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Global Dollar Exposure and Its Relationship with CIP Deviations

Prepared by Zixuan Huang and Aki Yokoyama

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ABSTRACT: This paper analyzes a global map of dollar exposures and examines the relationship between net dollar exposures, defined as the difference between dollar assets and liabilities, and covered interest parity (CIP) deviations. We find that the cross-sectional relationship is significantly negative in advanced economies but positive in emerging markets. CIP deviations represent the hedging cost that foreign holders of dollar assets or liabilities incur to manage exchange rate risk. To explain, we develop a model in which the CIP deviations are determined by the demand and the supply side of hedging. The negative correlation in advanced economies can be explained by the variations in hedging demand. Larger net dollar exposures increase the hedging demand, raising hedging costs (reflected as more negative CIP deviations) and producing a negative correlation. In contrast, the positive correlation in emerging markets is explained by the supply side of the hedging market. Limited hedging supply leads to wider CIP deviations (more negative), encouraging firms to borrow in U.S. dollars rather than local currencies, thereby reducing net dollar exposures and generating a positive correlation.

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WORKING PAPERS

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Global Dollar Exposure and Its Relationship with CIP Deviations *

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June 4, 2026

Abstract

This paper analyzes a global map of dollar exposures and examines the relationship between net dollar exposures, defined as the difference between dollar assets and liabilities, and covered interest parity (CIP) deviations. We find that the cross-sectional relationship is significantly negative in advanced economies but positive in emerging markets. CIP deviations represent the hedging cost that foreign holders of dollar assets or liabilities incur to manage exchange rate risk. To explain, we develop a model in which the CIP deviations are determined by the demand and the supply side of hedging. The negative correlation in advanced economies can be explained by the variations in hedging demand. Larger net dollar exposures increase the hedging demand, raising hedging costs (reflected as more negative CIP deviations) and producing a negative correlation. In contrast, the positive correlation in emerging markets is explained by the supply side of the hedging market. Limited hedging supply leads to wider CIP deviations (more negative), encouraging firms to borrow in U.S. dollars rather than local currencies, thereby reducing net dollar exposures and generating a positive correlation.

Keywords: Dollar assets, dollar liabilities, banks and non-banks, covered interest parity
JEL Codes: F30, F31, G10, G15

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1 Introduction

A noteworthy development since last year in global financial markets has been the weakness of the U.S. dollar, first following President Donald Trump's April 2 tariff announcement, and later after the Federal Reserve's rate cut in September. Analysts highlighted dollar-asset holders' rush to hedge the currency risk following the dollar depreciation, leading to widening deviations from covered interest rate parity (CIP) for some economies. These episodes triggered concerns among investors and policymakers about the financial instability faced by countries holding large stocks of dollar-denominated assets. As macroeconomic uncertainty surrounding U.S. policy increases, so does the urgency of understanding global dollar exposures and their implications for financial markets. Answering these questions requires knowledge of how much countries' dollar exposures are. This paper therefore provides an analysis of countries' dollar exposures and the relationship between dollar exposures and CIP deviations, for both advanced and emerging market economies.

We demonstrate two key facts. First, global dollar-denominated assets have risen substantially faster than liabilities, primarily driven by advanced economies, whose non-bank sectors have increasingly accumulated US dollar assets over the past decade. Second, the relationship between net dollar exposures, defined as the difference between dollar-denominated assets and liabilities, and CIP deviations is significantly negative for advanced economies. That is to say, countries with larger net dollar exposures have more negative CIP deviations in the past decade. In contrast, the relationship is significantly positive for emerging markets, driven by the non-bank sectors. We offer explanations for the divergence between advanced and emerging markets.

We begin by documenting the total amount of dollar-denominated assets and liabilities for a group of countries. For this purpose, we construct a dataset that quantifies countries' holdings of dollar-denominated assets and liabilities, providing a global map of dollar exposures across both time and countries. Our dataset combines multiple data sources, including IMF, US Treasury, BIS, central banks, and academic papers, to produce country-year observations for more than 40 countries from 2013 to 2024. We further disaggregate between bank and non-bank sectors to capture heterogeneity across asset and liability holders. The resulting dataset offers detailed cross-country and over-time view of dollar exposures.

We find that the global dollar-denominated assets have risen substantially faster than dollar-denominated liabilities. Dollar assets climbed steadily from under $20 trillion in 2013 to over $40 trillion in 2024, while dollar liabilities increased by less than $10 trillion during the same period. As a share of GDP, dollar assets expanded from about 130% to near 200% whereas dollar liabilities stayed relatively unchanged. This widening asymmetry has been driven primarily by advanced economies, whose non-bank sectors have increasingly accumulated U.S. dollar assets, while bank-sector positions remain broadly stable.

Yet, holding dollar assets does not necessarily translate into exposure to exchange rate risk. Investors can hedge their dollar positions using swap or forward contracts. As shown in the existing literature, these hedging activities affect deviations from covered interest parity (CIP), which reflect violations of an otherwise fundamental no-arbitrage condition in currency markets. Motivated by this linkage, we investigate the relationship between countries' dollar exposures and their CIP deviations across both advanced and emerging economies.

CIP deviations can be correlated with dollar exposures because of hedging. The cost to fully hedge an FX position using swaps, i.e. hedging cost, is directly observable as the CIP deviation, often referred to as the "basis". CIP deviations are defined as the interest rate differentials adjusted by forward premium. A negative CIP deviation implies a positive hedging cost for holders of dollar-denominated assets. Intuitively, a negative CIP deviation indicates a lower forward rate, meaning that, to hedge the exchange rate risk, dollar asset holders must sell dollars at a relatively low price in the future. As a result, they incur a cost by selling at a low price. In other words, they need to pay a premium to swap their dollar income back to their home currency to avoid currency risk. Similarly, a positive CIP deviation means a high forward rate, thus dollar liability holders, in order to hedge the exchange risk, must buy dollars at a relatively high price in the future. As a result, dollar liability holders effectively pay a cost for hedging.

Du et al. (2024) demonstrate a negative relationship between 3-month CIP deviations and countries' USD FX hedging of insurance, pensions and mutual funds, for 12 countries. Hedging volume to GDP ratio explains more than 70 percent of cross-sectional variations in CIP deviations. Consistent with Du et al. (2024), we confirm a significantly negative relationship between dollar exposures and CIP deviations among advanced economies, suggesting that higher hedging demand is associated with more negative CIP deviations. However, our empirical analysis also uncovers asymmetry between advanced and emerging markets. For emerging markets, the relationship becomes significantly positive. Countries with larger dollar exposures exhibit less negative or more positive CIP deviations.

To explain the divergent patterns, we develop a model in which CIP deviations arise endogenously from the interaction between the demand and the supply sides of hedging markets. On the demand side, dollar asset and liability holders choose how much dollar assets they want to hold and how much dollar debt they want to issue, respectively. Considering exchange rate risk and hedging costs, they seek swap or forward contracts to hedge the risk. On the supply side, arbitrageurs, typically global banks in the case of advanced economies, provide these contracts subject to balance sheet constraints. In equilibrium, CIP deviations are determined by the market clearing condition of the swap or forward market.

The model provides the prediction about the relationship between the CIP deviations and net USD exposures. Whether the cross-sectional correlation between net dollar exposures and CIP deviations is positive or negative depends on which side of the market drives the variation across countries. When the demand side dominates, greater dollar holdings increase hedging demand, pushing CIP deviations more negative and creating a negative correlation. On the other hand, when supply-side variations dominate, such as higher haircuts or regulatory limits that raise hedging costs, countries face large deviations (more negative CIP deviations) and respond by reducing dollar asset holdings and issuing more dollar liabilities. This leads to a smaller net dollar exposure, generating a positive correlation.

The observed correlation for advanced economies and emerging markets indicates the different drivers for cross-sectional variations in CIP deviations for two groups of countries. Among advanced economies, global banks form a shared supply of dollar funding across countries, so cross-sectional differences in CIP deviations primarily reflect the demand heterogeneity, leading to a negative relationship between dollar exposures and CIP deviations. Among emerging markets, local regulatory frictions and capital controls affect the ability of domestic institutions to supply hedging liquidity, implying that cross-sectional variation is driven mainly by the supply side[1]. Hence, we observe a positive relationship.

Literature. Since our paper studies countries' dollar holdings and their implications for CIP

[1] Indeed, as illustrated by Cerutti and Zhou (2024), global common factors are muted to affect the CIP deviations of emerging market economies.

deviations, it relates to a number of different strands of research in international finance and intermediary asset pricing. First, it contributes to the literature on countries' dollar asset holdings. Du et al. (2024) focus on global institutional investors including insurance companies, pension funds and mutual funds to estimate foreign investors' U.S. dollar security holdings as well as hedging practices. Compared to it, this paper attempts to capture the overall dollar exposures, including but not limit to institutional investors. Relevantly, Benetrix et al. (2019) and Allen and Juvenal (2025) estimate the currency composition of countries' external assets and liabilities. They primarily rely on data on international investment position (IIP) complemented by other data sources from IMF, BIS, and ECB. Different from these papers focusing on IIP which includes foreign direct investment and reserves, our paper excludes these two categories of assets because we focuses on dollar assets that are potentially linked to hedging activities[2]. Furthermore, our data distinguishes asset holders to banks and non-banks, providing a picture of who holds the dollar assets and liabilities.

Our paper is also related to the literature on CIP deviations and the drivers. It is well documented that the CIP deviations in advanced economies were very close to zero before the global financial crisis, but substantially changed after (Baba and Packer (2009)). Existing literature analyzes demand and supply factors affecting CIP deviations primarily through the lens of banking flows (Ivashina et al. (2015), Iida et al. (2018)). In contrast, a distinctive feature of our theoretical framework is that optimal hedging demand and supply are determined based on the stock of USD positions. This stock-based approach enables cross-sectional comparisons of hedging demand across countries. Literature also focuses on financial intermediaries' constraint on explaining the CIP deviations, see Du et al. (2018), Avdjiev et al. (2019), and Du and Schreger (2022). Sushko et al. (2016) emphasizes the demand to hedge USD forward as a driver of CIP deviations, other than transaction costs or credit risk. Similarly, Dao and Gourinchas (2025) also investigate the channel of hedging, alongside other factors such as dollar funding costs and global banks' balance sheet capacity. Our paper is closely to related to Dao and Gourinchas (2025), which find the

[2]Dollar-denominated assets in foreign direct investment (FDI) are often funded by dollar debt, reflecting a natural hedge. In addition, Foreign direct investors tend to focus primarily on the underlying asset returns rather than currency returns, which can lead to less active currency hedging of their investments compared to portfolio investors. Similarly, foreign exchange reserves are typically held by countries for official policy purposes. As a result, hedging activities related to foreign exchange reserves are usually minimal or limited since reserves represent official assets held for strategic rather than speculative or investment purposes

negative correlation between CIP deviations and dollar exposures for advanced economies and weakly positive correlation for emerging markets. As highlighted in the paper, the sign of the correlation for advanced economies is consistent with the theory, but not for emerging markets. It attributes the positive correlation for emerging markets to the measurement of the conventional CIP deviations. They build a "purified" CIP deviations and find a statistically negative correlation for emerging markets using the newly constructed "purified" CIP deviations just as advanced economies. Complementing this paper, we provides another possible explanation for the positive correlation: the cross-sectional variations in CIP deviations among emerging markets could be driven by supply side, rather than the demand side. We further discuss this paper in detail in section (4).

While the vast majority of the literature focusing on CIP deviations examine CIP deviations in advanced economies, our paper joins the group of studying emerging markets. Former studies on emerging markets include Du and Schreger (2016), Dao and Gourinchas (2025) and Cerutti and Zhou (2024). Our paper links the CIP deviations to dollar exposures and compares the different patterns between advanced economies and emerging markets.

Lastly, by studying dollar asset holdings, we also further the literature on the demand for dollar safe assets. Although not all dollar asset holdings studied in our paper are dollar safe assets such as US Treasuries, our dollar exposures partly reflect the countries' demand for dollar safe assets. As highlighted in Jiang et al. (2021) and Krishnamurthy and Lustig (2019), fluctuations in foreign demand for dollar safe assets can lead to CIP deviations. Our measurement on dollar exposures and findings about the relationship between the overall dollar exposures and CIP deviations emphasizes the role of US as not only the supplier of safe dollar assets but also as the supplier of general dollar assets.

The rest of this paper is organized as follows: Section (2) describes the method data construction and the data sources used to assemble the data set on dollar exposures and other data sources used in the empirical analyses. Section (3) presents the stylized facts on dollar exposures by holders and by types of countries. Section (4) shows the cross-sectional connection between CIP deviations and net dollar exposures, and provides a model to explain the difference between advanced economies and emerging markets. Finally, section (5) concludes.

2 Data

We construct a dataset on dollar-denominated assets and liabilities for 50 countries, covering both advanced economies and emerging markets, over the period 2013-2024. Actual data come from multiple data sources including IMF's Coordinated Portfolio Investment Survey (CPIS), U.S. Department of Treasury's Treasury International Capital System (TIC), Bank for International Settlements' (BIS) Locational Banking Statistics (LBS), IMF's Currency Composition of Official Foreign Exchange Reserves (COFER), IMF's International Reserves and Foreign Currency Liquidity (IRFCL), BIS' International Debt Securities (IDS), central banks, and academic papers Ito and McCauley (2020) and Chinn et al. (2022). The methodology and data sources are summarized below and comprehensively detailed in Appendix.

Estimating USD Assets. Dollar-denominated assets encompass equities, bonds, and bank claims. Data on equities and debt instruments are sourced from IMF's CPIS and US Treasury's TIC, whereas data on bank claims are from BIS' LBS.

We prioritize CPIS data on dollar-denominated equities and debt to TIC data for two main reasons. First, CPIS data are less affected by custodian bias than TIC data as it is reported by individual countries[3]. Second, since TIC just reports U.S. securities, it does not include dollar securities issued outside the U.S., whereas CPIS data include all cross-border portfolio investment. Therefore, we prioritize CPIS data and TIC data is incorporate to fill gaps whenever CPIS data in unavailable.

An additional refinement pertains to foreign exchange reserves. Unlike privately held dollar assets, foreign exchange reserves are typically held by countries for official policy purposes, and hedging activities are generally absent or limited[4]. Since this paper focuses on dollar assets that are potentially linked to hedging activities and their relationship with movements in CIP deviations, foreign exchange reserves are excluded. CPIS data, fortunately, does not include foreign

[3]TIC classifies foreign holdings of U.S. securities based on the country of residence of the holder, not the ultimate owner, which can lead to significant distortions, particularly for jurisdictions serving as financial conduits. Reported by individual countries, CPIS data are less affected by custodian bias than TIC data (Judson and Kim (2026)). However, for some jurisdictions where cross-border financial intermediation is significant, CPIS data may still capture the resident entities which can be owned or controlled by foreign countries. That is to say, while prioritizing CPIS data partially mitigates the issue by tracking the owner better than TIC data, we acknowledge a limitation inherent in these data sources that CPIS data are compiled on a residence basis rather than on a nationality basis.

[4]This is because central banks primarily manage reserves for liquidity, stability, and policy objectives rather than market-driven risk management.

exchange reserves, but TIC data does. Therefore, when TIC data is used for a country, official foreign exchange reserves denominated in US dollars are subtracted. To quantify US dollar reserves, we multiply the total reserves by the share of the US dollar.

Data on total foreign exchange (FX) reserves are either from IMF's IRFCL or from central banks or Haver Analytics. Data on share of the US dollar in FX reserves are from Ito and McCauley (2020) and Chinn et al. (2022). For countries not covered in Ito and McCauley (2020), we rely on IMF's COFER, which provides the global aggregate share of USD in FX reserves, and we apply it as a proxy at the country level.

Finally, dollar assets also include dollar-denominated bank loans and dollar deposits held by the non-bank sectors of the economy. We take the actual data on the former from BIS LBS, and use the information on counterparties for the latter. Specifically, all deposit liabilities reported by foreign countries that identify deposits from that country's non-bank sectors are summed up to estimate the total USD deposits held by the non-bank sector at the country level.

Estimating USD Liabilities. Liabilities denominated in US dollars include countries' issuance of US dollar debt, their borrowing in USD loans, and bank deposits in the US dollar. Data for BIS IDS is used to obtain dollar debt issuance. IDS records USD-denominated debt issued by countries in the international market. The drawback of using this dataset is that the dollar debt issued in the domestic market is not included. For dollar borrowing in the form of bank loans, counterparty information from BIS LBS data is again used, aggregating all dollar loans reported by each reporting country, for a given counterparty country. Finally, deposits denominated in US dollars are extracted directly from BIS LBS.

Uncaptured exposures. As aforementioned, this dataset we construct focuses on the cross-border positions, thus, local U.S. dollar positions are not covered. For example, the estimate does not capture local investors' exposures to US dollar assets issued by local institutions, such as Formosa bonds, which are bonds issued in Taiwan Province of China and denominated a currency other than the Taiwan dollar.

Banks and non-banks. We further decompose USD assets and liabilities by holders – banks and non-banks. Banks' assets and liabilities denominated in USD are corresponding components on banks' balance sheets. The remaining is held by non-banks. Note that non-banks should include both non-bank financial institutions and the corporate sector, which we are not able to separate according to the public datasets we rely on.

As a result, we construct a data on assets' and liabilities' exposures to US dollar for 40 countries from 2013 to 2024. The panel data is slightly unbalanced due to unavailability of some data components. Among the 40 countries[5], we have 30 advanced economies and 10 emerging market economies.

Other datasets. Other datasets are used for this study. To estimate the US dollar exposures relative to the monthly transaction volume of each local foreign exchange market, we divide the total amount of US dollar exposure of countries by the monthly FX turnover of the corresponding currency. The data on the FX turnover is from BIS Triennial Central Bank Survey. In addition, we compute three-month CIP deviations using interest rates, forward rates and spot exchange rates from Bloomberg and Refinitive. We elaborate details on constructing CIP deviations in section (4).

3 Stylized Facts

In this section, we present several stylized facts about countries' exposure to the US dollar. We find significant heterogeneity across countries, particularly between advanced and emerging market economies, as well as notable changes over the past decade. In the following, I will document the developments over time, followed by cross-sectional divergences among countries.

3.1 Rapid increase in USD exposures driven by non-banks

Figure (1) shows the USD asset exposures have increased over the past decade. To ensure comparability over years, we only include countries with data available for all years. Globally, USD-denominated assets amounted to 42 trillion in 2024[6]. This nearly doubled from 19 trillion in 2013. Du et al. (2024) also documents the growing importance of USD-denominated securities in international investors' portfolios. According to their estimate, foreign holdings of USD bonds and equities have increased sixfold in the last two decades (from $5.5 trillion in 2002). As a share of GDP, the average for countries in our sample rose from 132% in 2013 to 195% in 2024. Both absolute amounts and figures relative to GDP have increased significantly.

[5] including jurisdictions

[6] While our estimate is similar in magnitude to Du et al. (2024), the coverage differs. Our estimates include bank claims, whereas Du et al. (2024) only covers portfolio investments. In addition, Du et al. (2024) includes foreign exchange reserves, which we exclude as detailed in section (2).

Compared to USD-denominated assets, USD-denominated liabilities are much smaller, about forty percent less as of 2024. The absolute amount of liabilities has increased over the past decade, but less so than assets. As a result, foreign holdings of USD-denominated liabilities relative to GDP have remained roughly unchanged, peaking in 2015 and declining steadily thereafter, as shown in Figure (1).

To understand whether the increase in USD-denominated assets are driven by banks or non-banks, we examine holdings by these two investor types over the past decade. We find that the growth in USD-denominated assets primarily reflects rising non-banks' holdings, while USD assets held by the banking sector have remained stable, as seen in Figure (2). For USD-denominated liabilities, both banks and non-banks show stable patterns.

The increase in non-banks' holdings of USD assets in our estimate aligns with Du et al. (2024), which documents greater allocation to USD securities across insurance, pensions and mutual funds. This rise in USD assets allocation across these non-bank industries is attributed both to higher allocations to non-domestic investments and more active rebalancing within those non-domestic investments toward USD-denominated assets.

3.2 USD exposures show heterogeneity across countries

This subsection summarizes the USD asset holdings across countries. Consistent with previous subsection exploring the time trend, only countries with data available for all years are included. We explore emerging markets and advanced economies separately.

Figure (3) shows that emerging market economies exhibit more balanced USD assets and USD liabilities, which have remained aligned over the past decade. In contrast, USD assets noticeably exceed USD liabilities in advanced economies. The gap has widened due to a rapid increase in USD assets. Comparing emerging markets and advanced economies, the rise in global USD exposure has been primarily driven by advanced economies.

Figure (4) highlights the growing dominance of non-banks in advanced economies' USD asset holdings. While banks and non-banks each held roughly half of USD assets in 2013, non-banks accounted for over 65 percent by 2024, leaving banks with about 35 percent. In emerging markets, banks and non-banks hold similar amounts of USD assets. Figure (5) shows the time trends of USD liabilities by banks and non-banks in both advanced economies and emerging markets. Non-banks constitute a larger share of liabilities than banks in both groups, especially in emerging markets. Liability composition has remained relatively stable over the past decade.

Figure (6) and (7) compare USD assets and liabilities of banks and non-banks in advanced economies and emerging markets, respectively. In advanced economies, both banks and non-banks are net holders of dollar assets, having more dollar assets than dollar liabilities. However, in emerging markets, only banks are net dollar asset holders, while non-banks have more dollar liabilities than assets. This echoes the literature documenting the expansion of dollar debt among emerging market firms due to favorable interest rates and exchange rate expectations (see McCauley et al. (2015)).

The aforementioned figures reveal distinctive differences within groups. Given the drastic increase in USD assets alongside a stable trend for USD liabilities, we delve deeper into the marginal investor of USD assets. For the total USD asset holdings, non-banks play a significant role in advanced economies, whereas banks holder a larger share in emerging markets. This leads to our next question: who are the marginal investors of USD assets? Specifically, when a country's total USD asset holdings increase, do banks or non-banks primarily contribute to the growth? To explore this, we regress the change in USD assets held by banks and non-banks on the change in total USD assets, following the approach of Fang et al. (2025):

$$\frac{A_{i,t}(c) - A_{i,t-1}(c)}{A_{t-1}(c)} = \alpha_i \frac{A_t(c) - A_{t-1}(c)}{A_{t-1}(c)} + \alpha_c + \epsilon_{i,t}, \forall i, \tag{1}$$

where $A_{i,t}(c)$ are USD asset holdings by banks or non-banks of country c at time t, $i \in \{\text{banks, non-banks}\}$. $A_t(c)$ is the total USD assets of country c at time t. Both changes in USD assets by holders and total amount are scaled by the lagged total USD assets. By construction, the coefficient α_i for banks and non-banks sum up to one. To capture time variations, we include country fixed effects α_c. Standard errors are Driscoll-Kraay standard errors to allow cross-sectional and serial correlations.

Table (1) presents the results. Column (1) shows baseline estimates for all countries in our dataset. Column (2) and (3) report estimates for advanced and emerging market economies, respectively. Results show that non-bank investors contribute more to increases in total USD assets than banks in advanced economies, whereas the opposite is true for emerging markets. In advanced economies, where non-banks drive 83% of the increase in USD assets compared to 18% by banks. For emerging markets, non-banks account for 27% and banks 73%. This underscores the growing importance of non-bank investors in USD asset holdings in the last decade in advanced economies, contrasting with emerging markets where banks remain dominant.

3.3 USD exposures relative to FX markets

Countries with exposure to USD assets could be more susceptible if their foreign exchange (FX) markets are shallow. To account for this, we scale countries' USD exposures by the FX turnover. As discussed in section (2), we use data from BIS Triennual Survey which provides daily FX turnover figures for key currencies. We convert these daily turnover values to monthly and then divide each country's total USD assets by the corresponding monthly FX turnover volumes[7].

We find that the level of USD assets scaled by GDP does not perfectly correlate with the level scaled by FX turnovers. Figure (9) compares the average logarithm of USD assets scaled by GDP and by FX turnover for countries in our sample, illustrating the disparity between the two measures across countries. For instance, Luxembourg exhibits a relatively high ratio of USD assets to GDP, reflecting its prominent role as a global financial center. However, its USD assets scaled by FX turnover are comparatively lower, due to the depth of the Euro FX market. Conversely, Taiwan demonstrates a substantial volume of USD assets relative to the size of its FX market size but a smaller ratio when scaled by GDP, reflecting the relatively shallow FX market for the Taiwanese dollar.

4 USD Exposures and CIP Deviations

A growing literature has documented significant deviations from covered interest parity (CIP), also known as the CIP basis, especially after the global financial crisis. Before 2008, CIP deviations for advanced economies had been close to zero, consistent with the non-arbitrage condition. However, since the crisis, these deviations have become non-zero and more volatile, contradicting the CIP condition. Two primary interpretations have emerged: financial frictions faced by intermediaries and variations in hedging demand. The first explanation links the movements in

[7] Since the Triennual Survey is conducted every three years, we apply the reported numbers to adjacent years as approximations. Specifically, if the survey reports data for year t, we assign these reported values to years $t-1$ and $t+1$.

the CIP deviations to the fluctuating capacity of financial intermediaries to expand their balance sheets for risk-free arbitrage, see Du and Schreger (2022).

Our paper is more related to the second one, which posits that USD exposures drive CIP deviations. Foreign investors hedge their USD exposures to mitigate currency risk using FX forwards or FX swaps, thereby influencing CIP deviations. When dollar asset holders sell forward contracts, the forward exchange rate decreases, widening CIP deviations. Similarly, if hedging occurs via swaps, the cross-currency basis, i.e. CIP deviations, represents the hedging cost. Large hedging demand increases this cost, thus expanding CIP deviations.

Notable contributions to this area include Du et al. (2024) and Dao and Gourinchas (2025). Du et al. (2024) finds a strong relationship between USD hedging demand by financial intermediaries and CIP deviations across countries. Dao and Gourinchas (2025) states that the sign of CIP basis depends on the net dollar hedging demand. Countries with net dollar assets sell dollar forwards for hedging, resulting in negative CIP basis to compensate the intermediaries. Countries with net dollar liabilities buy forwards to hedge their exposure, implying a positive CIP basis.

We begin this section by defining CIP deviations in subsection (4.1), then analyze the relationship between CIP deviations and dollar exposures for banks and non-banks in advanced economies and emerging markets in subsection (4.2). Our findings reveal a negative cross-sectional relationship between CIP deviations and net dollar exposures in advanced economies, whereas a positive one in emerging markets. Finally, to explain, we develop a model to illustrate the distinct mechanisms that drive the divergent relationships in the two groups of countries in subsection (4.3).

4.1 CIP deviations

Following Du and Schreger (2022), we now formally define the CIP condition and the CIP deviation. The one-period CIP condition is defined as

$$1 + y_t^{\$} = (1 + y_t^i)\frac{S_t^{i/\$}}{F_t^{i/\$}} \tag{2}$$

where $y_t^{\$}$ denotes one-period USD interest rate in the cash market at time t, y_t^i denotes the corresponding interest rates in foreign currency i, $S_t^{i/\$}$ is the spot exchange rate between the dollar and foreign currency i, defined as units of foreign currency per dollar, and $F_t^{i/\$}$ denotes the one-period forward exchange rate known at time t. The equation states that the cost of borrowing USD in the cash market should equal the cost of borrowing USD in the FX swap market, ensuring no riskless arbitrage opportunity exists.

If this equality does not hold, we introduce the CIP deviation, or cross-currency basis, defined as $x_t^{i/\$}$, allowing a wedge on the right hand side of the equation (2).

$$1 + y_t^{\$} = (1 + y_t^i + x_t^{i/\$})\frac{S_t^{i/\$}}{F_t^{i/\$}} \tag{3}$$

In log terms, the CIP deviation represents the difference between the direct dollar interest rate from the cash market and the synthetic dollar interest rate from the FX swap market.

$$x_t^{i/\$} = y_t^{\$} - y_t^i + \rho_t^{i/\$} \tag{4}$$

where $\rho_t^{i/\$}$ is the forward premium of selling currency i in exchange for the US dollar, i.e. the log difference between the forward rate and the spot rate. Therefore, the sign of $x_t^{i/\$}$ indicates the relative cost of borrowing USD from the cash market versus the FX swap market. A negative CIP deviation means USD borrowing costs more in the FX swap market, while a positive deviation means USD borrowing is more expensive in the cash market. From a hedging perspective, a negative CIP deviation implies investors who sell dollar forwards incur a cost because the forward rate is too low. Similarly, a positive CIP deviation indicates a high forward rate, therefore investors who buy dollar forwards incur a cost due to the elevated forward rate.

Following Du et al. (2024) and Cerutti and Zhou (2024), we focus on the 3-month CIP deviations for several reasons. As emphasized by Cerutti and Zhou (2024), focusing on the short-term deviations mitigates concerns of credit risk, especially for emerging market economies. Moreover, short term forwards and interbank lending markets are significantly more liquid than the longer term ones, meaning the observed interest rates and forward rates better reflect the equilibrium prices. This liquidity ensures that the 3-month CIP deviations provide a more accurate and timely measure of market frictions.

Conventional CIP deviations may still raise concerns regarding credit risk contamination.

Dao and Gourinchas (2025) provides a "purified" CIP deviation measures to explicitly filter out sovereign credit risk, primarily targeting one-year maturities. Our focus on the 3-month CIP deviation naturally mitigates this concern as aforementioned. Furthermore, to empirically validate that our 3-month measure captures true market frictions rather than credit risk, we calculate the correlation between our 3-month CIP deviations and sovereign CDS spreads. We find this correlation to be near zero in our sample, confirming that our short-term measure does not reflect sovereign default risk.

Table (2) shows the summary statistics of the CIP basis of advanced economies and emerging markets in our sample from 2013 to 2024. Since our dollar exposure data are at annual, we compute the yearly CIP deviations as the daily average of CIP deviations over each year. It is shown that CIP deviations are mostly negative, with the median for both advanced economies and emerging markets below zero. This reflects a higher cost of borrowing USD in the FX swap market relative to the cash market.

4.2 USD Exposures and CIP Deviations

This subsection empirically explores the relationship between dollar exposures and CIP deviations by types of countries and by types of dollar holders. A growing literature links USD exposures to CIP deviations. Du and Schreger (2022) explores hedging volume and finds a significantly negative relationship between CIP deviations and hedging volume. Similarly, Dao and Gourinchas (2025) demonstrate net dollar hedging demand determines the cross-sectional variation in CIP deviations. Countries with net positive dollar exposures have negative CIP deviations, while countries with net negative dollar exposures have positive CIP deviations. Both Du and Schreger (2022) and Dao and Gourinchas (2025) emphasize the role of the investors' hedging demand in explaining the cross-sectional variations in CIP deviations and agree on the negative correlation between dollar exposures and CIP deviations. However, we find this relationship varies between advanced and emerging market economies. Figure (10) shows the plot of CIP deviations and net dollar exposures in 2024 for these two groups separately, revealing divergent patterns. In this subsection, our results indicate that a negative correlation holds for advanced economies, driven by both banks and non-banks, whereas in emerging markets, a positive correlation is observed, driven solely by non-banks.

In the following, we examine the relationship between CIP deviations and net dollar exposures for both banks and non-banks, demonstrating the heterogeneity across advanced economies and emerging markets. To explore the cross-sectional variations in CIP deviations, we implement the following regression with time fixed effects.

$$CIP_{it} = \gamma_t + \beta DollarExp_{it} + \nu_{it} \tag{5}$$

where CIP_{it} is the CIP deviations for country i at year t. $DollarExp_{it}$ denotes the net dollar exposure of countries, defined as the difference between dollar assets and liabilities, divided by monthly FX turnover of the corresponding currencies. We treat all countries using the Euro as a single aggregate by summing up their dollar assets and liabilities. Note that we scale net dollar exposure by FX turnover because potential disruptions to CIP deviations depend on the depth of the FX market. A deeper FX market implies more active FX trading activities, enabling hedging demands to be met more easily, thus weakening disruptions to CIP deviations caused by dollar exposures.

To examine cross-sectional variations, we include time fixed effects γ_t in the regression. Standard errors are calculated using Driscoll-Kraay standard errors, which allow for both cross-sectional and serial correlations. To further investigate whether the relationship between CIP deviations and net dollar exposures holds for both advanced economies and emerging markets, we estimate sub-sample regressions for advanced economies and emerging markets separately.

Table (5) shows the results of the regressions. Consistent with Dao and Gourinchas (2025), the relationship is statistically and significantly negative for advanced economies. For emerging markets, however, the coefficient is significantly positive. The negative relationship for advanced economies is consistent with the mechanism of hedging demand driving the cross-sectional variations in CIP deviations. Higher hedging demand driven by large net dollar exposures pushes up the dollar borrowing cost in the FX swap market, making CIP deviations more negative[8].

The positive coefficient for emerging markets, shown in column (3), partly aligns with Dao and Gourinchas (2025), who find a weak positive correlation. Dao and Gourinchas (2025) attributes the lack of a negative correlation for EM currencies to the measurement challenges with conventional

[8]Stronger hedging demand drives up the dollar borrowing rate in the swap market, making it higher than the dollar borrowing rate in the cash market, which implies a more negative CIP deviation.

CIP basis, notably the difficulty in obtaining risk-free local currency interest rates. To address this issue, they construct a "purified" CIP basis and find a significant relationship when using this measure rather than the conventional CIP basis. To explicitly control for potential credit risk contamination in our analyses on emerging markets, we add sovereign CDS spreads to regression (5). Our primary results remain robust in both magnitude and statistical significance and are shown in Appendix. Next, we present the results on banks and non-banks.

Banks and non-banks. We further examine whether the correlation between the CIP deviations and net dollar exposures is driven by banks or non-bank sectors, by running the following regression.

$$CIP_{it} = \gamma_t + \beta_1 DollarExp_{bk,it} + \beta_2 DollarExp_{nb,it} + \nu_{it} \tag{6}$$

where $DollarExp_{bk,it}$ and $DollarExp_{nb,it}$ denote the net dollar exposures by banks and non-banks, respectively. By definition as shown in section (2), the sum of banks' and non-banks' net dollar exposure is equal to the total net dollar exposure in the baseline regression (5). Similarly to the baseline regression, we include time fixed effects to capture the global factors that affect the CIP deviations for all countries and to explore the cross-sectional variations. We apply Driscoll-Kraay standard errors.

The coefficients of our interest are β_1 and β_2, which compare the roles of banks and non-banks in driving the relationship with the CIP deviations. We conduct this analysis separately for advanced economies and emerging markets. Banks and non-banks play different role in these regions. As illustrated in section (3), both banks and non-banks are net dollar asset holders in advanced economies, while non-banks are net dollar liability holders in emerging markets.

Table (6) shows the results. Columns (1), (2), (3) display the estimates on β_1 and β_2 for the sample of all countries, advanced economies, and emerging markets, respectively. The coefficients on net dollar exposures for both banks and non-banks are significantly negative in advanced economies. In contrast, for emerging markets, the coefficient on banks' net dollar exposure is statistically insignificant, while the coefficient on non-banks' net dollar exposure is statistically positive. Similarly, our findings remain robust to the inclusion of sovereign credit risk as a control variable. This positive relationship contradicts the hedging demand channel.

Non-banks in emerging markets typically have more dollar liabilities than assets, as shown in section (3). According to the hedging demand channel, as they hedge their open dollar liability positions, non-banks provide dollar funding into the FX swap market. This supply of dollars lowers the dollar borrowing costs implied by the FX swap. Therefore, countries with more dollar liabilities, equivalently smaller net dollar exposures, should lead to a narrower CIP deviations (i.e. less negative or even positive CIP deviation), indicating a negative relationship between CIP deviations and dollar exposures. However, the significantly positive coefficient in our analysis suggests an alternative mechanism is driving the cross-sectional variations in CIP deviations in emerging markets, which can be linked to the substantial dollar-denominates debt held by non-banks sectors in emerging markets.

4.3 Divergent relations between CIP deviations and dollar exposures

Then how do we understand the positive relationship between the CIP deviations and non-banks' net dollar exposure in emerging markets? We connect CIP deviations with firms' decision on currency of debt issuance and asset holdings. Our argument is that not only investors' dollar exposures and hedging demands influence CIP deviations. If the cross-sectional variation in CIP deviations is driven by the supply side, the relationship can be positive. To illustrate this, We first provide a brief example focusing on firms' decision on dollar debt issuance, followed by a full model that incorporates investors' choices concerning both dollar assets and liabilities, as well as traders who arbitrage CIP deviations. The model intentionally focuses on rationalizing the cross-sectional variations in CIP deviations rather than high-frequency time-series dynamics. Through the model, we study supply and demand factors of CIP deviations driven by the stock of net dollar exposures across countries.

4.3.1 CIP deviations and dollar debt issuance

Firms, especially those in emerging market economies, benefit from negative CIP deviations when issuing dollar-denominated debt and hedging via the swap market. Consider a firm that needs to issue debt to finance its local-currency investment. It could choose to issue the debt either in local currency or in USD. Borrowing in local currency does not bring any currency risk and incurs a cost denoted by

$$r_t^i \tag{7}$$

The other option for the firm is to borrow in US dollar, in the amount of $1/S$ dollars, where S is the spot exchange rate. Through a swap or a forward contract, The firm hedges the currency risk of the debt dollar exposure by swapping the proceeds from the dollar debt issuance to local currency and then after one period, they convert the local currency to US dollar and returning the debt payment. By doing this, the firm gets rid of currency risk just as borrowing in its local currency. Mathematically, the borrowing cost can be written as

$$\frac{1}{S_t^{i/\$}}(1+r_t^{\$})F_t^{i/\$}-1 \tag{8}$$

where $S_t^{i/\$}$ is the spot exchange rate, defined as units of foreign currency per dollar, same as the definition in (2). Thus the first term $1/S_t^{i/\$}$ represents the dollar amount needed to borrow one unit of local currency. The second term, $r_t^{\$}$ is the borrowing cost of dollar debt issuance. The last term is to convert the borrowing cost in local currency, with hedging the currency risk by securing the exchange rate at a forward rate $F_t^{i/\$}$.

Firms compare the borrowing cost in local currency in equation (7) and the borrowing cost in US dollar in equation (8). Following Liao (2020), we define the difference in borrowing costs as

$$\begin{aligned}\Phi &= r_t^i - \left(\frac{F_t^{i/\$}}{S_t^{i/\$}}(1+r_t^{\$})-1\right)\\ &= \underbrace{\log(1+r_t^i)}_{\text{Debt issued in LC}} - \underbrace{\log\left(\frac{F_t^{i/\$}}{S_t^{i/\$}}(1+r_t^{\$})\right)}_{\text{Debt issued in USD}}\end{aligned} \tag{9}$$

Log-linearization generates

$$\Phi = r_t^i - r_t^{\$} - f_t + s_t \tag{10}$$

where $f_t^{i/\$}$ and $s_t^{i/\$}$ denote the logarithm of forward and spot rates. Adding risk-free rates for both local currency and US dollar yields the following.

$$\Phi = \underbrace{(r_t^i - y_t^i) - (r_t^\$ - y_t^\$)}_{\text{Difference in credit spreads}} - \underbrace{(y_t^\$ - y_t^i + \rho_t^{i/\$})}_{\text{CIP deviations as shown in equation (4)}} \tag{11}$$

This equation shows that if the firm fully hedges its liability in USD, the borrowing cost differential not only depends on the credit spreads in local currency and US dollars, but also depends on the CIP deviations. A more negative CIP deviation increases Φ in equation (11), making USD borrowing cheaper. Firms with USD-denominated liabilities benefit from negative CIP deviations by earning from hedging as they effectively provide dollar funding to the market, where there is a dollar shortage.

This channel could lead to a positive relationship between the CIP deviations and non-banks' net dollar exposures in emerging markets. More negative CIP deviations incentivize firms to increase dollar debt issuance, leading to higher USD liabilities and thus smaller net USD exposures. This example reflects how firms' borrowing decisions respond to dollar funding conditions signaled by CIP deviations. We formalize this channel in the following section.

4.3.2 Model

Inspired by Liao (2020), we now formally specify the problem. Assume a representative firm that operates in the domestic market , generating revenues and paying costs in local currency. The firm wants to issue debt, D, and it chooses the share of debt issuance in USD dollar, μ_d, given a predetermined hedging ratio, h_d, in order to minimize the costs while managing the exchange rate risk. The firm exhibits a distaste for exchange rate volatility. In a static setting, the firm maximizes the expected utility of its end-of-period wealth W, considering borrowing costs and the disutility from exchange rate risk. Following Liao (2020), we normalize the exchange rate to one as it does not enter into the decision. Its optimization can be written as

$$\max_{\mu_d} E\left[\frac{W^{1-\rho_d}}{1-\rho_d}\right] \tag{12}$$

where

$$W = D(1+r_a) - \underbrace{(1-\mu_d)D(1+r_d^i)}_{\text{funded by debt issuance in LC}} - \underbrace{\Big(\mu_d D h_d(1+r_d^\$+x) + \mu D(1-h_d)(1+r_d^\$+\phi)\Big)}_{\text{funded by debt issuance in USD}} \tag{13}$$

D represents the total debt issuance and equivalently, the total investment. The first term in (13) is the return from the investment, assumed to be exogenous, r_a. The second term is the borrowing cost in local currency (LC), $(1-\mu_d)D(1+r_d^i)$, with the local interest rate r_d^i. The third and the fourth terms are borrowing costs in in US dollar for hedged and unhedged portions: hedged at cost $r_d^\$ + x$, with x representing CIP deviations reflecting hegding costs, and unhedged at cost $r_d^\$ + \phi$, with ϕ representing the currency cost due to the exchange rate movement. ϕ is a random variable with the expectation $\bar{\phi}$ and variance V. The uncertain exchange rate brings about uncertainty to the end-of-period wealth. CRRA utility function reflects firm's distaste for uncertainty. The degree of risk aversion of the dollar debt issuer is captured by the coefficient ρ_d.

Using the second-order Taylor expansion and taking the first-order condition with respect to μ_d, we have the optimal share of debt issuance denominated in USD as

$$\mu_d^* = \frac{r_d^i - \left(r_d^\$ + h_d x + (1-h_d)\bar{\phi}\right)}{\rho_d(1-h_d)^2 V} \tag{14}$$

where the numerator is the expected difference in borrowing costs, where the terms inside the parenthesis is the average cost of borrowing in USD accounting for both hedged and unhedged portions. A more risk-averse firm (larger ρ_d) or greater exchange rate risk (larger variance V) leads to a smaller optimal share of USD debt issuance. Crucially, the firm would like to issue in US dollar if its cost, including hedging cost captured by the CIP deviation x, is lower than the local currency debt costs, despite bearing some exchange rate risk. This is also where the hedging cost, i.e. CIP deviation, comes in. A higher CIP deviation (more positive) reflects increased hedging cost for dollar debt, raising the overall cost of borrowing in US dollar and reducing the dollar debt issuance. In contrast, a negative CIP deviation lowers dollar funding costs, incentivizing more dollar borrowing.

Equation (14) provides insights into emerging market firms' borrowing in foreign currency.

Generally speaking, whether firms choose to issue dollar debt depends on the average borrowing costs of dollars, which combine CIP deviations (x), reflecting hedging costs, and UIP deviations ($\bar{\phi}$), reflecting the expected currency returns, weighted by the hedge ratio h_d. The term x quantifies how hedging costs adjust dollar borrowing costs in the presence of CIP deviations, while $\bar{\phi}$ quantifies how expected exchange rate movements adjust dollar borrowing cost of the unhedged portion of debt in the presence of UIP deviations. Together, these terms determine the overall dollar borrowing costs.

Similarly, we consider a firm that is a dollar asset holder, funded by local currency denominated debt. Its maximization problem can be written as

$$\max_{\mu_a} E\left[\frac{W^{1-\rho_a}}{1-\rho_a}\right] \tag{15}$$

where

$$W = \underbrace{(1-\mu_a)A(1+r_a^i)}_{\text{invested in in LC assets}} + \underbrace{\Big(\mu_a A h_a(1+r_a^\$ + x) + \mu_a A(1-h_a)(1+r_a^\$ + \phi)\Big)}_{\text{invested in dollar assets}} - A(1+r_d) \tag{16}$$

A is the total assets. Other variables including r_a^i, $r_a^\$$, x, ϕ, μ_a, and h_a are defined analogously to the liability side in equation (13). The optimal dollar asset ratio can be solved as

$$\mu_a^* = \frac{\left(r_a^\$ + h_a x + (1-h_a)\bar{\phi}\right) - r_a^i}{\rho_a(1-h_a)^2 V} \tag{17}$$

Similarly to the dollar debtor, the firm holds dollar assets only if the average expected return of dollar assets exceeds that of local currency assets, even though it needs to bear exchange rate risk for the unhedged part of the dollar assets. A negative CIP deviation ($x < 0$) implies a positive hedging cost, reducing dollar asset returns. Nonetheless, if expected dollar asset returns remain sufficiently attractive, the firm will hold dollar assets even at the expense of these hedging costs.

So far, we are thinking of partial equilibrium where the representative firm chooses dollar debt or dollar assets, taking the CIP deviation x as given. To endogenize the CIP deviation, we follow Liao (2020) by introducing a currency forward (or swap) trader who clears the market. We can think of banks as the financial intermediaries participating in the forward market and arbitraging

CIP deviations. The trader allocates capital between exploiting CIP deviations x and engaging in an alternative investment opportunity, such as making loans. Upon entering a forward transaction, the trader set aside a haircut H, proportional to the forward size s:

$$H = \gamma s \tag{18}$$

The trader thus maximizes

$$\max_{s} -xs + \phi_0 I - \frac{1}{2}\phi_i I^2 \tag{19}$$

where I denotes the capital that the trader devotes to the alternative investment opportunity.

$$I = W - H = W - \gamma|s| \tag{20}$$

When the CIP deviation is negative ($x < 0$), firms are net sellers of forwards. Thus, the trader benefits from buying forwards ($s > 0$). This leads to opposite signs for x and s, explaining the negative sign in front of xs in the objective function (19). The trader's optimal forward position is

$$s = sign[-x]\frac{1}{\phi_1\gamma}(\phi_0 - \phi_1 W) - \frac{x}{\gamma^2\phi_1} \tag{21}$$

Equivalently,

$$x = sign[-s]\gamma(\phi_0 - \phi_1 W + \gamma\phi_1|s|) \tag{22}$$

Following Liao (2020) we make an additional assumption that $W = \frac{\phi_0}{\phi_1}$, which means that the trader has just enough wealth W to take advantage of all positive NPV investment opportunities in the alternative project. This assumption is equivalent to assume that the CIP deviation x is zero when there is no net demand for forward contracts, but becomes non-zero once net hedging demand arises. With this assumption, we have the optimal forward size as

$$s = -\frac{x}{\gamma^2 \phi_1} \tag{23}$$

Equivalently,

$$x = -\gamma^2 \phi_1 s \tag{24}$$

Market clearing conditions can be expressed as

$$\mu_d D h_d - \mu_a A h_a + s = 0 \tag{25}$$

The first two terms in (25) represent the forward transactions conducted by dollar debt holders and dollar asset holders respectively. Both μ_d and μ_a, the ratio of dollar debt and dollar assets, are functions of x, the CIP deviation. The last term s denotes the position that the trader holds. The market clearing condition determines the CIP deviation x in equilibrium.

Incorporating the optimal dollar ratio μ_d^*, μ_a^*, and traders' forward position s^*, we have the following.

$$D h_d \frac{r_d^i - (r_d^\$ + h_d x + (1 - h_d)\bar{\phi})}{\rho_d (1 - h_d)^2 V} - A h_a \frac{r_a^\$ + h_a x + (1 - h_a)\bar{\phi} - r_a^i}{\rho_a (1 - h_a)^2 V} - \frac{x}{\gamma^2 \phi_1} = 0 \tag{26}$$

where the first two terms represent the net demand for forwards and the last term is the supply of forwards by traders.

This equilibrium condition captures how dollar debt and asset holders' optimal allocations, influenced by CIP deviations and exchange rate risks, together with the limited-capital trader's arbitrage position, jointly determine the endogenous CIP deviation x. Figure (11) illustrates the relationship between net dollar exposures and CIP deviations. From the demand perspective, more negative CIP deviations indicate higher hedging costs for dollar asset holders, reducing the demand for dollar assets and increasing the demand for dollar liabilities. Therefore, the demand curve is **upward** sloping. Conversely, from the supply perspective, higher hedging costs for dollar asset holders incentivize suppliers to provide more hedging instruments for asset holders, leading to a **downward** sloping supply curve. The intersection of the demand and supply curve determines the CIP deviations and net dollar exposures in equilibrium, where the financial friction plays an important role in shaping the hedging activities, changing the equilibrium level of the price and the quantity.

Cross-sectional variations. We can now think of cross-sectional variations in CIP deviations x from equation (26). The cross-sectional variations in CIP deviations x could be driven by either demand or supply factors. Firms with net dollar liabilities and net dollar assets demand hedging instruments, while the traders represent the supply side of hedging market. If differences in CIP deviations between countries stem from the **demand** side, for example, if one country holds more dollar assets than another, i.e. the second term in equation (26) is larger, the CIP deviation in that country must become wider (more negative) to clear the market. More dollar assets, holding the hedge ratio constant, increase hedging demand for selling dollar forwards, pushing up hedging costs and making CIP deviations more negative, i.e. $\frac{\partial x^*}{\partial A} < 0$. Similarly, if a country has larger dollar liabilities than another, i.e. the first term is larger, firms demand more hedging from the liability side, meaning a larger demand for buying dollar forwards. The CIP deviation x has to be less negative or more positive to make the market clearing condition hold, i.e. $\frac{\partial x^*}{\partial D} > 0$. In both cases, the CIP deviations are negatively correlated with countries' dollar exposures. This is illustrated in the first panel in Figure (12). A demand shifter drives a negative correlation between CIP deviations and net dollar exposures.

However, if **supply** factors drive cross-sectional CIP variation, the correlation between CIP deviations and dollar exposures turns positive. For example, consider two countries that are both net dollar asset holders, requiring traders to supply forward or swap contracts, producing negative CIP deviations per equation (24). Should one country imposes a higher haircut, i.e. a larger γ, on traders, constrained capital available leads traders to supply fewer swap contracts, pushing the hedging cost x to be more negative, $\frac{\partial x^*}{\partial \gamma} < 0$. With a more negative x, dollar asset holders will hold fewer dollar assets due to higher hedging cost (i.e. a smaller μ_a^*), and dollar liability holders will issue more dollar debt because of them benefiting more from a widened CIP deviation (i.e. a larger μ_d^*). Fewer dollar assets and more dollar debt reduce the country's dollar exposure. Hence, the CIP deviations and net dollar exposures are positively correlated cross-sectionally. In other words, the supply curve in the second panel of Figure (12) shifting to the left or the right generates a positive relationship between CIP deviations and net dollar exposures.

Indeed, the literature has documented that CIP deviations in advanced economies are closely linked to the balance sheet and funding constraint of global banks (Du and Schreger (2022), Du et al. (2023), Cerutti et al. (2021)). Sharing a common groups of suppliers, global banks, implies that cross-sectional variations in CIP deviations across advanced economies can be largely shaped by demand-side factors, i.e. hedging demand as shown in Du et al. (2024). In contrast, CIP arbitrage is more complicated in emerging market economies. Many emerging market countries impose capital flow restrictions or foreign exchange regulations that limit cross-border arbitrage. As discussed in Dao and Gourinchas (2025), international investors may not have access to the local money markets, and countries differ in capital controls, taxation, and domestic legal and regulatory frameworks. Therefore, traders' ability to supply forward or swap contracts to arbitrage CIP deviations is likely to differ substantially across jurisdictions. Hence, in emerging market economies, cross-sectional variation in CIP deviations may be primarily driven by supply-side factors.

In summary, the sign of the cross-sectional relationship between net dollar exposures and CIP deviations depends on whether the variations in CIP deviations originate from demand or supply side factors. Empirical evidence shown in subsection (4.2) indicates that in advanced economies, hedging demand primarily drives the cross-sectional variation in CIP deviations, resulting in a negative correlation between net dollar exposures and CIP deviations. In emerging markets, however, supply side factors dominate the cross-sectional variation in CIP deviations, producing a positive correlation between net dollar exposures and CIP deviations.

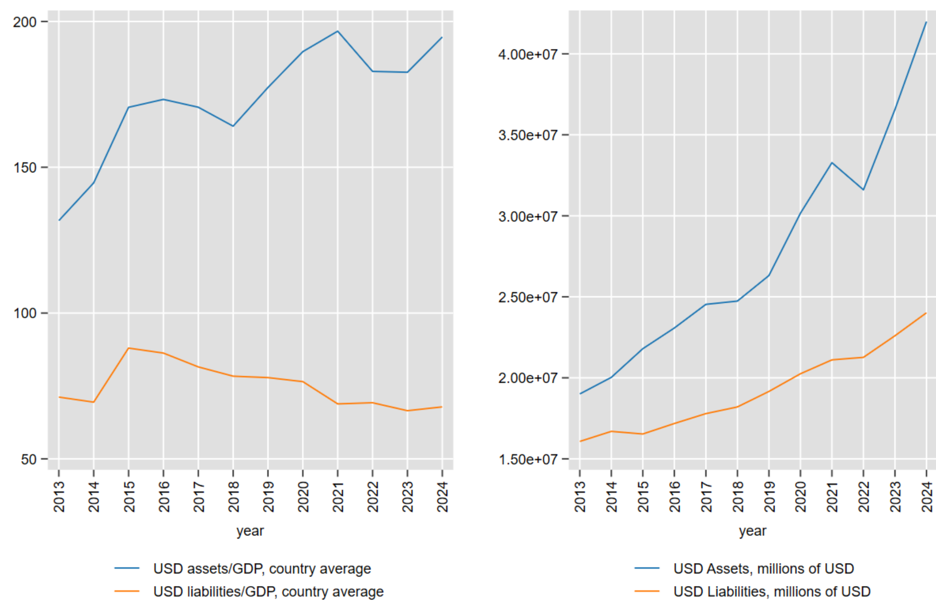
5 Conclusion

By analyzing a newly assembled dataset on dollar exposures, we find that the global steady increase in foreign holdings of USD assets has been primarily driven by non-bank sectors in advanced economies.

We further connect dollar exposures with CIP deviations for both advanced economies and emerging markets. Our analysis reveals a negative correlation between net dollar exposures and CIP deviations in advanced economies, while in emerging markets, the correlation is positive. To explain these patterns, we build a model in which CIP deviations are determined endogenously by the interplay of hedging demand and supply. As suggested by the model, the negative correlation observed in advanced economies is likely driven by the cross-sectional variations in hedging demand, where the positive correlation in emerging markets is primarily due to cross-sectional variations in supply-side factors.

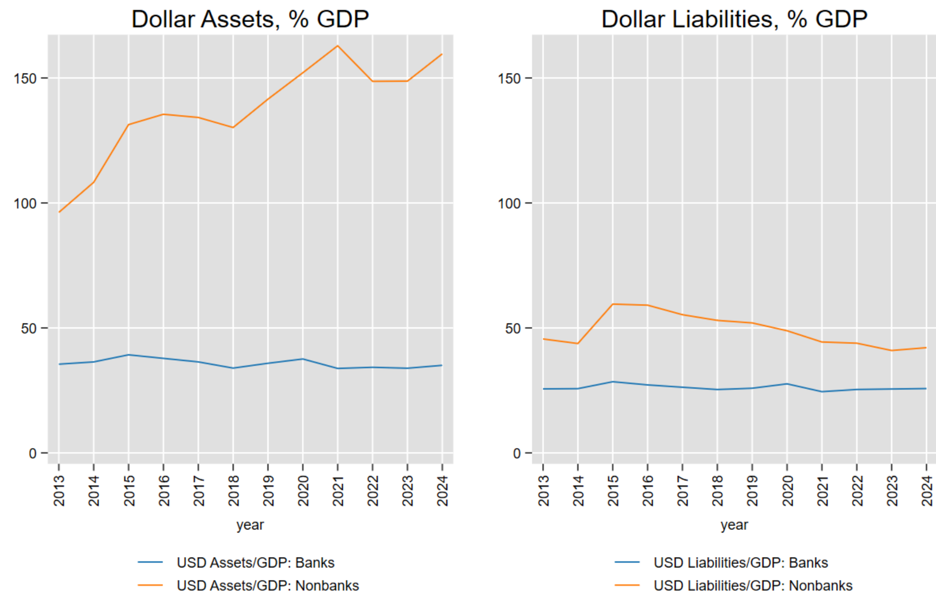
FIGURES

Figure 1: USD Assets and Liabilities, 2013-2024



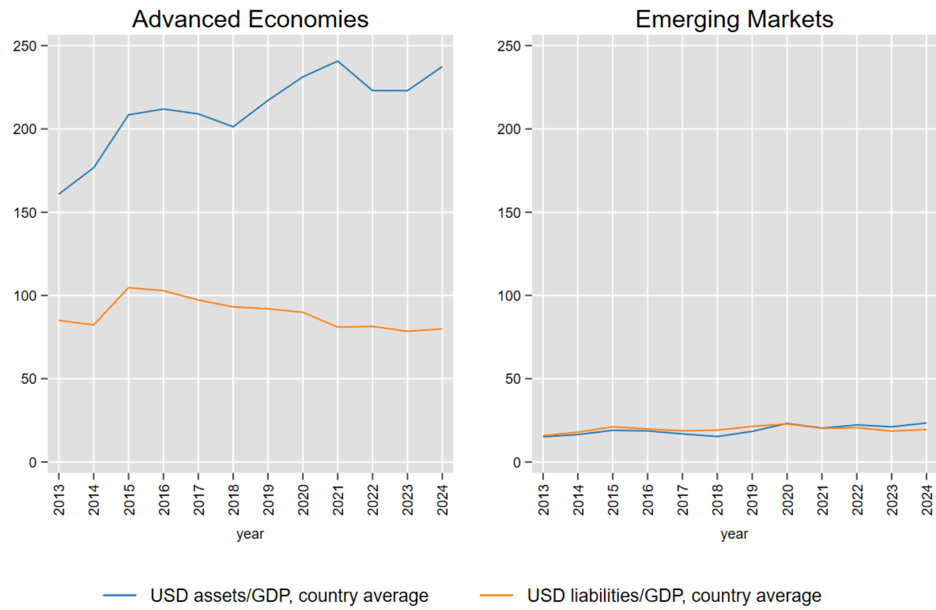
Note: This figure plots USD-denominated assets and liabilities from 2013 to 2024. The left chart plots the amount relative to GDP, whereas the right one plots the absolute amount of assets and liabilities. USD-denominated assets include equities, debt, and bank claims. USD-denominated liabilities include debt issuance, loans and, and bank loans. Data sources include International Monetary Fund's Portfolio Investment Positions by Counterpart Economy Dataset, Currency Composition of Office Foreign Exchange Reserves, and International Reserves and Foreign Currency Liquidity, the US Treasury's Treasury International Capital system, Bank for International Settlements' Locational Banking Statistics and International Debt Securities, central banks, Ito and McCauley (2020), and Chinn et al. (2022). Details are documented in Appendix.

Figure 2: USD Assets and Liabilities, by Banks and Non-banks



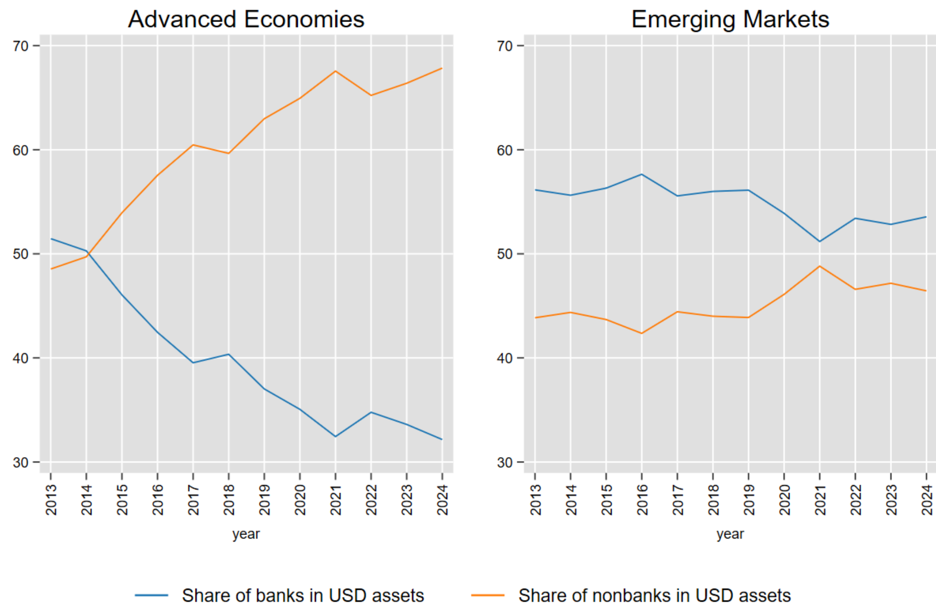
Note: This figure plots USD-denominated assets and liabilities as a share of GDP for banks and non-banks, respectively. USD-denominated assets include equities, debt, and bank claims. USD-denominated liabilities include debt issuance, loans and, and bank loans. The non-banks' assets and liabilities are the difference between the total amount and the banks'. Data sources include International Monetary Fund's Portfolio Investment Positions by Counterpart Economy Dataset, Currency Composition of Office Foreign Exchange Reserves, and International Reserves and Foreign Currency Liquidity, the US Treasury's Treasury International Capital system, Bank for International Settlements' Locational Banking Statistics and International Debt Securities, central banks, Ito and McCauley (2020), and Chinn et al. (2022). Details are documented in Appendix.

Figure 3: USD Assets and Liabilities, by Advanced Economies and Emerging Markets



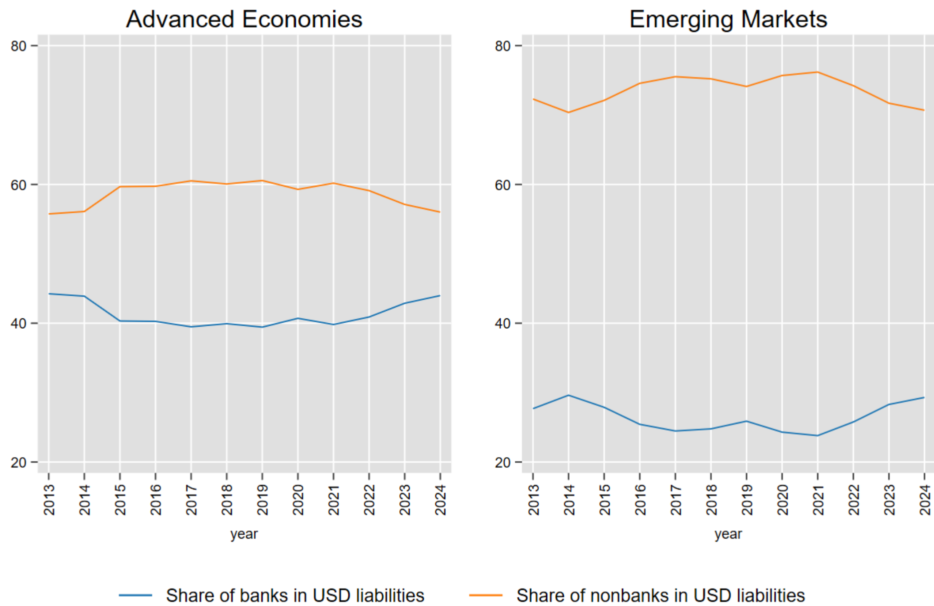
Note: This figure plots USD-denominated assets and liabilities from 2013 to 2024 for advanced economies and emerging market countries, respectively. Only countries where all data from 2013 to 2024 are available are included. Advanced economies include Australia, Austria, Belgium, Bermuda, Canada, Cayman Islands, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Luxembourg, Spain, Sweden, Switzerland, Taiwan Province of China, and United Kingdom. Emerging market countries include Brazil, Chile, India, Mexico, and South Africa. USD-denominated assets include equities, debt, and bank claims. USD-denominated liabilities include debt issuance, loans and, and bank loans. Data sources include International Monetary Fund's Portfolio Investment Positions by Counterpart Economy Dataset, Currency Composition of Office Foreign Exchange Reserves, and International Reserves and Foreign Currency Liquidity, the US Treasury's Treasury International Capital system, Bank for International Settlements' Locational Banking Statistics and International Debt Securities, central banks, Ito and McCauley (2020), and Chinn et al. (2022). Details are documented in Appendix.

Figure 4: USD Assets, by Types of Holders



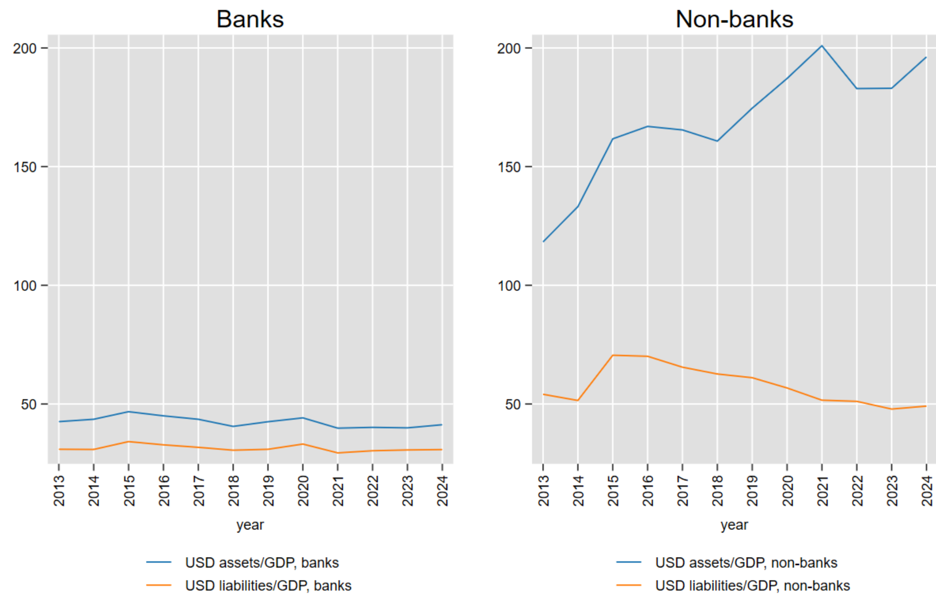
Note: This figure plots the share of banks and non-banks in USD-denominated assets from 2013 to 2024 for advanced economies and emerging market countries, respectively. Only countries where all data from 2013 to 2024 are available are included. Advanced economies include Australia, Austria, Belgium, Bermuda, Canada, Cayman Islands, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Luxembourg, Spain, Sweden, Switzerland, Taiwan Province of China, and United Kingdom. Emerging market countries include Brazil, Chile, India, Mexico, and South Africa. USD-denominated assets include equities, debt, and bank claims. Data sources include International Monetary Fund's Portfolio Investment Positions by Counterpart Economy Dataset, Currency Composition of Office Foreign Exchange Reserves, and International Reserves and Foreign Currency Liquidity, the US Treasury's Treasury International Capital system, Bank for International Settlements' Locational Banking Statistics and International Debt Securities, central banks, Ito and McCauley (2020), and Chinn et al. (2022). Details are documented in 5.

Figure 5: USD Liabilities, by Types of Holders



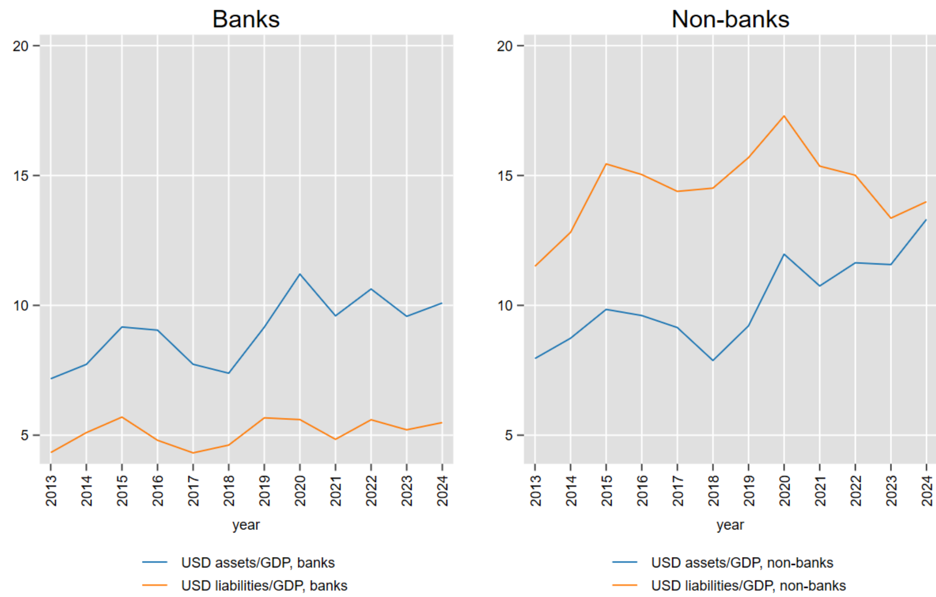
Note: This figure plots the share of bansk and non-banks in USD-denominated liabilities from 2013 to 2024 for advanced economies and emerging market countries, respectively. Only countries where all data from 2013 to 2024 are available are included. Advanced economies include Australia, Austria, Belgium, Bermuda, Canada, Cayman Islands, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Luxembourg, Spain, Sweden, Switzerland, Taiwan Province of China, and United Kingdom. Emerging market countries include Brazil, Chile, India, Mexico, and South Africa. USD-denominated liabilities include debt issuance, loans and, and bank loans. Data sources include International Monetary Fund's Portfolio Investment Positions by Counterpart Economy Dataset, Currency Composition of Office Foreign Exchange Reserves, and International Reserves and Foreign Currency Liquidity, the US Treasury's Treasury International Capital system, Bank for International Settlements' Locational Banking Statistics and International Debt Securities, central banks, Ito and McCauley (2020), and Chinn et al. (2022). Details are documented in 5.

Figure 6: USD Assets and Liabilities: Banks and Non-banks in Advanced Economies



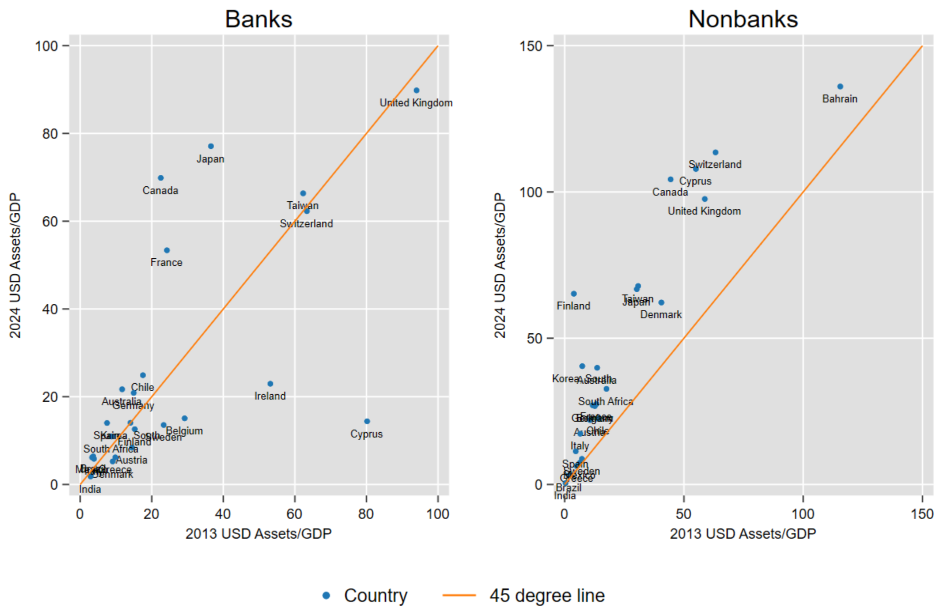
Note: This figure plots USD-denominated assets and liabilities as a share of GDP for banks and non-banks in advanced economies, from 2013 to 2024. Only countries where all data from 2013 to 2024 are available are included. Advanced economies include Australia, Austria, Belgium, Bermuda, Canada, Cayman Islands, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Luxembourg, Spain, Sweden, Switzerland, Taiwan Province of China, and United Kingdom. USD-denominated assets include equities, debt, and bank claims. USD-denominated liabilities include debt issuance, loans and, and bank loans. Data sources include International Monetary Fund's Portfolio Investment Positions by Counterpart Economy Dataset, Currency Composition of Office Foreign Exchange Reserves, and International Reserves and Foreign Currency Liquidity, the US Treasury's Treasury International Capital system, Bank for International Settlements' Locational Banking Statistics and International Debt Securities, central banks, Ito and McCauley (2020), and Chinn et al. (2022). Details are documented in 5.

Figure 7: USD Assets and Liabilities: Banks and Non-banks in Emerging Markets



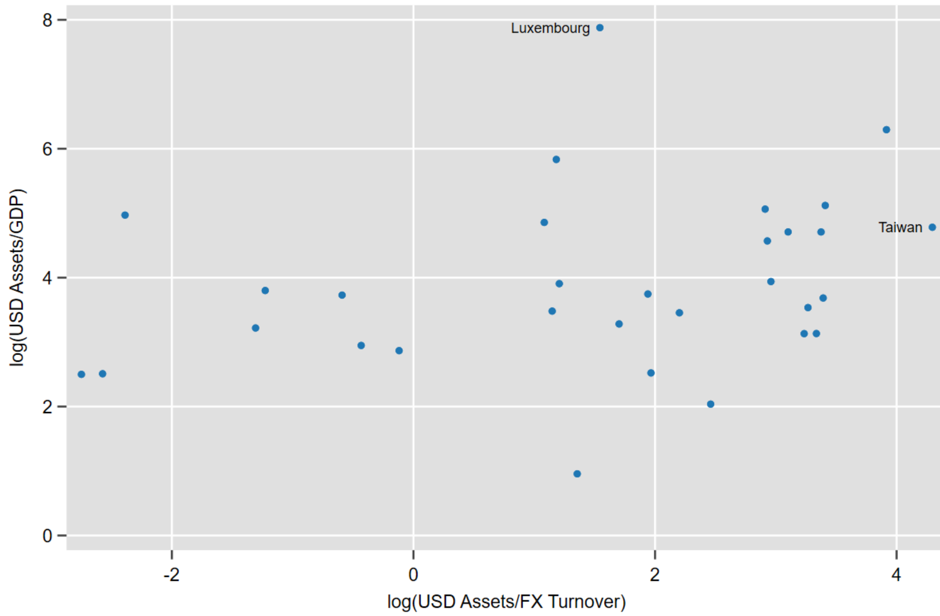
Note: This figure plots USD-denominated assets and liabilities as a share of GDP for banks and non-banks in emerging market economies, from 2013 to 2024. Only countries where all data from 2013 to 2024 are available are included. Emerging market countries include Brazil, Chile, India, Mexico, and South Africa. USD-denominated assets include equities, debt, and bank claims. USD-denominated liabilities include debt issuance, loans and, and bank loans. Data sources include International Monetary Fund's Portfolio Investment Positions by Counterpart Economy Dataset, Currency Composition of Office Foreign Exchange Reserves, and International Reserves and Foreign Currency Liquidity, the US Treasury's Treasury International Capital system, Bank for International Settlements' Locational Banking Statistics and International Debt Securities, central banks, Ito and McCauley (2020), and Chinn et al. (2022). Details are documented in Appendix.

Figure 8: USD Assets 2013 and 2024, by Banks and Non-banks



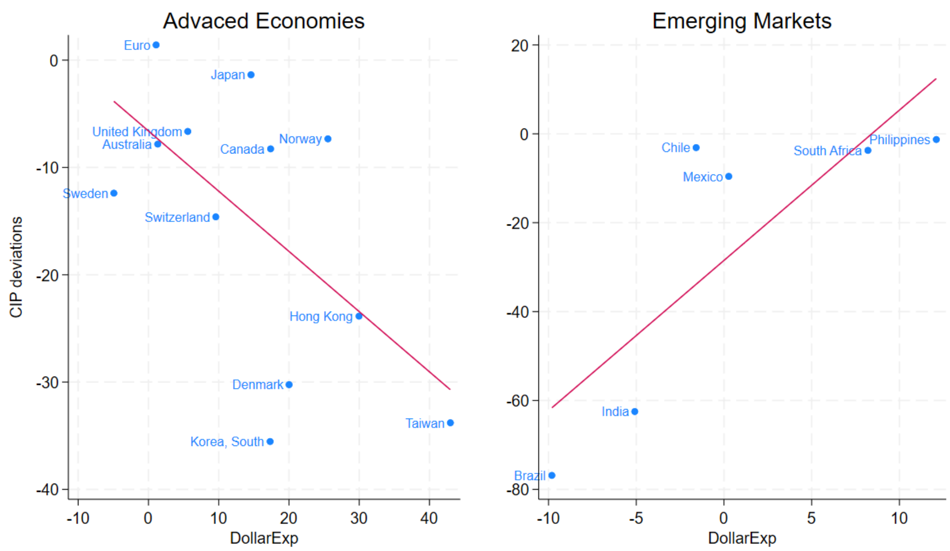
Note: This figure plots USD-denominated assets and liabilities as a share of GDP for banks and non-banks, in 2013 and 2024. Only countries where all data from 2013 to 2024 are available are included. USD-denominated assets include equities, debt, and bank claims. Data sources include International Monetary Fund's Portfolio Investment Positions by Counterpart Economy Dataset, Currency Composition of Office Foreign Exchange Reserves, and International Reserves and Foreign Currency Liquidity, the US Treasury's Treasury International Capital system, Bank for International Settlements' Locational Banking Statistics and International Debt Securities, central banks, Ito and McCauley (2020), and Chinn et al. (2022). Details are documented in Appendix.

Figure 9: USD Assets, scaled by GDP and FX turnover



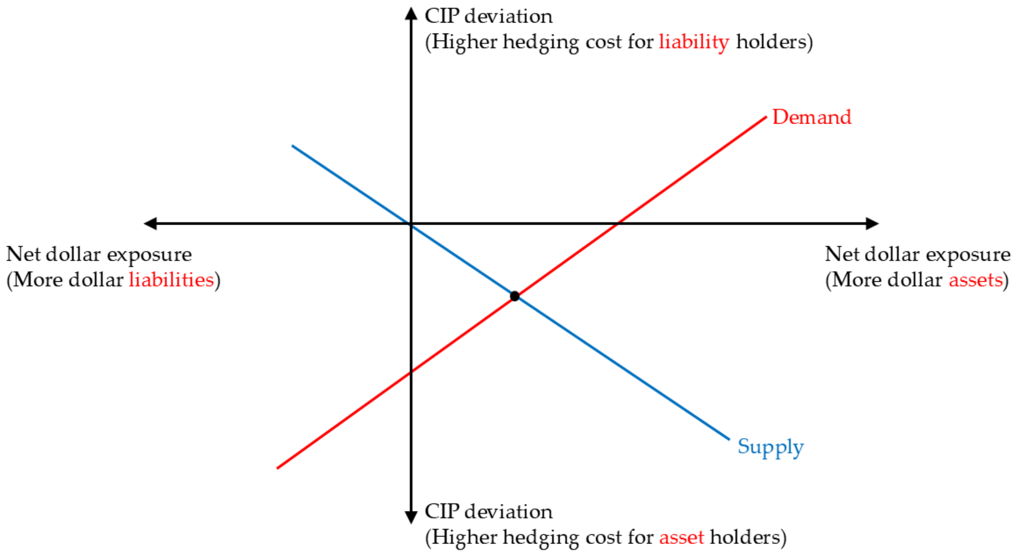
Note: This figure plots the logarithm of USD-denominated assets as a share of GDP and as a share of monthly foreign exchange turnovers. Only countries where all data from 2013 to 2024 are available are included. Economies include Australia, Austria, Belgium, Bermuda, Brazil, Canada, Cayman Islands, Chile, Cyprus, Denmark, Finland, France, Germany, Greece, India, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, South Africa, Spain, Sweden, Switzerland, Taiwan Province of China, and United Kingdom. USD-denominated assets include equities, debt, and bank claims. Data sources include International Monetary Fund's Portfolio Investment Positions by Counterpart Economy Dataset, Currency Composition of Office Foreign Exchange Reserves, and International Reserves and Foreign Currency Liquidity, the US Treasury's Treasury International Capital system, Bank for International Settlements' Locational Banking Statistics, International Debt Securities, and Triennial Central Bank Survey, central banks, Ito and McCauley (2020), and Chinn et al. (2022). Details are documented in Appendix.

Figure 10: CIP Deviations and Net Dollar Exposures for Advanced Economies and Emerging Markets, 2024



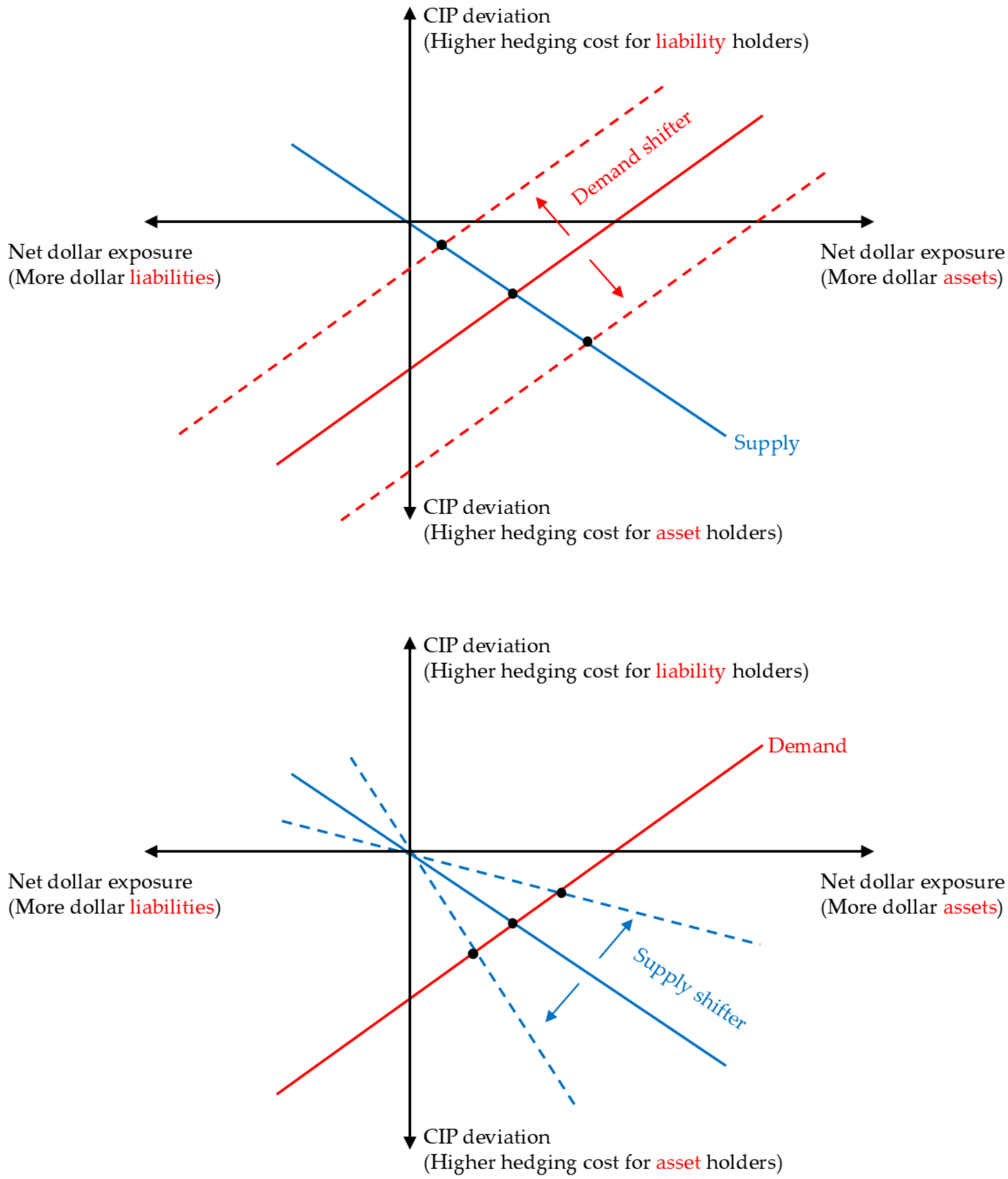
Note: This figure plots the relationship between CIP deviations and net dollar exposures in 2024, for advanced economies and emerging markets separately. Net dollar exposures are defined the difference between dollar-denominated assets and dollar-denominated liabilities. Data sources include International Monetary Fund's Portfolio Investment Positions by Counterpart Economy Dataset, Currency Composition of Office Foreign Exchange Reserves, and International Reserves and Foreign Currency Liquidity, the US Treasury's Treasury International Capital system, Bank for International Settlements' Locational Banking Statistics and International Debt Securities, central banks, Ito and McCauley (2020), and Chinn et al. (2022). Details are documented in Appendix. CIP deviations are defined as the interest rate differentials between US dollar and foreign currencies, adjusted by the forward premium. See section (4) for details.

Figure 11: CIP Deviations in Equilibrium



Note: This figure illustrates how the CIP deviation is determined by demand and supply in equilibrium, described in equation (26). The demand curve is illustrated in equation (14) and (15). The supply curve is illustrated in equation (23).

Figure 12: CIP Deviations in Equilibrium: Demand and Supply Shifters



Note: This figure illustrates how the CIP deviation is determined by demand and supply in equilibrium, described in equation (26). The first chart shows how the demand shifter changes the equilibrium, and the second one shows how the supply shifter changes the equilibrium.

TABLES

Table 1: Marginal Holders of USD Assets

	ΔUSD Assets$_t$ / USD Assets$_{t-1}$		
	(1)	(2)	(3)
	All	Advanced Economies	Emerging Markets
Banks	0.25***	0.18***	0.73***
	(0.057)	(0.036)	(0.059)
Nonbanks	0.76***	0.83***	0.27***
	(0.058)	(0.034)	(0.059)
Country FE	Yes	Yes	Yes

Note: This table estimates the marginal holders of USD assets for three groups of countries from 2013 to 2024. Column (1), (2), and (3) are for the sample of all countries, advanced economies and emerging markets, respectively. Country fixed effects are denoted at the bottom of the table. Driscoll-Kraay standard errors are in reported in the parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 2: Summary Statistics of CIP Deviations across Major Currencies

group	Obs	P10	P25	P50	P75	P90
All countries	236	-90.11	-59.48	-33.09	-8.32	3.18
Advanced economies	142	-69.58	-50.56	-23.51	-9.73	-4.3
Emerging markets	94	-108.42	-75.49	-44.73	-2.09	53.21

Note: This table summarizes statistics of annual CIP deviations across countries from 2013 to 2024. The annual CIP deviations are computed as the daily average of the 3-month interest rate differentials, adjusted by 3-month forward premia. Data on interest rates, forward rates, and spot rates are from Bloomberg and Refinitive, following Cerutti and Zhou (2024).

Table 3: Relationship between Net Dollar Exposures and CIP Deviations

	(1)	(2)	(3)
	CIP deviations	CIP deviations	CIP deviations
DollarExp	-0.15	-1.06***	3.43***
	(0.245)	(0.243)	(0.639)
Observations	210	139	71
Time Fixed Effects	Yes	Yes	Yes

Note: This table presents the results of regressing CIP deviations on dollar exposures for three groups of countries. Column (1), (2), and (3) are for the sample of all countries, advanced economies and emerging markets, respectively. Euro area countries are aggregated by summing up their dollar exposures. Time fixed effects are denoted at the bottom of the table. Driscoll-Kraay standard errors are in reported in the parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4: Relationship between Banks' and Nonbanks' Net Dollar Exposures and CIP Deviations

	(1)	(2)	(3)
	CIP deviations	CIP deviations	CIP deviations
DollarExp_{bk}	-0.78*	-1.36**	1.14
	(0.366)	(0.514)	(0.942)
DollarExp_{nb}	0.32	-0.76***	6.10***
	(0.512)	(0.078)	(0.961)
Observations	210	139	71
Time Fixed Effects	Yes	Yes	Yes

Note: This table presents the results of regressing CIP deviations on dollar exposures of banks and non-banks for three groups of countries. $\text{DollarExp}_{\text{bk}}$ and $\text{DollarExp}_{\text{nb}}$ represent banks' and non-banks' dollar exposures. Column (1), (2), and (3) are for the sample of all countries, advanced economies and emerging markets, respectively. Euro area countries are aggregated by summing up their dollar exposures. Time fixed effects are denoted at the bottom of the table. Driscoll-Kraay standard errors are in reported in the parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Appendix

A Data construction

Since no comprehensive dataset currently exists for US dollar exposures by country and year, we construct a novel dataset using information derived from a combination of multiple statistics. We quantify countries' exposure by measuring both US dollar denominated assets and liabilities. This section provides a detailed description of the data construction methodology to address the critical data challenge.

Estimating US dollar-denominated assets. Dollar-denominated assets encompass equities, bonds, and bank claims. Data on equities and debt instruments are sourced from the IMF's Portfolio Investment Positions by Counterpart Economy dataset (formerly Coordinated Portfolio Investment Survey, or CPIS) and the US Treasury's Treasury International Capital (TIC) system, whereas data on bank claims are extracted from Bank for International Settlements' (BIS) Locational Banking Statistics (LBS). The CPIS dataset, a voluntary survey coordinated by the IMF, collects cross-border portfolio investment data on equity and debt securities. Participating economies report data on their holdings of portfolio investment securities.

$$\text{USD assets} = \text{USD equities} + \text{USD bonds} + \text{USD bank claims} \tag{27}$$

The TIC dataset surveys U.S. securities issuers, compiling data on both foreign holdings of U.S. securities and U.S. holdings of foreign securities. It disaggregates these holdings by security types (equities, debt, long-term, short-term) and by counterpart countries. However, TIC data have several limitations relative to the CPIS data. First, TIC classifies foreign holdings of U.S. securities based on the country of residence of the holders, not the ultimate owners, which can lead to significant distortions, particularly for jurisdictions serving as financial conduits, while CPIS data are more likely to track the ultimate owner[9]. Second, TIC focuses solely on U.S. securities, which are not necessarily denominated in U.S. dollars, whereas CPIS provides information on the currency

[9] Reported by individual countries, CPIS data are more likely to capture the ultimate owner than TIC data. However, for some jurisdictions where cross-border financial intermediation is significant, CPIS data may still capture the resident entities which can be owned or controlled by foreign countries.

composition of assets. Third, since TIC just reports U.S. securities, it does not include dollar securities issued outside the U.S., whereas CPIS data include all cross-border portfolio investments.

To address this issues, we prioritize CPIS data on dollar-denominated equities and debt. TIC data are incorporated to fill gaps whenever CPIS data is unavailable. For countries where TIC data is used, this approach assumes that U.S. securities reported in TIC are all denominated in U.S. dollars, a reasonable approximation given that U.S. equities, Treasury securities, agency bonds and the majority of corporate bonds are denominated in U.S. dollars[10].

An additional refinement pertains to foreign exchange reserves. Since the analysis considered here focuses on private holdings of US dollar assets, foreign exchange reserves are excluded. CPIS data, fortunately, does not include foreign exchange reserves, but TIC data does. Therefore, for any country where TIC data is used to drive the assets, official foreign exchange reserves denominated in US dollars are excluded. To quantify the reserves in US dollars, we multiply the total reserves by the share of US dollars.

Although many countries report the total foreign exchange reserves to the IMF's International Reserves and Foreign Currency Liquidity (IRFCL), the IRFCL does not cover some economies such as Taiwan Province of China. For these cases, their foreign exchange reserves are manually collected from central bank websites or Haver. Additionally, the IMF IRFCL does not provide information on the currency composition. To address this issue, staff rely on the data collected by Ito and McCauley (2020). which provides a panel dataset on currency shares of foreign exchange reserves for countries up to 2020. It is assumed that these shares remain stable post-2020. For some countries, 2019 data is used whenever 2020 data is not available. Lastly, for countries not included in Ito and McCauley (2020) we rely on the IMF's Currency Composition of Official Foreign Exchange Reserves (COFER). COFER provides the global aggregate share of USD in foreign exchange reserves, which is applied as a proxy at the country level.

The last component of dollar assets is bank claims, estimated using BIS LBS data. BIS LBS measures international banking activity by location of banks' residence, capturing outstanding claims (financial assets) and liabilities of internationally active banks located in the reporting countries on counterparties. Availability of currency breakdown in LBS enables the estimation of the US

[10] The aggregate share of USD-denominated corporate bonds in the US is reported in TIC, being 82.7% for 2024 June and 81% for 2023 June.

dollar-denominated loans and deposits in the international market.

BIS Locational Banking Statistics (LBS) is employed to estimate 1)dollar-denominated loans and deposit claims held by banks, and 2) dollar deposits held by the non-bank sectors of the economy. To estimate the former, we directly extract LBS data on loans and deposits denominated in US dollars from banks' asset holdings. To estimate the latter, we leverage the information on counterparties. Specifically, all deposit liabilities reported by foreign countries that identify deposits from that country's non-bank sectors are aggregated. This sum provides an estimate of the total USD deposits held by the non-bank sector at the country level in the international banking system.

$$\text{Country A's deposits in USD} = \Sigma_{i=1}^{N}\text{deposit liabilities issued by reporting country } i \text{ to country A} \tag{28}$$

where there are a total of N countries reporting to having deposit liabilities from country A.

Estimating USD-denominated liabilities. Next, data construction on dollar-denominated liabilities is considered. To quantify liabilities denominated in US dollar, staff consider countries' issuance of US dollar debt, their borrowing in US dollar loans, and bank deposits in US dollar.

$$\text{USD liabilities} = \text{USD debt issuance} + \text{USD loans} + \text{USD bank deposits} \tag{29}$$

Data for BIS International Debt Securities (IDS) is used to obtain dollar debt issuance. IDS records USD-denominated debt issued by countries in the international market. The drawback of using this dataset is that the dollar debt issued in the domestic market is not included. For dollar borrowing in the form of bank loans, counterparty information from BIS LBS data is again used, aggregating all dollar loans reported by each reporting country, for a given counterparty country. Finally, deposits denominated in US dollars are extracted directly from BIS LBS.

B Robustness Checks

The following two tables assess the robustness of our results by re-running regressions (5) and (6) with sovereign CDS spreads to control for local credit risk. As demonstrated, the coefficients remain consistent in both magnitude and statistical significance, confirming that our findings are not driven by default risk premiums.

Table 5: Relationship between Net Dollar Exposures and CIP Deviations

	(1) CIP deviations	(2) CIP deviations	(3) CIP deviations
	(1) CIP deviations	(2) CIP deviations	(3) CIP deviations
DollarExp	-0.15	-1.06***	4.69***
	(0.245)	(0.243)	(0.985)
Observations	210	139	57
Time Fixed Effects	Yes	Yes	Yes
Control	/	/	Yes

Note: This table presents the results of regressing CIP deviations on dollar exposures for three groups of countries. Column (1), (2), and (3) are for the sample of all countries, advanced economies and emerging markets, respectively. Euro area countries are aggregated by summing up their dollar exposures. Time fixed effects are denoted at the bottom of the table. Control variables include CDS spreads. Driscoll-Kraay standard errors are in reported in the parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 6: Relationship between Banks' and Nonbanks' Net Dollar Exposures and CIP Deviations

	(1) CIP deviations	(2) CIP deviations	(3) CIP deviations
DollarExp_{bk}	-0.78*	-1.36**	1.18
	(0.366)	(0.514)	(1.148)
DollarExp_{nb}	0.32	-0.76***	7.23***
	(0.512)	(0.078)	(1.200)
Observations	210	139	57
Time Fixed Effects	Yes	Yes	Yes
Control	/	/	Yes

Note: This table presents the results of regressing CIP deviations on dollar exposures of banks and non-banks for three groups of countries. $\text{DollarExp}_{\text{bk}}$ and $\text{DollarExp}_{\text{nb}}$ represent banks' and non-banks' dollar exposures. Column (1), (2), and (3) are for the sample of all countries, advanced economies and emerging markets, respectively. Euro area countries are aggregated by summing up their dollar exposures. Time fixed effects are denoted at the bottom of the table. Control variables include CDS spreads. Driscoll-Kraay standard errors are in reported in the parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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PUBLICATIONS

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