign currency investments (Du and Viceira (2024))

[6]Pensions and insurances can also face foreign investment limits, above which further investments must be hedged back to domestic currencies. In Table A1, we summarize the foreign investment limits on pensions and insurances whose hedging strategies we study. At a glance, these limits seem generous and unlikely to be dictating pensions' and insurers' hedging decision.

insurers from their respective central bank. We further obtain aggregate information on all insurers in the EU and the European Economic Area through the European Insurance and Occupational Pensions Authority (EIOPA). Finally, we collect information on Israeli insurers using monthly statistics from the Bank of Israel. For all insurers, we assemble information on their overall portfolio size and their USD security holdings.[7] For all but EIOPA insurers, we are able to obtain information to estimate the insurer's USD hedge ratio: the share of USD investment whose FX risk is hedged.

For the pension sector, we identify countries whose pensions have the largest investment portfolios (OECD (2020)) and study each in detail. The top six non-US countries: the U.K., the Netherlands, Australia, Canada, Switzerland, and Japan, can be grouped based on their industry structures. Japan, the Netherlands, and Canada have highly concentrated pension markets, so we directly analyze filings from the largest pension funds in these markets. The pension industries in Australia, Switzerland, and the U.K. are much more fragmented, so we analyze various industry-level statistics compiled by industry groups or national authorities. Apart from these six countries, we also include in our sample pensions from Denmark, Sweden, Israel, Chile, and 9 other mostly Latin American countries where pensions are important relative to the size of the local economy. Similar to insurance, we gather information on the total portfolio size and total USD investments of pensions in each country. We are able to estimate the USD hedge ratio for all pensions in the sample except for those in the UK and several Latin American countries.

We study foreign mutual funds' allocations to USD by using a data set of holdings from open-ended funds and exchange-traded funds (ETF) domiciled in 64 non-US countries.

[7]For both insurances and pensions, when information is only available for total foreign investment, we estimate the share of foreign investment that is denominated in USD using a variety of methods, including calculating the share of USD investments in representative firms and leveraging relevant academic studies. For EIOPA, total USD investment is conservatively estimated as investment in the U.S.

Our security-level data are from Morningstar and are similar to data used in Maggiori, Neiman, and Schreger (2020) and Coppola et al. (2021). We estimate USD bond holdings by aggregating bond securities denominated in USD, and estimate USD equity holdings by obtaining each fund's share in U.S. equity. We assess the hedging strategy of mutual funds at the share-class level. Specifically, we estimate mutual funds' USD hedge ratio using a combination of share-class disclosure (e.g., hedging status is "completely hedged") and benchmark choice (e.g., "U.S. Corporate Bond EUR Hedged").

Finally, we estimate the aggregate foreign holdings of USD securities by Banks, Hedge funds, Non-financials, and the Official Sector. To estimate holdings of USD securities by non-US banks, we use BIS Locational Banking Statistics (LBS). We focus on non-US banks' USD debt holdings,[8] and estimate it to be the difference between foreign banks' total USD assets and USD loans, with an adjustment factor applied. Our estimated series has a 0.98 correlation with LBS' confidential series on non-US banks' cross-border holdings of USD debt securities.[9] To estimate non-US hedge funds' investments in U.S. equities, we leverage 13F reporting requirements, whereby institutional investment managers with at least $100 million in assets under management (AUM) must disclose their equity holdings quarterly. For non-financials, we conservatively estimate foreign non-financial companies and households' USD holdings by using the IMF's Coordinated Portfolio Investment Survey (CPIS) data. Of the 81 countries reported as having assets in the United States, 56 countries report their investment separately for the non-financial sector. Finally, we estimate the foreign official sector's holdings of U.S. securities from TIC. Our assumption is that the official sector —

[8]We focus on holdings of debt securities by banks because these — along with loans — make up the preponderance of a typical bank's assets. It is much more capital intensive for banks to hold equity securities.

[9]This time series is confidential and available only to central banks. This information cannot be deduced from United States' reporting to the BIS because the U.S. reports only U.S. banks' loan and deposit positions and does not include debt securities positions.

central banks, sovereign wealth funds, and other public financial agencies — do not obtain significant USD assets from non-US entities.

2.2 Deviations from Covered Interest-Rate Parity

We measure the degree of deviations from covered interest-rate parity (CIP) using cross-currency basis, henceforth, CIP basis. Following convention (e.g., Du, Tepper, and Verdelhan (2018)), we define $X^{c,\$}_{t,\tau}$, the τ-month tenor CIP basis of foreign currency c vis-à-vis the USD as

$$X^{c,\$}_{t,\tau} = \frac{R^{\$}_{t,\tau}}{R^{c}_{t,\tau}} \left(\frac{F_{t,\tau}}{S_t} \right)^{\frac{12}{\tau}} - 1, \tag{1}$$

and the log version as $x^{c,\$}_{t,\tau} = \ln\left(1 + X^{c,\$}_{t,\tau}\right)$. We use $R^{c}_{t,\tau}$ to denote the annualized spot gross τ-month risk-free interest rate in foreign currency c available at time t, and $R^{\$}_{t,\tau}$ for the corresponding interest rate in USD. We express exchange rates in units of foreign currency per USD. That is, an increase in the spot exchange rate at time t, S_t, is a depreciation of the foreign currency and an appreciation of the USD. The τ-month forward exchange rate at time t is $F_{t,\tau}$.

The classic CIP condition is that $x^{c,\$}_{t,\tau} = X^{c,\$}_{t,\tau} = 0$, which occurs when the forward exchange rate is priced based on the interest rate differential. The more negative the cross-currency basis, the more expensive it is to hedge USD exposure for non-US investors. To see this, if the cross-currency basis $x^{c,\$}_{t,\tau}$ is negative, then the forward exchange rate is priced too low relative to the prevailing interest rates, or the risk-neutral fair value of the derivative. For foreign investors to hedge their USD exposure, they need to sell USD forward in exchange for their local currency using the FX forward. A lower forward exchange rate thus translates to more expensive FX hedging.

We measure R using IBOR in different countries, and focus on the three-month tenor

because the prevailing hedging practice is to continuously roll over short-term hedges. We obtain daily data on IBOR and spot and forward FX rates from Bloomberg using London closing rates.

2.3 Supply and demand of FX Hedging from Banks

The dollar hedging demand from mutual funds, insurances and pensions is partially met by the supply of FX hedging from the banking sector. The banking sector can serve as the intermediary for FX hedging by matching dollar hedging demand from institutional investors with dollar hedging supply from customers in other sectors, such as hedge funds and non-financial corporations. When the dollar hedging supply from customers does not meet the dollar hedging demand from institutional investors, the banking sector can function as a net provider of dollar hedges by borrowing dollars in the cash market and lend dollars in the FX swap market. In addition, the banking sector might also use FX swaps to fund their own dollar assets and on net demand synthetic dollar funding in the FX swap market. Even though we do not observe hedging supply by other non-bank customers, we can use the BIS banking statistics to estimate the overall net dollar hedging supplied and demanded by banks in different countries.

Following the approach by Borio et al. (2016) and Borio et al. (2018) and adapting to the enhanced BIS banking statistics, we define the "dollar funding gap" of non-U.S. banks as the difference between the on-balance-sheet dollar assets and on-balance-sheet dollar liabilities. We assume that non-U.S. banks use FX derivatives to cover this difference. In other words, facing a positive dollar funding gap, the bank borrows dollars in the FX swap market on net; conversely, facing a negative dollar funding gap, the bank lends dollars in the FX swap market on net.

To estimate non-U.S. banks' dollar funding gap, we use the BIS Locational Banking Statistics (LBS). LBS reports local and cross-border positions for all banks located in a particular country (residency-based definition) or all bank branches whose headquarter is in a particular country (nationality-based definition). Following Borio et al. (2016), we prefer the dollar funding gap at the bank nationality level, which allows banks to use their global business operations to manage their FX exposure. The nationality-based, consolidated statistics is available for Canada, Japan, Sweden, Switzerland, the United Kingdom, and six countries in the EU (Belgium, France, Germany, Italy, Netherlands, Spain). For those countries where the consolidated statistics is not available, we use the funding gap measured by residence as a proxy.

Banks in the U.S. are uniquely positioned to provide USD funding as they have access to a broad U.S. deposit base. For the U.S. banks, we follow a similar methodology and infer their net dollar lending as the difference between foreign-currency assets and foreign-currency liabilities on their balance sheets. The assumption is again that any open on-balance-sheet FX position needs to be hedged by FX derivatives off balance sheet. Therefore, if a U.S. bank has more foreign currency assets than foreign currency liabilities on balance sheets, it implies that the bank is on net borrowing foreign currency and lending dollars in the FX swap market. One data caveat is that unlike other BIS reporting countries, the US only includes cross-border loans and liabilities in its BIS statistics. Therefore, the implied FX swap positions of U.S. banks do not take into account banks' foreign currency securities holdings or any local positions in foreign currencies. If U.S.-based banks do hold material foreign currency securities cross border, but have negligible local positions denominated in foreign currencies, then our methodology would underestimate the amount of FX hedging provided by U.S. banks.

2.4 Other data and sample currencies

We include several other data series to contextualize the foreign USD holdings and hedging data we constructed. From BIS, we obtain the Triennial Central Bank Survey on Foreign Exchange and Derivatives Market Activities from 2001 through 2022, as well as the Debt Securities Statistics. From the World Bank, we obtain the public stock market capitalization. From Preqin, we obtain the AUM by U.S. and global private equity funds. From SIFMA, we obtain the amount of outstanding debt securities in the U.S., which is compiled from data from Bloomberg, the Federal Reserve, US Agencies, and the US Treasury.

Finally, from Bloomberg we obtain historical yields on the generic ten-year government bond yield and the major equity index in the U.S. and 12 other countries and regions. We use these data and the FX market data from Bloomberg to study the historical correlations between asset returns and currency returns. The 12 currency areas that we study 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 12 currency areas form the core of our sample because we are able to obtain for each, hedging data in mutual funds and at least one of insurance or pensions. Our coverage includes 9 advanced economies and 3 emerging economies.

3 Stylized Facts on Foreign USD Holdings and Hedging

In this section, we present three stylized facts on foreign investors' aggregate dollar holdings and currency hedging patterns.

Fact 1: Foreign investors show increasing preference for USD securities.

Figure 1 shows that foreign holdings of USD securities reached $33.4B by the middle of 2021. Our estimate is higher than the comparable estimate from TIC because we include the substantial USD debt issued by non-US residents. Our estimate is also nearly double the comparable estimates from CPIS, which relies on reporting countries to break out their cross-border holdings either by country or by currency. We estimate that the overall foreign holdings of USD securities grew six-fold since the start of our analysis period in 2002 ($5.5B). This dramatic increase happened over a period where world GDP (ex-US) expanded less than three times.

The rise in the foreign holdings of USD securities is broad based across security types and investor types. As illustrated in Figure 2, foreigners increased their holdings of both USD bonds and equities over our sample period. In the aggregate, foreigners hold about two thirds of their USD securities in bonds and one third in equities (Panel (a)). Foreigners' holding of USD bonds makes up a larger share of the total amount of USD bonds outstanding compared to the share of USD equities held by foreigners (Panel (b)).[10] From Panel (b), we further see that, in both equities and bonds, foreign holdings make up an increasingly large share of the total amount outstanding. This increase is in part driven by foreigners' growing preference for dollar assets.

In Figure 3, we illustrate the portfolio allocation to USD securities in three industries over time, where portfolio allocation is defined as the ratio of USD bonds and equities to total asset.[11] Panel (a) explores this allocation in the insurance industry. Total USD allocation by

[10] We estimate total outstanding USD debt as the sum of outstanding US fixed income securities and USD cross-border debt issued by non-US residents. We estimate the total amount outstanding equities to be the sum of the market cap of U.S. listed stocks and AUM of U.S. private equity funds.

[11] In particular, our definition of allocation to USD securities does not include investments in real estate and infrastructure. Anecdotally, the share of USD real estate and infrastructure has also been rising, leading

insurers in Japan, Taiwan, and Israel all show a marked increase after the Financial Crisis of 2007-09. Insurers in Taiwan, in particular, are allocating close to 50% of their portfolio to USD securities in recent years. The allocation to USD by insurers in the UK and EU regions (under the supervisory authority of EIOPA) are much lower: by the end of 2020, allocation to USD bond and equity is 16% in Sweden, 14% in Denmark, 12% in UK, and a little under 4% in all other EU countries. The lower allocation to USD reflects EU insurers' preference for euro-denominated assets. Indeed, insurers in the 19 Eurozone countries[12] have only about 17% of their portfolios in assets from countries outside of the Eurozone.

Panel (b) of Figure 3 shows portfolio allocation to USD bonds and equities by pension funds. Almost all pension funds in the data have a marked increase in their portfolio share of USD assets.[13] By 2021, pensions in Canada, Japan, the Netherlands, Chile, and Australia all had more than 20% of their total assets in USD securities. Notably, the share of USD securities in Dutch pensions is around 30%. This stands in contrast to insurers in the Eurozone, who strongly favor euro-denominated assets.

Non-US mutual funds' total USD allocations are shown in panel (c). In aggregate, equity mutual funds increased their USD allocation from 6% in September 2007, on the eve of the financial crisis, to 21% in September 2020. Similarly, fixed income mutual funds increased their USD allocations from 13% just before the financial crisis in 2007, to 27% in September 2020.

We analyze USD allocation in foreign private investors' overall portfolios and their foreign portfolios in Table 2. Columns (1) and (2) examine the gross USD allocation by insurers,

to an even higher overall portfolio exposure to USD assets.

[12]Croatia adopted the euro on January 1, 2023. Because our data ends in June 2021, Croatia is not considered a Eurozone country.

[13]The only exceptions are the U.K., which shows a mild decrease in allocation post the Financial Crisis of 2007-09; and Chile, which significant reduced its USD exposure in 2018 and 2019 but increased its dollar holdings again starting in March 2020.

pensions, and mutual funds in our 12 sample currency areas (9 advanced economies and 3 emerging economies, see Section 2.4). From Column (1), we see that post-GFC, investors on average increased their portfolio allocation to USD securities by 7.7 percentage points. From Column (2), the linear trend in investors' total USD allocation is highly statistically significant with an average growth of 0.23% per quarter. Furthermore, investors' increased USD allocation is not simply a reflection of diminished home-bias. Looking at Columns (3) and (4), investors increased USD holdings as a share of their foreign investment. On average, the share of USD securities in investors' foreign portfolio is about 6.6 percentage point higher post-GFC, and again, there is a linear trend, albeit with a flatter slope compared to the growth in gross USD allocation.[14]

Fact 2: There is substantial amount of hedging in actively-managed industries post-GFC despite rising hedging cost.

Foreign investors have large and rising holdings of USD assets, but they do not necessarily want to take all the USD currency risk associated with their holdings. As of June 2020, we estimate that the hedge ratio for insurance, pensions, and mutual funds was 44%, 35%, and 21%, respectively. Collectively, hedging demand from these three sectors was over $2 trillion. Figure 4 illustrates this snapshot of hedging practices.

Table 3 examines the general trend in FX hedging using our micro data. The unit of observation in these regressions is currency-industry-time. Columns (1) and (2) show that the hedge ratio, or the share of investors' USD securities that is FX hedged, increased post-GFC. After controlling for industry by currency fixed effect, post-GFC hedge ratios increase

[14]In Appendix Figure A1, we plot the share of USD bonds in global bond market and the share of US equity in global equity market. Neither share significantly increased post-GFC relative to pre-GFC, which suggests that the increase in foreign investors' allocation to USD securities cannot be fully explained by the increase in the relative supply of USD securities.

by about 14.8 percentage points on average. Investors' increased hedging activities are corroborated with aggregate data on FX derivative trading. In Appendix Figure A2, we plot the daily average turnover in FX markets using the BIS Triennial Central Bank Surveys. Transactions in FX forward and FX swap that have USD as one of the two transacting currencies have been steadily increasing between 2001 and 2022, outpacing the increase in spot transactions. In particular, this trend holds within the sample of FX derivatives transactions where one party is an institutional investor. Transactions by institutional investors most closely relate to hedging activities from insurance, pensions, and mutual funds.[15]

However, we note that despite the large increase in investors' hedging tendency, investors' dollar exposure rose. Column (3) of Table 3 shows that investors' unhedged USD allocation, or their dollar exposure, went up by 6.6 percentage points post-GFC. In other words, the increase in hedge ratio tempered but did not neutralize the growth in investors' FX exposure due to their higher total USD allocation (Column (2) of Table 2).

Interestingly, investors' FX hedging is more concentrated when the cost of hedging is high. FX hedging is predominantly done through FX forwards or FX swaps. The CIP condition governs the pricing of these FX derivative contracts in a risk-neutral no-arbitrage world. CIP held before the Financial Crisis of 2007-09. Since then, deviations from CIP have been large and fluctuating. The more negative the CIP basis, the more costly it is to hedge USD proceeds back to domestic currency. Yet hedge ratio loads negative on the 3-month cross-currency basis (Column (4) and (5)). This positive correlation between the hedge ratio and the cost of hedging (negative correlation between the hedge ratio and CIP basis) suggests that institutional investors' hedging demand is not completely deterred by

[15]BIS uses the label "institutional investors" to mean "such as mutual funds, pension funds, insurance and reinsurance companies and endowments. Primary motives for market participation are to trade FX instruments eg for hedging, investing and risk management purposes. A common label for this counterparty category is 'real money investors'." BIS (2022)

the rising hedging cost[16] and that there could be substantial financial cost to hedging.[17]

We estimate the total hedging cost as the product as hedging volume and the negative of CIP basis.[18] Overall, for just the pensions and insurers in our sample, the total hedging cost due to CIP deviations amounted to \$2.1-\$4 billion during 2017-2020. The average annual hedging cost over these four years is about \$2.7 billion, which is about 0.1% of all the USD securities that these two sectors manage.[19] We note that our estimates use the CIP deviations implied by Bloomberg quotes. In practice, market power of dealers can make clients pay more than the inter-dealer spreads in the FX derivatives market (Hau, Hoffmann, Langfield, and Timmer (2021)). Our estimates may therefore underestimate the actual cost of financial hedging.

Fact 3: Hedging behaviors exhibit heterogeneity across geographies.

While most countries and sectors have been increasing their hedge ratio, there is considerable heterogeneity in the level of hedge ratios. This heterogeneity manifests across currencies and sectors, as well as between bonds and equities.

Table 4 reports the snapshot of the USD security holdings and hedging at the end of

[16]Investors are not moving away from FX forward and swaps to other FX derivatives because of larger CIP deviations. In Appendix Figure A4, we plot the share of non-forward and non-swap FX derivatives as a share of all FX derivatives, and find that this share has been stable. If anything, this share has been decreasing since 2013.

[17]Investors' rising hedging activity cannot be fully explained by regulatory requirements regarding currency risk management. Mutual funds generally do not face regulations curtailing their FX exposure. In Appendix Table A1, we summarize the foreign investment limits for pensions and insurers whose hedging activities we study. Most countries in our sample do not impose investment limits on dollar securities.

[18]Specifically, we use the quarterly snapshot of hedging volumes and quarter-average of daily CIP 3M basis. The use of 3M IBOR CIP basis in this calculation assumes that investors use short-term forwards to hedge and continuously roll over these short-term hedges, which is consistent with industry practices.

[19]For the purpose of calculating the cost of hedging, we assume that countries other than Denmark and Sweden but are covered by EIOPA hedge at the industry average. Similarly, we assume that pension in the U.K. hedge at the industry average. For insurers in the U.K., we estimate the cost of hedging using the 2016Q1-2020Q4 average hedge ratio estimated by Czech et al. (2022).

2019. We see that the average hedge ratio across mutual funds, pensions and insurances ranges from 10% for Canada to 57% for Denmark. Figure 5 illustrates the time-series of hedge ratios in each industry. Even within the same industry, hedge ratios span a wide range across countries. This is particularly pronounced in pensions (Panel (b)), where hedge ratios can be as low as 5% in Japan, and as high as 80% in Denmark. Mutual funds (Panel (c)) has the smallest range, but hedge ratios still varies from near 0% to almost 30%. One potential explanation for this disparity is that different investors have different mixes of USD bond vs. equity, and hedge different types of securities differently.

Campbell, de Medeiros, and Viceira (2010) suggest that investors in advanced economies should hedge bonds at greater proportions than equities. Although most investors in our sample do not breakout hedge ratio separately for bonds and equities, we do find suggestive evidence supporting the prediction of Campbell, de Medeiros, and Viceira (2010) among those investors that do report this breakdown. In Figure 6, we show that fixed income mutual funds hedge at substantially higher hedge ratio than equity mutual funds (Panel (a)), and Australian and Dutch pensions also hedge their bonds at a higher ratio (Panel (b)).

Fact 4: Major banking sectors on net provide dollar FX hedging

Table 4 reports the dollar FX hedges supplied by banks, as estimated according to the methodology in Section 2.3. A negative (positive) number suggests that banks on net supply (demand) dollar hedges. We can see large heterogeneity in banks' business models. Japanese banks stand out in terms of positive net demand for FX swaps. In contrast, banks in Australia, the euro area, the UK and the US are net suppliers of FX swaps.

We can moreover see that the total net supply of dollar hedges from banks in our sample

amounts to only $333 billion. By comparison, the total dollar hedges demanded by mutual funds, pensions and insurance countries amount to about $2 trillion. Given that the dollar hedging demand from institutional investors significantly exceeds net dollar hedges supplied by banks, our result indicates an important role for other non-banks to ultimately provide global dollar funding and thereby supply dollar FX hedges.

4 FX hedging: theory and practice

Foreign investors show increasing preference for dollar-denominated securities and they hedge a substantial amount of their USD FX exposure. Moreover, USD hedging has increased post-GFC despite rising hedging cost and hedging practices exhibit considerable heterogeneity across countries. In this section, we model the market for FX hedging as a canonical mean-variance investor that demands FX hedges on the one side, and a constrained financial intermediary that supplies FX hedges on the other side. Our model could generate the broad pattern of rising holdings and hedging of USD securities, as well as the positive correlation between CIP deviations and hedging in the time-series. Our model moreover has predictions of FX hedging and CIP deviations in the cross-section. We take these predictions to data to study the drivers of hedging and the impact of hedging on CIP deviations.

4.1 Investor's problem

We start by studying a mean-variance investor who allocates his portfolio between a local risk-free asset and a USD asset while taking the price of all assets as given. The foreign investor has a portfolio of size $A_{i,l}$, where i indexes type, e.g., pension, and l indexes currency, e.g., JPY. Because each investor solves his unique portfolio allocation problem, we drop all investor subscripts in this section. The investor chooses the share of his portfolio invested

in the USD asset, and decides whether to take the currency risk associated with the USD asset.

We denote the log return on the local risk-free asset as rf. The log return on the USD asset measured in dollars is given by $r^{\$}_{t+1}$, referred to as the "U.S. asset return", and the USD risk-free rate is given by $rf^{\$}_t$. The foreign investor cannot directly earn $r^{\$}_{t+1}$, and the return in her local currency on holding the USD asset depends on her currency hedging strategy. If the foreign investor does not hedge the currency risk, the unhedged excess returns of investing in the USD asset is given by

$$\begin{aligned} rx^{\$,NH}_{t+1} &= r^{\$}_{t+1} + \Delta s_{t+1} - rf_t \\ &= (r^{\$}_{t+1} - rf^{\$}_t) + (rf^{\$}_t + \Delta s_{t+1} - rf_t) \\ &\equiv rx^{\$}_{t+1} + rx^{FX}_{t+1}, \end{aligned}$$

which is equal to the sum of U.S. asset return over the USD risk-free rate, $rx^{\$}_{t+1}$, and the currency returns of going long the USD risk-free rate, and shorting the local currency risk-free rate, rx^{FX}_{t+1}, which we refer to as the "USD FX return."

If instead, the foreign investor decides to fully hedge the currency risk of the USD asset by selling USD forward using a forward contract in exchange for local currency, then the hedged excess return over the local currency risk-free rate becomes

$$\begin{aligned} rx^{\$,H}_{t+1} &\approx r^{\$}_{t+1} + (f_t - s_t) - rf_t \\ &= r^{\$}_{t+1} - rf^{\$}_t + [rf^{\$}_t + (f_t - s_t) - rf_t] \\ &= rx^{\$}_{t+1} + x_t. \end{aligned}$$

Therefore, the hedged return for the foreign investor is approximately equal to the sum of the U.S. asset excess return and the CIP basis. A negative CIP basis reduces the hedged return for foreign investors in the USD asset. The approximation is needed because the expression ignores a second-order FX hedging error. As investors are unable to perfectly forecast the price of the dollar asset at $t+1$, so the dynamic FX hedging position based on current exposure might under or over hedge the dollar proceed next period.

The foreign investor maximizes a CARA utility over his portfolio returns. The investor has a risk aversion parameter γ. He chooses w_{US}, the portfolio share in total USD asset, and w_{NH}, the portfolio share in unhedged USD asset, and leaves $1 - w_{US} - w_{NH}$ in the local risk-free rate asset.

The mean-variance investor maximizes:

$$\max_{w_{US}, w_{NH}} \mathbb{E} rx_{t+1}^P - \frac{\gamma}{2} \mathbb{V}(rx_{t+1}^P),$$

where rx_{t+1}^P is the log excess return of the entire portfolio given by:

$$\begin{aligned} rx_{t+1}^P &= w_{NH}(rx_{t+1}^{\$} + rx_{t+1}^{FX}) + w_H(rx_{t+1}^{\$} + x_t) \\ &= w_{NH}(rx_{t+1}^{\$} + rx_{t+1}^{FX}) + (w_{US} - w_{NH})(rx_{t+1}^{\$} + x_t) \\ &= w_{US} rx_{t+1}^{\$} + w_{NH} rx_{t+1}^{FX} + (w_{US} - w_{NH}) x_t. \end{aligned}$$

The expected return and the variance of the portfolio are:

$$\begin{aligned}
\mathbb{E}[rx_{t+1}^P] &= w_{US}\mathbb{E}[rx_{t+1}^{\$}] + w_{NH}\mathbb{E}[rx_{t+1}^{FX}] + (w_{US} - w_{NH})x_t, \\
&\equiv w_{US}\overline{rx}^{\$} + w_{NH}\overline{rx}^{FX} + (w_{US} - w_{NH})x, \\
\mathbb{V}(rx^P) &= w_{US}^2\sigma_{\$}^2 + w_{NH}^2\sigma_{FX}^2 + 2w_{US}w_{NH}\sigma_{\$,FX},
\end{aligned}$$

where $\bar{z}$ is the expected return on z_{t+1}, $\sigma_{A,B}$ is the covariance between asset A's return and asset B's return, and σ_C^2 is the variance of asset C's return. Note that while the portfolio's expected return depends linearly on CIP basis, x, its variance does not. CIP basis is determined at time t and therefore does not contribute to the conditional variance.

4.1.1 Optimal Portfolio Allocation and Hedging

From the investor's first-order conditions, we derive the investor's optimal allocation in the USD asset and FX exposure:

$$w_{US}^* = \frac{(\overline{rx}^{\$} + x)\sigma_{FX}^2 - (\overline{rx}^{FX} - x)\sigma_{FX,\$}}{\gamma(\sigma_{FX}^2\sigma_{\$}^2 - (\sigma_{FX,\$})^2)}, \tag{2}$$

$$w_{NH}^* = \frac{(\overline{rx}^{FX} - x)\sigma_{\$}^2 - (\overline{rx}^{\$} + x)\sigma_{FX,\$}}{\gamma(\sigma_{FX}^2\sigma_{\$}^2 - (\sigma_{FX,\$})^2)}. \tag{3}$$

With the optimal portfolio shares solved, the optimal hedge ratio is given by

$$HR^* = 1 - \frac{w_{NH}^*}{w_{US}^*} = \frac{(\overline{rx}^{\$} + x)(\sigma_{FX}^2 + \sigma_{FX,\$}) - (\overline{rx}^{FX} - x)(\sigma_{\$}^2 + \sigma_{FX,\$})}{(\overline{rx}^{\$} + x)\sigma_{FX}^2 - (\overline{rx}^{FX} - x)\sigma_{FX,\$}}. \tag{4}$$

To understand the intuition of the hedge ratio, we define a few important parameters to

simplify the expression:

$$\lambda \equiv \sigma_{FX}^2/\sigma_{\$}^2,$$
$$\beta \equiv \sigma_{FX,\$}/\sigma_{\$}^2,$$
$$\phi \equiv \frac{\overline{rx}^{FX} - x}{\overline{rx}^{\$} + x}.$$

First, the parameter λ denotes the ratio of the volatility of the USD FX return over the volatility of the U.S. asset return. Second, the parameter β denotes the regression coefficient of the USD FX return on the U.S. asset return, an important measure of the correlation between currency risk and U.S. asset return. Third, the parameter ϕ denotes the ratio of the "FX return" (in contrast to "USD FX return", this return from going long USD and shorting the local currency is achieved using an FX forward) over the hedged U.S. asset return. We note that the CIP basis, x, enters into the expression for both the numerator and the denominator. This is because the investor in the model cannot directly long or short the U.S. risk-free interest rate. Instead, both currency hedging and speculation have to use the FX forward, and the CIP basis acts as a wedge for both the USD FX return and the FX-hedged U.S. asset return. A negative CIP basis reduces the FX-hedged U.S. return, but increases the USD FX return.

We can now rewrite the hedge ratio only in terms of these three parameters,

$$HR^* = 1 + \frac{\beta - \phi}{\lambda - \phi\beta}. \tag{5}$$

Therefore, the optimal hedge ratio depends on the volatility of the FX return relative to the return of the underlying U.S. asset, the correlation between the FX return and the U.S. asset

return, and how the expected FX return compares to the FX-hedged U.S. asset return.

4.1.2 Comparative Statistics of the Optimal Hedge Ratio

We study the drivers of the investor's optimal hedge ratio by examining its comparative static with respect to its various components. Compared to the portfolio problem in Campbell, de Medeiros, and Viceira (2010), which minimizes the portfolio variance without taking into account the effect on the portfolio returns, our framework allows for the expected return differential between hedged and unhedged return and the cost of hedging to also affect the optimal hedge ratio.

In particular, the comparative static with respect to ϕ shows the impact of returns on the hedge ratio, while comparative statics with respect to λ and β inform the effect of the variance-covariance structure of returns on the hedge ratio. We start by examining the effect of ϕ:

$$\frac{\partial HR^*}{\partial \phi} = \frac{\beta^2 - \lambda}{(\lambda - \phi\beta)^2} \propto sign((\sigma_{FX,\$})^2 - \sigma_{FX}^2\sigma_{\$}^2) < 0.$$

Therefore, given $\phi \equiv \frac{\overline{rx}^{FX} - x}{\overline{rx}^{\$} + x}$, the mean-variance investor's optimal hedge ratio increases in the USD FX return, decreases in the U.S. asset return, and decreases in the hedging cost.

$$\frac{\partial HR^*}{\partial \overline{rx}^{FX}} < 0, \qquad \frac{\partial HR^*}{\partial \overline{rx}^{\$}} > 0, \qquad \frac{\partial HR^*}{x} > 0. \tag{6}$$

These comparative statics with respect to expected returns and the cost of hedging are intuitive. An increase in the expected USD FX return increases the incentive to leave the USD asset unhedged, reducing the hedge ratio. A more negative CIP basis ($x \downarrow$) increases the cost of hedging currency risk, also reducing the hedge ratio. Finally, an increase in the expected U.S. asset return increases total allocations to U.S. asset (w_{US}) but, all else equal,

does not increase unhedged allocation (w_{NH}) commensurately, leading to a higher hedge ratio.

Facts 1 and 2 in Section 3 show that foreign investors have been holding more USD assets and hedging more. Abstracting from time variation in the variance-covariance structure of returns, these two facts are jointly consistent with higher expected returns from USD assets, which affect the portfolios of all investors.

In the cross-section, currency areas have distinct interest rate regime, leading to differences in expected USD FX return, and they also have persistent CIP basis. Equation 6 thus leads to the following predictions:

Prediction 1. *Comparing investor's mean-variance portfolio across geography, the FX hedge ratio for USD assets decreases in the expected USD FX return.*

Prediction 2. *In the cross-section, the mean-variance investor's hedging exhibits a positive correlation between CIP basis and hedge ratio.*

Next, we examine the effect of β on the hedge ratio:

$$\frac{\partial HR^*}{\partial \beta} = \frac{\lambda - \phi^2}{(\lambda - \phi\beta)^2} \propto sign\left(\frac{\overline{rx}^{\$} + x}{\sigma_{\$}} - \frac{\overline{rx}^{FX} - x}{\sigma_{FX}}\right)$$

The partial of the hedge ratio with respect to β informs the comparative static with respect to the covariance between FX risk and the U.S. asset return. The sign of the comparative statistic depends on the relative Sharpe ratio of the FX-hedged U.S. asset return, and the Sharpe ratio of the FX return. The intuition is as follows. The mean-variance investor wants to minimize portfolio variance holding all else is equal. An increase in the covariance between the FX return and the U.S. asset return is not desirable. The investor thus wants to reduce

her exposure to either the U.S. asset or the USD FX exposure. If the FX-hedged U.S. asset has a higher Sharpe ratio, the investor reduces the dollar FX exposure by hedging more.

Thus, the hedge ratio increases in the covariance between the USD FX return and U.S. asset return

$$\frac{\partial HR^*}{\partial \sigma_{FX,\$}} > 0 \qquad \text{if} \qquad \frac{\overline{rx}^{\$} + x}{\sigma_{\$}} > \frac{\overline{rx}^{FX} - x}{\sigma_{FX}}. \tag{7}$$

Empirically, given the large FX volatility, the Sharpe ratio of going long USD and shorting a single foreign currency is generally inferior to the Sharpe ratio of the broad U.S. bond and equity returns, so the condition $\frac{\overline{rx}^{\$}+x}{\sigma_{\$}} > \frac{\overline{rx}^{FX}-x}{\sigma_{FX}}$ typically holds well in the data.

Prediction 3. *Suppose the exchange rates are sufficiently volatile, comparing investor's mean-variance portfolio across geography, the FX hedge ratio for USD assets increases in the covariance between USD FX return and U.S. asset return.*

Finally, we examine the effect of λ on the hedge ratio:

$$\frac{\partial HR^*}{\partial \lambda} = \frac{\beta - \phi}{(\lambda - \phi\beta)^2} \propto sign\left(\frac{\overline{rx}^{\$} + x}{\sigma_{\$}^2} - \frac{\overline{rx}^{FX} - x}{\sigma_{FX,\$}}\right).$$

Whether the FX volatility increases the hedge ratio thus depends on another Sharpe ratio comparison:

$$\frac{\partial HR^*}{\partial \sigma_{FX}^2} > 0 \qquad \text{if} \qquad \frac{\overline{rx}^{\$} + x}{\sigma_{\$}^2} > \frac{\overline{rx}^{FX} - x}{\sigma_{FX,\$}}. \tag{8}$$

Building on the earlier discussion that $\frac{\overline{rx}^{\$}+x}{\sigma_{\$}} > \frac{\overline{rx}^{FX}-x}{\sigma_{FX}}$ generally holds in the data, a sufficient condition for the comparative statics to be unambiguously positive is that FX volatility is more volatile than the U.S. asset return ($\sigma_{FX} > \sigma_{\$}$).

Prediction 4. *Suppose the exchange rates are sufficiently volatile, comparing investor's mean-variance portfolio across geography, the FX hedge ratio for USD assets increases in*

FX volatility.

To assess the extent that mean-variance preference describes investors, we test these cross-sectional predictions after we complete our sketch of the FX derivatives market with the intermediary's problem.

4.2 Intermediary's problem

To hedge his dollar exposure, the foreign investor can go into FX forward or FX swap contracts with a financial intermediary. The intermediary sets the price on FX derivative contracts.

Because the intermediary can offset the FX risk of providing dollar hedges by borrowing dollars in the cash market, offering FX derivative contracts carries no risk but expands the size of the balance sheet. Fact 2 shows that, in the time-series, CIP basis becomes more negative when there is more hedging, suggesting that expanding the balance sheet is costly and that the supply of FX hedges is not perfectly elastic. One reason for costly balance sheet is new regulations enacted post-GFC, which assess capital charges based on the total size of the balance sheet. The intermediary thus requires a return for providing FX hedges to offset the cost of balance sheet expansion. We assume that the intermediary faces a total leverage constraint, so that in the short-term term, the size of intermediary's balance sheet consisting of H, the net notional amount of FX derivative, and I, the amount of other investment, must not exceed the a fixed balance sheet size W.[20] Furthermore, we assume that the intermediary

[20]Intermediary's balance sheet size is fixed in the short-run due to capital market frictions that prevent it from raising outside equity quickly and cheaply.

in our model operates with a segmented balance sheet across currency l:

$$\begin{aligned} |H_l| + I_l &= W_l, \\ H_l &= \sum_{i \in l} A_{i,l} \cdot (w_{US}^{i,l} - w_{NH}^{i,l}), \\ \sum_l W_l &= W \end{aligned}$$

The segmented intermediary balance sheet assumption is consistent with evidence in Siriwardane, Sundaram, and Wallen (2022). For example, trading desks in different countries might be allocated with different balance sheet capacity, depending on the size of the market and investment opportunities. Due to frictions within large banking organizations, balance sheet space allocation does not flexibly adjust and investment opportunities are not perfectly equalized across countries. We note that each investor makes his own hedging decisions considering his portfolio, $A_{i,l}$, but the financial intermediary only cares about the net total hedging demand across all investors in a currency. In reality, the size of each investor's hedging demand is likely small relative to the total hedging demand in a currency. For this reason, although we allow total hedging demand to affect CIP deviations in the intermediary's problem, we nonetheless model the mean-variance investor to take the price of FX forwards as given.

The intermediary offers FX derivative contracts to maximize its risk-adjusted total return subject to its balance sheet constraint:

$$\begin{aligned} &\max_{H_l} \mathbb{E}[x_l H_l + f(I_l)], \\ &\text{s.t. } |H_l| + I_l = W_l. \end{aligned}$$

We use $f(I)$ to denote the risk-adjusted return of the intermediary's other investments. In particular, $f(I)$ is net of other regulatory costs such as risk-weighted capital requirements, which apply to other investments but not FX derivatives. We use x to denote the compensation that the intermediary expects for offering balance-sheet intensive FX derivative contracts. Post-GFC, new regulations on balance sheet size lead to the intermediary equating, at the margin, $|x^*| = f'(I^*)$. This x corresponds to CIP basis in practice and follows the same sign as the net FX derivative position, H.[21] If there were no regulations on balance sheet size, then because offering FX derivatives does not increase risk-weighted capital requirement, it presents no trade-off to doing other investments, and the intermediary would optimally maximizes H and I separately. The pricing of H in the absence of regulatory constraint would be governed by CIP and the supply of H would be perfectly elastic.

Following Ivashina, Scharfstein, and Stein (2015), a convenient simple case is where $f(I) = \theta \log(I) - I$. This functional form assumes diminishing marginal return from investments and limited profitable opportunities. This leads to:

$$|x_l^*| = \frac{\theta}{W_l - |H_l^*|} - 1.$$

Because x is compensation for using the balance sheet, x is 0 when there is no net demand for FX derivatives. This amounts to saying that $\theta = W$. With this,

$$x_l^* = \frac{H_l^*}{W_l - |H_l^*|} \tag{9}$$

[21] To illustrate, if the intermediary uses USD as the reference currency, and non-US investors demand to buy USD today and sell USD tomorrow to hedge, then because the intermediary takes the opposite trade, its net derivative position H_l is negative today. In this instance, the intermediary would demand $x_l < 0$ as compensation.

From Equation 9, we see that the CIP basis becomes more negative as investors in country l demands more FX derivatives to hedge USD exposure. This is consistent with Fact 2's negative correlation between foreign investors' hedging activities and the CIP basis. Moreover, Equation 9 makes clear that what matters to the intermediary is not simply the absolute amount of net FX derivative contracts demanded, but that demand relative to the size of the balance sheet the intermediary has made available to country l. This leads to a prediction that quantitatively links FX hedging with CIP basis in the cross-section:

Prediction 5. *CIP basis is not uniform in the cross-section. The more net FX derivative a country demands relative to the intermediary's balance sheet available for that country, the larger CIP basis is in absolute terms.*

4.3 Testing model predictions

By modeling the two-sides of the FX derivatives market, we generate predictions of investors' hedging decisions and of the CIP deviations in the cross-section. In this subsection, we test these predictions in turn.

4.3.1 Predictions of hedging decisions

Predictions 1 through 4 highlight that in the cross-section, four variables could vary: the expected USD FX return, the variance of the USD FX return, the covariance between the USD FX return and the U.S. asset return, and the CIP basis, or the additional cost of hedging. To test these predictions, we need to estimate the empirical covariance matrix for USD FX returns and proxies of U.S. asset returns. We consider several proxies for U.S. asset returns in estimating the relevant covariance, including USD bond returns, equity returns, and the portfolio return of USD assets constructed using investor-specific bond-

equity portfolio split. For bonds, we use ten-year (10Y) US government bonds,[22] and for equity, we look at the S&P stock market index. Focusing on annualized one-month (1M) holding period excess returns, we estimate the following:

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

Our estimation period is the two decades between June 2002 and June 2021, corresponding to our sample period and inclusive of the GFC. We use month-end non-overlapping returns and we proxy both $r_{1M,t}$ and rf_t with 1M IBOR. In estimating the covariance structure, we rely on realized returns, but to test Predictions 1 through 4, we also need to proxy investors' expected USD FX return. We explore two alternative approaches. One approach appeals to the persistent violation of uncovered interest-rate parity: on average, high interest-rate currencies do not depreciate enough relative to the interest rate differential and low interest-rate currencies do not appreciate enough. In other words, if the U.S. interest rate is higher than that of a foreign country, the expected USD FX return from investing in USD is on average positive; vice versa. We therefore use the interest rate differential between the USD and local currency as one proxy for the expected USD FX return. Our second approach is to appeal to analysts' forecasts. Specifically, we collect quarter-ahead exchange rate forecasts from Bloomberg, and combine these forecasts with spot rates and interest rates to estimate the expected USD FX returns.

[22] According to TIC, foreigners' US bond holding is primarily in government securities, about 2/3.

In Tables 5 and 6, we present panel regression results from regressing investors' hedge ratio on proxies of expected USD FX return, variance of USD FX return, covariance of USD FX return and U.S. asset return, and CIP basis. All regressions control for time and industry fixed effects. Table 5 use interest rate differential to proxy expected USD FX return and Table 6 use exchange rate forecasts to estimate expected USD FX return. Both tables examine five different proxies for asset returns to evaluate the covariance with USD FX return: Column (1) uses returns to USD bonds and USD equities, Column (2) uses the return to the USD portfolio with investors' observed bond-equity portfolio split, Column (3) adds returns of local bonds and local equities, Column (4) adds the return to the local portfolio with investors' observed bond-equity portfolio split, and Column (5) uses the return to investors' overeall portfolio, following investors' empirical allocation to bond vs. equity and to USD vs. non-USD. In all of these specifications, the hedge ratio increases in interest rate differential while Prediction 1 postulates a negative correlation. Moreover, the covariance between returns is mostly negatively correlated with hedge ratio, contradicting Prediction 3. Only *var(FX)* always enters with the sign that's consistent with Prediction 4 (positive). Finally, we note that the cross-sectional correlation between hedge ratio and CIP basis is also consistently negative, contrary to Prediction 2. Given the persistence in the cross-section of CIP basis, this result lends support to our modeling assumption of an intermediary with segmented balance sheet. In other words, when managing FX exposure, investors face a localized, upward sloping FX hedging supply.

4.3.2 Predictions of CIP deviations

We empirically test the relationship between the cross-section of CIP basis and hedging demand in Prediction 5. To do so, we assume that the intermediary segments its balance sheet

in proportion to GDP because 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 and positive cross-section correlation between GDP and banks' trading asset allocation.

Figure 7 shows that there is indeed a striking linear relationship between the time series average of country-specific CIP 3M basis and GDP-normalized total hedging volume.[23] In the cross-section, the linear correlation between CIP basis and normalized hedging demand has an R^2 of 0.77. Importantly, this relationship holds across advanced and developing economies. In Table 7, we confirm the cross-section relationship using all available data. Column (1) shows that in general, CIP basis becomes more negative (larger in absolute value) when there is more GDP-normalized hedging demand. Column (2) shows that this is true in the cross-section. In fact, after controlling for time FE, the negative correlation is stronger in magnitude and in statistical significance.

4.4 Where does the evidence leave us?

Our novel data show that foreign investors have been increasing their holdings and hedging of USD securities over the past two decades. The empirical facts we document in Section 3 motivate us to describe the market for FX derivatives as having a mean-variance investor demanding FX hedges on the one side and a constrained financial intermediary supplying FX hedges on the other side.

Our model rationalizes the empirically negative relationship between hedging and CIP basis, lending support to intermediary-based asset pricing. The fact that aggregate local

[23] Total hedging volume is estimated according to the methodology in Table 4.

hedging contributes to cross-sectional difference in CIP deviations moreover highlights the importance of understanding the drivers of FX hedging, especially in the cross-section.

The mean-variance framework is a natural starting point for thinking about portfolio allocation and FX hedging. Yet, our empirical analyses have highlighted the limitation of the mean-variance framework in fully explaining variations in the hedging demand. The mean-variance framework, under the assumption of common risk aversion parameter, generates predictions about the cross-section of FX hedging that are at odds with the data. In particular, controlling for return covariance and volatility, investors in low interest-rate countries on average hedge more than investors in high interest-rate countries, despite having a more appealing expected USD FX return. This puzzling result sets our analysis apart from previous studies that focus solely on variance minimization (e.g., Campbell, de Medeiros, and Viceira (2010)), but also raises the question: what are the additional drivers for FX hedging decision?

Among possible additional drivers for FX hedging demand, concerns for liquidity can increase the demand for FX hedging. All else equal, a manager who faces more uncertain redemption requests has lower tolerance for volatility and is likely to do more FX hedging. We illustrate this point with a comparison of FX hedging done by Japanese pensions versus insurance. The Japanese pension that we study is the government pension fund, GPIF. GPIF is governed by Japan's Employee Pension Insurance Act, which requires the government to prepare a forward-looking budget for GPIF once every five years (Government of Japan (1954)). As such, GPIF has relative stable medium-term outflows and may not need to sell its USD assets on short notice. Consequently, GPIF has historically done little to no FX hedges. This contrasts with the Japanese insurers, who face much more volatile premium income and redemption outflows, and have historically maintained USD hedge ratios of

between 30% to 60%.

Liquidity needs could differ across country as a result of interest rate regimes. Higher interest rates increase the opportunity cost of holding money, and induce investors to convert low-yield bank deposits to higher yielding investments (Nagel (2016)). Generalizing this to the international context, in countries where interest rates are low, investors are more likely to withdraw cash from higher yielding investment products such as mutual funds and insurance. All else equal, concerns for liquidity lead to the observed pattern of more FX hedging in countries with lower interest rates. Viewed through the lens of the mean-variance framework, concerns for liquidity increase an investor's risk aversion for return volatility. In other words, although investors from low interest rate countries stand to gain more in expected USD FX return, their liquidity-induced-risk aversion leads them to hedge away more FX exposure.

5 Conclusion

We collect an immense array of industry statistics and company filings to study foreign investors' holding and hedging of USD securities. We document a six-fold increase in foreign investors' USD holding, driven by investors' increasing portfolio allocation to USD securities. We show that investors hedge a substantial amount of their USD exposure post-GFC despite large CIP deviations, which leads to substantial financial costs. We document that there is considerable cross-country heterogeneity in hedging practices. Importantly, we note that the global banks aren't fully bearing the USD FX risks hedged away by institutional investors.

We present a simple mean-variance framework for the optimal currency hedging decision, where the hedge ratio depends on the volatility of the USD FX return, the covariance between USD FX and U.S. asset returns, and UIP and CIP deviations. We find substantial

deviations between the cross-section of empirically observed hedge ratios and the mean-variance framework. Nevertheless, once we allow for a constrained financial intermediary with segmented balance sheet, our model points to a relationship between hedging demand and the cross-section of CIP basis, which is strongly supported in the data.

Our results represent the first comprehensive and empirical investigation into foreign investors' holdings and hedging of USD assets. The large and rising hedge ratio of foreign investors suggests that the motivation behind the cross-border demand for USD assets extends beyond mere exposure to USD currency risk. Instead, our findings highlight a substantial intrinsic demand for U.S. assets themselves. This shift in understanding opens new avenues for further research into the drivers of international investment flows and the strategic management of currency risks.

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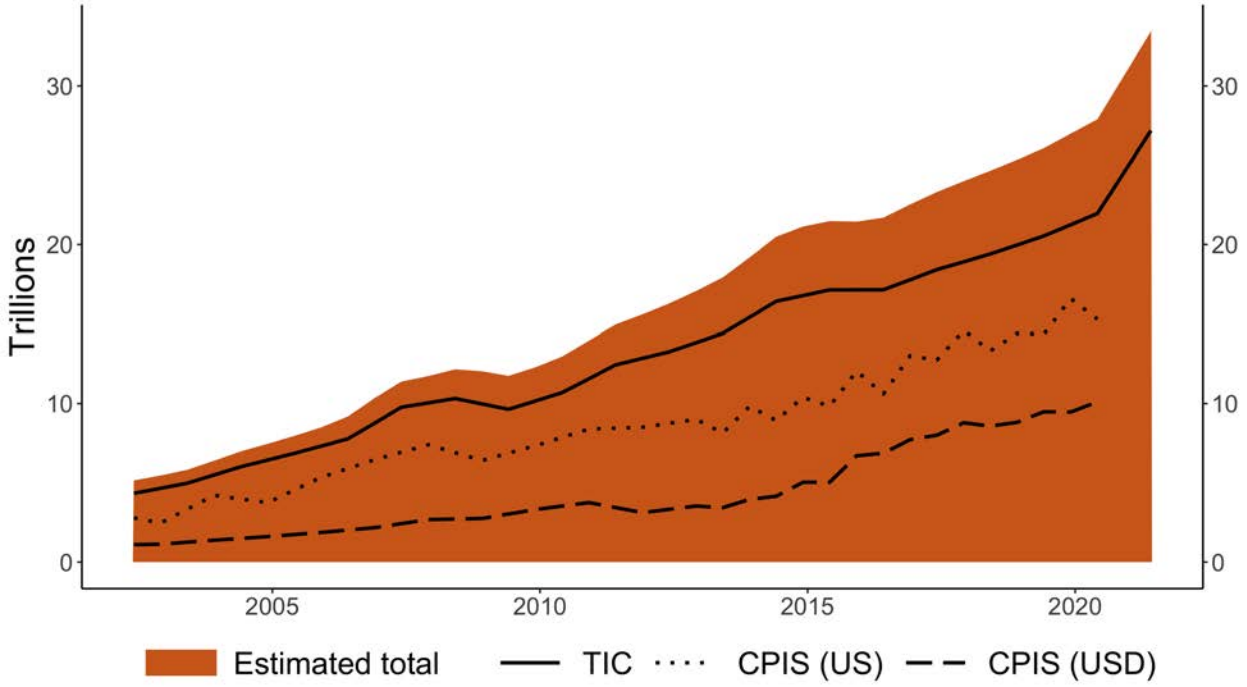
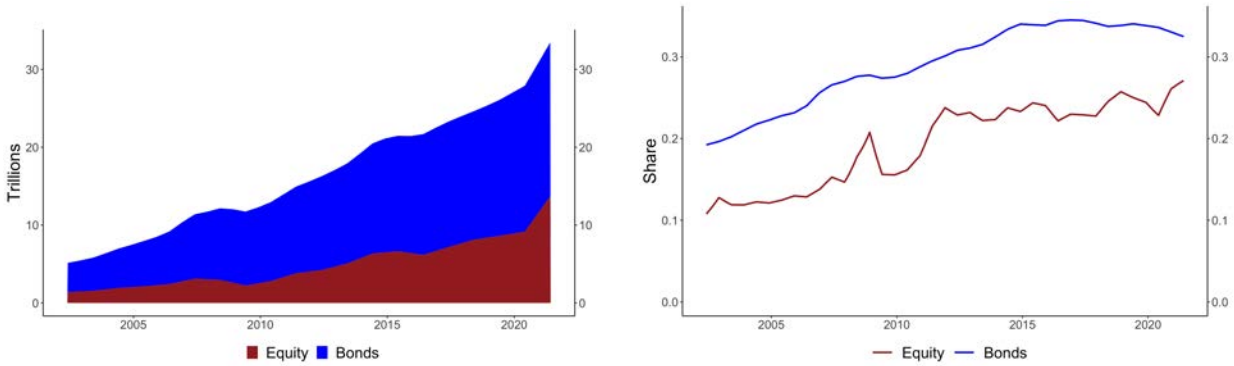
Figures and Tables

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



Notes: This figure plots different estimates of foreign holdings of USD securities. Plotted in orange shade is our estimate, 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.

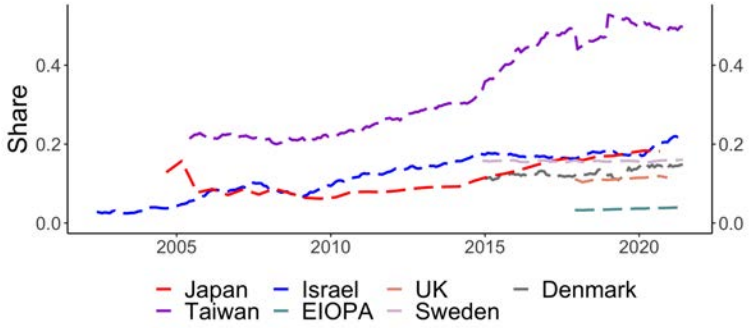
Figure 2: **Foreign USD holdings by security type**



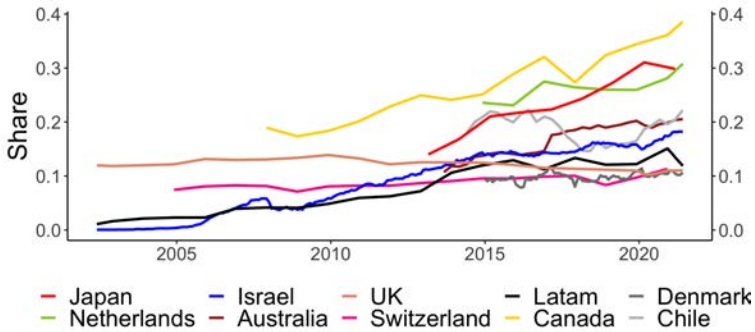
(a) **Volume** (b) **Share of total outstanding**

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.

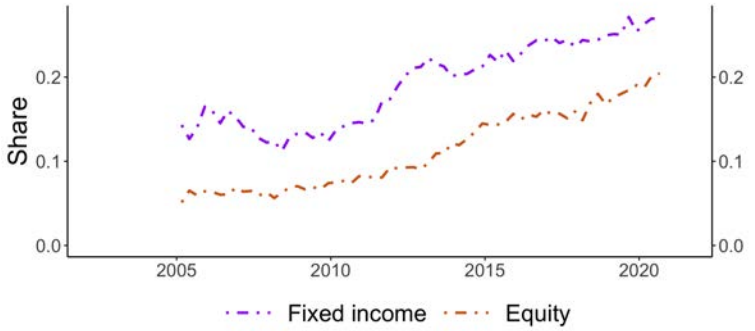
Figure 3: **Portfolio allocation to USD securities across industries**



(a) **Insurance**



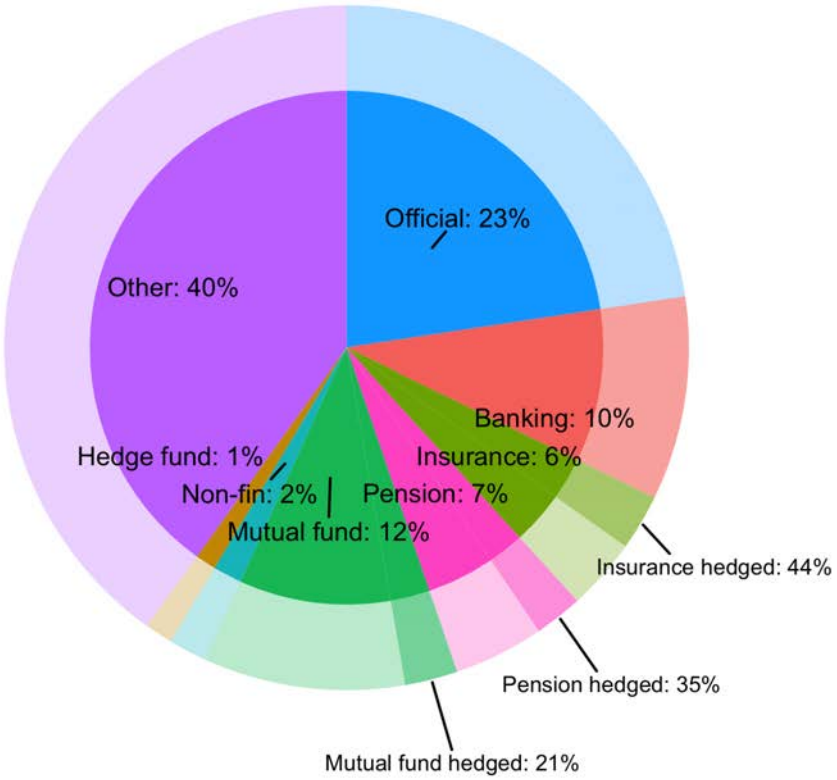
(b) **Pensions**



(c) **Mutual funds**

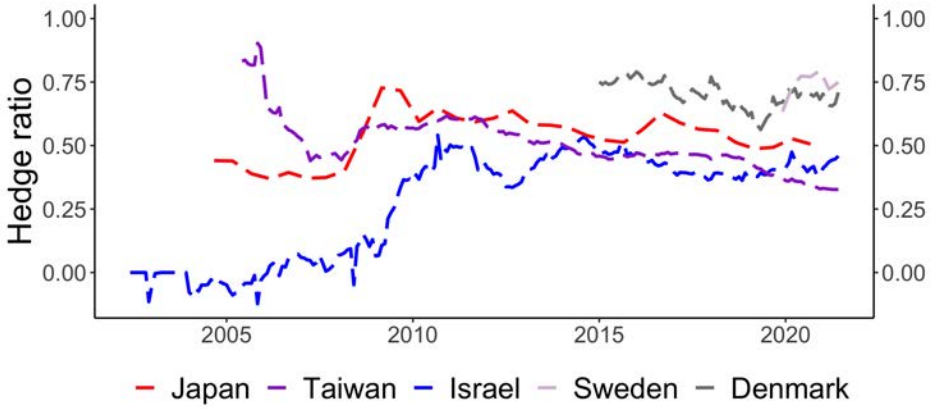
Notes: This figure plots foreign investors' portfolio allocation to USD securities. Allocation is estimated as the ratio of USD securities to total assets. See Table 1 for sample period coverage of different series. This figure is best viewed in color. Each country is plotted in the same color across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

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

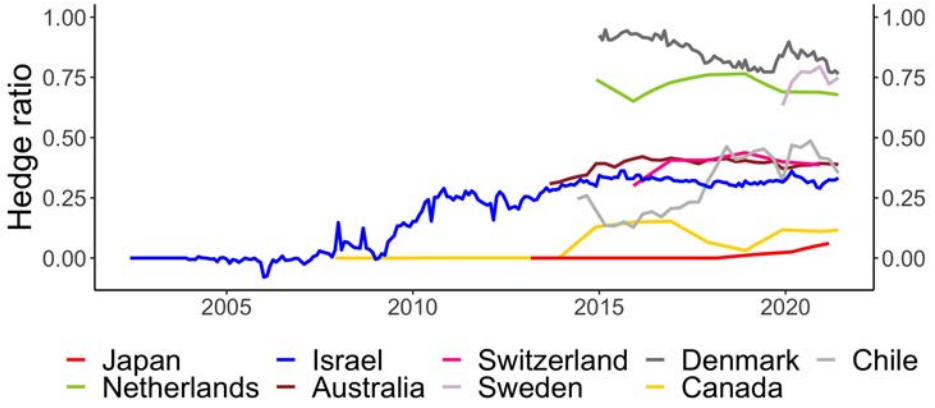


Notes: This figure illustrates foreign investors' USD holdings and hedging, by industry, as of June 2020. Each slice of the inner pie corresponds to industry holdings as a percentage of the total amount of USD securities held by foreign investors. Different shading on the outer ring corresponds to hedging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

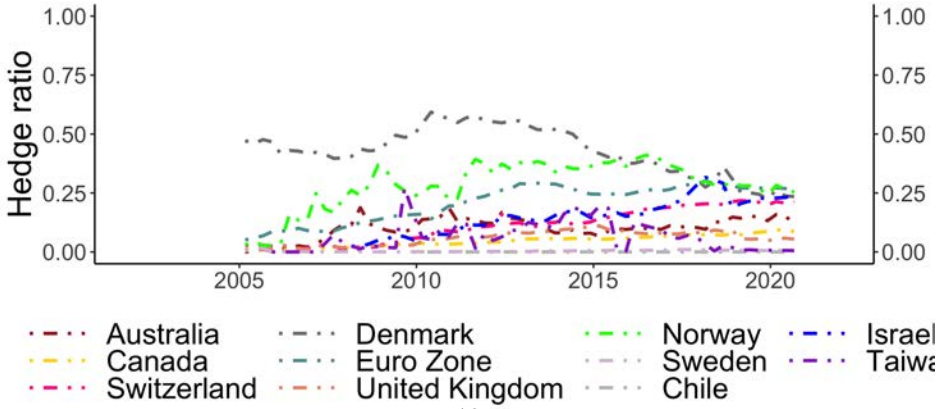
Figure 5: **USD hedging across industries**



(a) **Insurance**



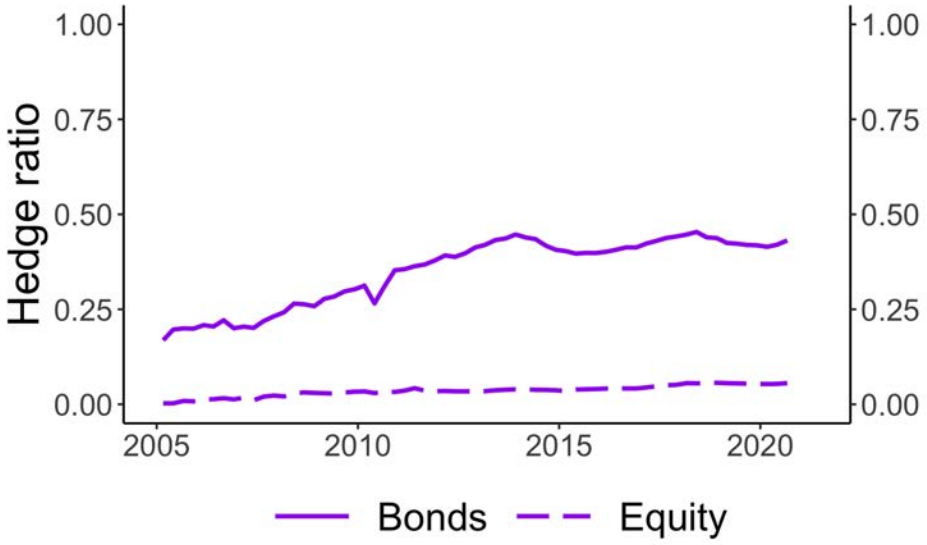
(b) **Pension**



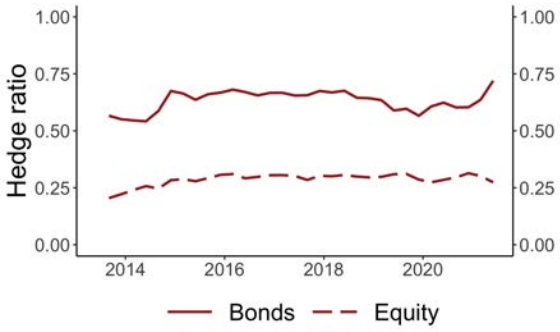
(c) **Mutual funds**

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.

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



(a) **Mutual funds**

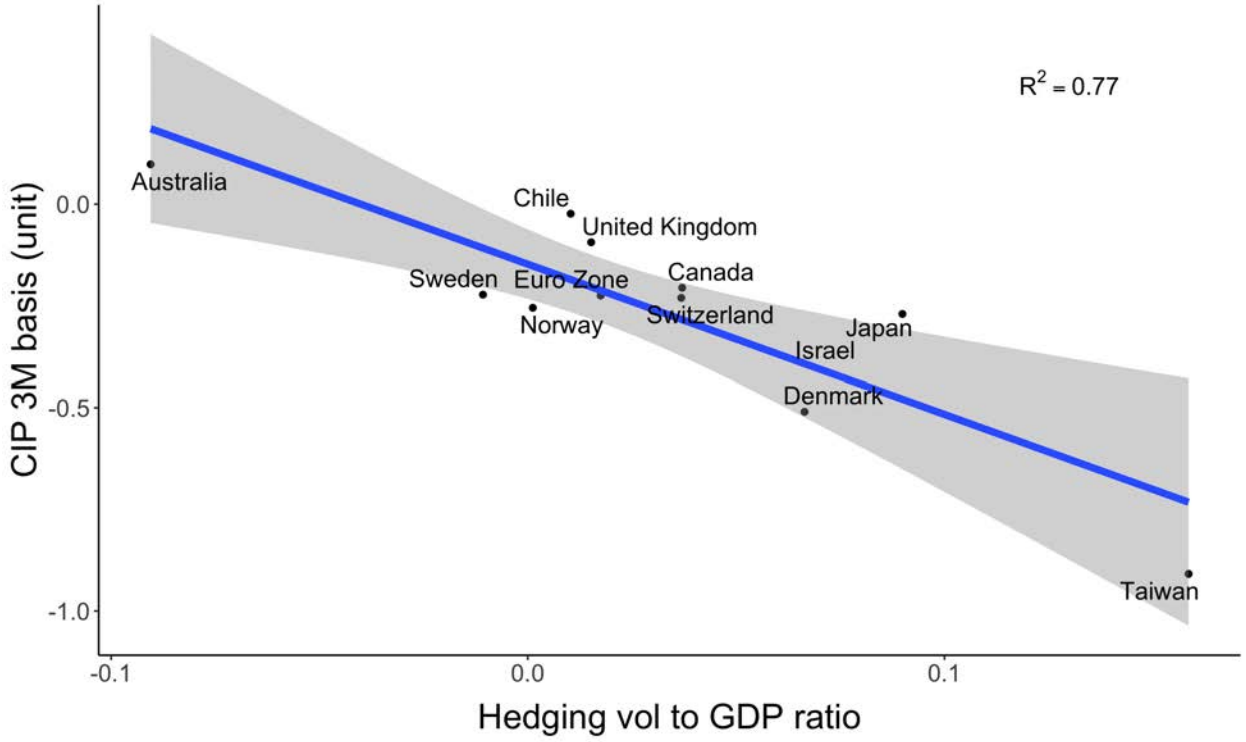


(b) **Australian pensions**

(c) **Dutch pensions**

Notes: This figure plots hedge ratios for USD bonds vs. equities in mutual funds, Australian pensions, and Dutch pensions. See Section 2.1.1 for estimation methodologies.

Figure 7: **Cross-section of hedging and CIP basis**



Notes: This figure plots each country's time-series average of 3M IBOR CIP basis against their time-series average of hedging volume to GDP ratio. 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 securities allocation 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

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. Sample 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: **Hedging behavior in the time-series**

	Hedge Ratio		Unhedged USD alloc	Hedge Ratio
	(1)	(2)	(3)	(4)
Indicator: Crisis	0.052***	0.079***	0.026*	
	(0.016)	(0.022)	(0.014)	
Indicator: Post-Crisis	0.160***	0.147***	0.066***	
	(0.016)	(0.017)	(0.011)	
CIP 3M Basis Qtr Avg				-0.041**
				(0.015)
Currency X Industry	No	Yes	Yes	Yes
Observations	1,229	1,229	1,060	893
R^2	0.07	0.86	0.70	0.91

Notes: This table examines time-series patterns in hedging. "Hedge ratio" is the ratio of the amount of USD securities with currency exposure hedged to the amount of all USD security holdings. "Unhedged USD alloc" is the share of the portfolio invested in USD securities and not hedged. Sample 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	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. "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: **Hedging behavior in the cross-section: UIP**

	USD hedge ratio				
	(1)	(2)	(3)	(4)	(5)
Diff USD vs. local 3M IBOR	0.070***	0.070***	0.074***	0.060***	0.053***
	(0.009)	(0.008)	(0.012)	(0.010)	(0.007)
var(FX)	1.11***	1.79***	1.17***	1.69***	2.65***
	(0.164)	(0.320)	(0.205)	(0.273)	(0.147)
cov($bond, FX)	-3.04***		-3.32***		
	(0.516)		(0.641)		
cov($stock, FX)	-1.95***		-1.49***		
	(0.244)		(0.240)		
cov($portfolio, FX)		-0.201		-1.03*	
		(0.590)		(0.565)	
cov(dom bond, FX)			-0.831		
			(0.712)		
cov(dom stock, FX			-0.454**		
			(0.205)		
cov(dom port, FX)				0.674	
				(0.445)	
cov(overall port, FX)					-0.919***
					(0.071)
CIP basis 3M	-0.114***	-0.152***	-0.106***	-0.154***	-0.159***
	(0.022)	(0.018)	(0.026)	(0.017)	(0.018)
Time	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes
Observations	934	934	934	934	934
R^2	0.47	0.45	0.47	0.46	0.51

Notes: This table examines cross-section 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. "Diff USD vs. local 3M IBOR" is calculated as USD 3M IBOR less local 3M IBOR. "CIP basis 3M" is calculated using IBOR in the log version of Equation 1. "var(FX)" is the variance of USD FX return of long USD 3M IBOR and short local 3M IBOR. The covariance controls are all between the USD FX return and an asset return, where "$bond" is US 10Y Treasury bond, "$stock" is US S&P 500 index, "dom bond" is local 10Y sovereign bond, "dom stock" is local equity index, "$portfolio" is the investor's USD portfolio with average bond-equity split, "dom port" is the investor's domestic portfolio with average bond-equity split, and "overall port" is the investor's overall portfolio with average bond-equity split and average USD-domestic split. Estimation period is July 2010 through September 2020, 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 6: **Hedging behavior in the cross-section: Forecast FX**

	USD hedge ratio				
	(1)	(2)	(3)	(4)	(5)
Forecast 3M FX return	0.292***	0.461***	0.263***	0.221**	0.283***
	(0.089)	(0.094)	(0.087)	(0.093)	(0.090)
var(FX)	0.837***	1.73***	0.384**	1.47***	2.36***
	(0.168)	(0.192)	(0.151)	(0.179)	(0.117)
cov($bond, FX)	-3.86***		-5.25***		
	(0.646)		(0.694)		
cov($stock, FX)	-0.958***		-0.651		
	(0.276)		(0.464)		
cov($portfolio, FX)		1.06***		-1.90***	
		(0.339)		(0.638)	
cov(dom bond, FX)			2.35***		
			(0.394)		
cov(dom stock, FX			-0.299		
			(0.253)		
cov(dom port, FX)				2.00***	
				(0.355)	
cov(overall port, FX)					-1.10***
					(0.082)
CIP basis 3M	-0.146***	-0.177***	-0.134***	-0.171***	-0.173***
	(0.025)	(0.029)	(0.020)	(0.021)	(0.025)
Time	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes
Observations	934	934	934	934	934
R^2	0.42	0.39	0.43	0.42	0.47

Notes: This table examines cross-section 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. "Forecast 3M FX return" is the USD FX return assuming future spot equals to forecast spot exchange rate in 3M. "CIP basis 3M" is calculated using IBOR in the log version of Equation 1. "var(FX)" is the variance of USD FX return of long USD 3M IBOR and short local 3M IBOR. The covariance controls are all between the USD FX return and an asset return, where "$bond" is US 10Y Treasury bond, "$stock" is US S&P 500 index, "dom bond" is local 10Y sovereign bond, "dom stock" is local equity index, "$portfolio" is the investor's USD portfolio with average bond-equity split, "dom port" is the investor's domestic portfolio with average bond-equity split, and "overall port" is the investor's overall portfolio with average bond-equity split and average USD-domestic split. Estimation period is July 2010 through September 2020, 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 7: **CIP deviations and hedging**

	CIP 3M Basis	
	(1)	(2)
Hedging vol to GDP ratio	-1.55***	-2.16***
	(0.384)	(0.246)
Time	No	Yes
Observations	492	492
R^2	0.13	0.33

Notes: This table examines the relationship between CIP basis and hedging in 12 currency areas. All variables are quarter averages. Estimation period is July 2010 through September 2020. Standard errors are calculated using Driscoll and Kraay (1998). *, **, *** 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 tackle foreign holdings of USD securities issued by U.S. residents. We obtain "TIC Foreign Holding of U.S. Securities" directly from the TIC system. In particular, we access the annual reports on *Foreign Residents' Portfolio Holdings of U.S. Securities* from June 2002 through June 2021. These reports show non-U.S. residents' holdings of securities issued by U.S. residents, separately reported for equities and bonds. U.S. residents need not issue only USD securities. To estimate "TIC Foreign Holdings of Non-USD Securities", we use TIC's reporting of non-USD debt held by foreign investors.

We next tackle foreign holdings of USD securities issued by non-US residents. To do so, we first estimate "USD Securities Outstanding Outside the U.S." from the international debt securities statistics published by the Bank for International Settlements (BIS). We then net out the amount of foreign-issued dollar-asset held by U.S. residents, or "U.S. Investors' Cross-border USD Holdings." In its *U.S. Residents' Portfolio Holdings of Foreign Securities*, TIC reports the currency breakdown of US residents' foreign holdings by country annually starting in 2007. Using this statistic, we find that US residents primarily hold USD debt abroad: the by-country mean fluctuates between 72% and 79%. For the period of 2002 to 2007, we estimate the share of US-held foreign-issued USD debt as the mean between 2007 and 2021.

A.2 Sector-specific USD Security Holdings and Hedging

Foreign Insurance Companies' Holdings and Hedging

For Japan, we hand-collect quarterly filings since 2004 from all of the 25 active domestic companies and 12 foreign-controlled companies. The largest 11 of these Japanese insurance companies break out their portfolio holdings by currency. For each of these, we record total assets, investments in USD and all other foreign currencies, and investments in foreign equity and foreign debt. We take the split of equity vs. debt in foreign investments as informative of Japanese insurers' risk-return preference, and we estimate the amount of USD equity and debt as proportional to the the share of USD in the foreign investment portfolios. We estimate Japanese insurers' hedging practice directly from company-level filings on FX derivatives positions, available at the semiannual frequency. Because we are interested in the management of long dollar positions, we estimate the total USD hedge as the sum of net forward USD sales positions and USD swaps.[24] The net forward position is the difference in notional between USD forward sold and USD forward bought. We exclude small positions in FX options.

[24] This contrasts with the Japanese insurers' hedging activities reported by Liao and Zhang (2020), where the authors consider hedging of all foreign investments irrespective of currency.

In Taiwan, the Central Bank of Republic of China publishes *Financial Statistics Monthly*, which details life insurers' total assets and foreign investments. We locate physical copies of these publications going back to 2005 to form a monthly series of aggregate investment. To further understand the share of USD in foreign investments and the split between debt and equity, we hand collect detailed information from the annual reports of the 6 of the largest Taiwanese life insurers. The central bank's monthly reports contain information on the aggregate FX hedging undertaken by life insurers in the footnote to Appendix Table 8.

We leverage the quarterly filings made by all insurers to the European Insurance and Occupational Pensions Authority (EIOPA) to study insurers' portfolio allocations in the EU and the European Economic Area (EEA). Thirty-one countries are in the sample, including 19 in the eurozone (as of 2022), 11 others in the European Economic Area, and the U.K. We estimate the dollar holding from European insurers as investments in bonds and equities from US issuers. Our estimate of European insurers' USD bonds holding is likely conservative due to USD security issuance by non-US residents. EIOPA data collection started in 2017. For 2013Q4 to 2017Q4, we use ECB's Securities Holdings Statistics (SHS) to estimate holdings of insurers in the 19 eurozone countries. Estimates using the SHS data are also conservatively based on investments in securities from US issuers. SHS contains reporting by both insurers and pensions; we subtract from our SHS estimates what we estimate as holdings by pensions in the eurozone (i.e., the Netherlands).

Denmark provides more detailed reporting for its insurers. Instead of EIOPA, we use the monthly reporting by Danmarks Nationalbank to track Danish insurers' investment by currency and by security type. These monthly reports also outline total FX exposure and hedging by currency. We also opt for country-specific reporting for Swedish insurers. The Sveriges Riksbank releases semi-annual Financial Stability Report, where in certain issues, they report the historical quarterly investment holdings by insurance companies. Life insurers have the longest time series from 2009 through 2022, whereas data for non-life and unit-linked insurance products end in 2019. We use the ratio between life and other types of insurers prior to 2019 to impute the size of non-life insurers post 2019. The final series start in 2014 due to an adjustment that Sveriges Riksbank made in 2022. We use the split between debt and equity in the overall portfolio to be informative about the security type split of the foreign portfolio. Hedging information for Swedish life insurers is available starting in 2019.

Finally, we complement our sample of insurers with information from Bank of Israel's *Institutional Investors' Exposure to Foreign Exchange*. The monthly statistics start in 2002, and cover all foreign investments made by Israeli insurers and pension funds. We estimate Israeli insurers' USD investments from their total foreign investment portfolios and the typical share of USD in Israeli institutional investors' FX market activities.[25] We then estimate the

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

breakdown between USD equity and bonds using asset allocations in Israeli insurers' overall investment portfolio, which are available in Bank of Israel's *Assets Portfolio of the Institutional Investors by Securities*. Bank of Israel's *Institutional Investors' Foreign Exchange Exposure* further shows insurers' portfolio FX exposure before and after hedging. We use this information to estimate Israeli insurers' hedge ratio.

Foreign Pension Funds' Holdings and Hedging

The Japanese pension fund that we study in detail is the Government Pension Investment Fund (GPIF). GPIF is similar to Social Security in the U.S., and it makes up 72% of Japan's public pensions, or the equivalent of 76% of all private retirement assets in Japan (ICI (2021)). GPIF is almost exclusively invested through external managers to target specific benchmarks. For example, 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 investment manager-by-manager and estimate GPIF's USD investments as the amount of its portfolio allocated to track U.S. bonds or equity benchmarks. Similarly, we use allocation to target benchmarks that are explicitly hedged to estimate GPIF's FX hedging activities. To illustrate, investments in "FTSE US Government Bond Index (JPY hedged/JPY basis)" are considered hedged, whereas investments in "FTSE US Government Bond Index (no hedge/JPY basis)" are considered not hedged.

The pensions industry in the Netherlands is also very concentrated: the two largest pension funds, ABP and PFZW, manage assets equivalent to 1.5 times those of the next 15 biggest combined,[26] covering 50% of assets in all Dutch pension funds.[27]. We obtain from ABP's and PFZW's annual reports their total assets, USD investments, and the split between USD equities and USD bonds. Both funds disclose in their annual report their unhedged (or net) USD exposure after FX derivatives are factored in. We estimate their hedging activity as the difference between total and unhedged USD exposure. We make our estimates separately for bonds and for equities.

The two largest pension funds in Canada are the Canada Pension Plan Investment Board (CPP) and Caisse de dépôt et placement du Québec (CDPQ). These two funds have 45% of the AUM of the top eight public pension funds in Canada, which in turn represent two thirds of all pension assets in Canada.[28] For CPP, we collect from its annual reports its total assets, investment in the U.S., and target portfolio allocation. CPP stopped investing in foreign bonds after 2015 so that all of its exposure to the U.S. is from equity. We moreover analyze CPP's extensive discussions of hedging strategy. CPP conducts no currency hedging between 2004-2007 and after 2015. Between 2008 and 2014, it hedges only bond investments. For CDPW, we collect from its annual report its total asset, foreign portfolio along with the

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

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

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

split between debt and equity, and USD exposure. In recent years, CDPQ stopped reporting USD exposure and reports only exposure to the U.S., which we use as an estimate of the former, understanding that this would be a conservative estimate. Since 2013, CDPQ has been reporting its unhedged (or net) USD exposure. We estimate CDPQ's hedging as the difference between total USD exposure and unhedged USD exposure.

In Australia, the Australian Prudential Regulation Authority (APRA) publishes *Quarterly Superannuation Performance*, which provides statistics on all regulated pensions (any entity with more than four members). These statistics go back to 2004 and contain detailed information on total asset, foreign investments, and aggregated amount of FX hedging done. Foreign investments and hedging activities are separately reported for equities and bonds. To estimate the amount of USD bond and equity holdings, we complement the APRA statistics with the Australian Bureau of Statistics' (ABS) *Foreign Currency Exposure, Australia*. This ABS publication presents the results from a triennial survey of Australian resident enterprises with exposure to foreign currencies. In particular, we analyze the currency holding of non-bank financial institutions, which include pension funds, insurance companies, and other financial intermediaries. We take the shares of USD in non-bank financial institutions' foreign equity portfolios and foreign bond portfolios as representative of pension funds' exposure.

The Swiss Federal Statistical Office provides an annual publication akin to the APRA statistics. Similar to APRA, the Swiss publication reports pension funds' foreign investments but does not break down investments by currency. We supplement our analysis with Credit Suisse' Swiss Pension Fund Index 2020, which estimates the currency allocation of Swiss pension funds' investment portfolio between 2018 and 2020. Also similar to APRA, the Swiss publication does not distinguish domestic vs. foreign private equity investments. To be conservative, we exclude private equity in our estimate of USD equity holdings by both the Australian and the Swiss pensions. To estimate hedging activities by Swiss pensions, we use the industry aggregate hedge ratio from Swiss Pension Fund Study 2021 (Swisscanto Pensions (2021)).

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

The Superintendencia de Pensiones of Chile releases quarterly reports on the country's pension sector starting in 2014. Information is detailed and includes total assets, foreign investments, and net FX exposure after hedging. Information is available by currency and split by bond vs. equity.

Finally, we also consider pension funds in Denmark, Sweden, Israel and 9 other mostly

Latin American countries. The data for Danish, Swedish, and Israeli pensions are from the same sources as those for insurers in these countries, described above. Our data on Latin American countries come from Federación Internacional de Administradoras de Fondos de Pensiones (FIAP). FIAP releases annual series starting 2002 on foreign investments by pensions in Bolivia, Colombia, Costa Rica, El Salvador, Mexico, Peru, Dominican Republic, Uruguay, and Kazakhstan.[29]

Foreign Mutual Funds' Holdings and Hedging

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

We assess the hedging strategy of mutual funds at the share class level. Specifically, each share-class of a mutual fund in Morningstar reports its hedging status as completely hedged, partially hedged, or not hedged. In addition to relying on the self-reported currency hedging status, we also identify additional hedged share classes if their tracking benchmarks are currency-hedged, for example, "U.S. Corporate Bond EUR Hedged". We sum the AUM of all share-classes that are either completely hedged or partially hedged. Partially hedged share classes are not common in the data. However, we are aware of the data limitation that we do not observe the exact hedge ratio of mutual fund investments.

Foreign Banks' Holdings

We estimate holdings of USD securities by non-US banks using BIS Locational Banking Statistics (LBS). LBS provides quarterly data on the outstanding claims and liabilities of internationally active banks located in reporting countries. We focus on holdings of debt securities by banks because it is much more capital intensive for banks to hold equity securities. However, non-US banks' cross-border holdings of USD debt securities are a confidential time series only available to central banks.[30] We therefore apply an adjustment factor to the

[29] FIAP also has sparse reporting from Russian Fedration, Poland, and Romania; however, these reports stopped after 2013. For Chile, we use information obtained directly from Superintendencia de Pensiones instead of the aggregate statistics from FIAP.

[30] This information cannot be deduced from United States' reporting to the BIS because the U.S. reports only U.S. banks' loan and deposit positions and does not include debt securities positions.

difference between foreign banks' USD holdings and USD loans, to arrive at an estimate of debt securities holding. Our estimated series has a 0.98 correlation with LBS' confidential series.

Foreign Hedge Funds' Holdings

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

Foreign Non-Financial Sector's Holdings

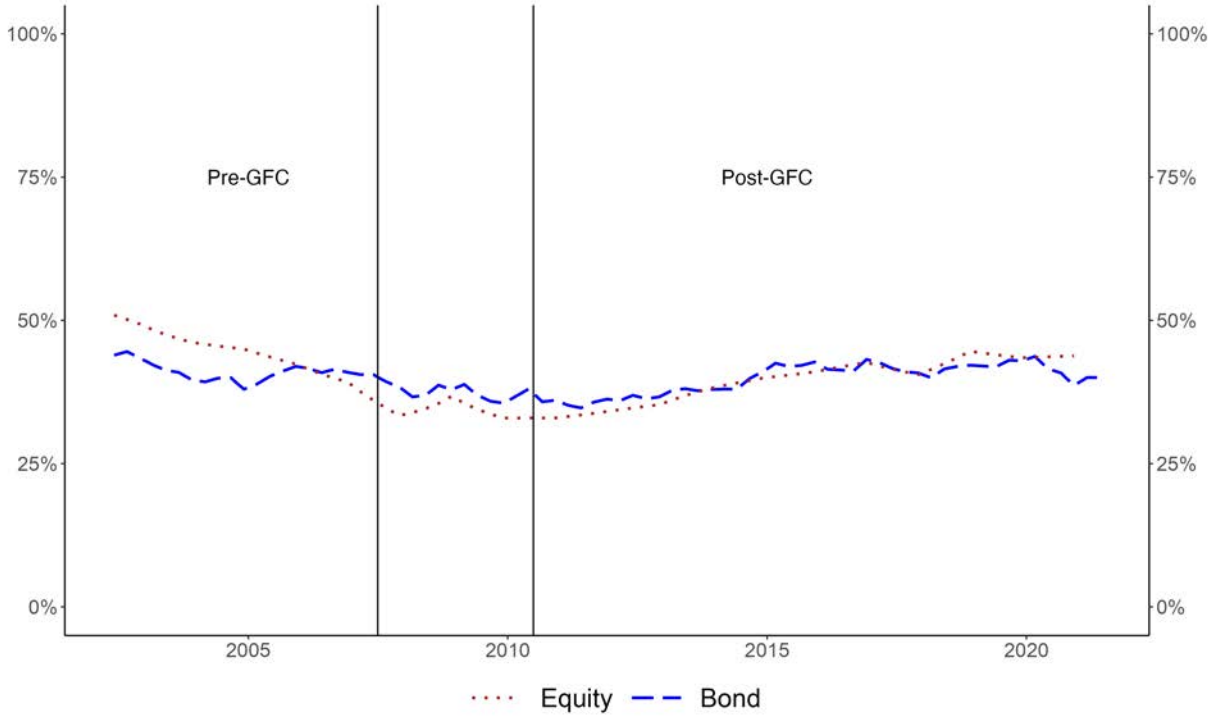
To estimate foreign non-financial companies and households' USD holdings, we use the IMF's Coordinated Portfolio Investment Survey (CPIS) data. CPIS reports bilateral investment portfolios that are sometimes broken out by currency and by sector. Yet because very few countries report cross-border investment by currency, our estimates are based on investments in the United States by the non-financial sector from a non-U.S. country reporting to the CPIS. Of the 81 countries reported as having assets in the United States, 56 countries report their investment separately for the non-financial sector. Our estimate is therefore conservative: there could be countries who own assets in the U.S. but choose to not report, there could be investments by the non-financial sector that were not separately reported, and there could be USD investments in non-US countries.

Foreign Official Sector's Holdings

We estimate the foreign official sector's holding of U.S. securities from TIC. Starting 2007, TIC reports securities held by the official sector in 237 countries and jurisdictions, separately for debt and equity. For years prior to 2007, we estimate the total as the sum of the official sector's holding of long-term debt and equity, provided by Bertaut and Judson (2014), and of short-term Treasury securities, as released by the Treasury's department. Our assumption is that the official sector — central banks, sovereign wealth funds, and other public financial agencies — do not obtain significant USD assets from non-US entities.

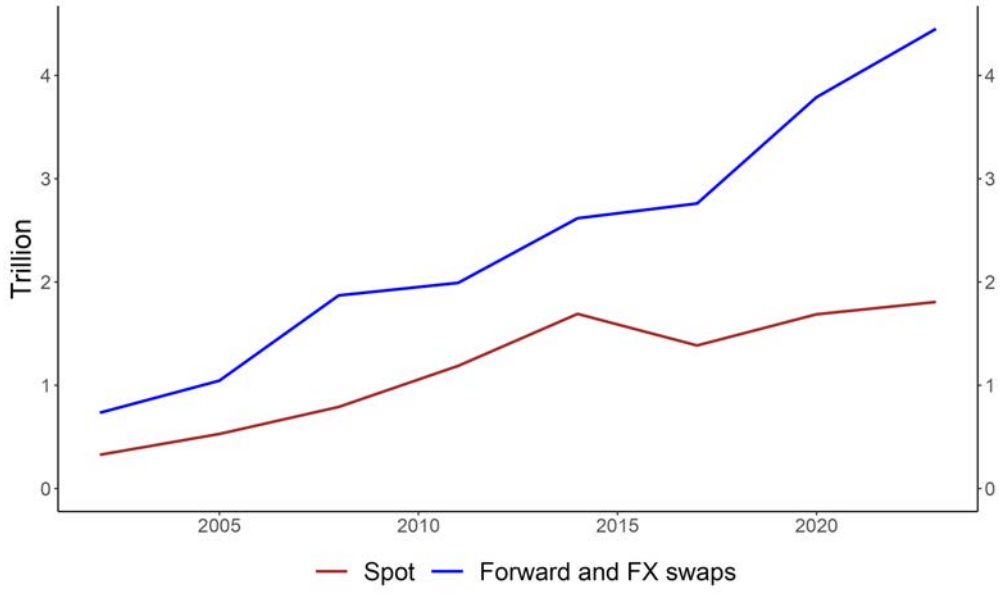
B Additional Figures and Tables

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

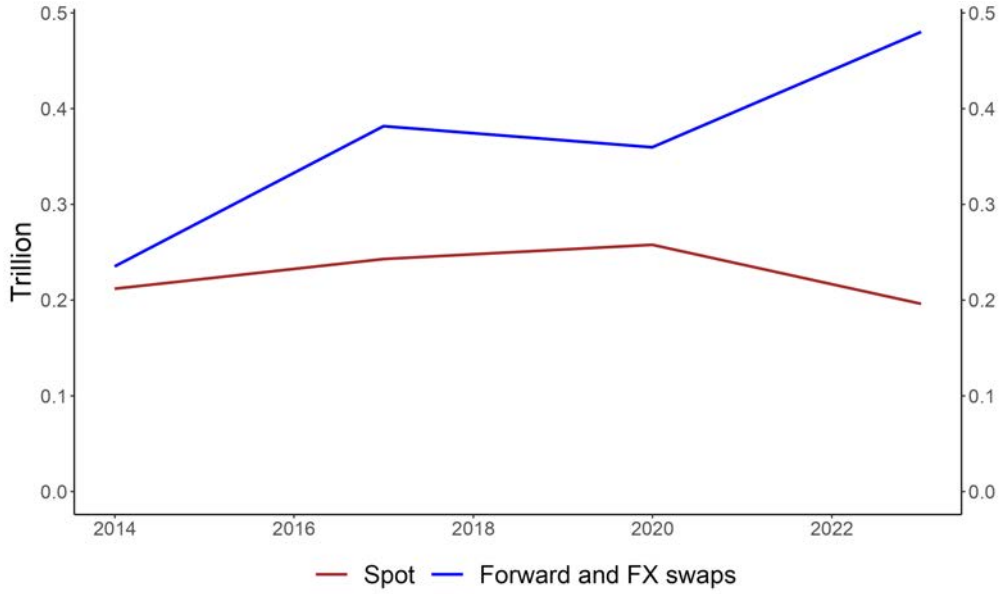


Notes: This figure plots the share of USD bonds and equities in their respective global markets. Global bond market size is calculated from BIS' debt securities statistics, inclusive of all issue markets. Global equity market is the sum of global public market cap and global private equity AUM. Global 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**



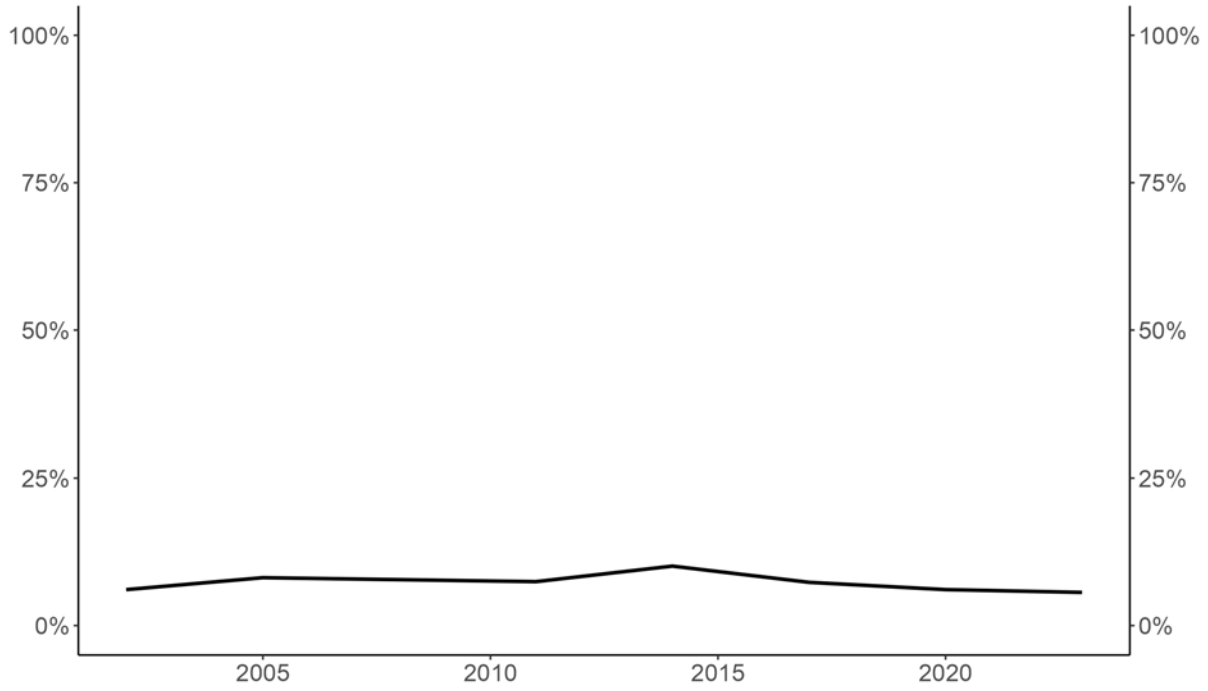
(a) **All volumes**



(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.

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.