Fragmentation in euro area banks' sovereign portfolios and its impact on international pricing

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Leveraging on a confidential dataset of euro area banks' portfolio holdings of government securities, I study the determinants of the deviations from covered interest rate parity (CIP), i.e., hedged euro-dollar yield differentials. First, I document stark fragmentation in banks' sovereign bond holdings across different euro area countries. This suggests that country's convenience yield and the characteristics of the banks holding the government bonds matter. Motivated by those facts, I estimate hedged euro-dollar yield differentials in euro area banks' sovereign portfolios and find sizable and heterogeneous CIP deviations across the euro area. Decomposing CIP into a risk-free interest rate differential and a currency convenience yield differential shows a currency convenience for the dollar across banks, thus not explaining the heterogeneity in the CIP violations across countries. In a second step, I link the CIP deviations to three factors: the cumulative asset purchases of government bonds from the ECB asset purchase programmes, bank home bias and regulatory constraints. The last two significantly explain the deviations from arbitrage, confirming the role of fragmented banking systems in affecting the transmission mechanism of a common monetary policy and providing supporting evidence for the emerging theoretical literature linking CIP and banks' balance sheets.

Keywords: heterogeneous portfolios, fragmentation, sovereign bonds, convenience yields, securities data, covered interest rate parity.
JEL codes: F3, G1, G2.

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1. Introduction

Arbitrage opportunities have persisted since the global financial crisis, revealing the breakdown of the covered interest rate parity (CIP), a fundamental concept in international finance.[1] A growing body of literature emphasizes micro-foundations as explanatory factors for CIP deviations.[2] However, limited empirical evidence necessitates a deeper understanding of how investor-side factors influence these deviations. This prompts exploration into the consistency of arbitrage strategies among various investors and the potential divergence in their approaches. The euro area, unified in monetary policy but fragmented among its constituent countries' investors, offers an ideal setting to investigate the micro-foundations behind CIP deviations. This paper delves into investigating potential heterogeneity in hedged euro-dollar yield differentials within banks' sovereign portfolios within a singular currency area and seeks to identify the determinants contributing to such deviations.

The reason for focusing on the banking sector and government bonds is multi-folded: first, government bonds provide a natural link between interest rates in different currencies, such as euro and dollars, largely unaffected by within-country compositions; second, the banking sector has been among the largest holders of sovereign bonds in the euro area and constraints to banks balance sheets can affect banks' arbitrage decisions; third, provided that the banking system in the euro area is fragmented and largely heterogeneous, this may give the variation needed to explain possible differences in arbitrage across euro area regions; and finally, government bonds have been at the center of recent unconventional monetary policies making the analysis of this asset type quite relevant.

By delving into granular data to scrutinize international pricing dynamics and understand the role played by the investor side, I raise the question: Do banks in the eurozone exhibit varying strategies for euro-dollar government bonds, leading to diverse currency premiums based on their portfolio composition? Employing security-level data encompassing 14,790 bonds from 126 countries, linked with supervisory statistics, I unveil fragmented government bond holdings across the euro area.[3] Moreover, my analysis highlights heterogeneous deviations in banks' CIPs among euro area regions since 2013. As I investigate the causes

[1] This breach is evident through hedged euro-dollar yield differentials. In a frictionless economy, CIP is a relationship in which the expected payoff between a domestic and a foreign asset is the same after hedging for currency risk.

[2] See, among other authors, Borio et al. (2016), Du et al. (2018a), Amador et al. (2020), Du et al. (2018a), Cerutti et al. (2021) and Du and Schreger (2021) for assessments on the failure of CIP since the global financial crisis.

[3] Fragmentation, typically associated with spreads among government bond rates, is defined here as a divergence in holdings across investors in different regions.

behind these disparities, the analysis provides evidence for spillover effects from investor-side frictions like home issuer bias on estimated currency premiums in sovereign bonds. These findings point to potential implications for the uneven transmission of monetary policy across borders.

The paper starts by documenting the international portfolio allocations in sovereign bonds of the twenty-six largest euro area banking groups situated in Austria (AT), Belgium (BE), Germany (DE), Spain (ES), Italy (IT), France (FR), and the Netherlands (NL) from 2013Q4 to 2021Q1. These banking groups represent 60% of the euro area banking sector's aggregate government bond holdings in 2014Q4, intermediating around 35% of the sovereign debt holdings in the euro area over the last decade. Analysis of these banks' portfolio shares of dollar- and euro-denominated sovereign bonds for different issuers reveals considerable heterogeneity in demand. Notably, there is evidence of a lack of diversification in currency and issuer country among banks in specific regions, indicating a home bias.[4] This bias is more pronounced in domestic banking groups historically associated with high-yielding sovereign bonds like Spain, Italy, and Belgium (averaging around 65% over the review period).[5] Moreover, there is a noticeable shift observed towards US-issued government bonds among banks in low-yielding countries like Germany, the Netherlands, and France.[6] Finally, domestic banking groups primarily demonstrate an issuer bias rather than a currency bias in their sovereign bond portfolios.

Since banks' portfolios in high-yielding countries are biased towards holding the bonds of their government and dollar holdings are larger for banks in low-yielding countries, it is likely that the return differential between euro and dollar per banking group is different across the euro area. This implies that within a single currency area, each country violates the non-arbitrage condition in the foreign exchange (Forex) market differently. In order to measure the CIP deviation in each banking group (bank-level CIP), by combining Faia et al. (2022) and Jiang et al. (2020), I devise a security-level econometric specification that allows me to identify the pricing impact of demand for currency denomination of sovereign bonds by individual banking groups, controlling for asset and issuer characteristics.Specifically,

[4]Banks in this sample are not representative of the entire banking sector in a country. For simplicity, 'domestic banking groups' or 'country-based banking clusters' refer to the collection of banking entities within a specific country in this study.

[5]Home issuer bias is measured as when the proportion of national sovereign bond holdings within the total holdings of the banking group exceeding 50%. Further references can be found in (e.g.,French and Poterba (1991), Coeurdacier and Gourinchas (2016)).

[6]I categorize euro area countries based on their sovereign yield spreads during the review period. High-yielding countries comprise BE, ES, and IT, while low-yielding countries consist of AT, DE, FR, and NL. Throughout, I'll refer to these groups as high/low-yielding countries.

I estimate portfolio-weighted hedged euro-dollar yield differentials for sovereign bonds in banks' portfolios, adjusting for sovereign risk by using sovereign CDS spreads, country and maturity fixed effects, and hedged exchange rate movements using cross-currency swaps.

Estimated bank-level CIP deviations vary significantly, with positive and negative median deviations of around 41 and -97 basis points, respectively. They largely differ across country-based banking clusters reflecting diverging arbitrage strategies across euro area regions. This reflects the currency premia that some banks (regions) are willing to pay for holding euro-denominated assets. Notably, banks in high-yielding countries (ES, BE, and IT) tend to accept lower yields on euro assets relative to dollar ones post-hedging, unlike low-yielding countries (NL, FR) where the opposite is observed.[7] Overall bank's euro-dollar arbitrage strategies are heterogeneous across the euro area, leading to potentially opposite forces on currency premia or even issuer country premia given the large intermediation size of the banking sector for government bonds in the euro area.

While banks' CIP deviations can indicate which could be the preferred arbitrage strategy by a bank (or investor interchangeably), other asset characteristics - such as its convenience - might shape investors' actual demand.[8] To further discern potential motives behind banks' holdings of euro and dollar sovereign bonds, I further analyse if the differences across banks' CIPs are due to demand-side factors reflecting a convenience for the currency or systematic constraints in banks' balance sheets.

First, to analyze currency convenience demand, I decompose banks' yield differentials into two parts: a risk-free interest rate gap and an investor-specific currency-convenience yield.[9] More specifically, I compute the euro-dollar convenience yield as a residual by additionally discounting from the yields the risk-free interest rates of the euro area and US. Banks across euro area regions show a larger currency-convenience yield from holding dollar assets, suggesting that the heterogeneity in their CIP deviations isn't likely explained by the currency convenience in sovereign bonds.

Second, I explore various micro-level factors influencing CIP deviations across euro area regions, categorized into regulatory changes affecting CIP arbitrageurs (Cenedese et al. (2021) and Du et al. (2018a)), differing monetary policies (Bräuning and Ivashina (2020b), Cerutti et al. (2021) and Faia et al. (2022)), and macro-financial frictions like FX derivative

[7] German banks appear to be a special case among high-yielding countries, demanding the lowest yields on euro assets compared to dollars.

[8] Convenience of an asset refers to a convenience service that an asset provides, such as a premium associated with holding the asset beyond fundamentals explaining the price of the asset.

[9] See Jiang et al. (2020) for the estimation of country-convenience yields across the euro area for a single currency.

risks and balance sheet changes due to dollar appreciation (Avdjiev et al. (2019) and Borio et al. (2018)). Using proxies such as banks' liquidity coverage ratio, monetary policy shocks (EA-MPD, Altavilla, et al.), and a bank-specific risk-aversion parameter, derived from a proprietary model [10], I delve into these determinants. Additionally, I incorporate banks' home issuer bias for sovereign bonds as an additional factor, addressing gaps in existing CIP deviation literature on sovereign bonds.

To measure the impact of home bias on bank CIP deviations, I use the growth in banks' home bias share, instrumented with the total maturing sovereign debt of the bank's country. This approach, inspired by Ongena et al. (2019), considers that in months with substantial maturing sovereign debt, banks will more likely be swayed by their government to hold newly issued debt that it needs to place to roll over the maturing one. This total value of maturing debt is predetermined and unrelated to current economic conditions or banks' sovereign debt demand. Home issuer bias appears to influence CIP deviations, explaining part of the variation among banks' CIPs. Banks with higher home bias demand lower yields for euro securities compared to hedged dollar ones. A growth of almost two standard deviations in the predicted home bias share correlates with a -18 basis points deviation in banks' CIP. Furthermore, regulation emerges as another influential factor, whereas banks' risk aversion does not.

My findings indicate that frictions in banks' balance sheets, such as home issuer bias and regulatory constraints, constrain banks' arbitrage across currencies impacting investors differently across the euro area. This can have implications for a heterogeneous transmission of monetary policy across borders. During the European Central Bank's (ECB) asset purchase period, the convenience yield for the dollar in euro area banks aligned with the ECB's sovereign bond purchase profile. However, the shift to US assets varied among banks across euro area regions potentially due to these frictions.

The decline in euro yields due to the drain of euro assets, increasing risk-bearing capacity in euro area banks' portfolios, might prompt return-oriented investors like banks to rebalance to alternative assets. While the dollar's convenience yield rose, the rebalancing into US assets after ECB purchases differed across regions, in an analysis of banks' security-level exposure to ECB purchases. My results suggest that banks in Countries with stronger home bias saw less rebalancing post unconventional monetary policy, potentially impacting CIP deviations.

This paper shows micro-founded frictions affecting parity conditions in asset prices which

[10] I extract the risk-aversion parameter for banks via a calibration excersis in where I match banks' sovereign portfolio exposure to macroeconomic risks à la Begenau-Piazzesi-Schneider (Begenau et al. (2015)) to a myopic portfolio choice model.

can lead to inefficient resource allocation as well as a heterogeneous transmission of monetary policies across borders. In addition, this paper shows evidence for broader implications such as the role of investor bases for currency pricing and convenience of bonds.

Related Literature. My paper relates to three different strands in the literature. First and foremost it links to the literature studying cross-currency yield differentials or UIP/CIP using more disaggregated data. Liao (2020) and Caramichael et al. (2021) employ traded bond data to analyse the role of currency pricing in firms' issuance decision, while Faia et al. (2022) also use portfolio data focusing on the role of investors' mandates and their demand for international bond prices. My econometric strategy builds on those recent methodologies using highly disaggregated data to compute CIPs (Liao (2020), Caramichael et al. (2021), Coppola (2021) and Faia et al. (2022)). However, I differentiate from these by analysing the government bond market instead of the corporate bond market and exposing fragmentation within a price-sensitive sector, namely the banking sector in the euro area. Additionally, I also further complement the literature on determinants explaining CIP deviations in sovereign bonds. While Itskhoki and Mukhin (2021) or Amador et al. (2020) analyse UIP and CIP deviations in theoretical frameworks, Curcuru et al. (2008) and Curcuru et al. (2011) estimate return differentials per asset type. Works by Du and Schreger (2016), Du et al. (2018a), Du and Schreger (2021) or Cerutti et al. (2021) provide empirical foundations for CIP deviations, such as regulatory constraints among others, which I also examine. Hereby, I also complement the set of determinants with banks' home bias in sovereign bonds as an additional friction leading to CIP deviations based on micro-founded facts from a security-level dataset. My contribution to the determinants is, therefore, two-folded, by testing in a micro-founded setting some of the determinants highlighted in the literature and by also linking home bias to the CIP deviation literature.

My paper also contributes to the literature on safe assets and convenience yields for sovereign bond markets. Safe assets are usually debt contracts that have money-like attributes, which make them attractive as a store of value, tool for liquidity management, and collateral (e.g., Nagel (2016), Caballero et al. (2016), J Caballero and Farhi (2018) and Bechtel et al. (2021)). Due to these attributes, safe assets usually carry a convenience yield (e.g., Krishnamurthy and Vissing-Jorgensen (2012), Gorton (2017)). Jiang et al. (2020) show convenience yields across sovereign bonds in the euro area, a single currency area. I show convenience yields across currency areas for euro area banks based on security-level holdings, relating it also to the CIP deviation.

Finally, my paper also relates to the large strand in the literature of intermediaries asset pricing as well as to the portfolio rebalancing channel. While Coppola (2021) examines the role of mutual funds and insurance companies investor base on bond pricing around specific events for US denominated assets and Faia et al. (2022) for the currency pricing by euro area investors for the corporate bond market, I look at banks' bases for the government bond segment. Additionally, it links also to recent studies exploiting the role of investors' granularity for asset pricing. Gabaix and Koijen (2020) or Koijen and Yogo (2019) exploit investor's granularity to construct instruments for asset demand. Moreover, in line with Koijen et al. (2017) who investigate portfolio rebalancing channel for sovereign bonds due to asset purchases, I do so for the international portfolio in euro area banks. Albertazzi et al. (2018) also analyse the portfolio rebalancing for euro area sectors and banks but across different assets types, while Bergant et al. (2020) analyse the rebalancing towards international assets across euro area sectors. I add to this by studying the international rebalancing due to asset purchases within the euro area banking sector.

The rest of the paper proceeds as follows. Section 2 describes the data on euro area bank holdings and bank characteristics, while Section 3 lays out the holding patterns in the data. Section 4 sets out the results of the empirical strategy in three parts; banks' hedged euro-dollar differentials, determinants for CIP deviations and banks' international portfolio rebalancing following large-scale asset purchases in the euro area. Section 5 concludes.

2. Data

My analysis significantly relies on proprietary data collected by the Securities Holdings Statistics by Group (SHSG), which details individual securities holdings of major banking groups headquartered in the euro area.[11] The SHSG dataset commences in 2013Q4 and provides security-by-security information for the 26 largest banking groups on a quarterly basis. The collected data primarily focuses on the holder side, specifying the amount held of a particular International Securities Identification Number (ISIN) by banking groups and encompasses short- and long-term debt securities, quoted shares, and investment fund shares/units.

In 2014Q4, the 26 banking groups represented roughly 60% of total banks' consolidated

[11] The scope of consolidation of the reported data by banking group follows the prudential scope in accordance with the Capital Requirements Regulation (CRR). This entails reporting the security holdings of domestic and foreign financial entities. However, certain entities, notably insurance undertakings are not covered by the prudential scope, and thus, their holdings are not reported. Additionally, securities held in custody for third parties are also outside the scope of SHSG.

assets in the euro area and collectively held approximately 18% of their assets in debt securities, equivalent to about EUR 3 trillion in nominal holdings.[12] My analysis focuses on their (nominal) holdings of short- and long-term government debt securities denominated in euro or dollar currency, where governments bonds account for about 40% of their total debt securities, out of which approx. 83% are denominated in euros and dollars.[13] Under the review period, the dataset under study comprises roughly 14,790 distinct government bonds issued by 126 different countries.

In addition, I present results at the bank's country level to demonstrate potential fragmentation across countries. I categorize the banking groups based on the country of their headquarters, encompassing the following geographical regions: AT, BE, ES, DE, FR, IT, and NL. Furthermore, I classify countries into two categories. High-yielding countries (BE, ES, IT) and low-yielding countries (AT, DE, FR, NL), following their historical s in sovereign yields. See Figure B3 in the Appendix.

To analyze price dynamics, I enhance the ISIN-level holdings data with reference information from the Centralised Securities Database (ECB, 2010). This database provides extensive details about individual securities, including security type, price, issuer name, country, maturity date, issue date, currency of issuance, and outstanding amount.

Moreover, for being able to compare assets issued in different currencies, I align residual bond maturities with cross-currency swap and interest rate swap horizons from Bloomberg to account for hedged forex movements.[14] Additionally, I cross-reference bond pricing information at both the issuer and residual maturity levels with sovereign CDS spreads from Refinitiv to account for sovereign default risk.[15]

In addition, I complement the data with bank's balance sheet information from the ECB's Supervisory Statistics starting in 2014Q4. This allows me to further control for idiosyncratic bank characteristics such as regulation. In a second step, I can inspect the role that these might have in bank's government bond holdings and currency pricing. Furthermore, I enhance bank characteristics with a proprietary time-varying risk-aversion parameter based on government bond market value holdings by banks and government bond returns. The

[12]The amount of nominal holdings in debt securities includes inter-group holdings of bank debt securities. The share of debt securities over total assets excluding inter-bank holdings would be of around 10% for 2014Q4. Both shares have remained rather constant over the review period.

[13]Holdings in SHS are available in nominal value or market value. Nominal value is based on prices at issuance. Thus, using nominal values captures the actual rebalancing as it is net of valuation effects. The government bond share would increase to around 70% when excluding interbank holdings in the total denominator. Figures correspond to 2014Q4 and have been rather stable.

[14]Details on the Bloomberg tickers for this data in Du et al. (2018b).

[15]CDS spreads refer to the Doc Clause in line with the 2014 ISDA definition or if not available, to 2003 ISDA definition.

latter have been constructed using zero-coupon yields bond yield for 1 to 10-year maturities from Bloomberg.

Finally, I exploit common shocks across banks - monetary policy shocks in the euro area - to further asses dynamics in banks' holdings. To this aim, I use as monetary policy surprise shock the high-frequency changes around the ECB's monetary policy press releases in the 2-year OIS rate, 10-year Italian yield and 10-year German yield obtained from the Euro Area Monetary Policy Event-Study Database (EA-MPD).[16] I focus on 10-year maturity for government bonds as unconventional monetary policy has a first impact on the long-term end of the yield curve. Additionally, I also use the security-level purchases under the ECB's sovereign purchase programme involving the Public Sector Programme starting in 2015Q1.

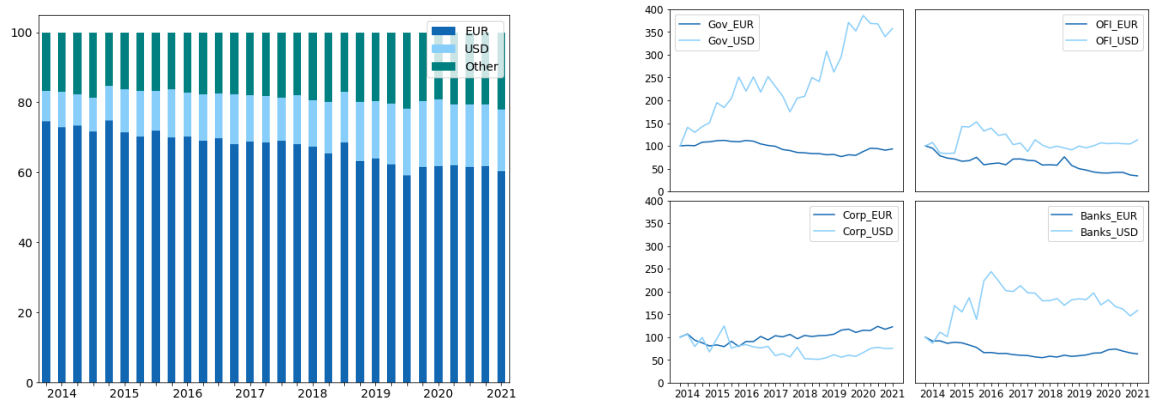
3. Stylized Facts

In this section, I leverage the provided data to document the holding patterns of government securities among euro area banks throughout the review period spanning from 2013Q4 to 2021Q1. I cross-cut the security-level data, examining it across various dimensions such as holder countries (domestic banking entities), issuers, and currencies. The objective is to discern preferences among banks regarding both the currency and issuer residency of government bonds, especially in view of CIP arbitrage opportunities present since the global financial crisis (Du et al. (2018a)).

Three primary observations come to light when examining the government bond holdings in euro area banks' securities portfolios, categorized by the banks' country of residence: i) Banks within specific countries exhibit limited diversification in both currency and issuer holdings, with a more pronounced home issuer bias observed in countries historically associated with high-yielding sovereign bonds like Italy, Spain, and Belgium. This bias not only highlights a lack of diversification but also emphasizes fragmentation in holdings across the euro area, influenced by the historical yield trends; ii) An observed trend reveals a shift towards US-issued government bonds coupled with a decline in holdings of domestically-issued bonds among banks in low-yielding countries such as Germany, the Netherlands, and France; iii) Domestic banking groups mostly exhibit an issuer bias, not a currency bias, in their portfolios.

[16] See Altavilla et al. (2019) for additional details.

Figure 1: Aggregate debt securities holdings across euro area banks



(a) By currency-denomination (percent) **(b)** By debt type and currency (2013Q4=100)

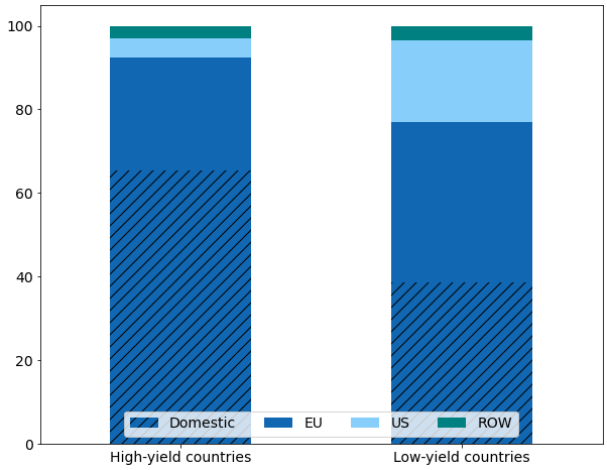
Notes: The left-hand side figure shows the currency share for aggregated debt securities holdings by the 26 largest banking groups. The right-hand side panels compares the growth in aggregated debt securities holdings by the 26 largest banking groups across debt issuer types and broken down by currency denomination. The holdings have been indexed at the start of the review period in 2013 Q4. Gov refers to sovereign bonds, Corp to non-financial corporate bonds, banks to bonds issued by deposit taking institutions and OFI to bonds issued by other financial institutions. Aggregation is on the security-level debt holdings in banks portfolios.

Banks' Aggregated Debt Securities Holdings By Currency and Debt Type. Figure 1a shows aggregate dynamics by the present euro area banking groups, indicating an increasing demand for foreign currencies, notably including the dollar. This demand persists despite the profit potential from shorting the dollar and investing in the euro via recently documented CIP arbitrage opportunities in sovereign bond markets. More specifically, total holdings of euro-denominated debt securities by the 26 banking groups have declined from 75% to 60% over the review period, while dollar-denominated securities have increased from 9% to 18%. The increase in the latter has been mainly driven by an increase in government bond holdings as shown in Figure 1b. The share of government-issued securities in banks' USD-denominated holdings incremented by about 29%, while it decreased for securities issued by other sectors such as non-financial corporations. All together are reasons for which I will focus on these banks' government bond holdings, denominated in euros and dollars, hereinafter.

Banks' Issuer Residency Preference. Examining whether aggregate dynamics persist across countries, Figure 2 groups banks by their headquarters's country and analyzes banks' government bond holdings based on the residence of the issuer, considering the known home bias in this segment (Acharya et al. (2014); Farhi and Tirole (2018); Ongena et al. (2019)).

Concretely, issuer countries are split into four groups: Domestic, EU, US and ROW.[17]. This allows to uncover banks' preferences for holding domestic-issued government bonds versus foreign government bonds. With this aim, I analyze the share of banks' holdings in domestic government bonds as a measure of home issuer bias.

Figure 2: Banks' sovereign holdings by issuer residency across low-yield and high-yield countries, average over 2013-2021 and weighted across countries (percent)



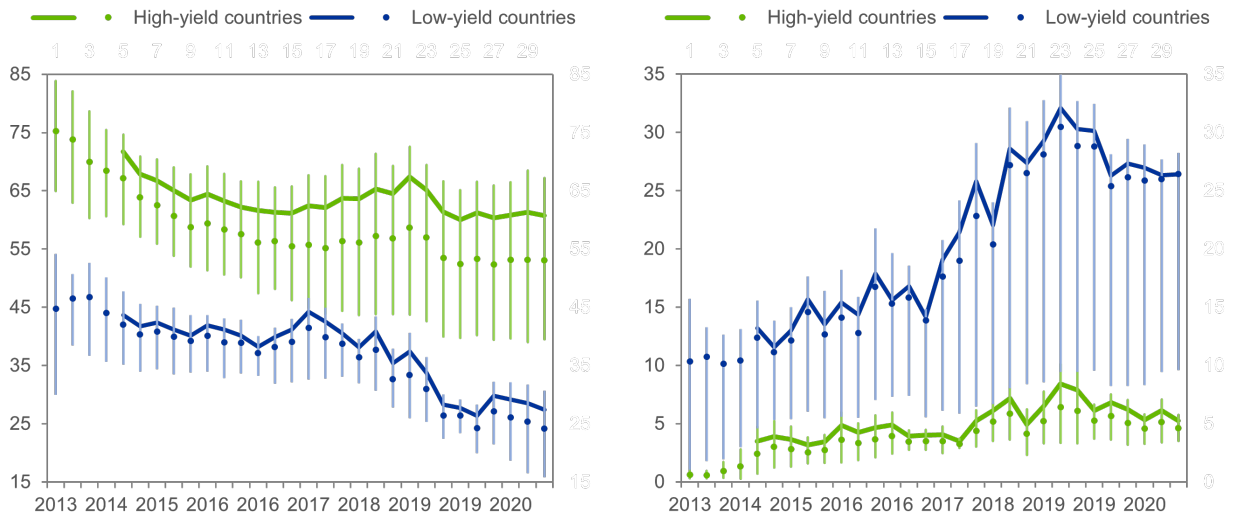
Notes: The figure shows the bank-asset weighted average of banks' dollar- and euro-denominated sovereign bond holdings,categorized based on the issuers, across high-yielding countries and low-yielding countries for the period 2013 Q4 - 2021 Q1. The average depicted represents an (weighted) aggregation of data across different countries (high-yield includes BE, ES, IT versus low-yield includes AT, DE, FR, and NL) within each time period (2013 Q4 to 2021 Q1). Holdings are categorized based on their share among domestic-issued government bonds, other EU-issued government bonds, US-issued government bonds, and bonds from other foreign entities.

Banks in high-yielding countries hold on average above 50% of their own country's government bonds in their government bond portfolio. More specifically, banks in Italy, Spain and Belgium hold close to two-thirds of their bond portfolio in domestic bonds on average throughout the review period. This sharply contrasts with the composition in the world market portfolio, where, for instance, Italian and Spanish bonds represent only approximately between 1% to 2%. Consequently, these banks hold a significantly higher proportion of Italian and Spanish bonds compared to these bonds' share in the world market portfolio. This difference underlines a significant inclination of Italian and Spanish banks towards favoring their own country's government bonds in their holdings, showcasing a pronounced preference or bias.[18] On the contrary, banks in low-yielding countries such as Germany,

[17]Domestic refers to the banking group's headquarters country. ROW are rest of the world issuers outside Europe (EU), different from US. Moreover, the currency composition of these portfolios would largely mirror the holdings of ROW and US for dollar-denominated bond and EU (including domestic) for euro-denominated bonds. See figure B2 in the Appendix

[18]Following Coeurdacier and Rey (2013), according to the International Capital Asset Pricing Model (CAPM) an investor is home biased if the share of domestic bonds held in its portfolio is larger than the bond's share in the world market portfolio. The share of Italian and Spanish government bonds in

Figure 3: Share of sovereign holdings by issuer residency across low-yield and high-yield countries during 2013-2021



(a) Home issuer (percent) **(b)** US issuer (percent)

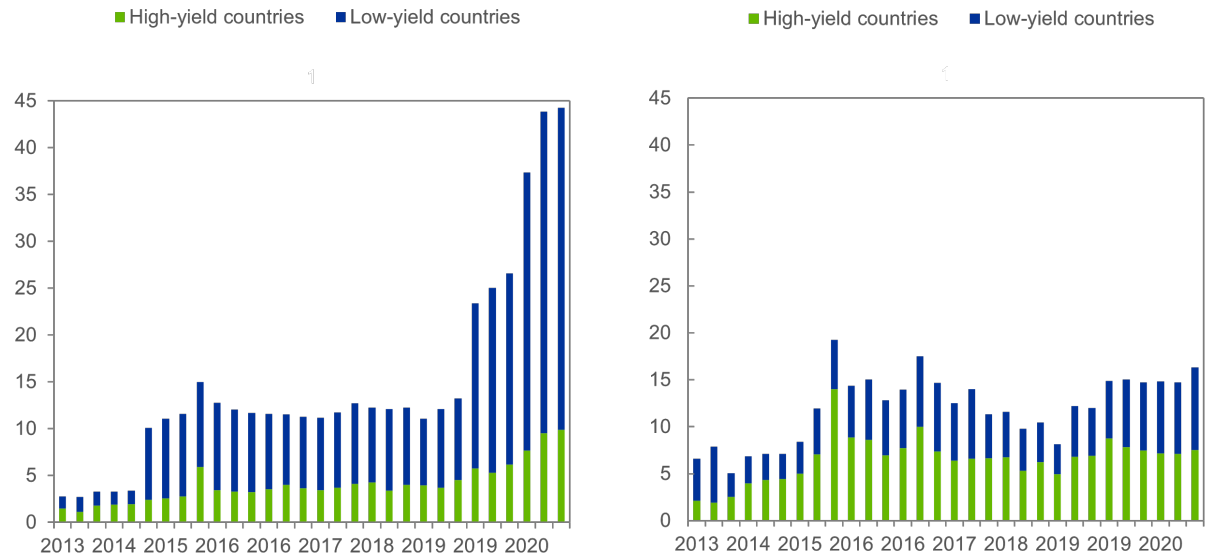
Notes: The time series plot illustrates the share of domestic-issued bonds holdings and US-issued government bonds holdings in banks' government bond portfolio, aggregated across low-yielding countries (AT, DE, FR, and NL) and high-yielding countries (BE, ES, IT). Specifically, it displays the bank-asset weighted average, as well as the average, 10th percentile, and 90th percentile across these countries.

France and Netherlands appear not to exhibit such a strong home issuer bias on the basis of holding a share below 50% and a substantial share in non-EU-issued bonds (e.g. US and ROW).

When examining the time-series dynamics, several points emerge. Figure 3 illustrates the (total bank asset) weighted average of banks' sovereign bond holdings across countries. It showcases these holdings across high-yielding and low-yielding countries, categorized by different types of issuers. The share of domestic government bonds has been declining across banks in all countries over the review period, coinciding as well with the start of the ECB's Asset Purchase Programme (see Appendix B for further figures on EU and ROW shares). However, this decline has been most pronounced in low-yielding countries. Germany, the Netherlands, and France have each decreased their respective shares by approximately 40 to 53 percent. Noticeably, banks in these countries have significantly shifted their holdings toward safe US government bonds. This contrasts with banks in high-yielding countries, which kept a more stable and elevated share in domestic government bond, especially despite the European Central Bank's extraction of euro area sovereign bonds starting in March 2015.

the (SSA government bond) world market portfolio have been computed based on aggregate statistics form the International Capital Market Association for August 2020. When considering the European market portfolio in May 2020, this share increases slightly to approximately 17% and 9%, for Italian and Spanish bonds respectively. Banks' bond portfolio shares refer to the average over the review period.

Figure 4: Euro- and dollar-denominated government bonds issued by ROW held across low-yield and high-yield countries



(a) Euro-denominated (billions) **(b)** Dollar-denominated (billions)

Notes: The Figures show the aggregated holdings of euro- and dollar-denominated assets issued by foreigners outside Europe (and excluding the US) aggregated across banks in high-yielding (BE, ES, IT) and low-yielding countries (AT, DE, FR, and NL).

Currency Preferences. To further disentangle whether banks have an issuer or currency preference, Figure 4 dissects securities by currency for selected issuer countries. Given that US-issued government bonds are denominated in dollars and bonds issued by EU governments are mostly euro-denominated, I examine banks' currency holding patterns of ROW-issued bonds to reveal any currency preferences. Interestingly, banks with a preference for holding US-government bonds (NL, FR and DE) have a euro-currency preference when holding other foreign issued bonds (ROW) despite ample and constant supply of dollar-denominated ROW bonds.[19] Thus pointing towards an issuer and not a currency preference for holdings of government (e.g. US-issued) bonds by these banks.

Combining these observations, it's evident that government bond portfolios among countries' domestic banking groups differ significantly in their issuer and currency diversification levels. As there's fragmentation in euro area sovereign bond yields (Figure B3 in the Appendix), which are mostly denominated in euro currency, heterogeneous portfolios with varying degrees of home issuer bias may have different implications for currency returns. To explore whether this diversity in banks' international portfolios also implies fragmentation in banks' currency returns and rebalancing behavior, I next estimate hedged euro-dollar yield differentials.

[19]Historically, South American countries included in the ROW category have largely issued government debt in dollar denomination.

4. Empirical analysis

Motivated by the stylized facts, a first tenet behind the empirical strategy rests on investors exhibiting fragmented holding patterns across euro and dollar securities. Concretely, since banks' portfolios of high-yielding countries are biased towards holding the bonds of their government and dollar holdings are heterogeneous across national banking sectors, it is likely that the return differential between euro and dollar per banking group is different. This implies that each country violates the non-arbitrage condition in the forex market differently. Moreover, these intermediaries seem large enough to have a meaningful impact on prices in the sovereign bond market, being thus relevant to measure their demand for currency denomination in sovereign bonds. Banks hold about 35% of total government bond holdings by euro area investors. They are among the largest sectors holding government bonds among euro area investors. Of these aggregate euro area banks' government bond holdings, 60% are held by the 26 banking groups analyzed here. Hence their heterogeneous and large demand can likely affect euro-dollar relative bond returns in this market segment.

The aim of the strategy is to identify investors' arbitrage opportunities in their international portfolios by measuring the currency premia and discerning what would be the desired rebalancing strategy to attain parity between euro(home/EU) versus dollar (US/foreign) yields. Moreover, to further disentangle factors behind deviations in the currency premia in investors' international portfolios, I first decompose bank's CIP into a risk-free and a currency-convenience yield differential to gouge at the latter component. Additionally, potential micro-founded drivers can shed light on the reasons behind heterogeneous currency premia in investors' portfolios.

4.1. Bank's hedged euro-dollar yield differentials

To measure yield differentials between holding euro or "domestic/EU" assets compared to dollar or "US/foreign" assets, I estimate investors/banks' currency premia in their sovereign portfolio as domestic/EU assets are largely denominated in euros while foreign assets are in dollars.

Investors' currency premia can be defined as a deviation from covered interest rate parity (CIP). CIP relies on a no-arbitrage condition where the payoffs of two investment strategies, involving two otherwise identical assets but with different currency denominations, are equivalent while perfectly hedging against exchange rate risk. Thus the following condition would hold:

$$CIP : \frac{(F_{t,\tau})}{S_t}(1 + r^{\$}_{t,\tau}) = 1 + r^{euro}_{t,\tau} \tag{1}$$

where S_t is the time-t spot exchange rate and $F_{t,\tau}$ is the time-t forward exchange rate with maturity τ in units of $euro/\$$. $r^{euro}_{t,\tau}$ and $r^{\$}_{t,\tau}$ are euro and dollar time-t risk-free interest rates.

Based on this condition, which applies to identical assets under different currency-denominations (dubbed as macro-CIP), I'm assessing the CIP within banks' international portfolios from the holder's perspective (dubbed as bank-level CIP). This assessment involves using a security-level econometric strategy to approximate the (portfolio weighted) hedged euro-dollar yield differences in the government bond portfolios of these banks. This allows for the determination of whether banks receive or pay a currency premium for their government bond portfolio composition and whether an optimal arbitrage strategy exists.

To this end, I combine Jiang et al. (2020) with the econometric strategy in Faia et al. (2022), to adapt the CIP estimation to the government bond market and to the bank level.[20] Concretely, I differentiate from Faia et al. (2022) in three ways: 1) I focus on the government bond market instead of on the corporate bond market; 2) I purge for country and security risk, hence sovereign credit (default) risk, via sovereign CDS spreads instead of controlling for security ratings;[21] and 3) I analyse heterogeneous behaviours from the holders perspective only within the price-sensitive banking sector, namely across banks.

Following this econometric strategy, a hedged euro-dollar yield differential different from zero will represent a deviation from CIP allowing for arbitrage. In a frictionless world, a macro-CIP arbitrage is treated as risk-less, as by construction FX swaps do not entail an open currency position. Additionally, credit, counterparty, market and liquidity risks involved are assumed to be negligible. Since sovereign bond prices include credit and term risk, I purge for those risks by discounting sovereign CDS spreads for different maturities and controlling for residual maturity fixed effects. Additionally, I control for country fixed effects, to capture any residual convenience yield left related to the issuer-country. Even after accounting for default risk, the convenience of holding, say, an Italian bond versus a German bond may differ due to, among others, specific market demands, such as the preference for certain sovereign bonds (e.g., German bonds) as collateral in repurchase agreement markets.

[20] See also Caramichael et al. (2021) who have a security-level strategy for the corporate market and from the issuance perspective.

[21] I use CDS spreads as these are largely available for sovereign bonds in different currency denominations and maturities, and might capture market sentiment and real-time changes more dynamically. This is also in line with the literature on sovereign bonds. See Jiang et al. (2020) in where they purge for country default risk in the euro area by using CDS Spreads.

This approach should further allow for the comparison of the "same bond" differing solely by its currency denomination. Hence, capturing currency premia in sovereign bonds. I estimate several variants of the following specification:

Baseline Specification

$$\tilde{y}_{j,b,t} = CIP_{b,t}\mathcal{I}_{EUR,j,b} + \gamma_{m,t} + \delta_{i,t} + \varepsilon_{j,b,t} \tag{2}$$

$\tilde{y}_{j,b,t}$ is the annualized *adjusted* yield taken from the secondary market for bond j held by bank b at time t. Yields have been purged from country default risk by subtracting sovereign CDS spreads. Additionally, I adjust the dollar-denominated yields into "synthetic euro" rates to be able to compare yields across currencies and I account for currency risk by using cross-currency swap rates. Moreover, the primary specification under review will consider portfolio weights in the yields ($\dot{\tilde{y}}_{j,b,t}$). $CIP_{b,t}$ is the coefficient on the indicator variable $\mathcal{I}_{EUR,j,b}$. The indicator variable equals one if bond j held by bank b is denominated in euros. $\gamma_{m,t}$ and $\delta_{i,t}$ are fixed effects for residual maturity buckets m and issuer-country i at date t. Regressions are estimated at the security cross-section for each date t and bank b. Standard errors are clustered at the currency-denomination level. The data is truncated on the dependent variable below 1% and above 99% at each quarter to control for outliers as well sovereign bonds issued by four countries in extreme crises are excluded.[22] All CIP figures are based on estimates with bonds above one year of residual maturity.[23] The estimated coefficient of interest - $CIP_{b,t}$ - represents the difference between the (weighted) average yield of euros and the (weighted) average yield of dollars for bank b at time t, after controlling for hedged exchange rate movements and other security characteristics. This captures the residual difference in the price of currency denomination for the same asset type. In other words it captures the average difference in euro and dollar investors' demand for, in this case, government bonds. Therefore, if it reflects if these banks are paying or receiving a premia for holding a specific currency composition in their government bond portfolio.

Yield adjustments. As CIP is build on the assumption that no risk factor in interest rates can explain the differences in yields, I first purge sovereign CDS spreads from sovereign yields

[22] I have excluded bonds issued by Ukraine, Venezuela, Argentina, and Greece from my sample. These countries have experienced extreme crises during the review period. Sovereign CDS spreads for countries in extreme crisis stop trading and are excluded form the sovereign debt market when the country defaults (See Jiang et al. (2020) for the exclusion of Greece in their sample).

[23] Please refer to Appendix A for further details on the data.

to account for sovereign default risk. More formally, the bond yield of an issuer-country i at period t with maturity τ for a given currency c can be decomposed into a risk-free interest rate $r_t^{c,\tau}$, a country-specific sovereign risk spread $\zeta_t^{c,i,\tau}$ and a convenience yield component $\omega_t^{c,i,\tau}$:

$$y_t^{c,i,\tau} = r_t^{c,\tau} + \zeta_t^{c,i,\tau} - \omega_t^{c,i,\tau} \tag{3}$$

I use sovereign CDS spreads as a measure for the sovereign risk component $\zeta_t^{c,i,\tau}$ in eq.(3). CDS spreads are matched across countries and by EUR or USD denomination.[24] The resulting purged yield will be equivalent to a combination of the risk-free component and the convenience yield component, $\hat{y}_t^{c,i,\tau} = y_t^{c,i,\tau} - \zeta_t^{c,i,\tau} = r_t^{c,\tau} - \omega_t^{c,i,\tau}$.

In addition, I vary $\hat{y}_t^{c,i,\tau} \equiv y_{j,t}$ to estimate a *hedged* yield differential that controls for currency risk by using swap contracts.[25] Specifications using this adjustment produce a yield differential akin to a covered interest rate differential, thus measuring CIP. Following Du et al. (2018b), I perform the hedged adjustment using cross-currency swap rates. Since currency forwards are less liquid at maturities greater than one year, the government basis is best measured with cross-currency swaps rates. Cross-currency swaps are more liquid at longer maturities which are observed in the data, with approximately 8 and 8.5 years average maturity for euro and dollar bond holdings, respectively. Details on this adjustment are reported in Appendix C. Yields are defined as follows:

$$\tilde{y}_{j,t} = \begin{cases} y_{j,t} & if\ euro \\ IRS_{euro,n,t} + BS_{euro,usd,n,t} - IRS_{usd,n,t} + y_{j,t} & if\ dollar\ \&\ hedged \end{cases} \tag{4}$$

where $IRS_{euro,n,t}$ is the interest rate swap contract in euros that trades fixed euro cash flow for floating euro cash flow (like Eurolibor), $BS_{euro,usd,n,t}$ is the cross-currency basis swap that trades the floating euro rate into a USD floating (Libor) rate and $IRS_{USD,n,t}$ is the interest rate swap in dollars that trades fixed dollar cash flow for floating dollar cash flow (Libor). Swap rates are matched to the yields by maturity.[26].

Finally, I account for portfolio weights to capture the relative importance of individual

[24]CDS spreads are assumed to be zero for supra-nationals bonds. Results are robust to the exclusion of holdings of supra-national bonds.

[25]Yield characteristics such as currency, issuer-country and maturity are embedded in bond j.

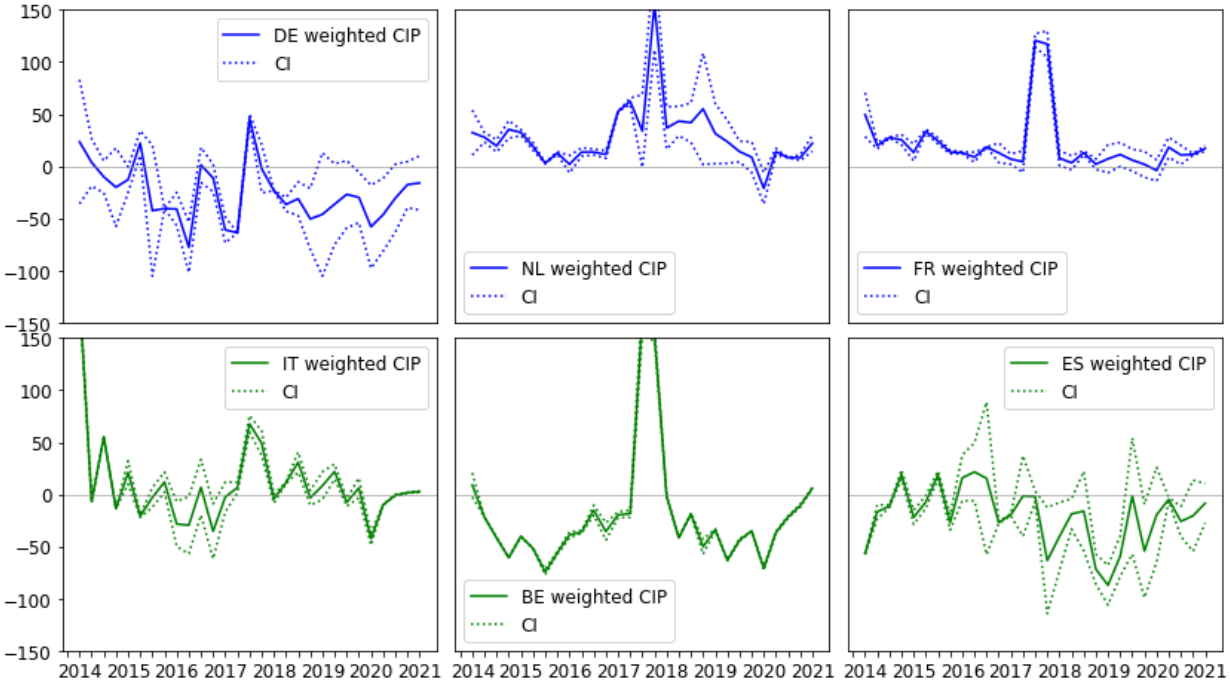
[26]The matching has been done across maturity buckets. Main regression results (Figure 5) are robust to different maturity bucket compositions used for matching the hedging and country default risk. See Figure C4 in the Appendix

securities within the bank's portfolio. I calculate the hedged euro-dollar yield differentials, weighted by time-varying portfolio currency shares. The determination of portfolio currency shares relies on lagged investor holdings to address potential endogeneity concerns, as detailed in Curcuru et al. (2008).[27] Formally portfolio-weighted yields are computed as follows:

$$\dot{\tilde{y}}_{j,t} = \sum_{j=1}^{N} w^{c}_{j,t-1} \tilde{y}^{c}_{j,t} \tag{5}$$

where $w^{c}_{j,t-1}$ is the holdings weight for security j at the end of period $t-1$ and $y^{c}_{j,t}$ is the period t yield for security j for currency c, and N is the number of bank's holdings for a given security in its portfolio.

Figure 5: Country averages of banks' weighted hedged yield differentials, $CIP_{b,t}$, by residency country (basis points)



Notes: Figure 5 plots the bank-level estimates, $CIP_{b,t}$, of the portfolio-weighted hedged euro-dollar yield differential in banks' sovereign portfolio, averaged across banks with residency in a same country. The sample covers all bonds (excluding sovereigns in default crises) with residual maturity above 1 year for the period 2013 Q4-2021 Q1. Each panel shows the portfolio-weighted yield differential (solid line) and its confidence bands (dotted line) at the 10% significance level. The econometric specifications is: $\tilde{y}_{j,b,t} = CIP_{b,t}\mathcal{I}_{EUR,j} + \gamma_{m,t} + \delta_{i,t} + \varepsilon_{j,b,t}$ where $CIP_{b,t}$ is the coefficient on the indicator variable $\mathcal{I}_{EUR,j,b}$ which equals one if bond j is denominated in euros. $\gamma_{m,t}$ and $\delta_{i,t}$ are fixed effects for maturity bucket m and issuer-country i at date t. The individual regressions are estimated at the security-level cross-section for each bank b at each date t. Standard errors are clustered at the currency-denomination and their country averages are estimated via seemingly unrelated estimation. The y-axis is truncated at 150 basis points for visualization purposes.

Figure 5 shows the results for the bank's portfolio-weighted hedged euro-dollar yield differential ($CIP_{b,t}$) following specification (2) over the 2013 Q4 - 2021 Q1 period. Portfolio-

[27] Results are robust to using contemporaneous holdings.

weighted results are the main results of interest to capture banks' currency demand. See Appendix C for unweighted results. Results are shown as the average of banks' CIPs across their country of residence (standard errors are estimated via seemingly unrelated estimation). Across all panels, we observe significant deviations from zero, reaching peaks of 190 basis points.[28] This would qualify as a violation of the covered interest rate parity in banks' government bond portfolios. Note that given the inclusion of sovereign CDS spreads, maturity and country fixed effects, the deviations in bank-level CIP are unrelated to country and security risk or other country characteristics such as its relative attractiveness (convenience).[29]

Noticeably, deviations are also heterogeneous across countries with some being positive and some negative. This indicates that banks violate the (bank-level) CIP condition for the euro-dollar currency pair differently across the euro area. More specifically, there appears to be a fragmentation between banks located in high-yielding countries and banks in low-yielding countries. Banks in the former group, more often pay a currency premia (negative deviations) in order to hold euro-denominated assets. Therefore, they appear to be willing to forgo return from their currency-composition. Concretely, banks in Belgium, Spain and Italy deviate from the parity line (zero-line) by -20 basis points, -21 basis points and 10 basis points on average over the review period. This stands in contrast with banks in high-yielding countries such as France and Netherlands which persistently require higher yields on their euro assets relative to their dollar assets. On average over the review period, the bank-level CIP deviates by 21 basis points for France and 26 basis points for the Netherlands. These deviations remain at least around 11 basis points above the average deviation observed for Italy.[30] German banks appear to be a special case among high-yielding countries who are still holding lower yields on their euro-denominated bonds relative to their dollar-denominated bonds even when accounting for hedged exchange rate movements.

The heterogeneity in the estimated average yield differentials across most countries remains consistent for different specifications, as detailed in Appendix C. This observation holds even when we exclude country fixed effects, assuming that country default risk largely

[28] Across the individual bank level, the absolute median deviation is in between approx. 1 to 97 basis points. In the case of BE there are fewer observation, so std. errors might not be well identified. Nevertheless, increasing the number of clusters in the std. errors still would provide significant estimates for BE.

[29] Liquidity risk is also assumed to be negligible given that bid-ask spreads for each of these currencies (or main representative country bond) can be considered comparable. Caramichael et al. (2021) show that currency premia estimation for the euro-dollar corporate bond market remains robust after the inclusion of a liquidity risk control. Hence, bid-ask spreads for euro assets and for dollar assets are likely analogous.

[30] When excluding an extreme case of Italy's CIP at the beginning of the sample, its average deviation declines to around 3 basis points.

explains the convenience yield for the country. In addition, Figure C6 shows that as the sample size increases, given this specification without country fixed effects, standard errors become more narrow (confidence bands are tighter around the estimate).

CIP Decomposition Generalizing, deviations of the estimated bank-level CIPs can be interpreted as follows: i) a negative CIP deviation means a lower return on euro assets relative to dollar assets even when accounting for hedged Forex movements. In other words, it also means that banks optimal arbitrage strategy would be to short the the euro and invest into dollar assets; ii) a positive deviation represents a larger return on euro assets relative to the dollar and thus the opposite arbitrage strategy is true.

Additionally, as these yield differentials have been purged from country and security risk, and other country characteristics such as the convenience for the issuer-country, the deviations can be interpreted as the relative currency-convenience yields and the difference in the risk-free rates across countries/currency areas.[31] Therefore, to further understand if the heterogeneity in the deviations across the euro area is explained by a currency-convenience yield, I further use the bank-level CIP decomposition into a risk-free interest rate differential component and a convenience yield component to measure banks' relative currency convenience (see also Jiang et al. (2020) for an application for country convenience yield within a same currency area).

Following eq.(3), bank-level CIP can be further decomposed to exclusively measure banks' convenience regarding currency-denomination. Concretely, the following decomposition applies for the euro-dollar currency pair:

[32]

$$\begin{aligned} y_t^{euro,i,\tau} &= r_t^{euro,\tau} + \zeta_t^{euro,i,\tau} - \omega_t^{euro,i,\tau}, \\ y_t^{dollar,i,\tau} &= r_t^{dollar,\tau} + \zeta_t^{dollar,i,\tau} - \omega_t^{dollar,i,\tau} \end{aligned} \tag{6}$$

By defining $\hat{y}_t^{c,i,\tau} = y_t^{c,i,\tau} - \zeta_t^{c,i,\tau}$ as the country-risk purged yield for each currency c, eq.(7) further derives the currency convenience yield as a residual by discounting the risk-free rate for each currency.

[31] Note there is a common risk-free rate r_t across investors in the euro area.

[32] For simplicity, given the composition in my sample, I assume one risk-free rate per currency, but otherwise the risk-free rate of each country (currency area) could be applied. In Appendix C, I demonstrate that the results for the currency convenience yield remain valid when considering only government bonds issued by euro area countries and the US. This validity persists due to the predominant issuance of euro and dollar assets within these currency areas in my sample.

$$\begin{aligned} \hat{y}_t^{euro,i,\tau} - r_t^{euro,\tau} &= -\omega_t^{euro,i,\tau}, \\ \hat{y}_t^{dollar,i,\tau} - r_t^{dollar,\tau} &= -\omega_t^{dollar,i,\tau} \end{aligned} \tag{7}$$

Converting the residual yield ($\Gamma_t^{c,i,\tau} = \hat{y}_t^{c,i,\tau} - r_t^{c,\tau}$) into a "synthetic euro" yield, if dollar-denominated and similar to equation (4), while controlling for security characteristics (i and τ) by using sovereign CDS spreads, country and maturity fixed effects,[33] allows for the measurement of the average differential between the convenience yield for the euro and the dollar within each bank portfolio b.

$$\Gamma_{t,b}^{euro} - \Gamma_{t,b}^{SyntheticEuro} = \omega_{t,b}^{SyntheticEuro} - \omega_{t,b}^{euro} \tag{8}$$

where *SyntheticEuro* represents a yield in euros on dollar-denominated assets. A positive differential will imply a larger convenience for the dollar then the euro, taking into account hedged movements in exchange rate markets. Hence, the relative currency-convenience yield also encompasses any potential costs for hedging against foreign currency fluctuations in financial markets.

I bring this decomposition to the data by running again the portfolio-weighted specification 2 on the residual yield differential (risk-free rate and country risk adjusted hedged euro-dollar yield). To proxy for the risk-free rate for the US and the euro are I use Eonia based overnight swaps and Federal Funds Rate based overnight swap (e.g.,OIS), respectively, matched by currency and maturity. Note that given the inclusion of country fixed effects on the convenience yields (residual yields), any variation in convenience due to the issuer-country should be accounted for.

Finally, eq.(8) would be equivalent to the following decomposition of the risk-free interest rate differential and a currency convenience yield differential on the right-hand side:

$$\hat{y}_t^{euro} - \hat{y}_t^{SyntheticEuro} = (r_t^{euro} - r_t^{dollar}) - (\omega_t^{euro} - \omega_t^{SyntheticEuro}) \tag{9}$$

In this case, the risk-free interest rate differential can be seen as the divergence between the

[33] Discounting sovereign risk from the yield controls for the variation across countries i due to default risk which could also largely impact the country convenience yield. In order to isolate the convenience for the currency alone, I include country fixed effects on the residual yields to control for any convince related to the issuer country.

monetary policy in the US and the euro area.[34]

Figure 6 shows the estimation of eq.(8) for the weighted CIP. Concretely, it plots the currency convenience yield differentials between the euro and the dollar. A positive deviation on the currency convenience yield differential signals a larger convenience yield on the dollar than on the euro for sovereign bond holdings.

Several factors appear behind this decomposition. First, all investors appear, on average, to have a larger currency convenience yield from holding dollar-denominated bonds relative to euro-denominated ones. Therefore the heterogeneity in bank-level CIP, previously estimated, does not seem to be explained by a convenience yield for the currency. More specifically, banks in high-yielding countries, who appeared more willing to forgo return in exchange for holdings euro-denominated bonds (negative bank-level CIPs), do not show a convenience for euros.

Second, the pattern of the convenience yield appears to mirror the cumulative sovereign purchases by the ECB. During the period under review, the ECB undertook large outright purchases in the sovereign bond market. The extraction of euro bonds, alongside a silent US monetary policy at the time, may shape the currency convenience for holding dollar-denominated bonds in euro area price-sensitive investors' portfolios (e.g. banks) as per eq. (9).[35] Overall, the relative convenience yield for the dollar held in euro area banks appears to increase with purchases of sovereign bonds by the ECB.

Based on the observations from the decomposition analysis, where the convenience factor for the currency seemingly fails to account for the varied breaches of bank-level CIP across the euro area, and why banks might not engage in their optimal arbitrage strategies to exploit returns by adjusting to a different portfolio currency composition, I am further exploring other potential drivers that could explain bank behavior. Specifically, I will investigate whether friction on the investor side, such as those in the bank's balance sheet, accounts for these varied violations.

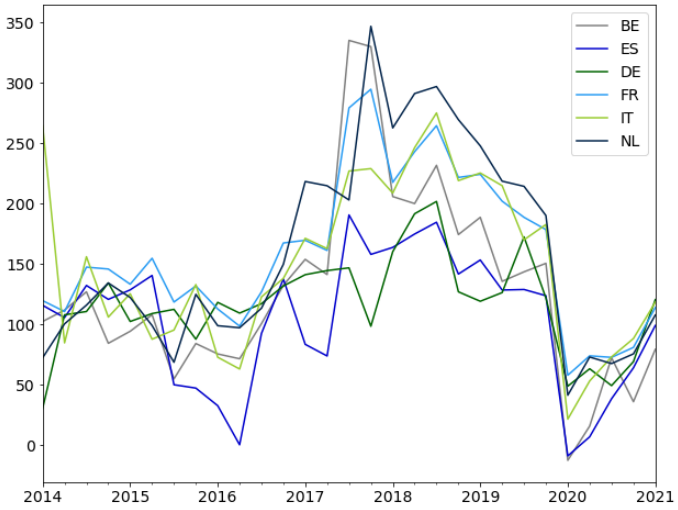
4.2. Factors explaining deviations in hedged yield differentials

The post-Global Financial Crisis (GFC) era witnessed significant shifts in the economic landscape, which brought forth an array of interrelated potential drivers contributing to de-

[34] Following eq.(4), the hedge would enter as an additive element on the right-hand side decomposition. Therefore only one of the components on the right-hand side will bear the heading cost.

[35] A wider divergence between monetary policies as measured by the risk-free interest rate differential, with euro area monetary policy being more accommodative, would account for a wider convenience yield for the dollar asset following eq. (9)

Figure 6: Averages of banks' currency convenience yield differential ω_t^c by holder country (basis points)



Notes: Figure 6 plots the currency convenience yield differential obtained from the CIP decomposition as per $\Gamma_{t,b}^{euro} - \Gamma_{t,b}^{SyntheticEuro} = \omega_{t,b}^{SyntheticEuro} - \omega_{t,b}^{euro}$ where $SyntheticEuro$ represents the yield in euros on dollar-denominated assets and $\Gamma_{t,b}^{c}$ is the sovereign-risk and risk-free adjusted yield (the residual yield). The sample covers all bonds (excluding sovereigns in debt crises) with residual maturity above 1 year for the period 2013 Q4-2021 Q1. The regressions are estimated at the security-level cross-section for each bank b at each date t. Standard errors are clustered at the currency-denomination.

viations in CIP.[36] Recent literature has extensively documented several factors that broadly fall into three categories: i) structural factors encompassing pivotal regulatory changes for financial intermediaries (Rime et al. (2017) and Du et al. (2018a)), ii) unconventional monetary policies (Liao (2016), Bräuning and Ivashina (2020a), Cerutti et al. (2021), Faia et al. (2022)) and iii) escalated macro-financial frictions, such as risks associated with FX derivatives, among other elements (Avdjiev et al.(2017), Borio et al. (2018)).

I am investigating how these factors, encompassing investor-side frictions like those found in banks' balance sheets, contribute to explaining deviations in CIP within the sovereign portfolios of euro area banks. Additionally, I'm expanding the factors within the CIP literature by considering banks' home issuer bias in sovereign bonds as another aspect of bank balance-sheet frictions. The presence of a significant home issuer bias share in specific banking portfolios serves as the basis for diverse euro-dollar yield differentials among euro area banks. Therefore, I hypothesize that the home issuer bias could impact the currency premia of sovereign bonds. To explore these aspects, I'm selecting representative measures that shed light on these factors.

Hereafter I present the measures I use for the four drivers potentially explaining deviations in bank's CIPs.

[36] See, among other authors, Borio et al. (2016), Avdjiev et al. (2019), Cerutti et al. (2021), Tola et al. (2020), Du and Schreger (2021) for assessments on the failure of CIP since the global financial crisis.

a) To gauge regulatory limitations within banks, I consider their liquidity coverage ratio (LCR). The LCR requires banks to hold a stock of high-quality liquid assets (HQLA) at least as large as expected total net cash outflows over a stress period of 30 days. This regulatory tool is designed to make sure that banks can cover short/term liquidity need sin times of stress.

Engaging in cross-currency arbitrage strategies amplifies banks' exposures, potentially leading to higher capital requirements if currency risks remain unhedged. Hedging these risks through derivatives can trigger margin calls, draining liquidity. This surge in outflows tends to reduce the LCR. However, as margin call LCR requirements are calculated retrospectively, the impact on the LCR materializes gradually over time.[37] Consequently, this hedging approach necessitates additional prudential requirements, particularly in terms of liquidity. Hence, implementing a cross-currency arbitrage strategy can pose regulatory costs for banks, compelling them to opt for euro-dollar compositions aligned with their desired regulatory thresholds.

More specifically, I include banks LCR as an indicator variable which will equal one for banks with an LCR above the 25th percentile in each period in my sample. Note that banks over-comply with regulatory constraints as these are also indicative of the bank's health relative to peers, see (Bonner and Eijffinger (2016) and Kedan and Ventula Veghazy (2021)). Therefore, a threshold above the minimum requirement of 100% is required to asses banks' compliance, also relative to peers.

b) To assess the impact of euro area monetary policy, I utilize monetary policy surprise shocks in sovereign yields (from EA-MPD).[38] Specifically, I calculate the difference between the changes in the 10-year Italian (IT) and German (DE) bonds to capture the yield spread alteration caused by an exogenous monetary policy shock. An increase indicates a widened spread post-monetary policy shock, and vice versa. This spread measure represents the monetary policy shock, encompassing unconventional monetary policies which had likely a more pronounced effect on long-term bonds. Central bank bond purchases aim to reduce the premium associated with duration risk via the asset valuation channel, particularly affecting longer-term bonds, which are more sensitive to such risk (Andrade et al. (2016)). Moreover, this measure also pertains to fragmentation in sovereign yields, potentially influencing sovereign bond holdings

c) To proxy for macro-financial frictions, such as re-denomination risks or flight-to-safety

[37] See article 40.56 in the Basel Framework .

[38] To match the quarterly frequency, I take the closest monetary policy meeting before the end of the quarter.

dynamics, I include a time-varying parameter for banks' risk aversion for their sovereign bond portfolio. I obtain this parameter with a calibration exercise (see Appendix E). Concretely, following Begenau et al. (2015), I compute euro area banks' exposures to macroeconomic risks factors through their sovereign bond positions by representing them in simple factor portfolios. I match these factor portfolios with the optimal factor portfolios derived according to a myopic portfolio choice model. This allows me to extract the corresponding bank risk-aversion levels. A higher value in the calibrated parameter points to more risk-averse banks.

d) I introduce a novel potential factor - a balance sheet friction - explaining CIP deviations in sovereign bonds, which to my knowledge is unexplored in the international finance literature on sovereigns. Concretely, I investigate the impact of home bias in sovereign bonds on banks' CIP deviations, for instance, on the currency premia they appear willing to pay. The underlying hypothesis is that euro area banks with significant home bias in their sovereign holdings might demand lower yields on their euro assets due to the convenience of holding these assets which are largely denominated in euros. To ensure the exogeneity of the home bias measure,[39] I instrument the growth in the home bias share with the debt redemption profile of the bank's home country (total amount of maturing sovereign debt). Specifically, I use the deviation in a country's redemption profile from its median between 2013 and 2021. Ongena et al. (2019) show that in months of large maturing debt, banks are more likely persuaded by the government to increase their holdings of newly issued debt needed to roll over the maturing one. Given that the total value of maturing debt in a country is predetermined, it is thus exogenous to current economic conditions as well as to banks' current sovereign debt demand.

Lastly, I include bank fixed effects to control for various aspects of banks' business model, bank size and other time-invariant bank characteristics.[40] This encompasses factors such as a banks being natural recipients of dollar-deposits or if they have their constant requirement for specific collateral used for a stable recourse to central bank operations.

Table 1 shows the summary statistics of the drivers and controls by country and across the 26 banking groups over the period 2013Q4-2021Q1 (conditional on availability). [41] Note that there has been a declining trend in the home bias share across countries over the review

[39] Banks might have profit-related or business model motives (e.g., for collateral reasons) to hold domestic assets per se.

[40] Considering the composition of banks in my sample, namely the largest euro area banking groups, their sizes have shown relative stability throughout the review period. Consequently, the inclusion of additional metrics to gauge bank size results in collinearity issues with the bank fixed effects.

[41] Note that these statistics only comprise a number of selected banking groups in each country.

Table 1: Summary statistics of representative measures for determinants driving CIP deviations

		MP spread shock	LCR	Risk aversion	Home bias share growth*
High Yield	mean		158%	0.57	-0.63
	std.deviation		*33%*	*0.17*	*8.41*
Low Yield	mean		145 %	0.48	-1.21
	std.deviation		*43%*	*0.22*	*41.04*
Total	mean	-1.34p.p.	150 %	0.51	-0.98
	std.deviation	*4.95p.p.*	*40%*	*0.21*	*33.49*

Notes: The table shows the mean across the sample period except for the in-sample quarterly growth rate of the home bias share (Home bias growth share*). The latter is represented as the median across the sample period for each group. The in-sample share excludes holdings with residual maturity below one year as well as holdings of bonds of four crises countries in line with samples used in the previous section. See Section 1.4.1 for a more extensive description of the data in the sample. MP spread refers to the monetary policy spread in the surprise change following monetary announcements around the 10 Italian and German bond yield. Risk aversion is a parameter and refers to banks' risk aversion. LCR refers to the Liquidity coverage ratio.

period as seen in Figure 3 in Section 3. Nevertheless the quarterly growth rate declined less for the median bank in countries like Belgium, Spain and Italy relative to low-yielding countries.

To uncover the impact of factors on the estimated CIPs I run variants of the following model:

$$\begin{aligned}
\text{1st stage:} \quad GrowthHomeBiasShare_{t,b} &= \beta DevCountryDebtRedemption_{t,c} \\
&+ \tau LCR_{t-1,b} + \gamma RiskAversion_{t-1,b} \\
&+ \chi MonetaryPolicyShock_t + \upsilon_b + u_{t,b} \\
\text{2nd stage:} \quad \hat{CIP}_{t,b} &= \beta \hat{GrowthHomeBiasShare}_{t,b} + \tau LCR_{t-1,b} \\
&+ \gamma RiskAversion_{t-1,b} + \chi MonetaryPolicyShock_t + \upsilon_b + u_{t,b}
\end{aligned} \tag{10}$$

where $\hat{CIP}_{t,b}$ is the estimated weighted hedged euro-dollar yield differential for each bank b and time t. $GrowthHomeBiasShare_{t,b}$ is the growth in the share of domestic government bonds for bank b at time t corresponding to bank-level CIP sample. $LCR_{t-1,b}$ is an indicator variable which equals one if the bank has a ratio above the 25th percentile in $t-1$. The LCR variable is lagged to avoid endogeneity with the dependent variable. $RiskAversion_{t-1,b}$ is lagged and bank-specific, while $MonetaryPolicyShock_t$ is common across banks. Bank fixed effects are denoted by υ. In the first stage, $GrowthHomeBiasShare_{t,b}$ is instrumented by $DevCountryDebtRedemption_{t,c}$ which is the deviation in each country's redemption profile from its median over the period under review 2013Q4 to 2021Q1.

Table 1 shows the results of regression (10). Column (1) shows the *first stage* regres-

sion where the dependent variable $GrowthHomeBiasShare_{t,b}$ is positively and significantly correlated with the deviation in the country's total debt redemption profile. Column (2) shows the *second stage* results. The growth in home bias share -the measure of interest - is significant and negative. It signals that, even after adjusting for hedged Forex movements, banks require a lower yield on euro denominated bonds compared to the dollar assets. The Kleibergen-Paap Wald F-statistics for several specification of these regression are around conventional thresholds for instrumental variable analysis.[42]

To understand the impact of the drivers on the portfolio-weighted yield differentials, I examine the respective magnitudes. A 15% growth in the predicted home bias share, almost two standard deviations across all countries and time, leads to an 18 basis points drop in the bank-level CIP. This can be considered economically meaningful taking into account that the median of the weighted bank-level CIP is 0.5 basis points, the mean is -1.6 basis points and the standard deviation is around 62 basis points in my sample. This outcome suggests that home bias in sovereign bonds is likely a contributing factor explaining the observed heterogeneity across banks' CIP. This provides evidence for spillovers of investor-side frictions, such as domestic frictions in banks' balance sheets, on the currency premia of sovereign bonds. Further specifications for the same regression model provide robustness for this driver. See Appendix D.

Regarding the other drivers, regulation also appears to be a critical factor driving CIP deviations, further supporting the evidence provided in the literature so far (i.e., Du and Schreger (2021)). Hence, this analysis supports finding of regulatory impact on CIP deviation with a micro-founded analysis for the banking sector. The result is not surprising as the data is end-of-quarter and will likely largely capture regulatory effects, which are more pronounced during those periods. However, given the lagged nature of the impact of hedging derivatives via margin calls on LCRs the sign of the coefficient has to be treated with caution.

4.3. Assessing the international rebalancing behaviour following ECB's PSPP and PEPP

Frictions in banks' balance sheets can lead to segmented portfolio holdings within a single currency area having implications for a cross-border transmission of a common monetary policy.

[42]See Andrews et al. (2019) for theory and practice of instrumental variable regressions.

Table 2: CIP deviations on determinants

	(1)	(2)
	1st stage	*2nd stage*
Dependent variable	*GrowthHomeBias*	*weighted CIP*
Dev. country debt redemption	0.355***	
	(0.127)	
Growth Home Bias		-1.248*
		(0.734)
Lagged LCR	-10.92***	-13.139**
	(2.603)	*(5.598)*
Lagged banks' risk aversion	14.703	20.574
	(28.534)	*(34.795)*
MP spread shock	0.615*	0.303
	(0.343)	*(0.377)*
Bank fixed effects	Yes	Yes
Observations	519	519

Notes: Regressing the weighted yield differential, $CIP_{b,t}$, estimated in eq. (2) on potential drivers during the sample period 2014Q4-2021Q1 by using a instrumental variable approach. Concretely, the first stage is $GrowthHomeBiasShare_{t,b} = \beta DeviationCountryDebtRedemption_{t,c} + Controls2ndStage$ and the second stage $\hat{CIP}_{t,b} = \beta \hat{GrowthHomeBiasShare}_{t,b} + \tau LCR_{t-1,b} + \gamma RiskAversion_{t-1,b} + \chi MonetaryPolicyShock_t + \upsilon_b + u_{t,b}$. Dependent variable in the second stage is the estimated investor differentials for the weighted CIP. Bank fixed effects have been partialled out. The regression is done with clustered standard errors at the country level. P-values indicated as: *** p<0.01, ** p<0.05, * p<0.1.

As we observed heterogeneous deviations in hedged yield differentials across euro area regions together with an overall currency-convenience yield for the dollar increasing with the ECB's purchase programmes, next I analyse the rebalancing behaviour of banks into US government bonds. This examination occurs within an environment in which the ECB has been implementing highly accommodative monetary policies in comparison to those of the US via its large/scale asset purchase programmes. Concretely, I examine if banks rebalanced their euro-denominated versus dollar-denominated assets following the shock represented by the ECB's Public Sector Purchase Programme and Pandemic Emergency Sector Programme (PSPP and PEPP, respectively). Given that large part of dollar-denominated holdings in my sample are US government bonds, I will henceforth focus on US-issued bonds only.[43]

Between 2015Q1 and 2022Q3 the Eurosystem purchased large quantities of euro-denominated government bonds issued by euro area governments under PSPP and PEPP (henceforth APP).[44] To measure banks rebalancing into US bonds due to these large purchases, I focus on the stock effect of ECB's purchases operating through the local supply or scarcity channel

[43]US government bonds are also likely viewed as the closest foreign substitute for euro area government bonds given its associated safety and thus would be first in demand in a context of rebalancing towards foreign assets.

[44]APP is a separate program from PEPP, but for simplicity I refer to APP for sovereign purchases done under the two programs APP-PSPP and PEPP.

whereby the ECB reduces the free-float of these assets, bidding up their price and thereby decreasing their yields.[45] The portfolio rebalancing channel can then trigger a rebalancing towards foreign assets.[46] Concretely, lower yields can induce price-sensitive banks to sell these securities, earning the associated capital gain. The liquidity received in exchange for the assets sold might not be seen as a perfect substitute. Thus return-oriented banks might prefer to reinvest and rebalance their portfolios towards other higher-yielding assets such as foreign securities (Hammermann et al. (2019)).[47] In addition, APP also leads to an extraction of duration risk from the yield term premium component particularly relevant for medium and long-term yields. This decreases the duration risk borne by private investors in their bond holdings as well as the aggregate duration risk born by the market (Eser et al. (2019)). In turn, it increases investors' risk-bearing capacity, thus incentivising them to restore the desired risk profile in their portfolio by investing in different assets.[48]

To this aim, in order to measure the stock effect of APP, I use as explanatory variable the cumulative nominal value purchased of an ISIN as a share of its respective outstanding amount at each point in time. In addition, I match the ISINs bought by the ECB with the ones held by the banks to capture the ECB's stock effect on individual bank's portfolios.

Formally I construct the ISIN-level measure for the APP impact on banks' balance sheet as follows:

$$weightedCumAPPshare_{t+1,b} = \sum_{j=1}^{N} w^{c}_{j,b,t-1} \frac{CummulativeGovPurchases_{j,b,t}}{OustandingAmount_{j,b,t}} \tag{11}$$

where $w^{c}_{j,b,t-1}$ is the bank's portfolio weight assigned to security j which is purchased by the ECB and held by bank b at the end of the period $t-1$ to avoid endogeneity between the bank's portfolio weight and the purchases. $\frac{CummulativeGovPurchases_{j,b,t}}{OustandingAmount_{j,b,t}}$ is the ECB share bought of security j which is also held by bank b over $j's$ outstanding amount at time t. This aggregates banks' individual exposures to securities bought by the ECB at the bank level.

While banks can know which securities are eligible to be purchased[49], banks do not know

[45] Note that the ECB has enabled a Securities Lending Programme after the start of asset purchases.

[46] In this section I focus on the portfolio rebalancing channel to asses changes in the direction and magnitudes of capital flows. However, the signalling channel of PSPP and PEPP can also contribute to the direction of capital flows and thus to the rebalancing behaviour of euro area banks.

[47] See Albertazzi et al. (2018) for portfolio rebalancing channel and De Santis and Holm-Hadulla (2017) for flow effects.

[48] See also Box 3 in Hammermann et al. (2019).

[49] Such as the allocation criteria across jurisdictions over the medium term as well as the issuer and issue limits constraining the quantity of purchases

ex-ante the total exact amount bought of each security at each point in time. Thus the total stock effect of purchases, hence this measure, is exogenous from the point of view of the bank.

I specify the following model:

$$\begin{aligned} ChangeShareUS2015Q1_{t,b} = {} & \beta weightedCumAPPShare_{t-1,b} \\ & + \beta TotalHoldings_{t-1,b} + \beta LeverageRatio_{t-1,b} \\ & + \gamma RiskAversion_{t,b} + \gamma TotalAssets_{t,b} + \eta_b + u_{t,b} \end{aligned} \tag{12}$$

$ChangeShareUS_{t,b}$ is the change in the share of US holdings over total holdings between t and the start of APP in 2015Q1 for bank b. $weightedCumAPPshare_{t-1,b}$ at the bank level is the lagged holdings-weighted average of the accumulated ISIN share purchased by the Eurosystem. To avoid a mechanical link between the APP purchases and the holdings in banks, the APP shock is lagged to $t-1$. The APP shock is computed at the security level and aggregate at the bank-level by using the bank's lagged holdings share to avoid endogeneity between the weights and the shock. See Appendix for robustness with different weighing options. To control for changes in the US share driven by a decrease in euro-denominated holdings (e.g. a base effect) as a consequence of the ECB's asset purchases itself, I include the level of government bond holdings by bank b at time t ($TotalHoldings_{t-1,b}$). I also include time-varying bank characteristics such as the lagged leverage ratio for regulatory constraints, total assets for bank size and the proprietary parameter for bank's risk aversion. Finally, I control for bank fixed effects which should account for banks' business models, including the pre-APP US-holdings share level. As the change in the $USshare$ covers only the period of APP, bank fixed effects should also account for banks acting as larger counterparts in the purchases, who usually sold relatively more to the ECB over that time period. Errors are bootstrapped and clustered on the fixed effect variable.

Table 3 presents the overall estimation results for equation (12), focusing on euro area banking groups and the breakdown by their residence country. Column (1) shows a positive and significant APP shock variable. This confirms the hypothesis that euro area investors significantly rebalanced their portfolios away from individual securities targeted under the PSPP into foreign assets, after controlling for a vast array of bank specific factors. Concretely, one (in sample) standard deviation in the APP shock would account for around 1.4% change in the US-holdings share, comparing to an average change of 4.7% in sample.

In addition, I run a specification for only the cumulative flow into US sovereign bonds as

dependent variable to confirm that results are driven by changes in foreign asset holdings and not just by a mechanical decrease in euro holdings as a result of purchases, e.g., a base effect (column (2)). Column (3) provides evidence of a more pronounced rebalancing into US bonds by banks with lower balance sheet frictions as measured by their pre-APP home bias share. Indeed, banks with a higher pre-APP home bias share reblanced less towards US assets following the ECB asset purchase shock. Additionally, in column (4) I compare if countries with lower sovereign yields have rebalanced more towards US assets as a consequence of APP. The interaction term which equals one for DE, NL, FR and AT is significant with a positive coefficient. Overall, this shows that banks in those countries have increased, on average, their US share by more than in high-yielding and home bias prone countries.

Results are in line with the dynamics in the CIP decomposition of an increase in the dollar convenience yield held by banks. Furthermore, they are also in line with the conjecture of a price-sensitive sector rebalancing towards other (foreign) assets following a shock to the yield of euro assets. Within the banking sector, those banks who could be more inelastic due to some frictions in banks' balance sheets, did indeed rebalance less towards foreign assets. This points to the importance of banks' balance sheet frictions for determining heterogeneous monetary policy spillovers across borders.[50]

5. Conclusions

Leveraging on a confidential securities dataset, this paper delves into euro area banks' pricing impact for currency denomination for sovereign bonds. Motivated by stylized facts revealing an issuer bias fragmentation between high- and low-yielding countries, I devise an econometric methodology that identifies banks hedged euro-dollar yield differentials in their sovereign bond portfolios. In addition, by further decomposing banks hedged yield differential, I uncover banks' currency-convenience yield in sovereign bonds. Banks in low-yielding countries such as NL and FR show positive weighted CIP deviations, requiring larger yields on euro assets relative to the dollar, while banks in high-yielding countries require lower euro ones. The decomposition shows that banks across all countries have a higher convenience yield from holding dollars with respect to euros, thus, not explaining the heterogeneity in bank-

[50] See Buch et al. (2019) for an assessment of cross-border transmission of conventional and unconventional monetary policy through banks for the United States, euro area, Japan, and United Kingdom. In line, their results also point to bank-specific heterogeneity influencing the magnitudes of transmission through lending.

Table 3: Portfolio rebalancing and ECB's sovereign purchases

	(1) $\Delta USshare$	(2) $\Delta USflow$	(3) $\Delta USshare$	(4) $\Delta USshare$
APP shock	0.183*	0.111***	0.721**	0.147***
	(0.10)	(0.04)	(0.28)	(0.04)
APPShockXpreHomeBias			-0.009**	
			(0.00)	
APPShockXLowSpreadCountry				0.197*
				(0.11)
Total Holdings	0.027	0.161***	0.060	-0.009
	(0.09)	(0.06)	(0.13)	(0.07)
Lagged leverage ratio	0.830	0.437	0.406	-0.658
	(0.86)	(0.34)	(1.28)	(0.84)
Total assets	-0.004	0.010	-0.002	0.004
	(0.03)	(0.01)	(0.03)	(0.00)
Bank risk aversion	25.985***	0.517	26.826***	13.606
	(8.73)	(1.75)	(9.31)	(8.82)
Constant	-13.458	-13.296	-14.205	-5.399
	(14.21)	(8.74)	(14.64)	(3.57)
Bank fixed effects	Yes	Yes	Yes	
Country fixed effects				Yes
Observations	515	515	515	515
R-squared	0.564	0.560	0.587	0.255

Notes: Regressing the change in banks' US holdings share on APP shock during the sample period 2015Q1-2020Q2. Bootstrapped standard errors clustered on the fixed effect variable. P-values indicated as: *** p<0.01, ** p<0.05, * p<0.1.

level CIP deviations. Motivated by these results, I further study potential micro-founded determinants affecting banks' currency-asset holdings such as frictions in banks' balance sheets. I find that home issuer bias provides evidence for heterogeneous CIP deviations in banks' sovereign portfolios, pointing to spillovers of investor-side frictions onto the currency premia of sovereign bonds. My results suggest for a heterogeneous transmission of a common monetary policy across borders. An analysis of banks' rebalancing behavior into foreign US assets following the ECB's sovereign purchases confirms this. The findings indicate that micro-founded frictions affect parity conditions in asset prices, leading to inefficient resource allocation and a heterogeneous transmission of monetary policies. The research also shows broader implications for the role of investor bases in currency pricing and bond convenience.

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A. Data

Euro Area Confidential Securities Data and Supervisory Banking Statistics The Securities Holdings Statistics (SHS), collected on a security-by-security basis, provides information on securities held by selected categories of euro area investors, broken down by instrument type, issuer country and further classifications. The legal basis for collecting SHS data is laid down in Regulation ECB/2012/24. This Regulation is complemented by Guideline ECB/2013/7, which sets out the procedures to be followed by national central banks when reporting to the ECB. SHS data have been collected in full since the fourth quarter of 2013 and covers the two main types of security: debt securities and equity securities (including investment fund shares). Between the first quarter of 2009 and the fourth quarter of 2013, reporting agencies were not obliged to report the data, but many did. The main feature of these data is that holding information is collected at the level of each individual security, i.e. security by security.

The SHS Group data module (SHSG) contains individual holdings by the 26 largest banking groups with head offices in the euro area since 2013Q4.[51] The scope of the reporting as defined in Article 1(4) of the SHS Regulation follows the prudential approach as set out in Directive 2013/36/EU and Regulation (EU) No 575/2013, i.e. the scope of prudential consolidation in accordance with the Capital Requirements Regulation (CRR). Consequently, the security holdings of all domestic and foreign financial entities of the groups (captured by the prudential scope) have to be included in the reporting. However, certain entities, notably insurance undertakings, are not covered by the prudential scope and, therefore, the holdings of insurance entities of the groups should not be reported in the SHSG data collection. Securities held in custody for third parties are also not in the scope of the SHSG data collection. Credit institutions have discretion whether or not to include subsidiaries or undertakings in the scope of CRR consolidation. Articles 19(1) and 19(3) of the CRR, clarifies cases where subsidiaries or undertakings in which a participation is held don't need to be included in the scope of consolidation. The security holdings of all worldwide entities of the banking group have to be reported centrally by the head of the group ("home approach"). The definition of the head of a banking group as the reporting agent pursuant to Article 1(10) of the SHS Regulation captures.

I complement the SHSG security-level holdings information with confidential banks' key solvency and leverage indicators from the Supervisory Banking Statistics collected in the

[51] See "Guidance notes to reporting agents on SHS regulation" May 2020 for more information on SHSG

context of the Single Supervisory Mechanism (ECB). The Supervisory Banking Statistics includes Pillar 3 information on banks directly supervised by ECB Banking Supervision that are designated as significant institutions (SIs).[52] The sample of SIs considered for each reporting period includes banks that are reporting COREP (capital adequacy information) and FINREP (financial information) at that point in time. For each bank in the sample, reporting is always considered at the highest level of consolidation within the Single Supervisory Mechanism (SSM). Concretely, it covers the same scope of reporting as for SHSG, namely the scope of prudential consolidation in accordance with (CRR). The Pillar 3 information comprises key solvency, leverage and liquidity coverage ratios for all significant institutions.

In addition, I enrich the the holdings information with the Centralised Securities Database (CSDB) that contains information such as price, issuer name and outstanding amount, precise debt type and issuer information for over six million outstanding debt securities, equities and investment fund shares. Finally, I merge information on the nominal value of the Asset Purchase Programme (APP and PEPP) holdings of the Eurosystem at the security level and quarterly frequency, amounting to a total of around EUR 2.4 trillion in Q4 2018. Note that I use the holdings in stocks and in nominal value (at issuance price) for the banking group holdings and the Eurosystem holdings. The latter ensures that the dynamics in the observations do not capture any valuation effects stemming from changes in current market price. Thus changes in holdings can b considered a pure rebalancing.

For the purpose of the present analysis, my sample only includes bonds with a residual maturity above 1 year. As the focus of the analysis is to consider the impact of semi-structural frictions in banks' balance sheets, like the share in domestic bond stocks or the LCR, on banks' arbitrage strategies (bank-level CIP), holdings of shorter maturities would less likely be influenced by these factors.

Data quality

To ensure good data quality, SHS data are regularly checked against comparable data sources. In particular, the data is checked against other ECB databases, such as the integrated euro area financial and non-financial accounts (EAA), Monetary, Financial Institutions (MFI) balance sheet statistics, insurance corporations and pension fund statistics, investment fund statistics and securities issues statistics, as well as with consolidated bank-

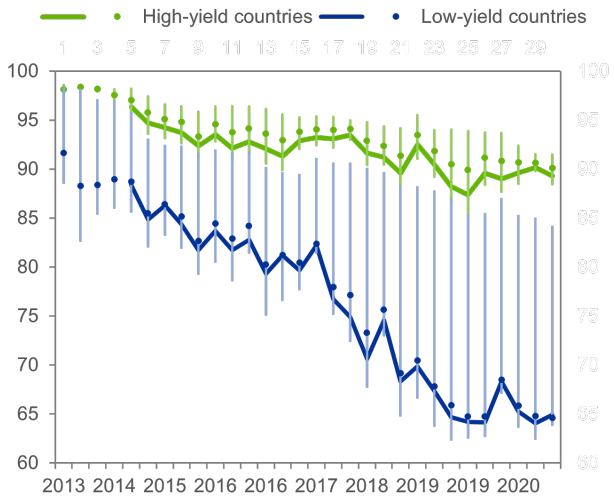
[52]For more information see the ECBs banking supervision statistics in here https://www.bankingsupervision.europa.eu/banking/statistics/html/index.en.html.

ing data. Nonetheless, the data set is massive and still requires considerable effort before it can be used for research purposes. A few common recurring errors include the temporary mislabeling of securities for example in terms of asset class or issuer, a different spelling of issuers over time, and other inconsistencies. Additionally, I apply some standard cleaning. Securities which have not been redeemed yet, but have a negative residual maturity can still be reported in the investors holdings portfolio. Thus I do not include holdings for securities with negative residual maturity according to CSDB. Additionally the data on the yield variable has been trimmed by dropping observations below 1% and 99% at each quarter to control for outliers.

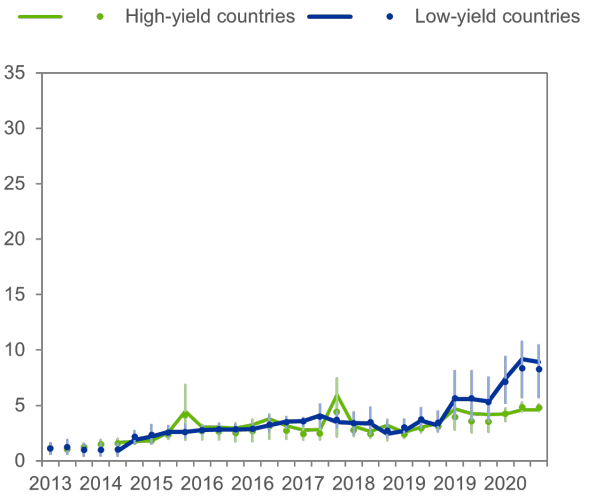
In Table 2, I trim the data on the explanatory variable, namely the growth in the home bias share for values above 400% to control for outliers as the shares are excluding holdings below 1 year maturity. Few observations are excluded.

B. Additional stylized fact charts

Figure B1: Banks' shares in domestic bonds for selected issuers, average across country groups



(a) EU government bond holding shares, aggregated at country level (percent)



(b) ROW government bond holding shares, aggregated at country level(percent)

Figure B2: Bank asset weighted currency share by country group (percent)

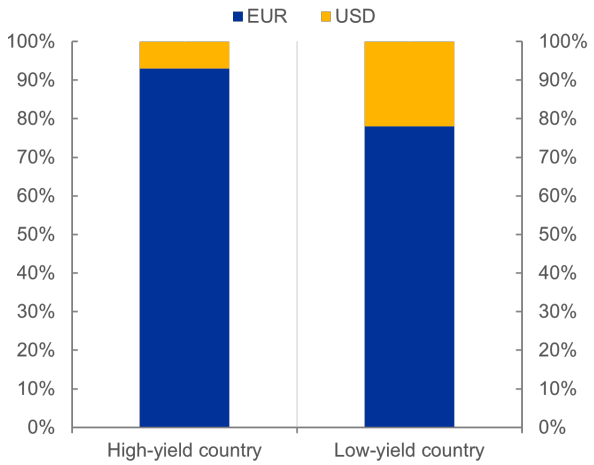
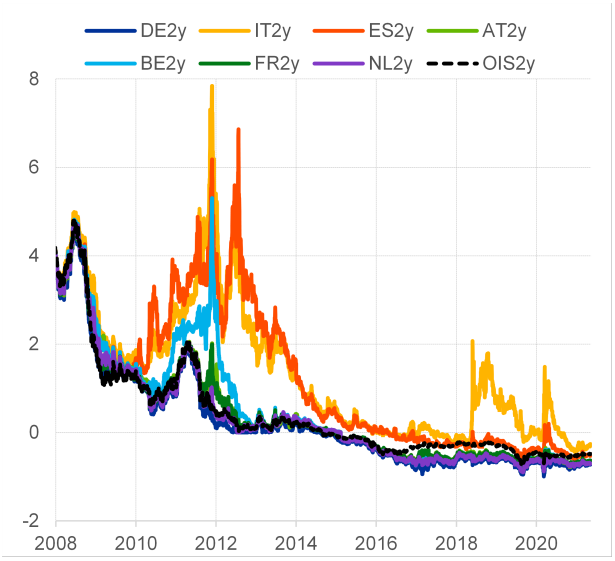


Figure B3: Sovereign bond yields across the euro area and the risk-free rate in the euro area (percent)



C. CIP deviations

C.1. Adjustment by Swap Rates

To do the swap adjustment, for short bonds we can proxy the currency premium in logs as:

$$\rho_{n,t} = \frac{1}{n}[log(F_{t,t+n}) - log(S_{i,t})] \tag{C.1}$$

measured as FC/USD. Following Du and Schreger (2021), for long bonds we can proxy the currency premium as:

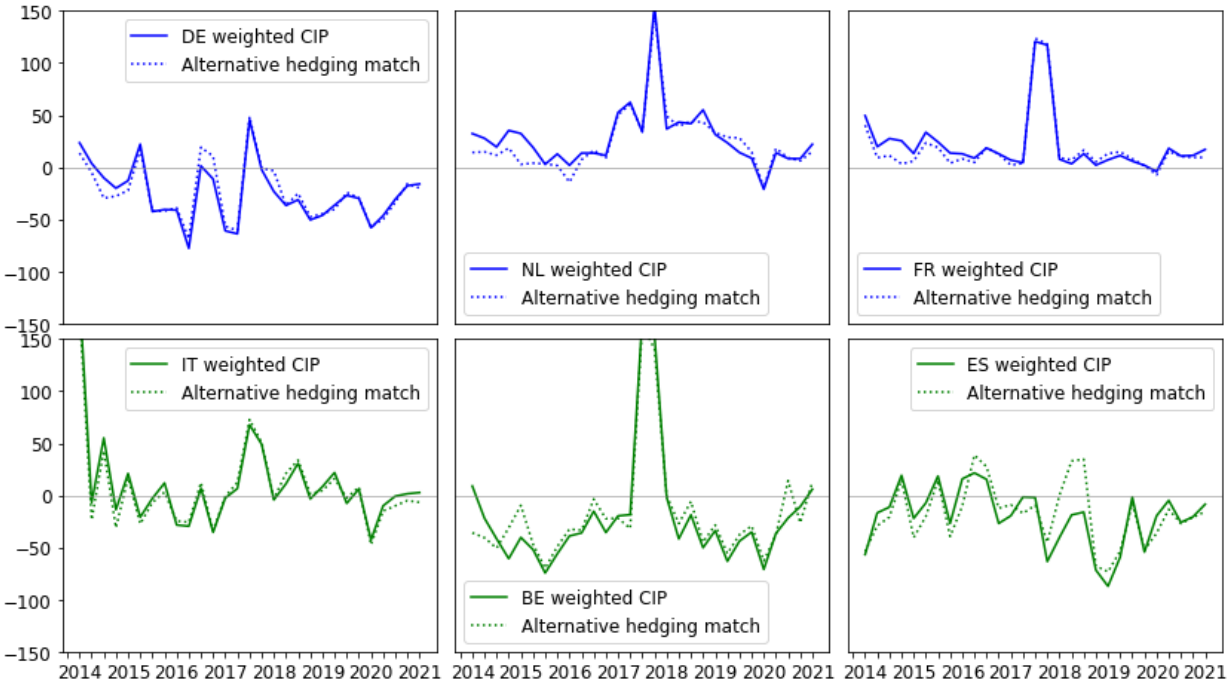
$$\rho_{n,t} = IRS_{euro,n,t} + BS_{euro,usd,n,t} - IRS_{usd,n,t} \tag{C.2}$$

where $IRS_{euro,n,t}$ is the interest rate swap in euros that trades fixed euro cash flow for floating euro cash flow (like Eurolibor), $BS_{euro,usd,n,t}$ is the cross currency basis swap contract that trades floating euro rate into USD floating (Libor) rate, $IRS_{USD,n,t}$ is the interest rate swap contract in dollars that trades fixed dollar cash flow for floating dollar cash flow (Libor). Also CIP violation is:

$$Y^{euro}_{n,t} - \rho_{n,t} - Y^{usd}_{n,t} \neq 0 \tag{C.3}$$

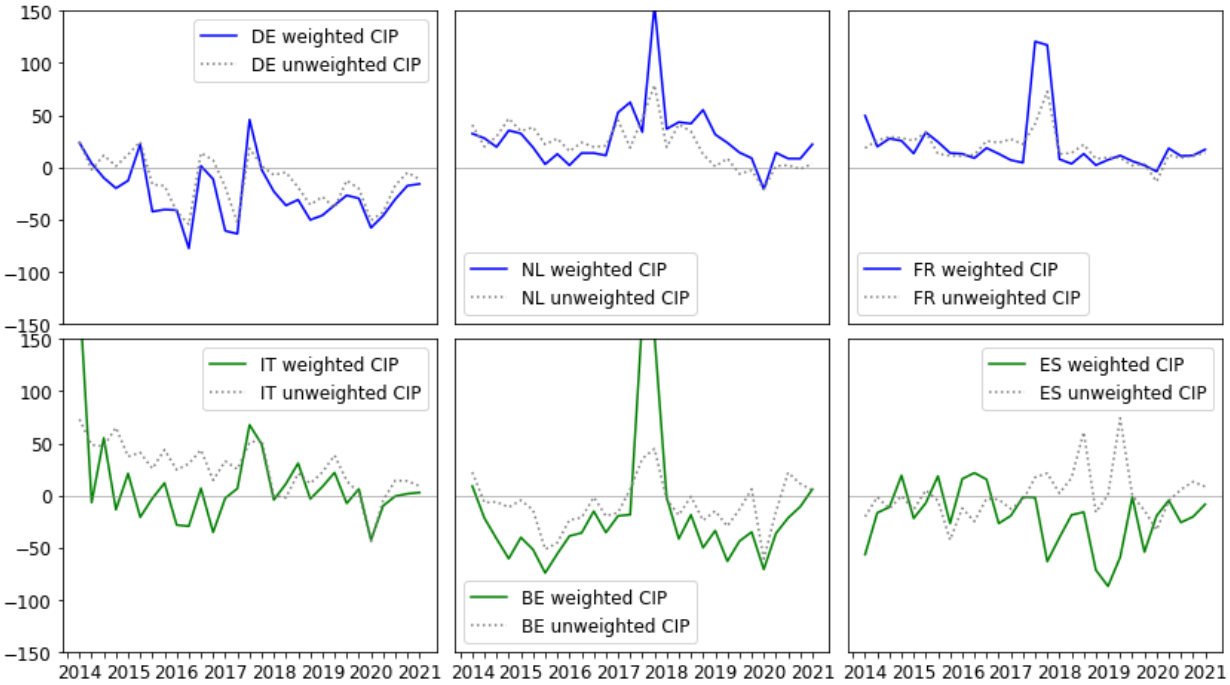
C.2. CIP deviations additional figures and robustness

Figure C4: Country averages of banks' weighted hedged yield differentials including alternative hedging match, $CIP_{b,t}$, by residency country (basis points)



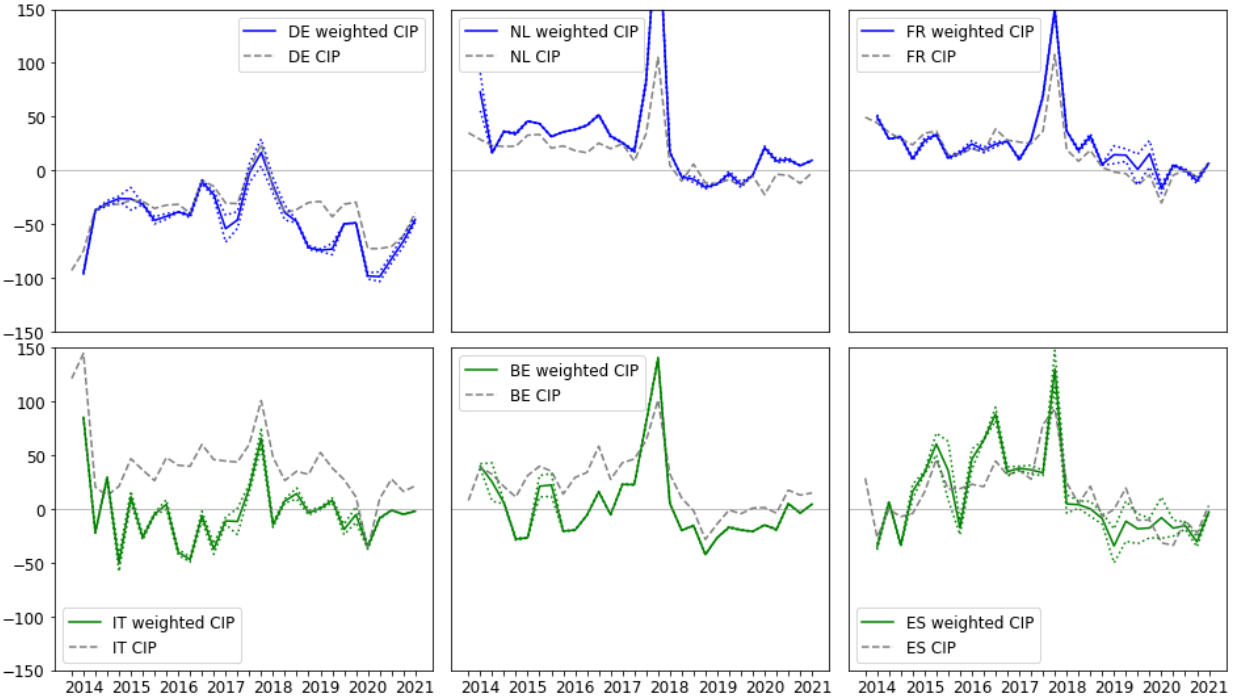
Notes: Figure C6 plots the bank-level estimates, $CIP_{b,t}$, of the portfolio-weighted hedged euro-dollar yield differential in banks' sovereign portfolio, averaged across banks with residency in a same country. The sample covers all bonds (excluding sovereigns in default crises) with residual maturity above 1 year for the period 2013 Q4-2021 Q1. Each panel shows the portfolio-weighted yield differential (solid line) and the alternative differential when using different maturity buckets to hedge for currency risk and purge for sovereign credit risk (dotted line).The econometric specifications is: $\tilde{y}_{j,b,t} = CIP_{b,t}\mathcal{I}_{EUR,j} + \gamma_{m,t} + \delta_{i,t} + \varepsilon_{j,b,t}$ where $CIP_{b,t}$ is the coefficient on the indicator variable $\mathcal{I}_{EUR,j,b}$ which equals one if bond j is denominated in euros. $\gamma_{m,t}$ and $\delta_{i,t}$ are fixed effects for maturity bucket m and issuer-country i at date t. The individual regressions are estimated at the security-level cross-section for each bank b at each date t. Standard errors are clustered at the currency-denomination. The y-axis is truncated at 150 basis points for visualization purposes.

Figure C5: Country averages of banks' unweighted and weighted hedged yield differentials, $CIP_{b,t}$, by residency country (basis points)



Notes: Figure C5 plots the bank-level estimates, $CIP_{b,t}$, of the unweighted and portfolio-weighted hedged euro-dollar yield differentials in banks' sovereign portfolio, averaged across banks with residency in a same country. The sample covers all bonds (excluding sovereigns in default crises) with residual maturity above 1 year for the period 2013 Q4-2021 Q1. Each panel shows the portfolio-weighted yield differential (solid line) and the unweighted differential (dotted line). The econometric specifications is: $\tilde{y}_{j,b,t} = CIP_{b,t}\mathcal{I}_{EUR,j} + \gamma_{m,t} + \delta_{i,t} + \varepsilon_{j,b,t}$ where $CIP_{b,t}$ is the coefficient on the indicator variable $\mathcal{I}_{EUR,j,b}$ which equals one if bond j is denominated in euros. $\gamma_{m,t}$ and $\delta_{i,t}$ are fixed effects for maturity bucket m and issuer-country i at date t. The individual regressions are estimated at the security-level cross-section for each bank b at each date t. Standard errors are clustered at the currency-denomination. The y-axis is truncated at 150 basis points for visualization purposes.

Figure C6: Country averages of banks' unweighted and weighted hedged yield differentials, $CIP_{b,t}$, estimated without country fixed effects (basis points)



Notes: Figure C6 plots the bank-level estimates, $CIP_{b,t}$, of the unweighted and portfolio-weighted hedged euro-dollar yield differential in banks' sovereign portfolio, averaged across banks with residency in a same country. Each panel shows the portfolio-weighted yield differential (solid line) and unweighted differential (dotted line). In this case, country fixed are excluded from the speficiation. The econometric specifications is: $\tilde{y}_{j,b,t} = CIP_{b,t}\mathcal{I}_{EUR,j} + \gamma_{m,t} + \varepsilon_{j,b,t}$ where $CIP_{b,t}$ is the coefficient on the indicator variable $\mathcal{I}_{EUR,j,b}$ which equals one if bond j is denominated in euros. $\gamma_{m,t}$ are fixed effects for maturity bucket m and at date t. The sample covers all bonds (excluding sovereigns in default crises) with residual maturity above 1 year for the period 2013 Q4-2021 Q1. The individual regressions are estimated at the security-level cross-section for each bank b at each date t. Standard errors are clustered at the currency-denomination and their country averages are estimated via seemingly unrelated estimation. The y-axis is truncated at 150 basis points for visualization purposes.

D. Additional Robustness

Table A1: CIP deviations on determinants

	(1)	(2)	(3)	(4)	(5)	(6)
	1st stage	*2nd stage*	*1st stage*	*2nd stage*	*1st stage*	*2nd stage*
Dependent variable	*GrowthHomeBias*	*weighted CIP*	*GrowthHomeBias*	*weighted CIP (FE)*	*GrowthHomeBias*	*weighted CIP*
Dev. country	0.355***		0.298***		0.284***	
debt redemption	*(0.117)*		*(0.084)*		*(0.082)*	
Growth Home Bias		-1.521**		-1.351**		-1.610***
		(0.688)		*(0.588)*		*(0.353)*
Lagged LCR	-12.048***	-21.101**				
	(3.301)	*(9.312)*				
Lagged			0.33	-1.76	1.07	-5.62**
Leverage Ratio			*(1.78)*	*(2.78)*	*(1.18)*	*(2.55)*
Lagged	-1.382	-17.782	6.326	17.745	-6.101	-5.878
Risk aversion	*(33.181)*	*(51.930)*	*(17.956)*	*(24.367)*	*(23.424)*	*(44.265)*
MP spread shock	0.323	0.785*	0.643	0.359	0.365	0.778
	(0.450)	*(0.446)*	*(0.365)**	*(0.393)*	*(0.474)*	*(0.519)*
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	579	579	598	598	666	666
F-statistic		9.17		12.56		12.10

Notes: Regressing the yield differential, $CIP_{b,t}$, estimated in eq. (1.2) and for its variation without counrty fixed effects on potential drivers during the sample period 2014Q4-2021Q1 by using a instrumental variable approach. Concretely, the first stage is $GrowthHomeBiasShare_{t,b} = \beta DeviationCountryDebtRedemption_{t,c} + Controls 2ndStage$ and the second stage $\hat{CIP}_{t,b} = \beta \hat{GrowthHomeBiasShare}_{t,b} + \tau RegulatoryVariable_{t-1,b} + \gamma RiskAversion_{t-1,b} + \chi MonetaryPolicyShock_t + v_b + u_{t,b}$. The regulatory variable is the bank-specific lagged LCR as an indicator equalling one if above the in-sample 25th percentile thresholds or the bank's lagged Leverage Ratio (transitional calculation). The dependent variable in the second stage is the estimated investor differentials for the weighted CIP under the baseline specification denoted by (FE) and without including country fixed effects. Bank fixed effects have been partialled out. The regression is done with clustered standard errors at the country level. P-values indicated as: *** p<0.01, ** p<0.05, * p<0.1.

E. Calibration Exercise

I compute euro area banks' exposures to macroeconomic risks through their fixed income positions by representing those positions in terms of simple factor portfolios. I compare these factor portfolios with the optimal factor portfolios derived from theory by following a myopic portfolio choice model.

I focus on sovereign bonds denominated in euro or dollar currency held by the largest 26 euro area banking groups. These banking groups account for around 60% of euro area banks' consolidated total asset and they held around 40% of their total debt securities in government bonds in 2014Q1. Government bonds denominated in euros or dollars are about 80%.

E.1. Empirical and theoretical framework

Factor model :

Following Begenau et al. (2015), I compute a factor model with four factors: interest rate risk for the euro area, interest rate risk for the US, credit risk for the euro area and credit risk for the US. First, I regress the returns of most of the sovereign bonds held in my bank's portfolios on the four factors. Then I compute factor portfolios of the sovereign position for every bank for every date.

Step1: Estimate exposure regressions (1) of returns on factors recursively

$$R^i = \alpha_i + \sum_{j=1}^{F} \beta_i^j \hat{R}^j + u^i \quad \text{where } R^i = 1, .., F; \hat{R}^j = 1, 2, 3, 4 \tag{E.1}$$

Step 2: Apply regression coefficients from first step to sovereign bond holdings in banks' balance sheets and obtain risk factor shares.

Myopic portfolio choice model :

Consider the following classic portfolio choice model (Campbell and Viceira (2001)). Two asset types are available for an investor at time t: one riskfree r_f and one risky R_{t+1} asset. The investor puts a share α into the risky asset(s) and prefers to have a high mean and a low variance of portfolio returns. Thus, the investor maximizes a linear combination of

mean and variance, with a positive weight on mean and a negative weight on variance. Substituting in the mean and variance of portfolio returns and subtracting the riskfree rate, we will have the below maximization problem. The solution of this maximization problem is a vector α of allocations to the risky assets. The portfolio share in the risky asset(s) should equal the expected excess return, or risk premium, divided by the conditional variance times the coefficient γ that represents aversion to variance.

Maximization problem:

$$\max_{\alpha} E[\alpha^T(R_{t+1} - r_f)] - \frac{\gamma}{2}\alpha^T\Sigma\alpha$$

FOC:

$$(\mu - r_f) - \gamma\Sigma\alpha = 0$$

$$\alpha = \frac{1}{\gamma}\Sigma^{-1}(\mu - r_f)$$

Calibration: Finally I calibrate the empirical results from the factor model to the theoretical results from the myopic portfolio choice model.

A mean-variance analysis comparison:

I compute the expected return and std. deviation for each of the factor portfolios of the 26 banking groups per date obtained from the factor model. I compute the mean-std. deviation as well for the optimal factor portfolio for different values of risk-aversion γ (between 0.1 and 2). In the latter case, the mean-variance analysis of the optimal portfolios will provide me with the efficient frontier for varying levels of risk-aversion. I calibrate the results obtained from the mean-variance analysis of the factor portfolio to the efficient frontier and extrapolate the risk-aversion of the 26 banks per date.

E.2. Data

Data variables:

- Interest rate risk for the euro area= return of zero-coupon 5-year German government

bond (Bloomberg)

- Interest rate risk for the US = return of zero-coupon 5-year US government bond (fitted yield curve FRED)
- Credit risk for the euro area= return of 3-6 year BBB - AAA EA corporate bond index spread (total return index, Iboxx Markit)
- Credit risk for the US = return 3-6 of year BBB - AAA US corporate bond index spread (total return index, Iboxx Markit).
- Fixed income instruments = return of 1 to 10 maturities of US, FR, DE, IT, ES, NL, AT, BE, GR, AT, CA and UK zero-coupon sovereign bonds (Bloomberg)
- Market value holdings of government bonds by the 26 EA banking groups (Quarterly, Securities Holdings Statistics)

Data manipulation:

- I compute 1-month ahead returns (end-of-month) for the government bonds by converting the yield into prices and taking the log difference as $lnP_{t+1,m-1} - lnP_{t,m}$
- I compute 1-month ahead returns (end-of-month) for the corporate bond index by taking the log difference of the total return index over time
- Empirically, I compute the final weights for each bank as $\frac{\sum MarketHoldings * \beta_{factori}}{TotalMarketHoldings}$
- Time series span: 31 December 2001-31 March 2021

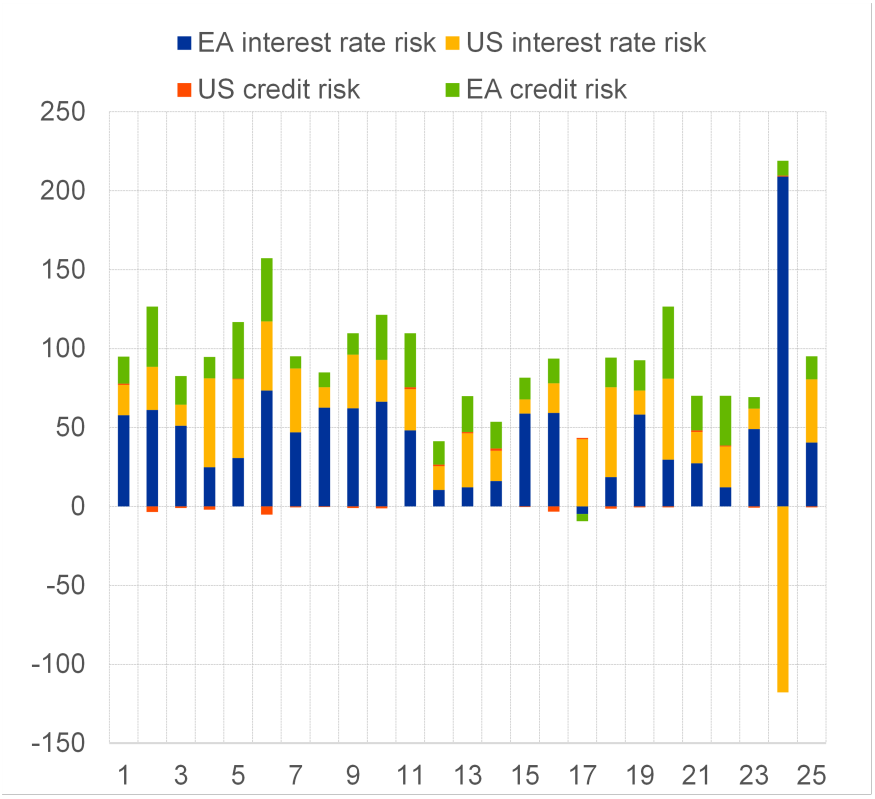
E.3. Results

Figure E7 depicts the portfolio exposures per bank to the four macroeconomic risk factors for 2021Q1 as per the factor model.[53] Sovereign banks portfolio are mostly exposed to EA interest rate risk, followed by US interest rate risk and EA credit risk in 2021Q1. The four factor exposures don't sum up to 100% as there is a residual factor corresponding to the exposure to the riskfree asset.

In Figure E8a I plot the mean-std. deviation analysis of the factor portfolios obtained from the empirical exercise (factor model) and theoretical exercise (myopic portfolio choice

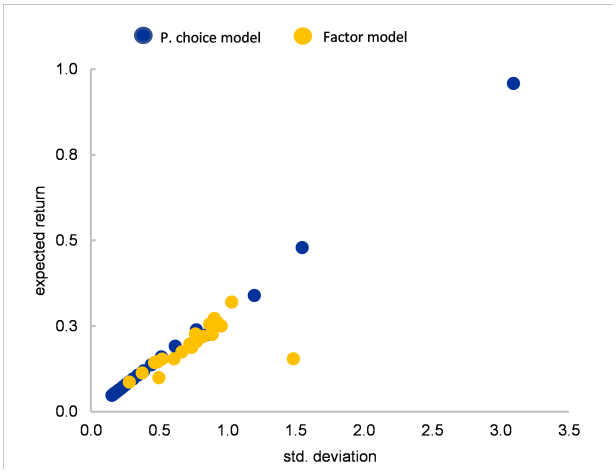
[53]This breakdown is available for each date.

Figure E7: Exposures to macroeconomic risk factors per bank for 2021Q1. Exposures are in percent.



model). The blue dots show the efficient frontier of exposures to these factors for different levels of risk-aversion. The yellow dots are the actual exposures that the different banks have to these factors. By matching the yellow dots to the blue dots I obtain the time-varying level of risk-aversion of the corresponding banks (Figure E8a).

(a) Mean-std. deviation of factor portfolios



Notes: Blue dots show the efficient frontier for the optimal portfolio choice for varying risk-aversion parameters γ. Green dots is the mean-st.deviation analysis of the 26 euro area banking groups' factor portfolios obtained from the factor model. Observations correspond to 2021Q1

(b) Range of banks' risk-aversion parameter across 26 largest EA banks