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

Alexia Ventula Veghazy*

Job Market Paper

Link to the most recent version.

November 14, 2022

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' 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 for euro area banks and find sizable and heterogeneous CIP deviations, despite their common currency. Decomposing the CIP into a risk-free interest rate differential and a convenience yield differential across currencies shows a convenience for holding dollars, albeit it differs across euro area regions. In a second stage, 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, G2, G4.

*Goethe University Frankfurt and European Central Bank. The opinions expressed are those of the author and do not necessarily reflect the view of the European Central Bank. I am sincerely grateful to my primary advisors Ester Faia and Steven Ongena for their advice and precious support. I am also grateful to Juliana Salomao for very helpful comments. Contact: Alexia.Ventula_Veghazy@ecb.europa.eu.

1. Introduction

Persistent arbitrage opportunities have been present since the onset of the global financial crisis, representing a failure of the covered interest rate parity (CIP), i.e., hedged euro-dollar yield differentials, a cornerstone in international finance. A growing theoretical and empirical literature underscores the importance of micro-foundations for the failure of arbitrage leading to deviations in CIP.[1] The euro area, a currency union with a common monetary policy but with fragmented investors across countries, thus provides the ideal ground to study micro-foundations for deviations in CIP. In this paper, I study whether hedged euro-dollar yield differentials in banks' sovereign portfolios are heterogeneous across banks in a single currency area and the determinants for 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 the largest holder of sovereign bonds in the euro area and constraints to banks balance sheets can affect arbitrage opportunities; 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 using security-level data on euro area banks' holdings of sovereign bonds, composed of around 176000 bonds issued by 128 countries and matched to banks' supervisory statistics, I document fragmented bond holdings and show with a security-level strategy heterogeneous deviations in banks' CIPs across euro area regions since 2013.[2] When I investigate the causes of such deviations, my empirical results provide evidence for banks' issuer home bias and regulatory constraints affecting deviations in CIP. Fragmentation across banks' balance sheets and a convenience yield for the dollar, uncovered in a CIP decomposition exercise, has implications for a heterogeneous transmission of monetary policy across borders.

My paper starts by documenting a set of facts on international portfolio allocations in sovereign bonds for the twenty-six largest euro area banking groups located in Austria,

[1] See, among other authors, Borio et al. (2016), Du et al. (2018), Amador et al. (2020), Du et al. (2018), Cerutti et al. (2021) and Du and Schreger (2021) for assessments on the failure of CIP since the global financial crisis. When assuming otherwise 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] Fragmentation has been commonly used to refer to spreads between rates in financial market segments. My definition of fragmentation also includes heterogeneity in portfolio holdings across investors.

Belgium, Germany, Spain, Italy, France and Netherlands for the period 2013Q4 to 2021Q1.[3] These banking groups represent 60% of the aggregate government bond holdings by the euro area banking sector in 2014Q1. The euro area banking sector intermediates around 35% of the sovereign debt holdings in the euro area and has been the largest holder of sovereign bonds among euro area investors over the last decade. The analysis of the dynamics of the portfolio shares of dollar- and euro-denominated sovereign bonds across holder banks and security issuers over the sample period reveals marked heterogeneity in demand. First, there is a lack of diversification in holdings in terms of currency and issuer for several national banking sectors.[4] Second, issuer home bias is more substantial for banking sectors in countries with historically high-yielding sovereign bonds such as Spain, Italy and Belgium (about 70%, 60% and 50% on average over the period 2013 to 2021, respectively).[5] Third, there has been a rebalancing towards US-issued government bonds together with a decrease in domestic-issued holdings for banks in low-yielding countries such as Germany, Netherlands and France. Finally, evidence suggests that national banking sectors have mostly an issuer bias and not a currency bias.

Since banks' portfolios of high-yielding countries are biased towards holding the bonds of their government and dollar holdings are heterogeneous across banks, it is likely that the return differential between euro and dollar per banking group is different.[6] This implies that each country violates the non-arbitrage condition in the Forex market differently. In order to measure the CIP deviation in each banking group, by combining Faia et al. (2022) and Jiang et al. (2020), I devise a security-level specification that allows me to identify the pricing impact of demand for currency denomination (or issuers) for sovereign debt securities by individual banking groups, controlling for asset and issuer characteristics. More specifically, I estimate portfolio weighted and unweighted hedged euro-dollar yield differentials for sovereign bonds by purging for sovereign risk, controlling for maturity fixed effects and accounting for hedged exchange rate movements. I use Sovereign CDS spreads to purge for sovereign risk and swap contracts to adjust the dollar return into a hedged "synthetic" euro

[3]Henceforth, I refer to Austria, Belgium, Germany, Spain, Italy, France and Netherlands as AT, BE, DE, ES, IT, FR and NL, respectively.

[4]Note that banks in this sample do not correspond to the totality of the banking sector in a country. For simplification, I define national banking sectors as the banking groups in my sample with residency in the same country.

[5]Issuer home bias is a measure of the total holdings in national sovereign bonds over total holdings by national banking sector. A home bias could be defined as a value above 50% following also definitions in the literature (e.g.,French and Poterba (1991), Coeurdacier and Gourinchas (2016)).

[6]I distinguish countries in the euro area according to the spread in the sovereign yields over the review period. High-yielding countries include BE, ES, and IT and low-yielding countries include AT, DE, FR and NL. In general, I will refer to these countries by using the definition of high/low-yielding countries.

bond. I find sizeable CIP deviations reaching up to 240 basis points, albeit heterogeneous across national banking sectors, accounting for different arbitrage opportunities across euro area regions. National banking sectors in higher-yielding countries (IT, BE) are more often willing to hold negative returns on their portfolio-weighted euro assets relative to the dollar assets, while banking sectors in low-yielding countries (NL, FR) hold on average larger returns on their euro assets over the review period. The CIP deviation for Germany further differentiates itself from the rest of the countries by requiring the lowest returns on euro assets relative to dollar assets.

While CIP deviations in banks' cross-currency portfolios can indicate which could be the preferred arbitrage strategy by a bank (or investor interchangeably), other asset characteristics - such as its convenience - might shape the actual investor's demand. To further discern potential motives behind banks' holdings, I decompose the estimated banks' yield differentials into two components - a risk-free interest rate differential and convenience yield differential across currencies.[7] This allows me to estimate the relative convenience yield between the euro and the dollar held in banks' sovereign portfolios. I compute the euro-dollar convenience yield as a residual by discounting the risk-free interest rates of the euro area and US, matched by maturity and currency, from the hedged euro-dollar yields at the security level. Banks appear to have a larger convenience yield from holding dollar assets across euro area regions. However, German banks have the lowest convenience from it compared to peers, having even larger convenience from holding euros at points in time. The dynamics of the convenience yield also appear to follow the purchase profile of the ECB's sovereign asset purchase programs.

As a nascent strand of the literature has highlighted the importance of micro-foundations for explaining deviations in CIP, I examine a set of micro-founded determinants which could explicate the deviations and heterogeneity in bank yield differentials observed across euro area regions. Deviations in hedged yield differentials in the post-crisis period have been related to a number of frictions and macro-financial factors. These drivers, often complementary, can be broadly grouped into three categories: key regulatory changes for CIP-arbitrageurs such as financial intermediaries (Cenedese et al. (2021) and Du et al. (2018)); asynchronous monetary policies across countries, including unconventional monetary policies (Bräuning and Ivashina (2020), Cerutti et al. (2021) and Faia et al. (2022)), and financial-market frictions such as risks associate with exposures to FX derivatives or changes to banks' balance sheet capacity stemming from dollar-appreciation (Avdjiev et al.

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

(2019) and Borio et al. (2018)). As representative measures for these three categories, I use the bank's leverage ratio (supervisory statistics), monetary policy surprise shocks (EA-MPD, Altavilla et al. (2019)) and a proprietary risk-aversion parameter for banks obtained from a calibration exercise (see Appendix D).[8] Additionally, motivated by the stylized facts, I add banks' home bias for sovereign bonds to the determinants of CIP deviations.

Armed with the estimates of the hedged euro-dollar yield differentials in banks' portfolios, I examine the determinants with an instrumental variable approach. To correctly measure the impact of home bias as a potential factor explaining CIP deviations, I instrument the growth in banks' home bias share with the bank's country total debt securities redemption profile.[9] Inspired by Ongena et al. (2019), in months of large maturing debt, banks will more likely be swayed by the government to hold newly issued debt that the government needs to place to roll over the maturing one. In line, as the total value of maturing debt in a country is predetermined, it is exogenous to current economic conditions as well as to banks' current sovereign debt demand. I find that home bias has an impact on CIP deviations, thus explaining some of the heterogeneity across banks' CIPs. Banks with larger home bias will require lower returns for euro securities relative to dollar ones after accounting for hedged exchange rate movements. A growth of around half a standard deviation in the home bias share accounts for a -13 basis points deviation in the bank's CIP. Additionally, I find that a monetary policy surprise shock to the spread between euro area sovereign yields positively impacts the bank's CIP deviations. Regulation is another relevant factor explaining deviations, while banks' risk aversion is not.

My results suggest that frictions to banks' balance sheets constrain arbitrage across currencies, thus conditioning investors heterogeneously across euro area regions. This can have implications for a heterogeneous transmission of monetary policy across borders. During the period of asset purchases by the European Central Bank (ECB), the convenience yield for the dollar held in euro area banks appears to have followed the purchase profile of sovereign bonds across banks. However, the rebalancing into US-issued assets has been heterogeneous across banks in different euro area regions, signaling the relevance of frictions. The decrease in euro-yields due to the drain of euro assets, increasing as well the risk-bearing capacity in euro area banks' portfolios, might trigger price-sensitive investors such as banks (e.g., return-oriented investors) to rebalance to alternative assets. While the relative convenience

[8] I extract the risk-aversion parameter for banks by measuring banks' sovereign portfolio exposure to macroeconomic risks à la Begenau-Piazzesi-Schneider (Begenau et al. (2015)) matched to a myopic portfolio choice model.

[9] More specifically, I use the deviation in the country's redemption profile from its median over the period under review from 2013 to 2021.

yield for the dollar has been increasing, the rebalancing into US assets following ECB's asset purchases has been heterogeneous across euro area regions as measured by the security-level exposure of banks' balance sheets to stock effects of ECB purchases. My results suggest that banks in countries with stronger home bias have rebalanced less following unconventional monetary policy, thus potentially affecting CIP deviations.

This paper shows evidence for broader implications such as the role of investor bases for pricing and convenience of bonds. In addition, micro-founded determinants affecting parity condition can lead to inefficient resource allocation as well as a heterogeneous transmission of monetary policies across borders.

Related Literature. My paper relates to three different strands in the literature. First and foremost it links to the literature studying cross-currency return' 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 deviation. 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. (2018), 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 soveriegn 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 6 concludes.

2. Data

My analysis is largely based on proprietary information from the Securities Holdings Statistics by Group (SHSG) data collection, which provides information on individual securities holdings for the largest banking groups with head offices in the euro area. SHSG starts in 2013Q4 and includes security-by-security information for the 26 largest banking groups at a quarterly frequency. The collected information focuses on the holder side (e.g., the amount held of a particular International Securities Identification Number (ISIN)) and covers short- and long-term debt securities, quoted shares and investment funds shares/units.

In 2014 Q1 the 26 banking groups accounted for around 60% of euro area bank's total consolidated assets and held in aggregate approximately 18% of their assets in debt securities, corresponding to about EUR 3 trillion in nominal holdings.[10] I focus on banks' holdings of short- and long-term government debt securities denominated in euro or dollar currency and in nominal value.[11] About 40% of their total debt securities are held in government bonds, with 80% denominated in euros or dollars. At date, the data consists of approximately 17600 bonds issued by 128 countries.

In addition, I show results at the country level to illustrate potential fragmentation across countries. I group banks by their headquarter's residency country, covering the following geographical locations: AT, BE, ES, DE, FR, IT and NL.

To assess price dynamics, I first enrich the ISIN-level information with reference data from the Centralised Securities Database (ECB, 2010), which contains rich information on individual securities such as security type and price, issuer name and country, maturity date and issue date, currency of issuance and outstanding amount. Second, to take into account the currency denomination of these assets, I match residual bond maturities with the horizons of both the exchange rate movements by professional forecasters sourced from Consensus Forecast and those in currency derivatives from Bloomberg and Refinitiv. I also match the bond pricing information at the issuer and residual maturity level with Sovereign CDS spreads (Refinitiv) to purge for default risk.

Moreover, 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 bank size and regulation. I can then inspect the role that these might have in bank's government bond holdings and currency pricing. In addition, I will enhance bank characteristics with a proprietary time-varying risk-aversion parameter based on market value holdings held by banks and government bond returns. The latter have been constructed using market data for 1 to 10-year maturities (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 high-frequency changes around the ECB's monetary policy press releases in the 2-year OIS rate, 2-year Italian yield and 2-year German yield obtained from the Euro Area Monetary Policy Event-Study Database (EA-MPD).[12] I focus on 2-year maturity

[10] The amount of nominal holdings in debt securities includes interbank holdings.

[11] 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.

[12] See Altavilla et al. (2019).

following the literature documenting more significant reactions in that maturity segment. Additionally, I also use the security-level purchases under the ECB's sovereign purchase programs involving the Public Sector Programme and the Pandemic Emergency Programme starting in 2015Q1.

3. Stylized Facts

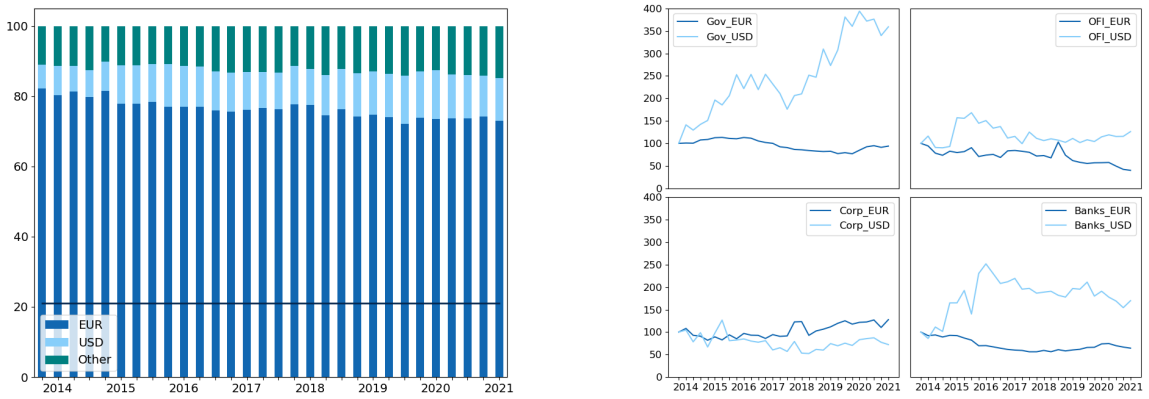
In this section, I use the described data to document euro area banks' holding patterns of government securities over the review period 2013Q4-2021Q1. I cross-cut the security-level data across different holder countries (national banking sectors), issuers and currencies. I aim to identify investors' currency and issuer residency preferences.

Four main points emerge when analyzing the holdings of government bonds in euro area banks' securities portfolios grouped by the holder's residence country: i) there is a lack of diversification in terms of currency and issuer holdings for several national banking sectors; ii) Issuer home bias is more substantial for banks in countries with historically high-yielding sovereign bonds, such as Italy, Spain and Belgium. Pointing to fragmentation in holdings on top of yields; iii) There has been a rebalancing towards US-issued government bonds together with a decrease in home-issued holdings for banks in low-yielding countries such as Germany, Netherlands and France; iv) National banking sectors mostly have an issuer bias, not a currency bias.

Bank's Total Debt Securities Holdings By Currency and Debt type. Total holdings of euro-denominated debt securities by the 26 banking groups have declined from 82% to 73% over the review period, while dollar-denominated securities have increased from 7% to 12% (Figure 1a). The increase in the latter has been driven mainly by an increase in government debt holdings (Figure 1b). Government debt holdings incremented 25% for total USD-denominated holdings, while holdings for other dollar debt types such as non-financial corporations and financial institutions decreased. Reason for which I will focus on banks' government bond holdings hereafter.

Bank's Issuer Residency Preference Given the well-documented home bias in banks' government bond holding (Acharya et al. (2014); Gennaioli et al. (2014); Farhi and Tirole (2018) and Ongena et al. (2019)), I group banks by their headquarter's country of residence and dissect their government bond holdings by the issuer's residence. Concretely, I split the issuer countries into four groups: Domestic, EU, US and ROW. This allows me to uncover banks' preferences for holding domestic government bonds versus foreign government bonds.

Figure 1: Aggregate debt securities holdings across euro area banks

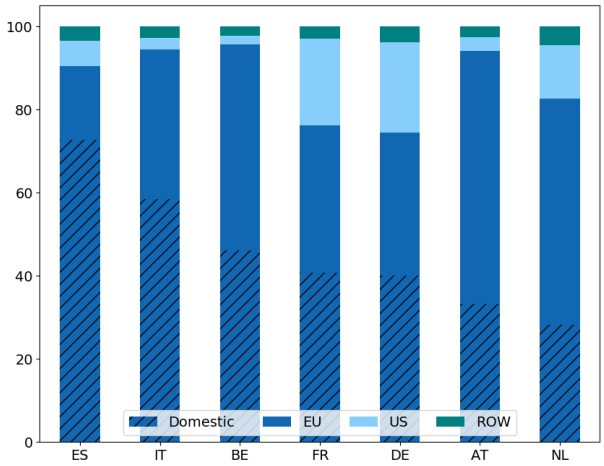


(a) By currency-denomination (percent) **(b)** By debt type and currency (2013Q4=100)

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

With this aim, I analyze the share of banks' holdings in domestic government bonds as a measure of issuer home bias.[13]

Figure 2: Banks' government bond holdings by issuer residency, average over 2013-2021 at the country level (percent)



Notes: The figure shows the average aggregate sovereign bond holdings across banks with residency in a same country for the period 2013 Q4 - 2021 Q1. Holdings are broken down by the share in domestic-issued government bonds, other EU-issued government bonds, US-issued government bonds and other foreigners.

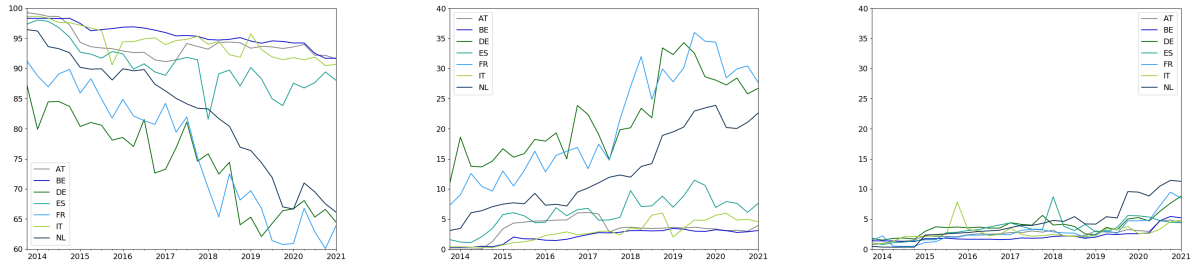
Banks in Italy and Spain depict the largest home bias holding, on average over the review period, about 60% and 70% of their own country's government bonds, respectively (Figure 2). On the contrary, countries such as Germany, France and Netherlands exhibit no home

[13]Domestic refers to government bonds issued by the country of residency of the banking group's headquarters. ROW are rest of the world issuers not included in the other foreign issuer such as the USA.

bias with a share below 50% and a substantial share in non-EU-issued assets (e.g., US and ROW). This points to fragmentation in holdings across banks in different euro area countries. Banks in specific geographical locations have less diversified government bond portfolios.

When examining the time-series dynamics, several points emerge. Figure 3 show banks' aggregate holdings shares at the country level for different issuer categories. The share in EU government bonds has been declining across banks over the review period coinciding with the start of the ECB's Asset Purchase Programme (see Appendix B for further figures). This decline has been most pronounced for Germany, Netherlands and France (decreasing their EU share by about 30pp, 30pp and 20pp, respectively), which have tilted their holdings towards safe US-government bonds. On the contray, countries with stronger home bias preference have slightly intensified their "relational" holdings of ROW-issued bonds.[14]

Figure 3: Share of holdings by issuer residency during 2013 - 2021



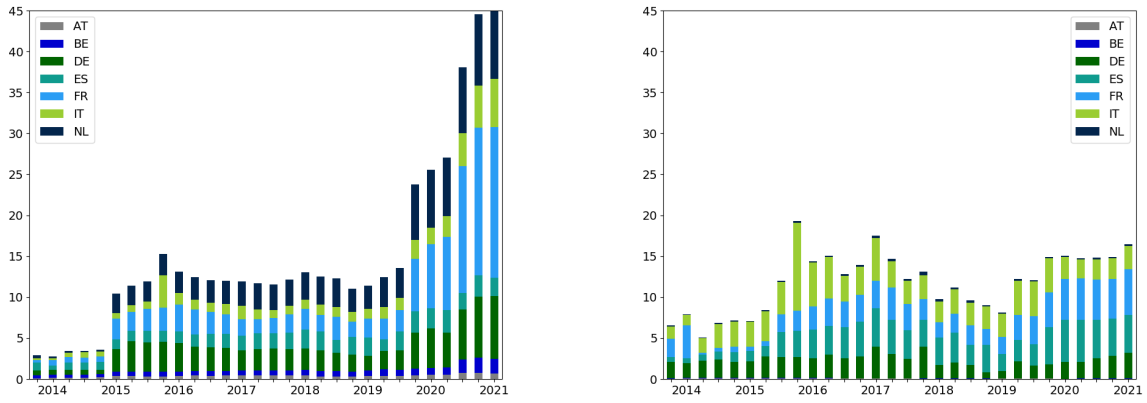
(a) EU issuer(percent) **(b)** US issuer(percent) **(c)** ROW issuer(percent)

Notes: Time series plot the holdings share in EU-issued, US-issued and ROW-issued government bonds, respectively, for aggregated holdings by national banking sectors.ROW are EU foreign assets not issued by the EU.

Currency Preferences. To further disentangle if banks have an issuer or currency preference, I dissect securities by currency for selected issuer countries. Given that US-issued government bonds are 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 ROW bonds (Figure 4a). Indicating thus an issuer and not a currency preference for the holdings of US-issued bonds by these banks. Banks in countries with stronger home bias appear to hold dollars mostly for foreigners which are not the USA (Figure 4b),most likely due to the business lines that they have with some foreign countries.

[14]Banks in euro area periphery countries have historically strong business lines with foreign countries outside the USA such as with South American countries. I refer to this as relational holdings.

Figure 4: Euro- and dollar-denominated government bonds issued by ROW



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

Notes: The Figures show the aggregated holdings of euro- and dollar-denominated assets issued by foreigners broken down by national banking sectors.

Taking together these stylized facts, it becomes apparent that government bond portfolios across banks are heterogeneous with varying levels of diversification across issuers and currencies. Given fragmentation in euro area sovereign bond yields (Figure B2 in the Appendix), heterogeneous portfolios with varying degrees of home bias can have different implications for returns. To understand further if this heterogeneity in banks' international portfolios also implies fragmentation in banks' returns and rebalancing behavior, I next estimate hedged euro-dollar yield differentials.

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 market, being thus relevant to measure their demand for currency. Banks hold about 35% of total government bond holdings by euro area investors. They are the largest sector 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 will 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 pricing of currency risk and discerning what would be the desired rebalancing strategy to attain parity between home/EU versus foreign returns. To further disentangle factors behind deviations in the currency pricing in investors' international portfolios, I decompose the bank's CIP into a risk-free and a convenience yield differential. Potential drivers can shed light on the reasons behind heterogeneous currency risk in investors' portfolios.

4.1. Bank's hedged euro-dollar yield differentials

To measure yield differentials between holding "domestic/EU" assets compared to "foreign" assets, I estimate investors' pricing of currency risk in banks' portfolios as domestic assets are largely denominated in euros while foreign assets are in dollars.

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

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

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

Using this CIP condition for otherwise identical assets (dubbed as macro-CIP), I estimate the CIP in banks international portfolio from the holder perspective (dubbed as banks' CIP) via a security-level econometric strategy to approximate the hedged euro-dollar differentials in their government bond portfolio. I do so by combining Jiang et al. (2020) with the econometric strategy in Faia et al. (2022), to adapt it to the government bond market and to the bank level.[15] 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 risk, via CDS Spreads instead of using security

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

ratings and issuer fixed effects;[16] 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 macro-CIP arbitrage is treated as riskless as by construction FX swaps do not entail an open currency position as well as credit, counterparty, market and liquidity risks involved are assumed to be negligible. Since bond prices include counterparty, credit and term risk, I purge for those risks by discounting Sovereign CDS spreads for different maturities and controlling for residual maturity fixed effects. I estimate several variants of the following specification:

Baseline Specification

$$y_{i,b,t} = \alpha_{b,t}\mathcal{I}_{EUR,i,b} + \gamma_{m,t} + \varepsilon_{i,b,t} \tag{2}$$

$y_{i,b,t}$ is the annualized yield taken from the secondary market for bond i held by bank b at time t which has been purged from country default risk by subtracting Sovereign CDS spreads. I adjust dollar denominated yields into "synthetic" euro rates to compare returns across currencies and I account for currency risk by using swap contracts as explained further below. α_t is the coefficient on the indicator variable $\mathcal{I}_{EUR,i}$ which equals one if bond i is denominated in euros. $\gamma_{m,t}$ are fixed effects for residual maturity buckets m at date t. Regressions are estimated at the security-level cross-section for each date t and bank b. Standard errors are clustered at the issuer-country level. The data is truncated on the dependent variable below 1% and above 99% at each quarter to control for outliers. All CIP figures inare based on estimates with bonds above one year of residual maturity.[17] The estimated coefficient $\alpha_{b,t}$ - the coefficient of interest - is the average euro minus average dollar yield differential for bank b at time t 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 or their stochastic discount factor.

Yield adjustments. I vary $y_{i,t}$ to estimate a *hedged* yield differential that controls for currency risk by using swap contracts. Specifications using this adjustment produce a yield differential akin to a covered interest rate differential, thus measuring CIP. Following Du

[16] See Jiang et al. (2020) in where they purge for country default risk in the euro area by using CDS Spreads. In Appendix C I include a specification using security-level ratings instead.

[17] See Appendix A for further details on the data.

et al. (2018), I perform the hedged adjustment using swap rates. Since currency forwards are less liquid at maturities greater than one year, the government basis is best measured with currency swaps. Those are more liquid at longer maturities observed in my data with approximately 8 and 8.5 years average maturity for euros and dollars respectively. Details on this adjustment and results using forward contracts are reported in Appendix C. Yields are defined as follows:

$$y_{i,t} = \begin{cases} y_{i,t} & if\ euro \\ IRS_{euro,n,t} + BS_{euro,usd,n,t} - IRS_{usd,n,t} + y_{i,t} & if\ dollar\ \&\ hedged \end{cases} \tag{3}$$

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).

Additionally, I compute hedged euro-dollar yield differentials weighted by time-varying portfolio currency shares. I compute portfolio currency shares using lagged investor's holdings (see Curcuru et al. 2008).[18] This allows to alleviate potential endogeneity concerns. Formally portfolio shares are computed as follows:

$$\overline{y}_c = \sum_{j=1}^{N} w_{j,t-1}^c y_{j,t}^c \tag{4}$$

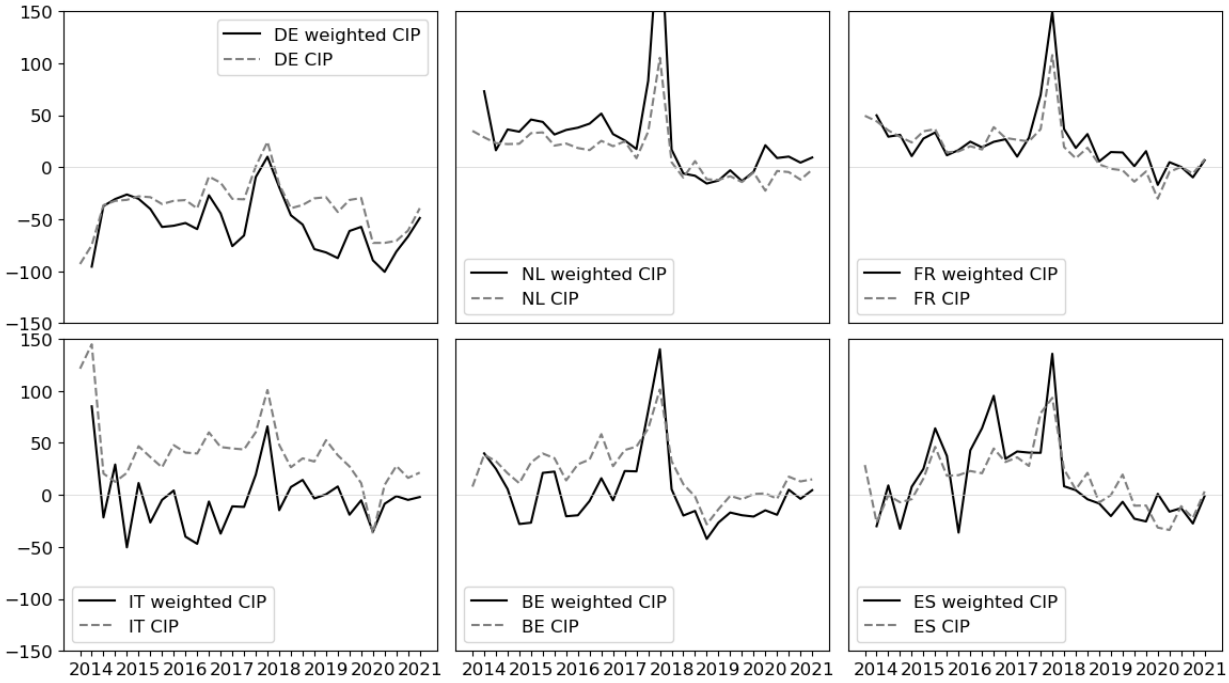
where $w_{j,t-1}^c$ is the holdings weight for security j at the end of period $t-1$ and $y_{j,t}^c$ is the period t yield for security j for currency c, and N is the number of investor's holdings for a given security in our data.

Figure 5 shows the results for the bank's hedged euro-dollar yield differential ($\alpha_{b,t}$) following specification (1) over the 2013 Q4 - 2021 Q1 period. Results are shown as the average of banks' $\alpha_{b,t}$ across their country of residence. All CIP figures are based on estimates with bonds above one year of residual maturity. In all panels we see quantitatively sizable deviations in the yield differentials (henceforth CIP) reaching up to 145 basis points for the unweighted estimates (grey dashed line) and 240 basis points for the weighted ones (black line).[19] This would qualify as a violation of the covered interest rate parity. Note that given

[18] Results are similar when used contemporaneous holdings.

[19] Results at the individual bank level would be more pronounced with deviations of around 220 and -330 basis points in the maximum case.

Figure 5: Averages of hedged yield differentials, $\alpha_{b,t}$, across banks by residency country (basis points)



Notes: Figure 5 plots the bank-level estimates, $\alpha_{b,t}$, of the hedged euro-dollar yield differential for the sovereign bond portfolio averaged across banks with residency in a same country. The sample covers all bonds with residual maturity above 1 year for the period 2013 Q4-2021 Q1. Each panel compares the unweighted (grey dashed line) and portfolio weighted yield differential (black line). The econometric specifications is: $y_{i,b,t} = \alpha_{b,t}\mathcal{I}_{EUR,i,b} + \gamma_{m,t} + \varepsilon_{i,b,t}$ where $\alpha_{b,t}$ is the coefficient on the indicator variable $\mathcal{I}_{EUR,i,b}$ which equals one if bond i is denominated in euros. $\gamma_{m,t}$ are fixed effects for rating bucket m at date t. The regressions are estimated at the security-level cross-section for each bank b at each date t. Standard errors are clustered at the issuer country level.

the inclusion of the Sovereign CDS spread and maturity fixed effects, the deviations in CIP are unrelated to country and security risk. Therefore no sovereign-default risk is present following this econometric strategy for the treasury market.

Deviations are also heterogeneous across countries indicating fragmentation across investors (banks). On average, German banks are holding lower yields on their euro-denominated bonds relative to their dollar-denominated bonds even when accounting for hedged exchange rate movements. French and Dutch banks almost persistently require higher yields on their euro assets relative to the dollar assets. On the other hand, Italian, Belgian and Spanish banks deviate less from the zero-line, denoting parity, in their weighted CIP, being it mostly negative when they deviate .[20] Overall, there seems to be a divergence between the sovereign hedged portfolio of banks in countries with larger issuer home bias and higher yields (ES, IT and BE) and those with less bias and lower country yields (DE, NL, FR).

CIP Decomposition. Generalizing, deviations of the estimated CIP can be interpreted

[20]Some Spanish banks do not hold foreign assets over the full period under review. Therefore, average deviations can be considered less representative for the holder country and can likely mirror the idiosyncratic behavior of a particular investor. The same applies for Austria.

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 banks optimal arbitrage 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, ζ_t the deviations can be interpreted as relative convenience yields, ω_t^c, across currencies and the difference in risk-free rates across countries r_t^c where c refers to currency and t to time period.[21] Formally, to further shed light on factors underlying the CIP, I decompose the CIP into a risk-free interest rate differential component and a convenience yield component as follows (see also Jiang et al. (2021) for an application within a same currency area):

The yield of country i at period t with maturity τ for a given currency c (e.g., euro and dollar) 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 $\omega_t^{c,i,\tau}$:[22]

$$\begin{aligned} y_t^{euro,i,\tau} &= r_t^{euro,\tau} + \zeta_t^{euro,i,\tau} - \omega_t^{euro,i,\tau}, \\ y_t^{dollar,i,\tau} &= r_t^{dollar,\tau} + \zeta_t^{dollar,i,\tau} - \omega_t^{dollar,i,\tau} \end{aligned} \tag{5}$$

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

Defining $y_t^{c,i,\tau} - \zeta_t^{c,i,\tau} = \chi^{c,i,\tau}$ as the country-risk purged yield and taking the average across currency after controlling for security characteristics (i and τ) I define:[23]

$$\begin{aligned} \chi^{euro} &= r_t^{euro} - \omega_t^{euro}, \\ \chi^{dollar} &= r_t^{dollar} - \omega_t^{dollar} \end{aligned} \tag{7}$$

Hedging for exchange rate movements with currency swaps, I convert the dollar assets

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

[22] For simplicity, given the composition in my sample, I assume one risk-free rate per currency, but otherwise the risk-free rate of each currency area could be applied. For robustness, in Appendix C, I run the same decomposition for only euro area and US-issued government bonds. Results hold as euro and dollar assets have been issued in its majority by these currency areas in my sample.

[23] Discounting sovereign risk from the yield controls for the variation across countries i due to default risk.

into *SyntheticEuro* assets:

$$\begin{aligned} \chi^{euro} &= r_t^{euro} - \omega_t^{euro}, \\ \chi^{SyntheticEuro} &= r_t^{SyntheticEuro} - \omega_t^{SyntheticEuro} \end{aligned} \tag{8}$$

Taking the difference across currencies I obtain the CIP akin to specification (1) on the left-hand side and its decomposition into a risk-free interest rate differential and a relative convenience yield across currencies on the right-hand side:

$$\chi_t^{euro} - \chi_t^{SyntheticEuro} = (r_t^{euro} - r_t^{SyntheticEuro}) - (\omega_t^{euro} - \omega_t^{SyntheticEuro}) \tag{9}$$

where *SyntheticEuro* is a euro-denominated dollar yield.

I bring this decomposition to the data by running again specification (1) on the risk-free rate adjusted hedged euro-dollar yields by additionally discounting from the sovereign bond yield the Eonia based overnight swap and the Federal Funds Rate based overnight swap (e.g.,OIS), matched by currency and maturity. This allows me to obtain the relative convenience yield as a residual:

$$\begin{aligned} y_t^{euro,i,\tau} - \zeta_t^{euro,i,\tau} - r_t^{euro,\tau} &= -\omega_t^{euro,i,\tau}, \\ y_t^{dollar,i,\tau} - \zeta_t^{dollar,i,\tau} - r_t^{dollar,\tau} &= -\omega_t^{dollar,i,\tau} \end{aligned} \tag{10}$$

Defining $y_t^{c,i,\tau} - \zeta_t^{c,i,\tau} - r_t^{c,\tau} = \Gamma_t^{c,i,\tau}$ as the residual yield, converting the residual yield into a "synthetic" euro if dollar-denominated and using the weighted CIP specification (akin to (1)) which also controls for maturity, I estimate the weighted average differential in the convenience yield across currencies for the portfolio of each bank b:

$$\Gamma_{t,b}^{euro} - \Gamma_{t,b}^{SyntheticEuro} = \omega_{t,b}^{SyntheticEuro} - \omega_{t,b}^{euro} \tag{11}$$

where *SyntheticEuro* is a euro-denominated dollar yield.

Figure 6 shows the decomposition of eq.(9) for the weighted CIP. Concretely, it plots the risk-free interest rate differential (light blue bar) and the convenience yield differential (dark blue bar) between the euro and the dollar. The difference between both bars will result in the weighted CIP. A positive deviation for the risk-free interest rate differential

represents a larger yield on euro assets relative to dollar assets. A positive deviation on the convenience yield differential signals a larger convenience yield on the dollar than on the euro. Several factors appear behind this decomposition. First, all investors appear, on average, to have a larger convenience yield form the dollar relative to the euro. Second, German banks are distinct from other national banking sectors. At periods they hold lower average returns on their euro assets compared to their dollar assets. At the same time they have the lowest convenience yield on dollar assets compared to their peers, holding even a larger euro relative convenience yield at some periods.[24] Second, the risk-free interest rate (light blue bars) is larger than the convenience yield in the first half of the sample for most of the national banking sectors (NL and BE). Note that dynamics coincide with a period of large open market operations in the sovereign market by the ECB. Third, Italian banks, a national banking sector with large home bias, seems to have an almost equal split between the average risk-free relative return they hold and the average convenience over the sample period. Thus differentiating themselves from the rest.

Overall, the pattern of the convenience yield appears to mirror the cumulative sovereign purchases by the ECB, likely indicating that the extraction of euro assets coupled together with a silent US monetary policy at the time, changes the relative convenience for holding the dollar in euro area investors' portfolios. The relative convenience yield for the dollar held in euro area banks appears to increase with purchases of sovereign bonds by the ECB.

Given the observed facts in the decomposition, next I study drivers explaining CIP deviation and investors' rebalancing behaviours as these might explain levels in the deviations and dynamics over time. First I examine frictions and macro-financial factors of CIP deviations to further understand if these explain the heterogeneous and fragmented portfolio composition across investors. Then, with an econometric specification, I measure the change between euro-dollar assets holdings since the start of APP to further shed light on dynamics by exploiting a shock to the sovereign bond market resulting from asset purchases.

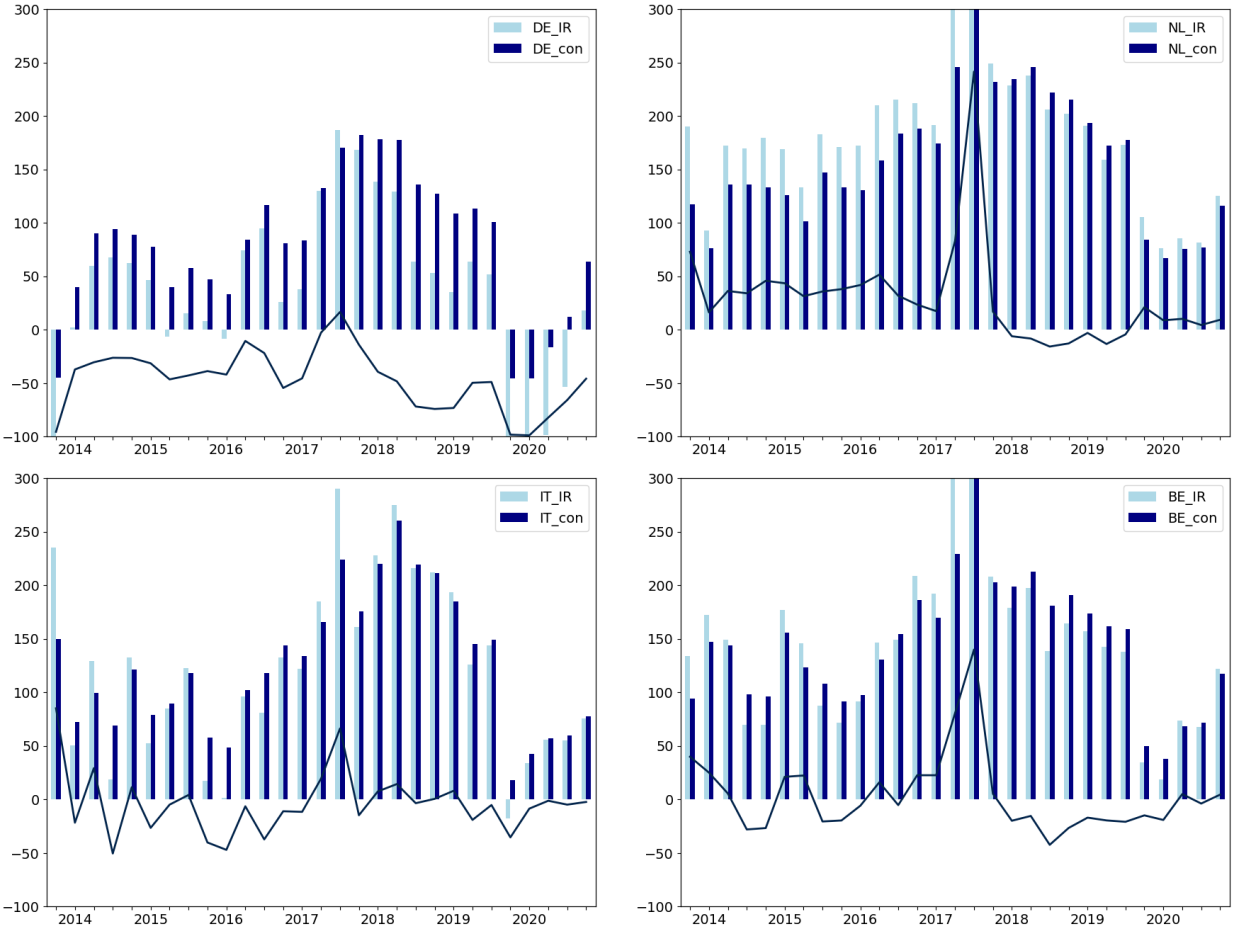
4.2. Factors explaining deviations in hedged yield differentials

The economic landscape changed in the aftermath of the GFC, and with it came the emergence of a range of often complementary potential drivers explaining CIP deviations.[25] Recent literature has documented a number of these factors. These broadly relate to three

[24] Some individual German banks hold even a larger convenience yield on the euro assets than the dollar asset compared to the average for German banks.

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

Figure 6: Averages of risk-free $\alpha_{b,t}$, r_t^c differential and ω_t^c differential across banks by residency country (percentage points)



Notes: Figure 6 plots the weighted bank-level estimates, $\alpha_{b,t}$, of the risk-free adjusted hedged euro-dollar yield differential for the sovereign bond portfolio averaged across banks with residency in a same country. It also shows the decomposition into at risk-free interest rate differential (light blue bar) and a convenience yield differential (dark blue bar) as per $\chi_t^{euro} - \chi_t^{SyntheticEuro} = (r_t^{euro} - r_t^{SyntheticEuro}) - (\omega_t^{SyntheticEuro} - \omega_t^{euro})$ where $SyntheticEuro$ is a hedged euro-denominated dollar yield and χ_t^c is the sovereign-risk adjusted yield. The sample covers all bonds with residual maturity above 1 year for the period 2013 Q4-2021 Q1. The econometric specifications is: $\Gamma_{i,b,t} = \alpha_{b,t}\mathcal{I}_{EUR,i,b} + \gamma_{m,t} + \varepsilon_{i,b,t}$ where $\alpha_{b,t}$ is the coefficient on the indicator variable $\mathcal{I}_{EUR,i,b}$ which equals one if bond i is denominated in euros. $\gamma_{m,t}$ are fixed effects for rating bucket m at date t. The dependent variable is the residual yield defined as $\Gamma_t^{c,i,\tau} = y_t^{c,i,\tau} - \zeta_t^{c,i,\tau} - r_t^{c,\tau}$. The regressions are estimated at the security-level cross-section for each bank b at each date t. Standard errors are clustered at the issuer country level.

categories: i) structural factors such as key regulatory changes for financial intermediaries (Rime et al. (2017) and Du et al. (2018)), ii) unconventional monetary policy (Liao (2016), Brauning and Ivanshina (2017), Cerruti et al. (2019), Faia et al. (2022)) and iii) intensified financial-market frictions such as exposures to risks associated with FX derivatives or changes in banks' balance-sheet capacity (Avdjiev et al.(2017), Borio et al.(2018)).

I analyze how these factors explain CIP deviations in euro area banks' sovereign portfolios by selecting some representative measures for them. In addition, I will also examine a semi-structural factor - home bias in sovereign bonds - explaining the heterogeneity in CIP deviations across euro area banks. The lack of diversification (e.g., a large home bias share) in some banking portfolios, together with fragmentation in euro area sovereign yields, sets

the basis for heterogeneous euro-dollar yield differentials. Additionally, following from the observation in the CIP decomposition analysis that banks with home bias, like Italy, had a balanced composition between the risk-free and convenience yield differential over time, I hypothesize that home bias can impact CIP deviations.

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

a) To represent regulatory constraints in banks, I use the bank's leverage ratio. This is measured as Tier I capital over total risk-weighted exposures. An increase in this measure thus means a larger fulfillment of the binding minimum requirement of 3% (Pillar I) in the euro area. Said differently, banks with a lower ratio are closer to binding, indicating a high level of debt to their Tier 1 capital. Since foreign assets would increase their total risk-weighted exposures, banks will be constrained by holding largely foreign assets. Thus they will choose optimal euro-dollar compositions in order to meet their desired regulatory level.[26]

b) For the impact of euro area monetary policy, I use monetary policy surprise shocks in sovereign yields (from EA-MPD).[27] Concretely, I will use the difference between the change in the 2-year IT and DE bonds. This measures the change in the spread between yields in these two countries due to an exogenous monetary policy shock. An increase signals that the spread has widened after the monetary policy shock or vice versa. I use this spread measure as the monetary policy shock because it accounts for unconventional monetary policy, also relating to fragmentation. I also show results for the surprise change in the 2-year OIS rate.

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

d) I include an additional potential driver, which to my knowledge, has not yet been discussed in the international literature for CIP deviations. I examine whether home bias in sovereign bonds impacts banks' CIP deviations. The hypothesis is that banks with sig-

[26]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 (2021).

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

nificant home bias in their sovereign holdings will require less yield on their euro assets as they have more convenience from holding these assets. To ensure exogeneity in the home bias measure, I instrument the change in the home bias share with the debt redemption profile of the bank's residence country (see Annex Z for the debt redemption patterns across countries). Banks might have profit-related or business model motives (e.g., for collateral reasons) to hold specific assets and would thus demand domestic assets per se. More specifically, I use the deviation in the country's redemption profile from its median over the period under review from 2013 to 2021. Ongena et al. (2019) show that in months of large maturing debt, banks are more likely persuaded to increase their holdings of newly issued debt needed to roll over the maturing one. Also in line, as 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.

Finally, I control for bank size measured as total assets and bank fixed effects. In table 1 are the summary statistics of the drivers and controls by country and for the aggregate 26 banking groups over 2013Q4-2021Q1 (conditional on availability).[28]

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

		Home bias share	**Leverage ratio**	**Risk aversion**	**Total assets**	**MP spread shock**
AT	mean	33%	6.1%	0.41	230 bn	
	std.deviation	*6%*	*0.6%*	*0.08*	*30 bn*	
BE	mean	39%	5.4%	0.37	210 bn	
	std.deviation	*10%*	*1.1%*	*0.07*	*50 bn*	
DE	mean	43%	4.0%	0.43	430 bn	
	std.deviation	*26%*	*0.8%*	*0.13*	*450 bn*	
ES	mean	73%	5.4%	0.63	670 bn	
	std.deviation	*19%*	*0.7%*	*0.15*	*470 bn*	
FR	mean	37%	3.9%	0.66	1200 bn	
	std.deviation	*23%*	*1.4%*	*0.18*	*520 bn*	
IT	mean	68%	4.9%	0.62	560 bn	
	std.deviation	*22%*	*1.3%*	*0.14*	*310 bn*	
NL	mean	33%	4.3%	0.52	650 bn	
	std.deviation	*29%*	*0.8%*	*0.37*	*210 bn*	
Total	mean	48%	4.5%	0.52	630 bn	-2.1
	std.deviation	*27%*	*1.2%*	*0.21*	*510 bn*	*4.6*

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

$$\begin{aligned} \text{1st stage:} \quad GrowthHomeBiasShare_{t,b} = {} & \beta DevCountryDebtRedemption_{t,c} + \tau LeverageRatio_{t-1,b} \\ & + \gamma RiskAversion_{t,b} + \chi MonetaryPolicyShock_t \\ & + \nu TotalAssets_{t,b} + \upsilon_b + u_{t,b} \end{aligned} \tag{11}$$

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

$$\text{2nd stage:} \quad \hat{CIP}_{t,b} = \beta \hat{GrowthHomeBiasShare}_{t,b} + \tau LeverageRatio_{t-1,b} + \gamma RiskAversion_{t,b} + \chi MonetaryPolicyShock_t + \nu TotalAssets_{t,b} + \upsilon_b + u_{t,b} \tag{12}$$

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. $LeverageRatio_{t-1,b}$ is lagged to avoid endogeneity with the dependent variable. $RiskAversion_{t,b}$ and $TotalAssets_{t,b}$ are 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 2013 Q4 to 2021 Q1.

Table 1 shows the results of regression (12). Columns (1) and (3) show the *first stage* regression where the dependent variable $GrowthHomeBiasShare_{t,b}$ is positively and significantly correlated with the deviation in the country's total debt redemption profile. Columns (2) and (4) show the *second stage* results. The growth in home bias share is significant and negative, signaling investors require a lower euro yield than the dollar yield after controlling for hedged Forex movements.[29] The Kleibergen-Paap Wald F-statistics for these regressions also surpass conventional thresholds for instrumental variable analysis.[30]

To understand the impact of the drivers on the portfolio-weighted yield differentials, I analyze the magnitudes. A 10% growth in the home bias share, shy of half standard deviation, decreases the weighted CIP deviation by 16 and 13 basis points. This can be considered economically meaningful taking into account that the median weighted CIP is four basis points and the mean minus six basis points in my sample. Overall, this result points to evidence of home bias in the euro area explaining fragmentation in CIPs.

Regarding the other drivers, all enter the unweighted banks' CIPs significantly, except for the banks' risk aversion measure. The latter is also in line with other studies such as Cerruti et al. (2019), who find that (macro) risk is the weakest of all the drivers in their analysis. Regulation is also a critical factor further supporting the evidence in the literature so far (i.e., Du et al. (2018)) and complementing it with a micro-founded analysis of 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. Concretely, results indicate that if a bank is less constrained by regulatory requirements such as the leverage ratio, it will require, on average, a lower yield on the euro relative to

[29]Forex is commonly referred to as the foreign exchange market for trading currencies.
[30]See Andrews et al. (2019) for theory and practice of instrumental variable regressions.

the dollar. This is likely for a composition in which banks hold the lowest yielding euro area government bonds or are willing to forgo return in exchange for more euro assets in their portfolio. Quantitatively a percent increase in the leverage ratio, about one standard deviation across banks in my sample, represents a euro-dollar yield difference of -11 to - 10 basis points. Finally, while the monetary policy shock, using as reference a conventional benchmark asset for transmission such as the (2-year) OIS, is not significant, the shock on the spread (2-year IT-DE yields) is positive and highly significant. An increase in the spread points to investors holding on average larger yields on euro securities relative to dollar ones accounting for hedged Forex movements and absent of other counterparty and credit (sovereign) risks. This measure is representative of fragmentation in the euro area market and goes in line with the potential channel of unconventional monetary policy (through outright purchases) affecting deviations in CIP (Faia et al. 2022). Given that the present analysis is for within a price-sensitive sector, the impact direction is also consistent.

Table 2: CIP deviations on determinants

	(1)	(2)	(3)	(4)
	1st stage	*2nd stage*	1st stage	2nd stage
Dependent varaible	*GrowthHomeBias*	*weighted CIP*	*GrowthHomeBias*	*weighted CIP*
Dev. country debt redemption	0.228***		0.237***	
	(0.000)		*(0.000)*	
Growth Home Bias		-0.016*		-0.013*
		(0.010)		*(0.008)*
Lagged leverage ratio	-2.13	-0.114**	-2.038	-0.097**
	(0.343)	*(0.047)*	*(0.37)*	(0.038)
Risk aversion	3.569	0.013	2.695	0.040
	(0.875)	*(0.320)*	*(0.908)*	*(0.244)*
Total assets	-0.012	-0.001***	-0.011	-0.001***
	(0.267)	*(0.000)*	*(0.378)*	(0.000)
MP shock	1.256*	0.009		
	(0.098)	*(0.015)*		
MP spread shock			0.098	0.011***
			0.739	(0.004)
Bank fixed effects	Yes	Yes	Yes	Yes
Observations	623	623	623	623
F-stat of excluded instrument		17.21		13.80

Notes: Regressing the yield differential, α, estimated in eq. (1) 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 $\hat{CIP}_{t,b} = \beta \hat{GrowthHomeBiasShare}_{t,b} + \tau LeverageRatio_{t-1,b} + \gamma RiskAversion_{t,b} + \chi MonetaryPolicyShock_t + \nu TotalAssets_{t,b} + v_b + u_{t,b}$. 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.

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

Frictions across banks' within a single currency area can lead to segmented portfolio holdings having implications for the cross-boarder transmission of monetary policy.

As we observed heterogeneous deviations in hedged yield differentials across euro area regions and an increasing convenience yield for the dollar changing with the ECB purchase programs(2015 Q1 - 2022 Q3), next I analyse the rebalancing behaviour of banks. Concretely, I examine if bank's rebalanced their domestic versus foreign assets following the shock represented by the ECB's Public Sector Purchase Programme and Pandemic Emergency Sector Programme (PSPP and PEPP, respectively).[31] Given that large part of US-denominated holdings in my sample are US-issued government bonds, I will henceforth focus on US-issued bonds only.

The portfolio rebalancing channel of the Eurosystem's sovereign bond purchase programs can trigger a rebalancing towards foreign assets.[32] The PSPP and PEPP bids up the price of purchased assets thereby decreasing its yields. 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 banks might prefer to reinvest and rebalance their portfolios towards other assets, such as foreign securities (Hammermann et al. (2019)).

The Eurosystem has purchased large quantities of euro-denominated government bonds issued by euro area governments between 2015Q1 and 2022Q3 under the PSPP and PEPP (henceforth APP).[33] To measure banks heterogeneous rebalancing into US bonds due to these large purchases, I will use as explanatory variable the cumulative quantity purchased of an ISIN as a share of its respective outstanding amount at each point in time. Concretely, I match the nominal value of the holdings by the Eurosystem at the security level and quarterly frequency with the securities held in the banking groups portfolios.

The ISIN's cumulative quantity purchased over its outstanding amount serves as a measure of the stock effect of ECB purchases operating through the local supply or scarcity channel

[31] Domestic refers to assets issued by the government of the bank's residency.

[32] In this section I will 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.

[33] APP is a separate program from PEPP, but for simplicity I will refer to APP for sovereign purchases done under the two programs APP (e.g., PSPP).

whereby the ECB reduces the free float of assets and decreases yields.[34][35] In addition, it also captures the extraction of duration risk from the yield term premium component particularly relevant for medium and long-term yields. Asset purchases and reinvestments decrease the duration risk borne by private investors for their individual bond holdings as well as the aggregate duration risk born by the market (Eser et al. (2019)). This increases the investor's risk-bearing capacity and incentives them to restore the desired overall risk profile of their portfolio by investing in different assets.[36]

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

$$weightedCumAPPshare_{t+1,b} = \sum_{j=1}^{N} w^{c}_{j,b,t-1} \frac{CummulativeGovPurchases}{OustandingAmount}_{j,b,t} \tag{13}$$

where $w^{c}_{j,b,t-1}$ is the holdings-weight for security j purchased by the ECB and held by bank b at the end of the period $t-1$ to avoid endogeneity between the portfolio weight assigned to the security bought. $\frac{CummulativeGovPurchases}{OustandingAmount}_{j,t}$ is the share bought of security j over its outstanding amount at time t. This measure aggregates at the bank level bank's individual exposure to securities bought under APP. While banks can know which securities are eligible to be purchased; the criteria of allocation of monthly purchases across jurisdictions to be fulfilled over the medium term; and issuer and issue limits constraining the quantity of purchases, banks cannot know 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, are exogenous from the point of view of the bank.

I specify the following model:

$$\begin{aligned} ChangeShareUS2015Q1_{t,b} = {} & \beta weightedCumAPPShare_{t-1,b} + \beta TotalHoldings_{t-1,b} \\ & + \beta LeverageRatio_{t-1,b} + \gamma RiskAversion_{t,b} + \gamma TotalAssets_{t,b} \\ & + \eta_b + u_{t,b} \end{aligned} \tag{14}$$

$ChangeShareUS_{t,b}$ 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

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

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

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

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 at the country level.

Table 3 presents the overall estimation results for equation (14), focusing on euro area banking groups and the breakdown by their residence country. We observe in column (1) that the APP shock variable is significant with a positive sign. This confirms the hypothesis that euro area investors significantly rebalanced their portfolios away from individual securities targeted under the PSPP and PEPP and into foreign assets, controlling for a vast array of bank specific factors. In addition, I run a specification for just the cumulative flow into US sovereign bonds as dependent variable to confirm 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)). In column (3) I compare if countries with lower spreads 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. This confirms that banks in those countries have increased, on average, their US share by more than in high-yielding and home bias prone countries. Finally, in column (4) - (10), I break down the impact of the APP shock on banks foreign asset rebalancing by euro area regions. Coefficients for German and Dutch bank's are significant and the rebalancing is also larger for these countries than for banks in Italy and Spain.

Results are in line with the dynamics in the CIP decomposition. Furthermore, they are also in line with the conjecture of a price-sensitive sector rebalancing towards other assets (foreign) following a shock to the the yield of euro assets. Within the banking sector, those banks who could be more inelastic due to some frictions or drivers, like Italy and Spain, did

indeed rebalance less.

Table 3: Portfolio rebalancing and ECB's sovereign purchases

	(1) $\Delta USshare$ All banks	(2) $\Delta USflow$ All banks	(3) $\Delta USshare$ All banks	(4) $\Delta USshare$ DE	(5) $\Delta USshare$ NL	(6) $\Delta USshare$ FR	(7) $\Delta USshare$ AT	(8) $\Delta USshare$ IT	(9 $\Delta USshare$ ES	(10) $\Delta USshare$ BE
App shock	0.262***	0.081***	0.084	0.233***	0.595***	0.080	0.145	0.111**	0.146*	0.064
	(0.10)	(0.02)	(0.06)	(0.09)	(0.15)	(0.11)	(0.15)	(0.05)	(0.09)	(0.04)
AppShockXLowYieldCountry			0.225**							
			(0.10)							
Total holdings	0.086	0.164**	0.072	0.513***	-0.003	0.164**	0.706**	-0.049	-0.162***	-0.123
	(0.12)	(0.08)	(0.06)	(0.18)	(0.37)	(0.08)	(0.35)	(0.04)	(0.05)	(0.09)
Lagged leverage ratio	0.444	0.965	0.308	1.685**	-7.999**	9.117***	0.018	-0.051	-3.212	0.193
	(2.35)	(0.60)	(0.74)	(0.82)	(4.00)	(2.56)	(1.31)	(0.17)	(2.80)	(0.39)
Total assets	-0.003	0.010	-0.001	-0.078***	0.098***	0.009	-0.019	0.023***	0.014	0.013
	(0.03)	(0.02)	(0.01)	(0.01)	(0.04)	(0.02)	(0.03)	(0.01)	(0.01)	(0.01)
Risk aversion	28.910***	0.085	28.535***	1.177	35.113*	38.558***	-1.512	-1.785	16.379*	-3.282
	(8.67)	(1.52)	(10.21)	(11.55)	(18.28)	(8.55)	(3.27)	(2.34)	(9.03)	(2.33)
Constant	-16.222	-16.114	-15.707	20.351***	-51.811	-62.635***	-6.015	-6.946	3.815	2.081
	(21.91)	(13.15)	(12.44)	(6.06)	(34.32)	(19.74)	(11.41)	(4.99)	(23.27)	(4.52)
Observations	455	455	455	140	60	100	20	60	55	20
R-squared	0.597	0.561	0.601	0.523	0.639	0.773	0.474	0.814	0.632	0.884

Notes: Regressing the change in banks' US holdings share on a APP shock during the sample period 2015Q1-2020Q2. The regression is done with bootstrapped clustered standard errors at the country level and bootstrap robust standard errors for the country specific regressions.The specification is: $ChangeShareUS2015Q1_{t,b} = \alpha_i + \beta weightedCumAPPShare_{t-1,b} + \beta TotalHoldings_{t-1,b} + \beta LeverageRatio_{t-1,b} + \gamma RiskAversion_{t,b} + \gamma TotalAssets_{t,b} + \eta_b + u_{t,b}$. P-values indicated as: *** p<0.01, ** p<0.05, * p<0.1.

5. Conclusions

Leveraging a confidential securities dataset, I study euro area banks' pricing impact for currency denomination (or issuers) for sovereign bonds. This has far-reaching consequences for asset safety. Motivated by a set of stylized facts showing an issuer bias fragmentation between high and low-yielding countries, I devise an econometric methodology that identifies investors hedged euro-dollar yield differentials. In addition, its decomposition into risk-free and convenience yield differentials allows me to uncover investors' convenience for currencies over time. 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 all national banking sectors have a higher convenience yield from holding dollars with respect to euros, except for Germany, which has the lowest one. Motivated by these results, I further study potential micro-founded determinants affecting bank preferences. These relate to frictions or macro-financial factors. I find that issuer home bias affects banks' CIP deviations, regulation, and unconventional monetary policy. These results suggest 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 fragmentation across euro area regions. Regions marked by more considerable home bias have

rebalanced less intensely into US assets following the ECB's purchases. My results point to the relevance of micro-founded drivers for CIP deviations, thus likely affecting pricing in the government bond segment. Furthermore, it provides insights on unconventional monetary policy, highlighting potential spillovers from policy normalization in the euro area to global financial conditions by also potentially reverting the capital flows direction conditional on US monetary policy.

References

Albertazzi, Ugo, Bo Becker, and Miguel Boucinha, "Portfolio rebalancing and the transmission of large-scale asset programmes: evidence from the euro area," 2018.

Altavilla, Carlo, Luca Brugnolini, Refet S Gürkaynak, Roberto Motto, and Giuseppe Ragusa, "Measuring euro area monetary policy," *Journal of Monetary Economics*, 2019, *108*, 162–179.

Amador, Manuel, Javier Bianchi, Luigi Bocola, and Fabrizio Perri, "Exchange rate policies at the zero lower bound," *The Review of Economic Studies*, 2020, *87* (4), 1605–1645.

Avdjiev, Stefan, Wenxin Du, Catherine Koch, and Hyun Song Shin, "The dollar, bank leverage, and deviations from covered interest parity," *American Economic Review: Insights*, 2019, *1* (2), 193–208.

Bechtel, Alexander, Jens Eisenschmidt, Angelo Ranaldo, and Alexia Ventula Veghazy, "Quantitative easing and the safe asset illusion," *University of St.Gallen*, 2021.

Begenau, Juliane, Monika Piazzesi, and Martin Schneider, "Banks' risk exposures," Technical Report, National Bureau of Economic Research 2015.

Bergant, Katharina, Michael Fidora, and Martin Schmitz, *International capital flows at the security level–evidence from the ECB's asset purchase programme*, International Monetary Fund, 2020.

Borio, Claudio EV, Mobeen Iqbal, Robert N McCauley, Patrick McGuire, and Vladyslav Sushko, "The failure of covered interest parity: FX hedging demand and costly balance sheets," 2018.

_ , Robert N McCauley, Patrick McGuire, and Vladyslav Sushko, "Covered interest parity lost: understanding the cross-currency basis," *BIS Quarterly Review September*, 2016.

Bräuning, Falk and Victoria Ivashina, "US monetary policy and emerging market credit cycles," *Journal of Monetary Economics*, 2020, *112*, 57–76.

Caballero, Ricardo J and Emmanuel Farhi, "The safety trap," *The Review of Economic Studies*, 2018, *85* (1), 223–274.

Caballero, Ricardo J, Emmanuel Farhi, and Pierre-Olivier Gourinchas, "Safe asset scarcity and aggregate demand," *American Economic Review*, 2016, *106* (5), 513–18.

Caramichael, John, Ms Gita Gopinath, and Gordon Y Liao, *Us dollar currency premium in corporate bonds*, International Monetary Fund, 2021.

Cenedese, Gino, Pasquale Della Corte, and Tianyu Wang, "Currency mispricing and dealer balance sheets," *The Journal of Finance*, 2021, *76* (6), 2763–2803.

Cerutti, Eugenio M, Maurice Obstfeld, and Haonan Zhou, "Covered interest parity deviations: Macrofinancial determinants," *Journal of International Economics*, 2021, *130*, 103447.

Coeurdacier, Nicolas and Pierre-Olivier Gourinchas, "When bonds matter: Home bias in goods and assets," *Journal of Monetary Economics*, 2016, *82*, 119–137.

Coppola, Antonio, "In Safe Hands: The Financial and Real Impact of Investor Composition Over the Credit Cycle," 2021.

Curcuru, Stephanie E, Charles P Thomas, Francis E Warnock, and Jon Wongswan, "US international equity investment and past and prospective returns," *American Economic Review*, 2011, *101* (7), 3440–55.

_ , Tomas Dvorak, and Francis E Warnock, "Cross-border returns differentials," *The Quarterly Journal of Economics*, 2008, *123* (4), 1495–1530.

Du, Wenxin, Alexander Tepper, and Adrien Verdelhan, "Deviations from covered interest rate parity," *The Journal of Finance*, 2018, *73* (3), 915–957.

_ and Jesse Schreger, "Local currency sovereign risk," *The Journal of Finance*, 2016, *71* (3), 1027–1070.

_ and _ , "Cip deviations, the dollar, and frictions in international capital markets," Technical Report, National Bureau of Economic Research 2021.

Eser, Fabian, Wolfgang Lemke, Ken Nyholm, Sören Radde, and Andreea Vladu, "Tracing the impact of the ECB's asset purchase programme on the yield curve," 2019.

Faia, Ester, Juliana Salomao, and Alexia Ventula Veghazy, "Granular investors and international bond prices: Scarcity-induced safety," *CEPR Press Discussion Paper No. 17454*, 2022.

French, Kenneth R and James M Poterba, "Investor diversification and international equity markets," *The American Economic Review*, 1991, *81* (2), 222–226.

Gabaix, Xavier and Ralph SJ Koijen, "Granular instrumental variables," Technical Report, National Bureau of Economic Research 2020.

Gorton, Gary, "The history and economics of safe assets," *Annual Review of Economics*, 2017, *9*, 547–586.

Hammermann, Felix, Kieran Leonard, Stefano Nardelli, Julian von Landesberger et al., "Taking stock of the Eurosystem's asset purchase programme after the end of net asset purchases," *Economic Bulletin Articles*, 2019, *2.*

Itskhoki, Oleg and Dmitry Mukhin, "Exchange rate disconnect in general equilibrium," *Journal of Political Economy*, 2021, *129* (8), 2183–2232.

Jiang, Zhengyang, Hanno N Lustig, Stijn Van Nieuwerburgh, and Mindy Z Xiaolan, "Bond convenience yields in the eurozone currency union," *Columbia Business School Research Paper Forthcoming*, 2020.

Koijen, Ralph SJ and Motohiro Yogo, "A demand system approach to asset pricing," *Journal of Political Economy*, 2019, *127* (4), 1475–1515.

_ , François Koulischer, Benoît Nguyen, and Motohiro Yogo, "Euro-area quantitative easing and portfolio rebalancing," *American Economic Review*, 2017, *107* (5), 621–27.

Krishnamurthy, Arvind and Annette Vissing-Jorgensen, "The aggregate demand for treasury debt," *Journal of Political Economy*, 2012, *120* (2), 233–267.

Liao, Gordon Y, "Credit migration and covered interest rate parity," *Journal of Financial Economics*, 2020, *138* (2), 504–525.

Nagel, Stefan, "The liquidity premium of near-money assets," *The Quarterly Journal of Economics*, 2016, *131* (4), 1927–1971.

Ongena, Steven, Alexander Popov, and Neeltje Van Horen, "The invisible hand of the government: Moral suasion during the European sovereign debt crisis," *American Economic Journal: Macroeconomics*, 2019, *11* (4), 346–79.

Santis, Roberto A De and Fédéric Holm-Hadulla, "Flow effects of central bank asset purchases on euro area sovereign bond yields: evidence from a natural experiment," 2017.

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.[37] 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

[37] 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).[38] 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.

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 banking 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

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

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. I also trimm the data on the explanatory variable home bias growth for values above 200% to control for outliers due to short-selling excluding very few observations.

B. Additional fact charts

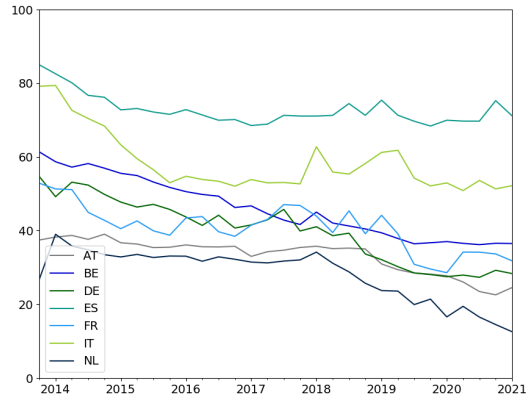


Figure B1: Bank's domestic government bond holdings shares, aggregated at country level (percent)

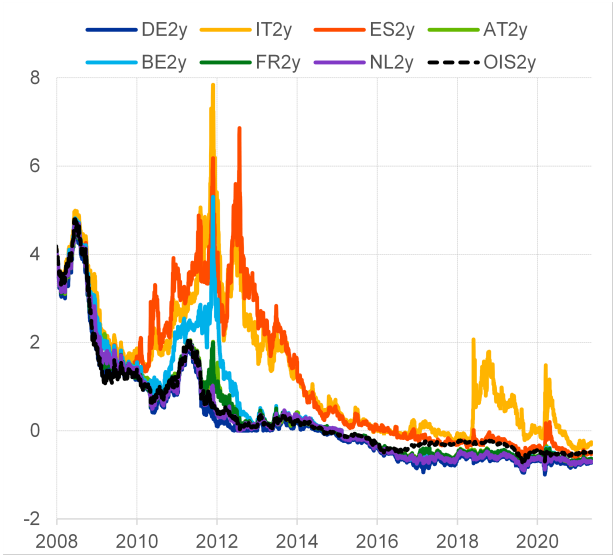


Figure B2: Sovereign bond yields across the euro area and the risk-free rate in the euro area (percent)

C. CIP deviations

C.1. Adjustment by Swap Rates

$$y_{i,t} = \alpha_t \mathcal{I}_{EUR,i} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t} \tag{C.1}$$

where $y_{i,t}$ is the yield for bond i at time t, and is the only variable that changes across specifications, α_t is the coefficient on the indicator variable $\mathcal{I}_{EUR,i}$, which equals one if bond i is denominated in the euro. $\beta_{f,t}$, $\gamma_{m,t}$, $\delta_{r,t}$ are fixed effects for firm f, maturity bucket m and rating bucket r at date t.

So far we run three types of estimates:

$$y_{i,t} = \begin{cases} y_{i,t} & if\ euro \\ (1+y_{i,t})(\frac{E(S_{t+n})}{S_t})^{1/n} - 1 & if\ dollar\ \&\ unhedged \\ (1+y_{i,t})(\frac{F_{t+n}}{S_t})^{1/n} - 1 & if\ dollar\ \&\ hedged \end{cases} \tag{C.2}$$

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

$$\rho_{n,t} = \frac{1}{n}[log(F_{t,t+n}) - log(S_{i,t})] \tag{C.3}$$

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

$$\rho_{n,t} = IRS_{euro,n,t} + BS_{euro,usd,n,t} - IRS_{usd,n,t} \tag{C.4}$$

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:

$$Y^{euro}_{n,t} - \rho_{n,t} - Y^{usd}_{n,t} \neq 0 \tag{C.5}$$

D. 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%.[39]

D.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

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

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

Choice of factors:

- Interest rate risk factor US(EA): Return on 5year US(EA) government bond
- Credit rate risk factor US(EA): Return on BBB-AAA US(EA) corporate bond index

[39] Currently this shares include also interbank positions.

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.

D.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

D.3. Results

Figure 1 depicts the portfolio exposures per bank to the four macroeconomic risk factors for 2021Q1 as per the factor model.[40] 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 1OO% as there is a residual factor corresponding to the exposure to the riskfree asset.

Figure 1

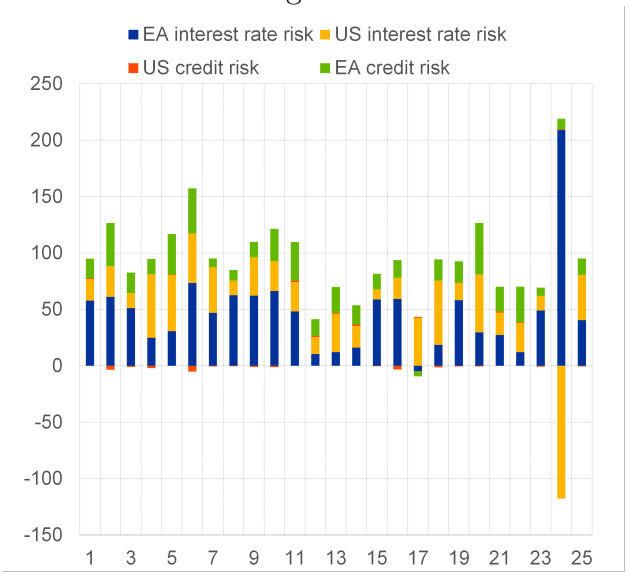


Figure D3: Exposures to marcoeconomic risk factors per bank for 2021Q1. Exposures are in percent.

In Figure 2 I plot the mean-std. deviation analysis of the factor portfolios obtained from the empirical exercise (factor model) and theoretical exercise (myopic portfolio choice 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 3).

[40]This breakdown is available for each date.

Figure 2

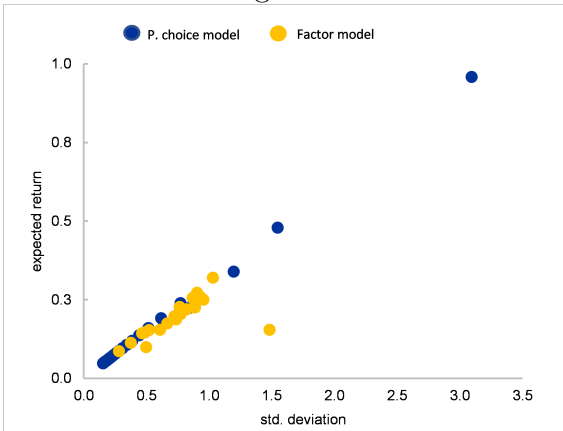


Figure D4: Blue dots show the efficient frontier for the optimal portfolio choice for varying risk-aversion parameters γ. Green dots is the mean-st.deviation analysis of the 26 euro area banking groups' factor portfolios obtained from the factor model. Observations correspond to 2021Q1

Figure 3

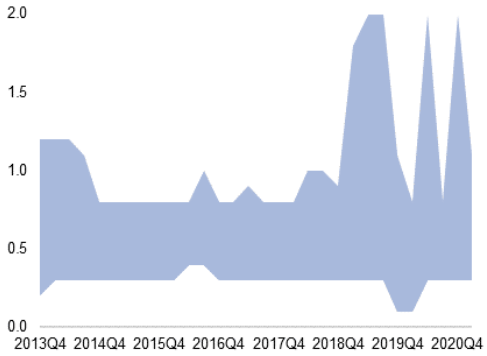


Figure D5: Range of banks' risk-aversion parameter across 26 largets EA banks