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GRANULAR INVESTORS AND INTERNATIONAL BOND PRICES: SCARCITY-INDUCED SAFETY

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JEL Classification: F3, G2, G4

Keywords: N/A

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Granular Investors and International Bond Prices: Scarcity-Induced Safety*

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JEL codes: F3, G2, G4. Keywords: heterogeneous mandates, large investors, market segmentation, securities data, uncovered and covered interest rate parity, scarcity channel, risk rabalance channel, asset safety.

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1. Introduction

One of the implications of the rise in capital flows is that large institutional investors, who intermediate most of the international capital flows, can have a big impact on bond prices across currencies, hence on their safety and on firms' funding costs. In this paper we evaluate the role of heterogeneous demand of granular[1] investors for bond pricing across currencies by leveraging on a unique (confidential) dataset with securities level information on holdings, asset characteristics and prices of all bonds issued by non-financial corporations held in the euro area.

Specifically we exploit a neat segmentation that we uncover between two large investors intermediating the majority of the corporate bonds market, namely insurance corporations and pensions funds on the one side and other financial institutions (which includes mutual funds) on the other. We find that the first have a strong preference for euro-denominated and locally issued securities and the second for dollar and foreign ones. Motivated by this observation we devise an econometric strategy that identifies the pricing impact of the demand for currency denomination, given asset characteristics and issuer characteristics. We show that the euro-dollar differential required by those large investors declines (even after adjusting or hedging for currency risk[2]) during the period of ECB asset purchase programmes, which was targeted at euro-denominated securities of euro area firms. This decline is even more evident when weighted by the respective portfolio shares.

Our evidence provides ground for a scarcity channel of currency pricing: the drain in euro securities, against their rising demand by insurance corporations and pension funds, created an excess demand and pushed their valuation upward and their premia, hence risk, downward. The decline of risk, particularly at longer maturities, induced a rebalance toward those securities, particularly so by those investors, whose clientele mandates and prudential constraints favour safer securities portfolios.

Our paper starts by documenting a set of facts on international portfolio allocation. The analysis of the dynamics of the portfolio shares of dollar and euro-denominated corporate bonds across investors and issuers over the sample period 2013-2021 reveals marked heterogeneity in demand. First, we find that aggregating across all investors, euro area investors hold a large share—over 70%—of their debt securities denominated in euros, even though about half of their debt portfolio is held in securities issued by

1 The terminology "granularity", as opposed to atomistic, has been introduced in Gabaix (2011).
2 See Du and Schreger (2021) or Du et al. (2018) for various motives for CIP deviation.

non-euro area firms. Hence, euro area investors display a strong local currency-bias, but not the well known home country asset bias. The demand of euro-denominated securities grew in our sample period reaching 75% of the holdings. Once we break down currency holding patterns per issuer country, we find that this growth is centered on U.S. issuers, whose euro-denominated share went from 18% in 2013 to 37% in 2021, while the dollar-denominated share of European issuers stayed low (from 2% in 2013 to 3% in 2021). It is likely that the decline in the euro yields increased the incentives of foreign firms to issue in this currency.[3]

Once we break down holdings of euro area investors by investor type, we find that the preference of euro securities is largely driven by insurance corporations and pension funds (ICPF), which exhibit both home (euro area) firm and local currency biases with 67% of their corporate portfolio holdings being securities issued by euro area firms and 93% being euro-denominated. This is in stark contrast to other financial institutions (OFI), which include mutual funds, as their holdings of euro-denominated bonds accounts only for 55% and of euro area issuers for 40%. This stark segmentation reflects their mandates, as induced by their clientele preferences and by regulation.[4] The granularity of those institutional investors (they hold 86% of euro area corporate bonds) implies that their demand for currency denomination may affect prices.

Motivated by those facts we test the role of heterogeneous investor demand, as measured by their portfolio composition, for international pricing, as measured by currency return differentials. In the first part of our empirical strategy, we devise a security level specification which, for given security and firm, allows us to estimate the residual role of investors' demand in currency pricing. More specifically we estimate euro-dollar yield differentials for each bond and controlling for maturity, rating and firms' fixed effects. We estimate our specification on the full sample, but also on the sample of firms issuing in both currencies, thereby isolating their relative demand for currency denomination.[5]

To isolate investor demand we also estimate variants controlling for exchange rate movements, using both survey expectations and derivative contracts to adjust the dollar return into a "synthetic" euro rate. The return differential estimated with survey expecta-

3 Still, we note that this new issuance remained lower than the drain in supply induced by the ECB asset purchase programme.

4 The latter is actually devised to reflect and protect clientele's preferences.

5 We also note that our investors are all euro area residents, and arguably subject to the same aggregate shocks, monetary policy and inflation risk, something which contributes to purge from other confounding factors.

tions represents deviations from the uncovered interest rate parity (UIP), while the one estimated with swap contracts represents deviations from the covered one (CIP). The estimates show that the investors' residual is negative and declines during the sample period, that is investors require a lower return for euro-denominated securities relative to dollar ones. The return differential is significantly large, reaching negative 270 basis points when adjusting for expected exchange rate movements and negative 63 basis points when hedging for this risk.

To dissect exactly the role of different investors from issuers we interact the investor average required returns with dummies for investor types, issuer types and asset type. The decline in the euro-dollar rates is stronger for securities issued by euro area firms, for long maturity bonds and for those held by ICPF, confirming that those investors, by requiring lower returns have higher demand for those securities. This finding is important for uncovering the scarcity channel: the assets in largest demand are precisely those drained by the ECB's asset purchase programme. This creates the conditions for the emergence of an excess demand pushing valuation up and returns downs.

To tighten the link between the decline in the investor's demand and the ECB asset purchase programmes, in the second part of our empirical strategy, we regress the estimated return differentials on the stock of purchases, finding a negative and significant relation. This relation is even more pronounced for long maturity bonds.[6]

We round up our results and examine the rebalance behaviour, by exploiting a unique feature of our data, namely the possibility of computing portfolio shares for each investor.[7] We examine the rebalancing channels in two exercises. First, we estimate our investor return differentials in an un-weighted and weighted fashion. The latter declines by more, and the more so for ICPF investors, indicating a rise in the share of lower-yielding euro-denominated securities (or higher-yielding dollar-securities) as return differentials decline. Second, we explore the link between rebalance of euro-denominated securities and expected differentials more formally in a regression linking the two. This is akin to calculating the demand elasticity of holdings with respect to differentials. We find again a negative and significant relation, that is the share rises as the UIP declines.

6 An incidental strength of our design is that during the sample period the Federal Reserve system had progressively reduced its own asset purchase programs. This conveniently provides large relative changes in asset supply between the two currency areas.

7 The data contains both investment in foreign and domestic securities. We compute portfolio weights with prices at issuance, thereby purging from valuation effects, and lag our portfolio shares to control for endogeneity.

The results on the rebalance coupled with the decline in the long term returns indicate that the asset purchases, by engineering a decline in excess returns, induced a decline in risk price for all euro-denominated securities. This heightened the incentives to increase the shares of securities with declining risk, particularly so for investors subject to clientele mandates and regulation that penalizes it.

We conclude by laying down a two country model in which heterogeneous investors make dynamic portfolio optimization decisions with bonds in different currencies. Investors' heterogeneity is devised to capture the differences in investors' demand observed in the data. In the model we capture UIP deviations and differences in the optimal portfolio compositions through heterogeneity in investors' preferences (see Sandulescu et al. (2021) for an analysis on of wedges in international SDFs), exploiting in particular the role of time-varying risk-aversion.[8] The latter determines different investors' elasticities of portfolio shares to returns, something which we derive analytically. We conceptualize CIP deviations through regulatory constraints. We use the model to explore the channels through which an asset purchase program may operate. We highlight in particular the scarcity channel, by which a drain in the supply of specific assets, by inducing an excess demand, affects prices through local market clearing and a risk rebalance channel by which a decline in asset risk triggers a rebalance toward safer securities.

Our results go beyond the specific episode and time period considered and have broader implications on the role of investor bases for pricing and safety of bonds, for the determinants of parity condition deviations and of convenience yields.

Literature Review. Our paper links first and foremost to the literature studying the determinants of cross-currency returns' differentials or UIP/CIP using more dis-aggregated data. Curcuru et al. (2008) and Curcuru et al. (2011) estimate return differentials per type of asset.[9] Other papers focused on estimated covered and uncovered interest parity deviations. Some specifications focused on macro data (Hassan (2013), Lustig and Verdelhan (2007) and Lustig et al. (2011)), while others examined deviations for emerging market economies (see Kalemli-Özcan and Varela (2021)). Our analysis goes one step further by estimating security level specifications and by distinguishing across type of investors and issuers. Works by Du and Schreger (2016), Du et al. (2018) or Du and

8 See Verdelhan (2010) among others for the role of time-varying risk-aversion in explaining asset price and currency facts.

9 They use the Treasury International Capital data and distinguished return differentials from debt and equities.

Schreger (2021) provided empirical foundations for CIP deviations, which we also examine in our data. Our theoretical arguments that link both the UIP and CIP deviations to investors' stochastic discount factors and or regulatory constraints relate our work to the international asset pricing literature and in particular to work by Sandulescu et al. (2021).

Our econometric approach builds on methodologies recently adopted to study cross-currency yields differentials using highly dis-aggregated data (Liao (2020), Caramichael et al. (n.d.) and Coppola (2021)). Liao (2020) and Caramichael et al. (n.d.) employ traded bond data to analyse the role of currency pricing in firms' issuance decision. We use portfolio data as our focus is on the role of investors' mandates and their demand for international bond prices.[10] Differently from Caramichael et al. (n.d.), we examine securities issued by firms based in the U.S., the Euro area, and the rest of the world, and held by euro area investors. This is crucial for an exact identification of our local supply channel: if investors were based in different currency areas, they would experience different monetary policy stances. Coppola (2021) assembles a dataset with portfolio holdings of mutual and insurance funds and examines the role of investor base on bond pricing around specific events. His paper focuses on dollar-denominated bonds and for this reasons does not consider the impact on currency pricing, which is instead the focus of our paper.

The link of asset scarcity to its safety relates our paper to a large literature on the conditions that make assets safe. Caballero et al. (2016)'s model closely captures the channel highlighted in our paper. Asset safety has been one of the main driver of the dollar dominance and its convenience yield (see Goldberg and Tille (2009) or Gopinath and Stein (2021) among others). Our results point at an erosion of that, which echoes other recent works (Du and Schreger (2021) or Gourinchas (2021).). The portfolio rebalance toward the safer asset links our evidence to a literature studying the impact of monetary policy on the yield curve (see Hanson and Stein (2015) for instance), and in particular to a recent literature discussing the local supply channel (see D'Amico and King (2013)) and the duration extraction channel of asset purchases (see Koijen et al. (2017) or Gourinchas et al. (2022)).

Our results reveal a strong local currency bias by the aggregate euro area investors,

10 Our data allows us to compute exactly the portfolio weights for each security, thereby providing a direct measurement of investors' composition and demand.

as in French and Poterba (1991) or Hale and Spiegel (2012).[11] Burger et al. (2018) and Maggiori et al. (2018)) re-examine this bias, although they adopt a somewhat different definition. They define home bias as the tendency of foreign investors to buy abroad asset in their own domestic currency. Consistent with Hau and Rey (2004), Hau and Rey (2008) and Maggiori et al. (2018), we find that mutual funds have a dollar bias, and in line with Koijen et al. (2017), we find that insurance funds have a euro bias. Interestingly, we do not find a bias of euro area investors as a whole for investing in securities issued by local firms, a fact which has been a hallmark of past literature in international finance (see among others French and Poterba (1991), Tesar and Werner (1995), Baxter and Jermann (1997), Cooper and Kaplanis (1994) or more recently Coeurdacier and Gourinchas (2016)).[12]

Our model builds on an emerging literature that studies the role of investor base and heterogeneity for asset prices and capital flows (see Koijen and Yogo (2019), Jiang et al. (2020), Coppola et al. (2020) or Hardy et al. (2021)). The role of different risk attitudes has been traditionally adopted to rationalize UIP deviations and explain other puzzles (see for instance Verdelhan (2010) or Gourinchas and Rey (2007)) and is acquiring prominence for the study of monetary policy transmission on risk premia (see Kekre and Lenel (2021)). The role of time-varying risk-aversion has been shown as well suited to explain asset price facts and UIP deviations (see Verdelhan (2010)). Deviations in CIP have instead been conceptualized through regulatory constraints or segmented markets: see for instance Lustig and Verdelhan (2019) or Gourinchas et al. (2022) among recent theoretical contributions in those areas. Itskhoki and Mukhin (2021) show how segmented market can also explain the Mussa puzzle.

Our paper links also to recent studies exploiting the role of investors' granularity for asset pricing. Gabaix and Koijen (2020), Koijen et al. (2017) or Koijen and Yogo (2020) exploit investor's granularity to construct instruments for asset demand. We instead rely on variation in investors' demand for the same asset and in response to the same shock, namely the large asset purchase. Our methodology includes the role of granularity when weighting the returns by the share of the largest investors. Both, our methodology and theirs controls for firms' characteristics to isolate the role of investors for pricing.

11 The bias is a manifestation of the familiarity bias, which has been found in several areas of portfolio investment (see for instance Huberman (2001), Zhu (2002) or Feng and Seasholes (2004).

12 Early works documented and theoretically rationalized the presence of this bias in equity (See for instance French and Poterba (1991), Tesar and Werner (1995) or Baxter and Jermann (1997)). More recently some authors argued that the full picture could be gathered only by considering other types of assets, such as debt bonds (see Coeurdacier and Gourinchas (2016)).

The rest of the paper proceeds as follows. Section 2 describes the data on euro area investor holdings, while Section 3 lays out the holding patterns in our data. Section 4 sets out the results of our empirical strategy and Section 5 presents a portfolio model with heterogeneous investors. Section 6 concludes.

2. Data

Our data is mainly sourced from Securities Holdings Statistics by Sector (SHSS) which has been collected by the European System of Central Banks (ESCB) on a quarterly basis since Q3 2013. SHSS covers two main types of securities: debt and equities. The data encompasses all holdings of securities by investors resident in the euro area, such as households in Germany or monetary financial institutions in France, and is reported at a disaggregated level i.e. security-by-security.[13]

The magnitude of the data is rather substantial. Total holdings by euro area investors amounted to around € 18 trillion at the end of June 2014, covering holdings of both debt securities and equity issued by euro area residents and by non-euro area residents. We have aggregate information on holders of each security (by institutional sector and/or country level, i.e. not by individual holder). We group the types of SHSS investors, in total 22, into six sectors: 1) monetary financial institutions (MFI); 2) insurance corporations and pensions funds (ICPF); 3) other financial institutions (OFI) which includes: investment funds, money market funds, financial vehicle corporations and other financial corporations; 4) households (HH); 5) government (GOV); and 6) non-financial corporations (NFCs).

We focus on euro area investors and exclude non-euro area investor holdings reported in SHSS.[14] This is for two reasons. First, in our analysis portfolio weights are crucial to assess the role of investor demand for each type of security. We can compute those only for securities held by euro area investors, as for them we have all holdings. Second, our econometric identification strategy, which is spelled out in Section 4, aims at isolating the role of investors' demand for euro-dollar yield differentials from firms and bonds characteristics, but also from other confounding factors, such as aggregate shocks and monetary policy. Focusing on euro area investors guarantees that all types of investors experience the same aggregate conditions and the same monetary stance.

13 More details on the dataset are in Appendix A.
14 SHSS reports only partial information of the total holdings by non-euro area investors.

While SHSS reports holdings of all equity and debt securities, including government bonds, we focus on non-financial corporate debt securities to study on the role of investor preferences in the price of currency risk, as these securities are usually held and issued in more than one currency. We focus on euro and dollar bonds as these comprise 95% of the total corporate debt holdings by euro area investors. Furthermore, these holdings are significant: euro and dollar-denominated corporate debt securities are equivalent to 8.3% of the euro area investors' debt portfolio at the end of June 2014 and total a nominal value of around €1.1 trillion. Finally, at that date, the data consist of approximately 18,200 bonds issued by about 5,700 firms from 87 countries.

The data includes the International Securities Identification Number (ISIN) of each security which allows us to merge security holdings with a number of other datasets. First, we use this identifier to enrich the SHSS data with information from the Centralised Securities Database (CSDB) on security characteristics (security type and price, issuer name and country, maturity date and currency of issuance). From the same database we gather securities' ratings, which includes information from four rating agencies: Fitch, Moody's, Standard & Poor's (S&P), and DBRS. To estimate euro-dollar yield differentials we match bond maturities with the horizons of both the exchange rate movements by professional forecasters from Consensus Economics and those in currency derivatives. Finally, to dissect investors' demand for local versus foreign issued securities we match the ISINs with issuers' residence.

3. Stylized Facts

In this section we use SHSS data to document holding patterns at securities level, and cross-cutting the data across different investors and issuers. Given the richness of our data several cuts of the data are possible, but we focus mostly on the patterns that inform our identification strategy. We aim at identifying investors' currency and issuer residency preferences and understand if specific institutional investors prefer holding euro-denominated assets issued by euro area firms, namely those eligible for the ECB's asset purchase programme.

We start by documenting patterns for securities aggregated across all issuers, but broken down across different types of investors and currencies (euro vs. dollar). Next, we classify the securities by issuer residency, aggregating across three groups (Euro Area, United

States, and Rest of the World) and study investor and currency segmentation inside each issuer group. While our focus is on informing our identification strategy, the facts detailed in this section also enrich previous findings on home asset and local currency biases.

Investors' Currency Preferences. We examine time-series trends for non-financial corporate debt securities holdings, issued both domestically and abroad, by breaking them down per investor type and by currency denomination. The goal is to examine portfolio composition per investor type, in order to detect potential heterogeneity in their currency preferences.

Figure 1 shows the breakdown of holdings per investor type (left panel) and per currency (right panel) since 2013. Three main points emerge. First, holdings have increased substantially, doubling since the start of the sample. This growth is consistent with a worldwide increase in savings and in global capital flows (see Lane and Milesi-Ferretti (2018)). Second, the increase has been driven by a rise in institutional investors, grouped in OFI and ICPF. This trend, which has also been noted in recent policy reports (see Board (2019)), is due to a rise in the demand for specialized financial services, particularly by high net worth investors. Finally, as is clear from the right panel, the euro is the dominant currency for euro area investors, with over 70% of the holdings. Euro area investors display a clear *local currency bias* in corporate debt holdings.

Note that Figure C1 in Appendix C presents the breakdown by currency for all six investor categories. There we observe that ICPF and OFI have quite a distinct share of dollar holdings. Because these are the two largest players in the market we focus on them since now on.

Figure 2 shows the break by currency of the debt securities held by OFI and ICPF respectively. The comparison between the left and right panels shows that OFI holds 55% in euro-denominated securities (45% in USD), while these are largely preferred by ICPF as 93% of their holdings are euro-denominated (7% in USD).

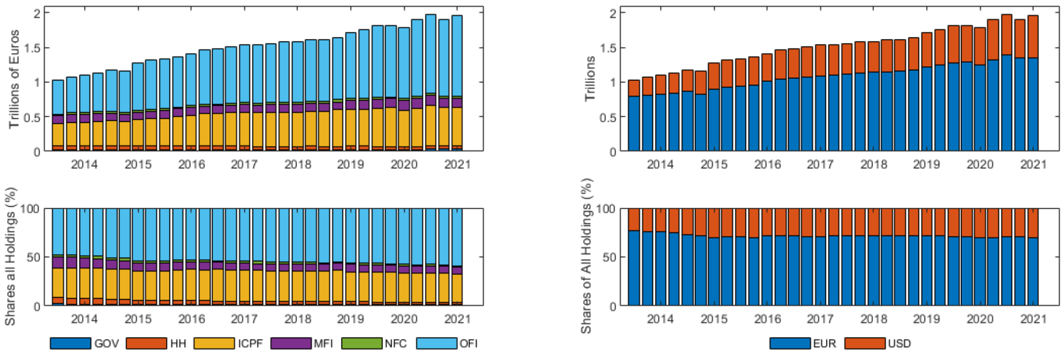
Our results on the currency bias are complementary among others to Burger et al. (2018) and Maggiori et al. (2018)), despite their different definition of this bias, which is probably tailored to their own data. [15] Burger et al. (2018) examines U.S. claims from the Treasury International Capital Statistics, hence they adopt a U.S. perspective. Maggiori et al. (2018) employ data for mutual funds from a U.S. custodian, Morningstar, and look at investment abroad. Since our data include the entire portfolio of euro area investors

15 In their definition of this bias they look at the share of foreign investment in local currency.

Figure 1

Non-financial corporate debt holdings by type of investor and per currency

Panel (a) shows a break down of all non-financial corporate debt securities by type of investor, namely government (GOV), households (HH), insurance company (ICPF), monetary financial institutions (MFI), non-financial corporations (NFC) and other financial institutions (OFI). Panel (b) shows a breakdown of all non-financial corporate debt securities per euro and dollars denomination. The sample period 2013 Q3 - 2021 Q1. Top panels show volumes in trillions of euro and the bottom panels show shares of holdings for each investor.



(a)
Per investor

(b)
Euro versus Dollars

we can measure the exposure of local investors to assets denominated in local currency. Our data reveal a strong preference of euro-denominated assets in aggregate as well as a euro bias for ICPF and a dollar bias for OFI, which includes mutual funds.

Several of the previous studies have the advantage of using fund level data across many countries, but do not compare asset holdings across different types of investors. We observe the portfolios of all types of investors: this allows us to flesh out the currency segmentation across investors, enriching previous results.

Overall this stark market segmentation reveals large heterogeneity in institutional investor mandates, which ultimately reflects their clientele preferences and prudential regulations. On a similar vein Bertaut et al. (2021) notes that mutual funds tend to intermediate high net wealth investors with a preference for timing the dollar. The opposite is true for ICPF.

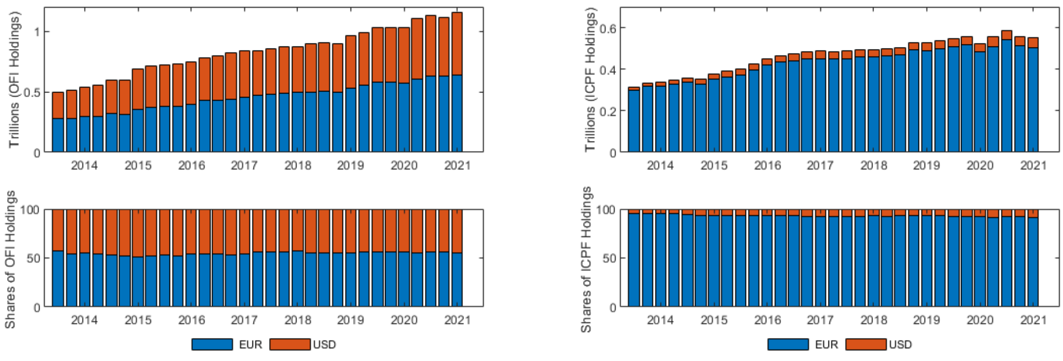
Investors' Preferences for Issuers and Currencies. A useful aspect of our data is that securities also report the issuers' identifiers. In this section we will use this information to condition securities holdings on issuers' residence. This allows us to uncover investors' preferences between securities issued by local firms or by foreign ones.

Figure 3 panel (a) shows the breakdown of all securities by residence of the issuing firm,

Figure 2

Debt in non-financial corporations by currency for OFIs and ICPFs

Break down of all non-financial corporate debt securities in U.S. dollars and euros held by other financial institutions (OFI) in figure 1a and insurance companies (ICPF). The sample period 2013 Q3 - 2021 Q1. For each panel, the top sub-panel shows volumes in trillions of euros and bottom sub-panel shows shares.



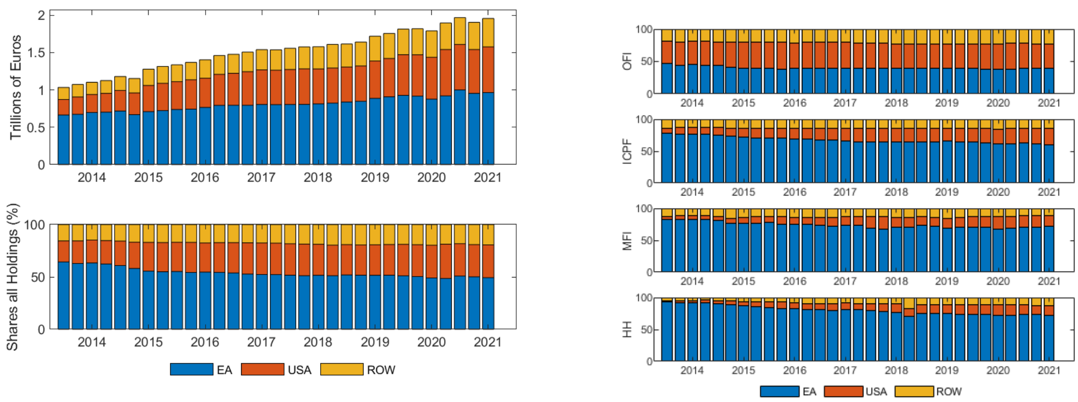
(a)
OFIs

(b)
ICPFs

Figure 3

Break down of debt in non-financial corporations by issuer residence

Panel (a) shows the breakdown of debt in non-financial corporations by residence of the issuing firm, which can be from the euro area, from the U.S. or from the rest of the world. Top panel shows volumes in trillions of euros and the bottom panel shows shares. Panel (b) shows the break down (in terms of shares) of debt in non-financial corporations by type of investors, focusing on other financial institution (OFI, first panel from the top), insurance corporations and pensions funds (ICPF, second panel from the top), monetary financial institutions (MFI, third panel from the top) and households (HH, last panel from the top). Sample period 2013-2020.



which we group in Euro Area (blue), the U.S. (red) or the Rest of the World (yellow). Top panel shows volumes and the bottom panel shows shares. We see that the home asset bias (preference for securities issued by local firms) was mild at the beginning of the sample and has vanished in recent years.

In addition, we observe that most of the debt held by euro area investors is issued by either Euro Area or U.S. firms (which accounts for respectively 53% and 36% of holdings), while the rest of the world accounts for a minority share. A preferential cross-holdings of assets among Western economies may again be linked to the familiarity within similar financial systems or may signal that U.S. firms are perceived as safer than others among euro area investors (see also recent evidence by Caramichael et al. (n.d.)).

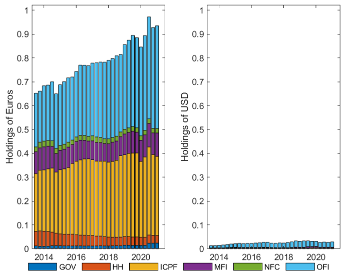
Panel (b) of Figure 3 shows the shares of securities of the three issuer groups across four main types of investors, and confirms investors' heterogeneity also in the preference for home country assets. While home asset bias is clearly visible to increasing degrees in ICPF, MFI, and HH, OFI exhibit no such bias. The preference for foreign securities by mutual funds has been noted also by Hau and Rey (2008). Our data highlights that also against other type of investors.

To fully assess investors' segmentation next we break down securities per currency denomination, per residence of issuer and across various type of investors. Figures 5 shows volumes (top panels) and shares (bottom panels) by breaking down the debt securities by currency (U.S. dollars in each right sub-panel and euro-denominated securities in each left sub-panel) and by type of investors. The two left figures focus on euro area issuers, the two middle figures focus on U.S. issuers and the two on the right on issuers from the rest of the world. Figure 6 shows a similar break-down, but only for OFI and ICPF. Taken together, the two sets of figures show that all investors, who prefer euro-denominated securities, also prefer euro area issuers (see for instance left panels of Figure 5) and that investors who prefer foreign securities also prefer dollar-denominated securities (see middle and right panel of Figure 5). The starkest segmentation emerges between OFI, which prefer dollar-denominated securities of foreign firms, and ICPF, which prefer euro-denominated securities issued by euro area firms. Note that, ICPF demand for euro securities is also on the rise. This, against the drain in supply induced by the large asset purchase of the ECB, has important implications for international bond prices. We elaborate on this more below.

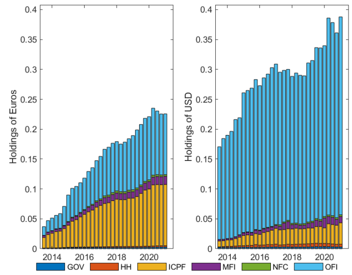
Finally, Figure 7 shows the breakdown of securities by currency denomination, dollars versus euros, and across the three issuers, and suggests that firms tend to issue in the currency preferred by the largest investors. Euro area investor holdings of securities issued by euro area firms (left panel) are for instance predominantly euro-denominated. Overall the importance of the euro has increased over time also for foreign issuers. For U.S. firms the share of euro-denominated securities is approaching 50% and for firms from the rest of

Figure 5
Debt in non-financial corporations by currency and investors

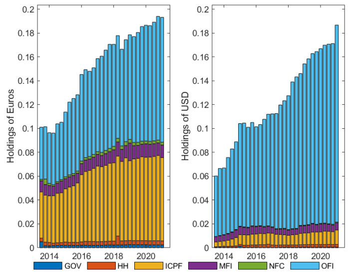
Figure 5 shows the breakdown (in levels) of debt in non-financial corporations by currency denomination, U.S. dollars (left sub-panels) versus euro (right sub-panels), and types of investor in different colors. Debt held by governments (GOV) is in blue, by households (HH) in orange, insurance corporations and pensions funds (ICPF) in yellow, monetary financial institutions (MFI) in purple, non-financial corporations (NFC) in green and other financial institutions in light blue. Top top three sets of panels show levels and the bottom panels show shares. Panels (a) and (d) show only securities issued by firms resident in the euro area, Panels (b) and (e) show only securities for issuers residents in the U.S. and Panels (c) and (f) show securities for issuers residents in the rest of the world. All figures show volumes. The sample period is 2013 Q3 - 2021 Q1.



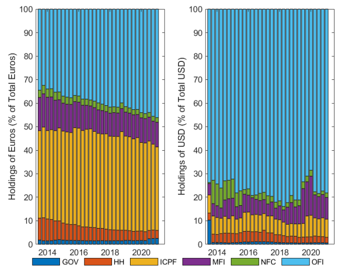
(a)
Euro area issuers



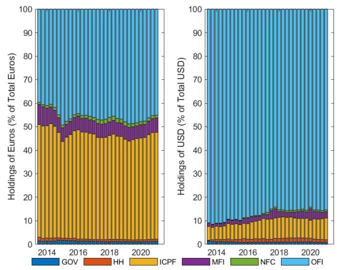
(b)
U.S. issuers



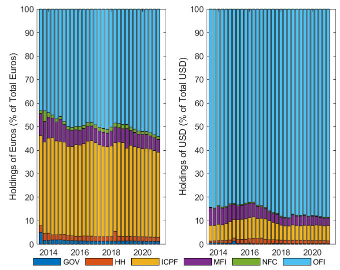
(c)
Rest of the World issuers



(d)
Euro area issuers



(e)
U.S. issuers



(f)
Rest of the World issuers

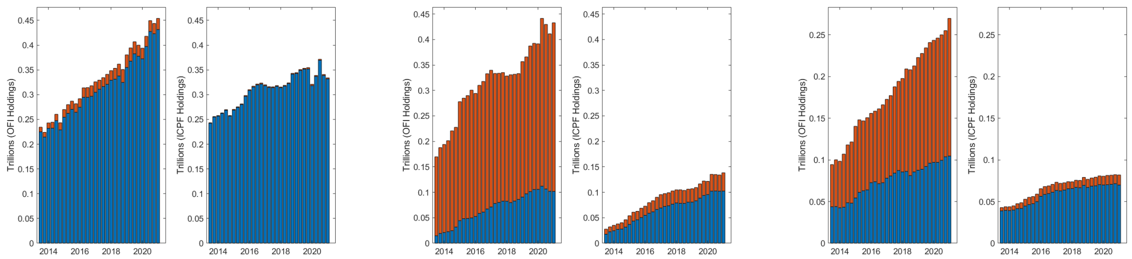
the world is above 50% for a large part of the sample. This is likely the result of the ECB asset purchase programmes that pushed down risk and further increased the demand of those assets by more risk-averse and more regulated investors. We shall note that the increase in issuance in euro securities that we observe in our euro holdings data has not overpassed the drain in supply induced by the ECB asset purchase programme.

One characteristic that may of course affect investor preferences is the location of the institutional investors, and more specifically whether it is located in a tax haven or not. It is well known for instance that many mutual funds are located in tax havens. Location may be another determinant of the currency portfolio composition, hence of investors preferences. This consideration however would not alter the fundamental tenet discussed so far, namely the segmentation of preference for dollar versus euro denomination.

Figure 6

Debt in non-financial corporations for OFIs and ICPFs by currency

Figure 6 shows the break down of debt in non-financial corporations per currency denomination, the U.S. dollar in red and the euro in blue. Investors are only OFI and ICPF. The top left panel shows only securities issued by firms resident in euro area, the top right panel shows only securities for issuers resident in the U.S. and the bottom panel shows securities for issuers resident in the rest of the world. All figures show shares.



(a)
Euro area issuers

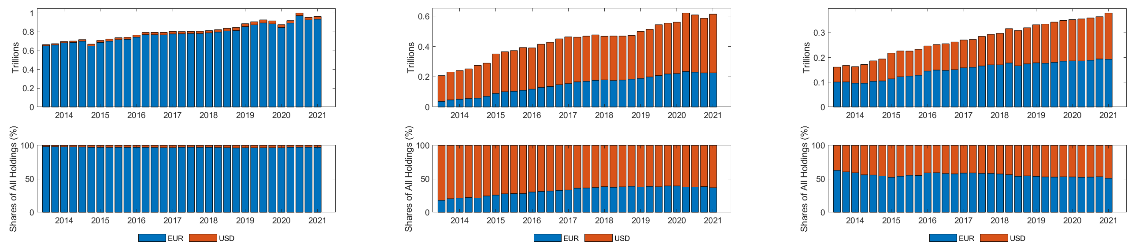
(b)
U.S. issuers

(c)
Rest of the World issuers

Figure 7

Break down of debt in non-financial corporations per currency denomination

Figure 7 shows the breakdown of debt in non-financial corporations per currency denomination, U.S. dollars versus euro. Top left panels shows only securities issued by firms resident in euro area, the top right panels shows only securities for issuers resident in the U.S. and the bottom panels shows securities for issuers resident in the rest of the world.



(a)
Euro area issuers

(b)
U.S. issuers

(c)
Rest of the World issuers

The observed currency and asset segmentation across institutional investors are likely to have consequences for the pricing of international bonds, even more so as the investors holding larger shares of those bonds are granular. We explore this next by estimating euro-dollar yields' differential at securities level. If granular investors have different preferences for the currency denominations of similar assets issued by the same firms, their demand will matter for currency pricing. We also exploit the large supply shock induced by the ECB asset purchases to measure the heterogeneous response of investor demand.

4. Empirical Results

Motivated by the facts documented in the previous section we devise an econometric strategy to analyze the impact of investor preferences on currency pricing. In subsection 4.1 we describe the security level specification used to estimate the euro-dollar yield differential. Results are presented in subsection 4.2.

4.1. Investor Demand Heterogeneity: Econometric Strategy

To exploit the richness of our granular data set we propose a securities level specification that allows us to estimate the dollar-euro yield differentials controlling for bond characteristics. The aim of the strategy is to identify the role of the investor's demand alone for the pricing of currency risk.

A first tenet behind the identification rests on institutional investors being granular, and hence large enough to have a meaningful impact on prices. Investors such as OFI and ICPF hold almost 90% of the non-financial corporate debt, hence they qualify as granular. Furthermore, these investors exhibit distinct holding patterns across euro and dollar securities. Hence their large and heterogeneous demand is likely going to have implications for euro-dollar relative bond returns.

Beyond large and heterogeneous investor demand, our strategy rests on three other pillars. First, since bond prices also depend on firm and asset risk characteristics we purge for those by including maturity and ratings dummies and firm fixed effects. Second, we select only securities held by euro area investors, as those are subject to the same aggregate shocks and inflation risk. This allows us to isolate differences in asset demand which are not due to country factors. Third, we exploit the large shock represented by the ECB asset purchase programme that focus on euro-denominated securities issued by euro area firms. This asset purchase generates a drain in the supply of euro securities, against their large and rising demand from certain institutional investors, and leads to changes in euro-dollar returns through local market clearing conditions.[16]

Baseline Specification We estimate several variants of the following specification:

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

16 For a description of the programme see: https://www.ecb.europa.eu/mopo/implement/app/html/index.en.html. See also speech by Philip Lane for a description of the channels behind the impact on yields: https://www.bis.org/review/r191126d.pdf.

$y_{i,t}$ is the annualized yield for bond i at time t taken from the secondary market and is the only variable that changes across specifications that we describe next, 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. Maturity control refers to residual maturity.[17] Regressions are estimated in the cross-section at each date t and standard errors are clustered on the fixed effect variable. The data is truncated on the dependent variable below 1% and above 99% at each quarter to control for outliers (see Appendix B for details). The coefficient of interest is α_t, which we dub the *investor residual.* This captures the residual difference in the price of currency denomination for the same asset issued by the same firm type. In other words it captures the average difference in euro and dollar investors' demand or their stochastic discount factor.

Return Differential Specification. We vary $y_{i,t}$ to estimate three variants of the baseline specification, namely equation (1): a *raw* yield differential that compares the yields without adjusting for exchange rate movements, a *survey adjusted* yield differential that controls for expected exchange rate movements using survey forecasts, and a *hedged* yield differential that controls for currency risk using swap contracts. From now on we refer to them as raw, unhedged, and hedged specifications. The second specification produces a return differential which is akin to an uncovered interest parity (UIP) deviation, while the third is akin to a covered interest parity (CIP) deviation. In the raw specification, y is the annualized yield to maturity of the bond from the secondary market and is expressed in euros or dollars depending of the currency of the bond. For the unhedged and hedged specifications we define the yield as follows:

$$y_{i,t} = \begin{cases} y_{i,t} & if\ euro \\ (1+y_{i,t})(\frac{E(S_{t+n})}{S_t})^{1/n} - 1 & if\ dollar\ \&\ unhedged \\ IRS_{euro,n,t} + BS_{euro,usd,n,t} - IRS_{usd,n,t} + y_{i,t} & if\ dollar\ \&\ hedged \end{cases} \quad (2)$$

where S_t is the spot rate at time t, $E(S_{t+n})$ is the forecast at time t on the expected spot rate (euro per dollar) at time of the contract maturity (in n years). $IRS_{euro,n,t}$ is the interest rate swap contract in euros that trades fixed euro cash flow for floating euro

17 Holdings data require the adjustment for residual maturity, rather than maturity at issuance.

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, $IRS_{USD,n,t}$ is the interest rate swap in dollars that trades fixed dollar cash flow for floating dollar cash flow (Libor).

Following Du et al. (2018) we performed the hedged adjustment using swap rates. Since currency forwards are less liquid at maturities greater than one year, the corporate basis is best measured with currency swaps. Those are more liquid at the longer maturities observed in our data. Details on this adjustment are reported in appendix D. Results for the hedged specification are also calculated using forward contracts (see Appendix C5).

Table A1 in Appendix B compare the mean and median maturities, both residual and at issuance, between euro and dollar-denominated bonds present in our data. The average maturity at issuance is higher for dollar-denominated assets, indicating that those usually carry larger risk and term premia.

Investors, Issuers and Long Term Specification. In the previous section we established that investors hold different preferences, particularly across currencies. The next step is to verify whether this heterogeneity implies that asset prices responds differently to shocks. The shocks we have in mind are the bond purchase programmes by the ECB during the period analyzed. These programmes represent a large drain in supply of longer maturity euro-denominated bonds issued by firms resident in the euro area. This shock, coupled with the rising demand of euro bonds by ICPF, generates an excess demand which affects euro-dollar prices through local market clearing conditions. To test this *scarcity channel* we twist our baseline specification by adding an interaction of the investor residual with a dummy that progressively selects either different issuers of euro securities (Euro area, US or rest of the world), different investors (ICPF or OFI) and different maturities (above 7 years). By focusing either on securities eligible for the programme, whose supply is being drained, or on investors that have a preference for those, the interacted specification is selecting securities in excess demand. We expect a larger rise in the valuation of longer maturities euro-denominated securities issued by euro resident firm and held by ICPF. Hence we should find a larger decline in the euro-dollar returns for those categories.

The interacted specification reads as follows:

$$y_{i,t} = \alpha_{1,t}\mathcal{I}_{EUR,i} + \alpha_{2,t}\mathcal{S}_{type} + \alpha_{3,t}\mathcal{I}_{EUR,i} * \mathcal{S}_{type} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t} \tag{3}$$

where $\mathcal{S}_{type}$ is a dummy capturing alternatively investors', security and issuers' types and the term $\alpha_{3,t}\mathcal{I}_{EUR,i} * \mathcal{S}_{type}$ is the effect of that specific sub-sample on the investors' residual. Our coefficient of interest is $\alpha_1 + \alpha_3$. The first term captures the average difference in euro and dollar investor demand and the second captures the changes in demand for the specific issuer or investor.

Portfolio Weighting A second channel through which the asset purchase programme can affect the yield curve is the risk rebalancing channel. By buying bonds, both corporate and Treasuries, the ECB reduces their yields, hence their risk. This induces institutional investors, whose portfolios are heavily skewed toward those securities, to increase the demand of eligible bonds. This allows them to reduce their portfolio risk and to meet prudential requirements at lower costs. To dissect this channel, we compare the estimated investor residual with the equivalent weighted by the time-varying portfolio shares. A larger decline of the weighted returns clearly indicates a rise in the portfolio share toward asset whose risk has declined. Importantly, note that portfolio shares are purged by valuation effects as they are built using nominal bond values at issuance.

We compute portfolio 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:

$$\overline{y}_c = \sum_{j=1}^{N} w^c_{j,t-1} y^c_{j,t} \tag{4}$$

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

4.2. Baseline Return Differential Results

Our aim is to dissect the impact of investors' demand on bond's currency pricing. We measure it through α_t estimated in equation (1). This coefficient is reported under the three specifications described earlier, namely the *raw*, *unhedged*, and *hedged*. All figures in the main text are based on estimates with bonds above one year of residual maturity. We exclude shorter maturities as those are not well aligned with exchange rate professional forecasts. For robustness Appendix C reports estimates with bonds above six months of maturity.

18 Results are similar when we use the contemporaneous holdings.

Figure 8 shows results over the 2013 Q3 - 2021 Q1 period. In each panel the black line is the unweighted residual and the red line is the weighted variant. The first panel shows the *raw*, the second the *unhedged* and the third the *hedged*.[19] Dashed lines indicate confidence intervals.

The first panel shows a steady and quantitatively sizable decline of the euro-dollar residual during most of the period. In equilibrium investors require lower yields on euro-denominated securities relative to the dollar-denominated ones. Given the inclusion of the rating, maturity and the firm fixed effects, the decline in the euro return is unrelated to firms and security risk. The middle figure shows that the residual deviation from the UIP remains large and sizable. Most interestingly even the residual from the swap adjusted specification (third panel), which reaches negative 50 basis points, qualifies as a remarkable violation of the covered interest rate parity. Results for the CIP are reported here for the baseline swap adjustments; robustness with forward rates adjustment is reported in C5. In all cases the decline in the residual is stronger when weighted by the portfolio shares. This implies that investors rebalance by increasing the share of lower yield securities. The decline in the cost of euro securities also explains the increase in their issuance reported in Figure 7.

Figure 8
Euro-dollar yields differential, UIP and CIP on SHSS sample

Figure 8 plots estimates for residual intercept for the raw specification (left panel), for the uncovered interest rate party (middle panel) and for the covered interest rate parity (right panel) using the SHSS corporate bond sample from 2013 Q3 - 2021 Q1, including all bonds with a maturity above 1 year. Each panel compares the residuals weighted with portfolio weights (red dashed line) with the un-weighted (black solid line). Econometric specification is: $y_{i,t} = \alpha_t \mathcal{I}_{EUR,i} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t}$, where $y_{i,t}$ is the local currency yield for bond i traded in the secondary market at time t. 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. The regressions are estimated in the cross-section at each date t. Standard errors are clustered at the fixed effect variable.

(a) Raw | **(b)** Unhedged | **(c)** Hedged

19 The raw differentials, though measured in different units, are still informative about the underlying channels. They capture the stylized situation of fully segmented markets in which each investors can only buy assets in their own currency.

4.3. Return Differential and Implied Channels

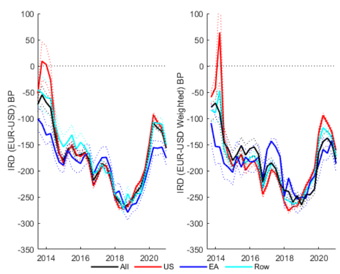
Next we present estimates from the interacted specification of equation (3). The coefficient of interest is $\alpha_1 + \alpha_3$. The term α_1 captures the average difference in euro and dollar investor demand and the term α_3 selects either different type of issuer residency, investors and bond maturity.[20] We present progressively estimates interacted with issuer dummy, investor dummy and maturity dummy. As we discussed previously, these sample cuts allow us to unveil the channels that drive the estimated return differential.

EA, US and ROW. Estimates with the issuer dummy are reported in Figure 9. As before, the first two panels show the results for the raw euro-dollar residuals, the next two for the survey adjusted (unhedged) and the last two, the hedged.[21] The blue line plots estimates for the specification that includes a euro area issuer dummy. Euro yields for those firms decline by more than those of foreign firms. The supply of those bonds was drained by the ECB purchase programme and their demand by ICPF was on the rise. The resulting excess demand flattened their yields by more.

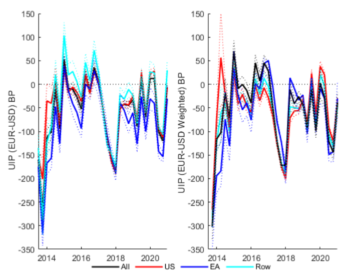
Figure 9

Euro-dollar yield differential, UIP and CIP - Break down by residence of issuing firm

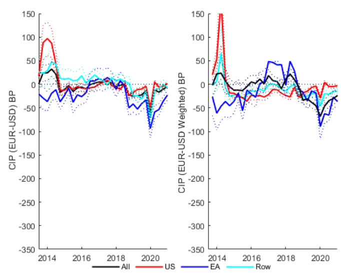
Figure 9 plots estimates of the intercept residual, in the raw specification (left panel), in the uncovered interest rate parity specification (middle panel) and in the covered interest rate parity specification (right panel). Results are shown for the baseline specification (black line) and for the one that includes an interacted dummy for issuers, namely U.S. firms (red line), euro area firms (dark blue line) and rest of the world (cyan line). Sample period is 2013 Q3 - 2021 Q1 and samples included all bonds with a maturity above 1 year. Econometric specification is: $y_{i,t} = \alpha_{1,t}\mathcal{I}_{EUR,i} + \alpha_{2,t}\mathcal{S}_{type} + \alpha_{3,t}\mathcal{I}_{EUR,i} * \mathcal{S}_{type} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t}$, where $y_{i,t}$ is the local currency yield for bond i traded in the secondary market at time t. α_t is the coefficient on the indicator variable $\mathcal{I}_{EUR,i}$, which equals one if bond i is denominated in 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 and $\mathcal{S}_{type}$ is the issuer dummy. The regressions are estimated in the cross-section at each date t. Standard errors are clustered at the fixed effect variable. Results shown correspond to $\alpha_1 + \alpha_3$.



(a)
Raw



(b)
Unhedged



(c)
Hedged

OFI vs ICPF. Estimates for the interaction with the investor dummy are reported

20 Our results don't include the $\mathcal{S}_{type}$ dummy due to collinearity as it is already controlled for by the other baseline controls. Note that, the specification in equation (3) is equivalent to the baseline specification in equation (1) but for different sub-samples.

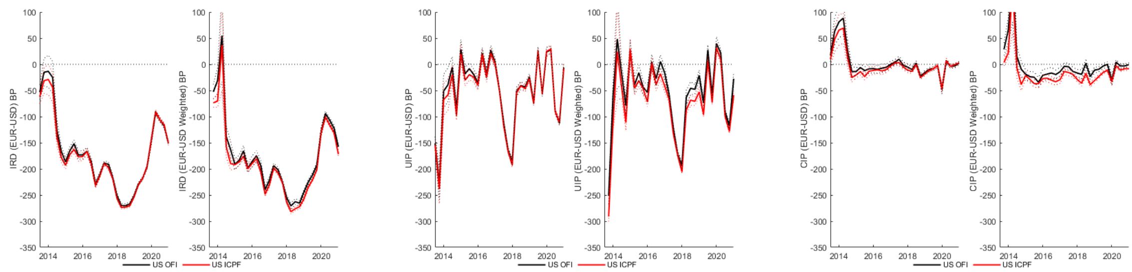
21 An alternative perspective on the same type of data cut is shown in **??** in Appendix C.

in Figure 10, where the black line plots the coefficient of interest, $\alpha_1 + \alpha_3$, for OFI and the red line reports the estimates for ICPF. To detect investor segmentation across asset markets we also report results for subsample of issuers: the first row of panels shows results for issuers from the U.S. and the second row for issuers from the rest of the world. As usual we present the raw, the unhedged, and the hedged residuals. First, the red line lies consistently below the black: ICPF require lower yields for euro-denominated assets as they like them more. This is so even when they buy securities issued by foreign firms (both rows): in this case they require an even larger expected rise in valuation. The declining euro yields also provides strong incentives for foreign firms to increase their euro issuance, a result which emerged in Figure 7.

Figure 10

Euro-dollar returns differential, UIP and CIP - Break down by type of investor

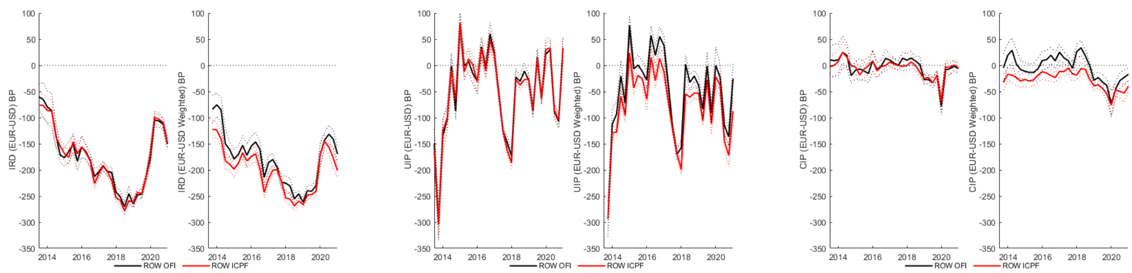
Figure 10 plots estimates for the intercept residual in the raw specification (left panel), in the uncovered interest rate parity specification (middle panel) and in the covered interest rate parity specification (right panel). All regressions include an interacted dummy for investors' type, more specifically for OFI (black lines) and ICPF (red line). Top three panels shows estimations for securities issued by for U.S. firms, bottom panels instead for securities issued by firms from the rest of the world. Sample period is 2013 Q3 - 2021 Q1 and samples included all bonds with maturity above 1 year. Each panel compares the residual weighted with portfolio weights (red and dashed line) with the un-weighted (black and dashed line). Econometric specification is: $y_{i,t} = \alpha_{1,t}\mathcal{I}_{EUR,i} + \alpha_{2,t}\mathcal{S}_{type} + \alpha_{3,t}\mathcal{I}_{EUR,i} * \mathcal{S}_{type} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t}$, where $y_{i,t}$ is the local currency yield for bond i traded in the secondary market at time t. 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 and where $\mathcal{S}_{type}$ is the investors' dummy. The regressions are estimated in the cross-section at each date t. Standard errors are clustered at the fixed effect variable. Results shown correspond to $\alpha_1 + \alpha_3$.



(a) Raw - U.S. Firms

(b) Unhedged - U.S. Firms

(c) Hedged - U.S. Firms



(d) Raw - R.o.W. Firms

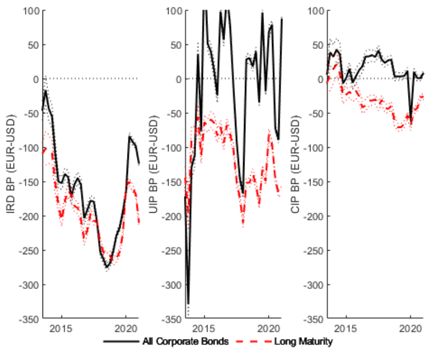
(e) Unhedged - R.o.W.. Firms

(f) Hedged - R.o.W. Firms

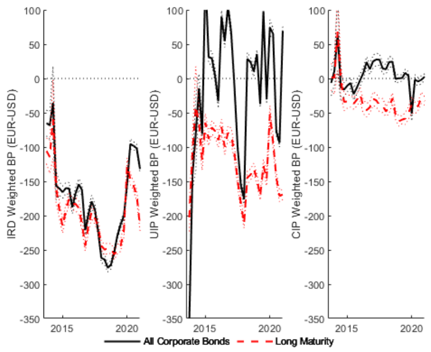
Long Maturity. At last Figure 11 plots the estimates for the specification interacted with a dummy for long maturity. The latter was indeed a prominent eligibility criterion of the asset purchase. The three panels on the left show the unweighted residual, while the three panels on the right show the weighted one. The decline is much stronger for long bonds, hence those eligible for the programme. Second, the decline of the weighted ones is generally stronger, indicating an increase in the share of securities eligible for the programme and whose valuations are expected to rise.

Figure 11
Euro-dollar yield differential, UIP and CIP - Break down per security maturity

Figure Figure 11 plots estimates of the intercept residual (left panel) under a specification that includes a long maturity dummy. The three panels on the left depict the unweighted residual, while the three panels on the right plot the weighted one. In each group of three panels, the left panel plots the raw residual, the middle panel plots the one for the uncovered interest rate parity specification and the right panel plots the one for the covered interest rate parity specification. Black line is the baseline residual and the red line includes the interacted term with the long maturity. Sample period is 2013 Q3 - 2021 Q1 and samples included all bonds with maturity above 1 year. Econometric specification is: $y_{i,t} = \alpha_{1,t}\mathcal{I}_{EUR,i} + \alpha_{2,t}\mathcal{S}_{type} + \alpha_{3,t}\mathcal{I}_{EUR,i} * \mathcal{S}_{type} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t}$, where $y_{i,t}$ is the local currency yield for bond i traded in the secondary market at time t. 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, and $\mathcal{S}_{type}$ is the long maturity dummy. The regressions are estimated in the cross-section at each date t. Standard errors are clustered at the fixed effect variable. Results shown correspond to α_1 and $\alpha_1 + \alpha_3$.



(a)
Long maturity securities - unweighted



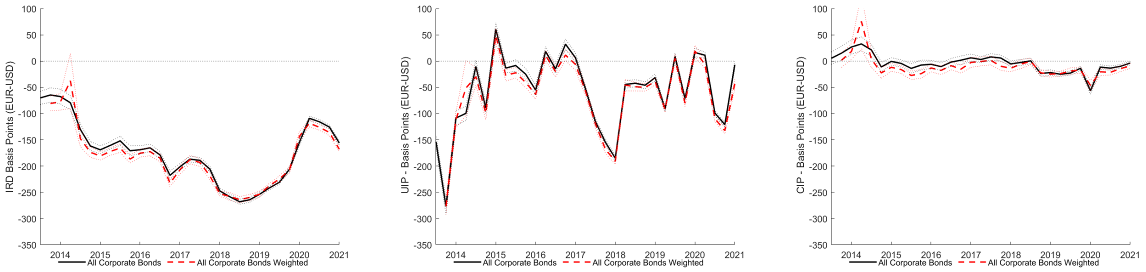
(b)
Long maturity securities - weighted

Threats to Identifications. To test robustness of our results we address here some potential threats to our identification. First, we are using the full sample of firms, including those that issue in a single currency. While this choice improves robustness of our results, it may instill a firm composition bias in our results. Even when controlling for firm fixed effects if the average risk of euro area firms issuing only in euros is lower than the average risk of foreign firms issuing only in dollar, the relative trends may induce a lower return on the euro. We check whether this potential threat is there. Specifically, we re-run our regressions by including only firms that issue in both currency. Results are in Figure 12

Figure 12

Euro-dollar yields differential, UIP and CIP for firms issuing in both currencies.

Figure 8 plots estimates for residual intercept for the raw specification (left panel), for the uncovered interest rate party (middle panel) and for the covered interest rate parity (right panel) using the corporate bonds from firms issuing in both, euros and dollars, time sample is from 2013 Q3 - 2021 Q1, including all bonds with a maturity above 1 year. Each panel compares the residuals weighted with portfolio weights (red dashed line) with the un-weighted (black solid line). Econometric specification is: $y_{i,t} = \alpha_t \mathcal{I}_{EUR,i} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t}$, where $y_{i,t}$ is the local currency yield for bond i traded in the secondary market at time t. 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. The regressions are estimated in the cross-section at each date t. Standard errors are clustered at the fixed effect variable.



(a) Raw **(b)** Unhedged **(c)** Hedged

and confirm the decline in the euro-dollar investor residual is present also when we restrict the sample only to firms issuing in both currencies, which are then unlikely to exhibit some trend difference. To further verify that there is no statistically significant difference between the results under the full and the restricted firm samples, Figure 13 shows results for the difference in the estimates of the raw differential. The difference between the two is always within 15 basis points.

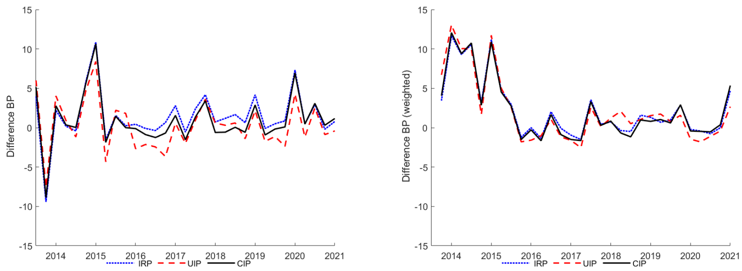
At last, on the investor side it is possible to entertain the possibility that mutual funds in tax havens are intermediating also foreign investors. This per se would not invalidate our hypothesis of the role of investor heterogeneous preferences for the currency pricing: foreign investors intermediated by mutual funds in tax havens would naturally have a preference for the dollar and this would be consistent with our results.

4.4. Heterogeneous Rebalance and its Channels

While our main focus is on the impact of the large asset purchases on the demand of different investor and on market prices, whose channels we discuss more in depth in the next subsection, it is instructive to estimate the investors' elasticities more generally. We measure them by regressing changes in their euro-denominated portfolio shares on the

Figure 13
Difference in Euro-dollar estimates between samples.

Figure 8 plots differences in the estimates for residual intercept for the raw specification, non weighted (left panel) and weighted (right panel) between the full sample and the one restricted to firms issuing in both currencies, time sample is from 2013 Q3 - 2021 Q1, including all bonds with a maturity above 1 year. Each panel compares the residuals weighted with portfolio weights (red dashed line) with the un-weighted (black solid line). Econometric specification is: $y_{i,t} = \alpha_t \mathcal{I}_{EUR,i} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t}$, where $y_{i,t}$ is the local currency yield for bond i traded in the secondary market at time t. 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. The regressions are estimated in the cross-section at each date t. Standard errors are clustered at the fixed effect variable.



(a) Unweighted

(b) Weighted

changes in the uncovered and covered interest rate parity. Specifically, we estimate the following specification:

$$\Delta EuroShare = \alpha + \beta(RD_t - RD_{t-1}) + \epsilon_t \quad (5)$$

The variable $\Delta EuroShare$ indicates changes or growth in the portfolio shares and we focus on the euro-denominated share. The variable RD_t is the either the UIP or the CIP adjusted return differential, hence the coefficient β captures the elasticity of a change in the return differential. Note that the RD_t are based on market returns, hence they are taken as given from the point of view of the individual investor. See also Tabova and Warnock (2021) for similar specification applied to Treasuries.

Table 1 shows the results. First and foremost, the only significant regressor is the UIP. This is consistent with the idea that portfolios are generally sticky and rebelance happens only for larger changes in the returns. Second, the sign of the estimated elasticities is surely negative for the UIP and the CIP. There are several channels behind a rebalance, which we actually also derive and discuss through our theoretical model later on. Investors increase their portfolio shares either toward the securities delivering the higher yields, namely a seek for returns channel, or toward the security with lower risk. Given the negative sign the second channel seems to prevail in the data. The asset purchases, by engineering

Table 1
Regressing the portfolio share of euro denominated securities over return differential either in UIP or CIP form. The econometric specification is $\Delta EuroShare = \alpha + \beta(RD_t - RD_{t-1}) + \epsilon_t$. P-values indicated as: *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
	change	growth	change	growth
UIP	-0.301 ***	-0.003 ***		
	(0.109)	(0.001)		
CIP			-0.425	-0.005
			(0.765)	(0.008)
Constant	-0.145 *	-0.002	-0.162 *	-0.002 *
	(0.088)	(0.001)	(0.097)	(0.001)
Observations	30	30	30	30
R-squared	0.255	0.254	0.026	0.028

a decline in excess returns, also induced a decline in risk, particularly so for long term securities. This heightened the incentives to increase the shares in euro-denominated securities, particularly so for investors whose mandates, a combined rejoin of their clientele preferences and of regulation, requires portfolios skewed toward low risk securities.

4.5. Monetary Policy Channels

During the sample period the largest shock was represented by the large asset purchases implemented by the ECB, which were conducted both on corporate bonds and Treasuries. The first acts as a drain on corporate bond supply, hence it is likely to have an impact on local market clearing conditions. By reducing the supply of corporate bonds, against their rising demand by ICPF documented earlier, the asset purchase results in an increase of those bonds valuations. This captures a local supply or a scarcity channel (see See D'Amico and King (2013)).[22] The second, namely the purchase of all bonds, reduced excess returns and risk along at all maturities. By reducing risk this channel induces investors to rebalance towards those assets, particularly so for investors whose regulation penalizes risk.

Figure 9 provides evidence on the scarcity channel. For the corporate bonds targeted by the purchase programme the decline in the yields is stronger. Note that this channel

22 See D'Amico and King (2013) provide evidence of the local supply channel on the yield curve of US bonds. Its implications for yield differentials across currencies have never been examined thus far.

would directly affect the targeted bonds, but would not necessarily spillover to bonds in the vicinity.

As for the risk rebalancing channel, this should be more pronounced for investors whose regulation penalizes risk.[23] Figures 10 and 11 confirm this channel. The euro-dollar investor residual declines by more when weighted by portfolio shares for ICPF and when focusing on long term bonds, which are penalized in regulation. The asset purchases of euro-denominated bonds, particularly those targeted at long term bonds, reduced asset risk and incentivizes their holdings in the portfolio of those investors. This is in line also with the estimates of the elasticities from equation (5).

The impact of both channels is enhanced by the build up of stocks, more than by the flows themselves. Figure 15 confirms that the decline of the residual (lower panel) reaches a peak in all our plots around in 2018, namely the date in which the stock of purchases (upper panel) arrives to its first peak[24]. The investor residual starts to rise again when in the slowdown-phase of the programme and declines back again in the last part of the sample when the programme is reactivated to counteract the pandemic recession. This last decline is less strong as asset purchases have been implemented during the pandemic also by the Fed. This pushed down also the dollar yields.

The evidence from the figures is confirmed formally through a regression specification. We regress the estimated investor residual, the α, on the current and lagged stock of asset purchases. As dependent variable we select the investor residual estimated under the UIP specification, both for all bonds and for long maturity bonds. There are several reasons for this choice.

First and foremost there is consensus, also based on modern open economy theoretical frameworks that to evaluate the effects of monetary policy one should take into account all possible deviations from interest rate parity.[25] Second, it is already well understood that quantitative easing policies have a larger impact on UIP deviations, than on the cross-currency bias.[26]

23 Insurance funds have been indeed increasingly subject to Solvency II constraints that penalize asset and currency risk.

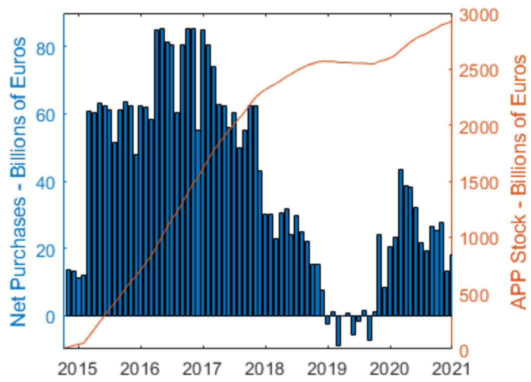
24 For convenience let us recall that monthly purchases averaged 60 billion euros from March 2015 to March 2016, 80 billion euros from April 2016 to March 2017, 60 billion euros from April 2017 to December 2017, 30 billion euros from January 2018 to December 2018, and 15 billion euros from October 2018 to December 2018.

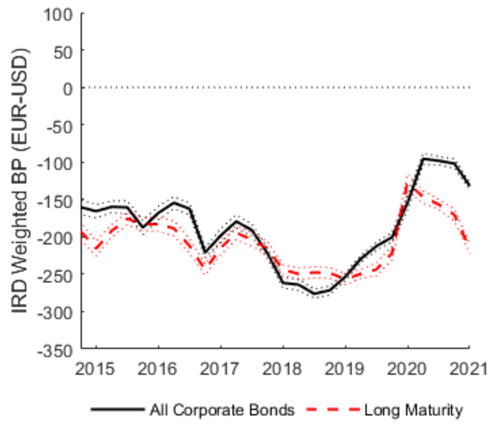
25 See for instance Engel (2016).

26 See Dedola et al. (2021), who study the impact of the ECB quantitative easing policies on euro-dollar exchange rate using a local projection specification of the UIP.

Figure 15
Asset purchases and return differentials

Figure 15 shows in the top panel the flows and cumulative stocks of the asset purchase programme and in the bottom panel the baseline return differentials. Sample period is 2013-2019.





The dependent variable is the weighted estimated residual. This is meant to capture the re-balance toward the assets experiencing the UIP deviations. Results are shown in Table 2. The coefficient is negative and significant, mostly so when we employ the residual estimated solely on long maturity bonds. This confirms the significance of the asset purchase shock in driving investor demand.

5. A Model with Dynamic Portfolio Optimization and Investor Heterogeneity

Our evidence shows that investors have heterogenous asset demand, which also responds differently to shocks. Asset demand of institutional investors is a consequence of their

Table 2

Regressing the investor differential, α, estimated from the first stage on the (net) stock of asset purchased (at current period in first row and 1-month lagged in second row) by the European Central Bank during the sample period 2013-2020. Dependent variables are the estimated investor differential estimated under a weighted UIP specification, either with all bonds (columns 1 and 2) or only with long maturity bonds (columns 3 and 4). The regression is done with robust standard error. P-values indicated as: *** p<0.01, ** p<0.05, * p<0.1.

	(1) UIP Residual Weighted All Bonds	(1) UIP Residual Weighted All Bonds	(3) UIP Residual Weighted Long Maturity	(4) UIP Residual Weighted Long Maturity
Total Stock	-0.00018		-0.00027***	
	(0.00011)		(0.00007)	
Stock Lagged		-0.00018		-0.00027***
		(0.00011)		(0.00006)
Constant	-0.20519	-0.21170	-0.70327***	-0.71485***
	(0.21884)	(0.20929)	(0.11611)	(0.10884)
Observations	26	26	26	26
R-squared	0.083	0.086	0.366	0.375

clientele risk-attitudes and regulation. More generally differences in risk attitudes conceptualize UIP deviations, while differences in regulation across investors conceptualize CIP deviations. Our empirical evidence examines both. In this section we lay down an open economy model in which investors perform dynamic portfolio optiimization choosing bonds in domestic and foreign currency.[27] We start by deriving currency return differentials due to investors' demand, so that deviations can map the empirical counterparts. Specifically, UIP deviations are obtained through heterogeneity in investors' risk-attitudes[28], exploiting in particular the role of time-varying risk-attitudes. Recent literature (see for instance Verdelhan (2010)) has shown that the time-varying risk attitudes induced by reference dependent preferences are well suited to explain the dynamic of UIP deviation, also in line with the Fama (1984) puzzle. Heterogeneity in risk attitudes also explains the differences in the investors' elasticities of their portfolio shares to returns, something which we derive analytically. We instead model CIP deviations through regulatory constraints. The notion

27 Likewise in the household finance literature, institutional investors perform portfolio optimization by taking into account clientele preferences. See Campbell (2006).

28 The notion that heterogeneity of investor preferences or risk-attitudes may matter for returns' differentials across countries has already been spelled out in Gourinchas et al. (2010).

that differences in regulation or market access across investors affect CIP deviations has been formalized recently by Ivashina et al. (2015), Du et al. (2018), Gabaix and Maggiori (2015), Lustig and Verdelhan (2019) or Gourinchas et al. (2022) among others. Within the model we also discuss how shocks, akin to the asset purchases, affect the portfolio shares and the return differentials.

5.1. Dynamic Portfolio Optimization.

Given the supply of bonds we start to lay down the optimization problem of one class of investors living in the euro area, to which we often refer as the domestic economy. The model is framed in a two country context and the problem of foreign investor is symmetric. Investor classes are identified by their preferences, which may differ by their risk-attitudes. For the time being we focus on one class of investors (and skip the investor index for notational convenience). Later on we introduce two and examine their role for pricing and portfolio rebalance. Domestic investors choose euro-denominated nominal bonds issued domestically (sometimes called domestic bonds), which we denote by $B_{h,t}$, and dollar-denominated nominal bonds issued abroad, which we denote by $B_{f,t}$ (sometimes called foreign bonds), to maximize their clientele expected discounted utility, $\sum_{t=0}^{\infty}\beta^t E_t[U(C_t)]$, subject to their budget constraint:

$$P_tC_t + B_{h,t} + e_tB_{f,t} = (1+i_{t-1})B_{h,t-1} + (1+i^*_{t-1})e_tB_{f,t-1} + P_tY_t$$

where E_t is the expectation operator with respect to the information set at time t, β is the time discount, P_t is the price level in the domestic economy, $B_{h,t-1}$ pay an interest $(1+i_{t-1})$ one period later, $B_{f,t-1}$ pay $(1+i^*_{t-1})$ one period later, e_t is the nominal exchange rate expressed in euro-dollar and Y_t is exogenous real income. In the benchmark model we assume no default risk for securities. In our empirical specification we had included securities rating and maturity dummy as well as fixed effects to account for firm risk. In Appendix E.1 we show how the model-based UIP can accommodate those additional deviations due to asset risk-premia by introducing default risk for foreign issued bonds.

Investors in the foreign economy have a similar budget constraint:

$$P^*_tC^*_t + \frac{B^*_{h,t}}{e_t} + B^*_{f,t} = (1+i_{t-1})\frac{B^*_{h,t-1}}{e_t} + (1+i^*_{t-1})B^*_{f,t-1} + P^*_tY^*_t$$

where the $*$ sign indicates foreign variables, hence $B^*_{h,t}$ and $B^*_{f,t}$ are respectively foreign holdings of domestic and foreign currency bonds.

Our model is an international finance monetary model that requires the price of all assets and the nominal exchange rate to be determined. The literature has taken different approaches. Our model, in which the supply of bonds is exogenous, follows the Helpman-Lucas tradition.[29] Specifically, investors have cash holdings, whose role is to pin down the price level. Underlying is the classical assumption upon which all cash is used to purchase good and all purchases are made in local currency, even when carried out by foreign residents. Being M_t the money balance of euro investors, the domestic and foreign price levels are determined by: $P_t = \frac{M_{t-1}}{Y_{t-1}}$ and $P^*_t = \frac{M^*_{t-1}}{Y^*_{t-1}}$. In principle cash holdings enter the budget constraint, but we skip them for convenience since they do not affect the optimal portfolio conditions. The nominal exchange rate is determined by the market clearing conditions on the foreign exchange market, in which investors trade the currency flows needed to buy the foreign bonds. We will return on this in section 5.4.

First order conditions for the portfolio optimization problem of domestic and foreign investors read as follows:

$$\frac{U_{c,t}}{P_t} = \beta E_t((1+i_t)\frac{U_{c,t+1}}{P_{t+1}}); \ \frac{U_{c,t}}{P_t}e_t = \beta E_t((1+i^*_t)\frac{U_{c,t+1}e_{t+1}}{P_{t+1}}) \tag{6}$$

$$\frac{U_{c^*,t}}{P^*_t e_t} = \beta E_t((1+i_t)\frac{U_{c^*,t+1}}{P^*_{t+1}e_{t+1}}); \ \frac{U_{c^*,t}}{P^*_t} = \beta E_t((1+i^*_t)\frac{U_{c^*,t+1}}{P^*_{t+1}}) \tag{7}$$

where $U_{c,t}$ and $U_{c^*,t}$ are the marginal utilities of domestic and foreign investors. Imposing arbitrage for euro-denominated bonds across the two investors, that is equating the returns in the first condition in equations (6) and (7), delivers:[30]

$$E_t(\frac{U_{c,t+1}P_t}{U_{c,t}P_{t+1}}) = E_t(\frac{U_{c^*,t+1}P^*_t e_t}{U_{c^*,t}P^*_{t+1}e_{t+1}}) \tag{8}$$

29 In traditional international business cycle models the exchange rate is determined by the current account relation and by introducing an Armington aggregator of domestically produced and imported goods. In monetary models the exchange rate is usually determined by market clearing conditions: Kouri (1976) and Kouri et al. (1978) use market-clearing in the foreign short-term debt market; Hau and Rey (2004) or Camanho et al. (2018) use the equity market clearing. Finally, Gabaix and Maggiori (2015) introduce, under market segmentation, speculators who determine the exchange rate and Koijen and Yogo (2020) employ market clearing under the assumptions of assets being imperfect substitute.

30 Note that the cross-country arbitrage between the foreign currency bonds would deliver a similar condition as (8).

Let us define x_t as the natural logarithm of the variable X_t and $\hat{x_t}$ as the change of the natural logarithm of X_t from its steady state value. Loglinearizing equation (8) delivers:

$$E_t(\hat{u}^*_{c_{t+1}} + \hat{p}^*_t + \hat{e}_t - \hat{u}^*_{c_t} - \hat{p}^*_{t+1} - \hat{e}_{t+1}) = E_t(\hat{u}_{c_{t+1}} + \hat{p}_t - \hat{u}_{c_t} - \hat{p}_{t+1}) \tag{9}$$

Upon defining the real exchange rate as $S_t = \frac{e_t P^*_t}{P_t}$, we can rewrite equation (8) as:

$$E_t(\hat{u}^*_{c_{t+1}} - \hat{u}^*_{c_t} + \hat{s}_t - \hat{s}_{t+1}) = E_t(\hat{u}_{c_{t+1}} - \hat{u}_{c_t}) \tag{10}$$

Defining the real stochastic discount (SDF) factors as $\mathcal{M}^h_{t,t+1} = \beta \frac{U'_c(C_{t+1})}{U'_c(C_t)}$ for domestic investors and $\mathcal{M}^f_{t,t+1} = \beta \frac{U'_c(C^*_{t+1})}{U'_c(C^*_t)}$ for foreign investors simplifies equation (10) to:

$$E_t(\hat{m}^f_{t,t+1} - \hat{m}^h_{t,t+1}) = E_t(\hat{s}_{t+1} - \hat{s}_t) \tag{11}$$

where $\hat{m}^h_{t+1}$ and $\hat{m}^f_{t+1}$ are the loglinear expressions for the SDFs of domestic and foreign investors. Define $(1 + r_t) = \frac{(1+i_t)}{1+\pi_t}$ and $(1 + r^*_t) = \frac{(1+i^*_t)}{1+\pi^*_t}$, where $1 + \pi_t = \frac{P_{t+1}}{P_t}$ and $1 + \pi^*_t = \frac{P^*_{t+1}}{P^*_t}$. Finally, using the equations (6) and (7) we obtain that $\hat{r}_t = -logE(\mathcal{M}^h_{t,t+1})$ and $\hat{r}^*_t = -logE(\mathcal{M}^f_{t,t+1})$. Note that, if SDFs are lognormal, we can define equation (11) as:

$$E_t(\hat{s}_{t+1} - \hat{s}_t) = \hat{r}_t - \hat{r}^*_t + \frac{1}{2}[Var(\hat{m}^h_{t,t+1}) - Var(\hat{m}^f_{t,t+1})] \tag{12}$$

Equation (12) highlights the link between UIP deviation and risk premia across different investors. In the next section we show how differences in investors' risk-attitudes induce deviations in UIP and as such they provide a micro-foundation for the α coefficient that characterizes equation (11). Following that we show how differences in regulations can induce CIP deviations.

5.2. UIP Deviations: Heterogeneity in Investors' Risk-Attitudes

In this section we show how differences in investors' preferences can induce UIP deviations. We start with classical CES preferences. We then move to reference-dependent utilities for two reasons. First, a recent literature (see Verdelhan (2010), Colacito and Croce (2013) or Bacchetta and Van Wincoop (2006) among others) argues that time-varying risk-attitudes are well suited to capture the dynamics of UIP deviations, especially in light of the Fama (1984) puzzles. For the purpose of the analytical derivations we place the source of uncertainty in consumption growth $\Delta\hat{c}_{t+1}$ and assume that it follows a normal distribution.

CES preferences. Under CES preferences $U(C_t) = \frac{C_t^{1-\sigma}}{1-\sigma}$ and hence the mean and expected value of the loglinear SDF are equal to $E_t(\hat{m}^h_{t,t+1}) = -\sigma E_t(\Delta\hat{c}_{t+1})$, and $Var(\hat{m}^{euro}_{t,t+1}) = \sigma^2 Var(\Delta\hat{c}_{t+1})$. If consumption growth follows a log normal distribution, the SDF follows a normal distribution. Hence $\hat{r}_t = -logE(\mathcal{M}^h_{t,t+1}) = -E_t(\hat{m}^h_{t,t+1}) - \frac{1}{2}Var(\hat{m}^h_{t,t+1})$ and $\hat{r}^*_t = -logE(\mathcal{M}^f_{t,t+1}) = -E_t(\hat{m}^f_{t,t+1}) - \frac{1}{2}Var(\hat{m}^f_{t,t+1})$. Substituting those expressions into equation (11) delivers:

$$E_t(\hat{s}_{t+1} - \hat{s}_t) = \hat{r}_t - \hat{r}^*_t + \frac{1}{2}\sigma^2[Var(\Delta\hat{c}_{t+1}) - Var(\Delta\hat{c}^*_{t+1})] \tag{13}$$

Remark 1. *The UIP deviation is given by the difference in risk premia required by investors,* $[\frac{(\sigma)^2}{2}(Var(\Delta\hat{c}_{t+1})) - (Var(\Delta\widehat{c^*_{t+1}}))]$. *Investors with higher risk aversion require higher premia that respond more to shocks.*

Few considerations are worth. First, the UIP deviation obtained above depends on investor preferences, hence on their demand or required average premium. For this reason it parallels the investor residual characterizing our empirical specifications for the return differential, namely the α. Second, the premium required by investors who are more risk averse responds more to shocks that affect risk. If an expansionary monetary policy reduces consumption risk, the required premium of investors with higher σ declines by more. This is in line with the larger decline of euro returns observed for ICPF investors.

At last, under a CES specification the risk-aversion parameter is constant. However, the investor residual in our empirical analysis declined significantly more with respect to the size of the monetary shock. This would be well captured by preferences exhibiting time-varying risk aversion. For this reason we now consider reference-dependent preferences, for which consumption risk loads onto the investor residual with a time-varying parameter. We consider the class of reference-dependent or habit preferences from Campbell and Cochrane (1999) as this has been shown to explain well UIP deviations and international asset pricing (seeVerdelhan (2010)).

Reference-dependent Preferences: Habits. We start with the class of preferences introduced by Campbell and Cochrane (1999) and by Verdelhan (2010) in an open-economy context. In this case the utility function depends upon the deviation of consumption from a reference level, which is given by past consumption. The deviation reads as follows: $X_t = \frac{C_t - H_t}{C_t}$, where H_t represents the habit. Employing the classical constant elasticity specification, the instantaneous utility function reads as follows: $U(C_t) = \frac{(C_t - H_t)^{1-\sigma}}{1-\sigma}$. The SDF in real terms is:

$$\mathcal{M}_{t,t+1} = \beta \left(\frac{C_{t+1} - H_{t+1}}{C_t - H_t} \right)^{-\sigma} = \beta \left(\frac{X_{t+1} C_{t+1}}{X_t C_t} \right)^{-\sigma} \tag{14}$$

The link between marginal utility and past consumption induces a time-varying absolute risk aversion coefficient. The larger the change of consumption deviation from the reference level in response to shocks, the higher the degree of investor risk-tolerance. Following Campbell and Cochrane (1999) and Verdelhan (2010), consumption growth is log normally distributed and the log of the consumption surplus, $x_t = log(X_t)$, moves according to the Markov process: $x_{t+1} = \nu x_t + (1-\nu)\overline{x} + \lambda(x_t)(\Delta \hat{c}_{t+1})$, where $\lambda(\hat{x}_t)$ gives the sensitivity of the surplus consumption ratio to consumption growth.[31] Hence given the process for the log normal distribution, it follows that the expected log linear SDF is:

$$-E_t \hat{m}_{t,t+1} = \hat{r}_t + \frac{1}{2} var(\hat{m}^h_{t,t+1}) = \hat{r}_t + \frac{1}{2} \sigma^2 (1 + \lambda(\hat{x}_t))^2 Var(\Delta \hat{c}_{t+1}) \tag{15}$$

for $\nu = 1$. Investors' risk-attitudes are defined by a time-varying coefficient of relative risk aversion, $\sigma^2(1 + \lambda(\hat{x}_t))^2$. When the surplus consumption ratio grows, the relative risk aversion coefficient declines. In face of large positive shocks, like an expansionary monetary policy, investors would assign lower price to future risk and would require lower risk premia, thereby flattening the yield curve. The more so, the larger their λ.

Using equation (15) and the foreign investor equivalent in equation (11) the UIP reads as follows:

$$E_t(\hat{s}_{t+1} - \hat{s}_t) = \hat{r}_t - \hat{r}^*_t + \frac{1}{2} \sigma^2 (1 + \lambda(\hat{x}_t))^2 [var(\Delta \hat{c}_{t+1}) - var(\Delta \hat{c}^*_{t+1}))] \tag{16}$$

Different Investor Classes. So far we have assumed that each country was populated by a single class of investors. Our data show that this is not the case and that different investors required different premia. In the parlance of the model this implies that investors have different degrees of risk-sensitivity. In the case of two investors, whose

31 Both studies also assume a positive consumption growth in the long run. Compatibly with our empirical analysis, which features a short sample, we set this to zero.

risk aversion parameters are respectively σ_1 and σ_2, their required premia would be $\frac{1}{2}\sigma_1^2(1+\lambda(\hat{x}_t))^2[var(\Delta\hat{c}_{t+1}) - var(\Delta\hat{c}^*_{t+1}))]$ and $\frac{1}{2}\sigma_2^2(1+\lambda(\hat{x}_t))^2[var(\Delta\hat{c}_{t+1}) - var(\Delta\hat{c}^*_{t+1}))]$. Reasonably ICPF represent more risk-averse or more risk-sensitive clienteles, hence their required premium declines by more in face of a decline in risk, triggered for instance by an expansionary policy. This would explain the larger decline observed in the data for assets eligible for the ECB purchase programme and held by ICPF.

Remark 2. *Under reference-dependent preferences the model based investor residual is given by* $\lambda(\hat{x}_t)[var(\Delta\hat{c}_{t+1}) - (\hat{x}_t)var(\Delta\hat{c}_{t+1})]$. *Investors with larger* λ *require premia which are more responsive to changes in consumption risk.*

In Appendix E.2 we also derive UIP deviations under a more general class of reference-dependent preferences, which include loss aversion. Those are particularly well suited also to capture the different gradation of responses to large shocks, such as those stemming from asset purchases.

5.3. CIP Deviations: Regulatory Constraints

Heterogeneity in institutional investor demand may arise because of differences in the risk attitudes of their clientele or because of differences in regulation. The presence of a constraint creates a limit to arbitrage that leads to CIP deviations (see also Ivashina et al. (2015), Du et al. (2018)). Furthermore, since different institutional investors face different regulatory constraints this leads to differences in limits to arbitrage.

First it is useful to detail some background. The institutional investors in our data are subject to different regulation. Some like ICPF are subject to stricter regulation, as this serves also the purpose of protecting the interest of their clientele who prefers safer investment. For instance Article 188 of the Solvency regulation, which applies to insurance and pension funds in Europe, requires additional capital charges for investment in foreign currency. There are general guidelines on how to cover currency risk, but the exact regulatory requirement eventually depends on the institutional investor exposure to currency risk, as represented by the type of debt instruments used, by the risk model adopted internally and by the type of hedging strategies. Hence, while it is not possible to design an exact prudential constraint, our goal here is to examine the impact on the average investor residual, hence on CIP deviations, of a cap on foreign currency exposure.

Cap on foreign currency exposure take the general form:

$$\frac{B_{f,t}}{B_{f,t}+B_{h,t}}=\kappa \tag{17}$$

Let us define μ_t as the Lagrange multiplier on constraint 17. The adjusted Euler equation on foreign bonds reads as follows:

$$\frac{U_{c,t}}{P_t}=\beta E_t(1+i_t^*)e_t\frac{U_{c,t+1}}{P_{t+1}}+\mu_t(1-\kappa) \tag{18}$$

Expressing 18 in real terms and loglinearizing delivers $E_t\hat{r}_t^*=E_t(\hat{u}_{c,t}-\hat{u}_{c,t+1})-\hat{\mu}_t$ and equating as before marginal utilities and asset returns by arbitrage delivers the adjusted return differential:

$$E_t(\hat{u}_{c,t+1}-\hat{u}_{c,t}+\hat{\mu}_t+\hat{s}_{t+1}-\hat{s}_t)=E_t(\hat{u}_{c,t+1}^*-\hat{u}_{c,t}^*) \tag{19}$$

where the steady state level of bonds has been set so that $\overline{\mu}$ becomes equal to one. The percentage variations in the Lagrange multiplier in this case contribute to the investors' residual, namely the estimated α in the data. The Lagrange multiplier acts as the shadow price of regulation and provides the extent of the costs in the limit to arbitrage. Importantly as different institutional investors face different regulatory constraints, they also face differences in their limits to arbitrage.

Upon substituting the SDF in E.2 and assuming the usual lognormal distribution, we can re-write E.2 as:

$$E_t(\hat{s}_{t+1}-\hat{s}_t)=\hat{r}_t-\hat{r}_t^*+\frac{1}{2}[Var(\hat{m}_{t,t+1}^h)-Var(\hat{m}_{t,t+1}^f)]-E_t(\mu_{t+1}) \tag{20}$$

The above expression provides a first assessment of the risk rebalance channel, discussed further below. Asset purchases by reducing the returns on euro-denominated bonds result in a decline of the risk component, $Var(\hat{m}_{t,t+1}^h)$. This in turn, by reducing the right hand side on impact, and for given exchange rate, results in an increase in the shadow price or regulatory cost of holding foreign bonds. This is the sense in which a reduction in the risk of euro-denominated assets, as fostered for instance by the asset purchases, can incnetivize their holdings.

5.4. Rebalance and The Impact of Asset Purchase Programmes

Following most international finance monetary models we close our model with a set of market clearing conditions, that jointly with the optimal portfolio weights, allow to determine asset prices. At any time t the outstanding value of securities is taken as given, along the tradition of endowment economies (see Lucas Jr (1978)). Given the outstanding amounts of each asset i, which we denote by $\mathcal{S}_{i,t}$, and assuming two investors home and foreign, the market clearing condition reads as follows:

$$MV_{i,t}\mathcal{S}_{i,t} = \omega_{i,t}W_t + \omega^*_{i,t}W^*_t \tag{21}$$

where MV is the market value of outstanding securities, ω^*_i ($= \omega_{i,t}$) is the optimal portfolio share of asset i held by foreign (home) investor in the domestic economy. W^j_t is wealth of domestic investor and $W^{j,*}_t$ is wealth of foreign investor. [32] This leads to the following portfolio share:

$$\omega_{i,t} = \frac{MV_{i,t}\mathcal{S}_{i,t} - \omega^*_{i,t}W^*_t}{W_t} \tag{23}$$

Note that to buy (sell) foreign assets investors need to do a corresponding transaction in the foreign exchange market. The market clearing in the latter determines the level of the nominal exchange rate.

Definition. *The asset purchase programme manifest as a change in the set of outstanding euro-denominated assets. Define AP_t as the amount of asset purchases of euro-denominated bonds issued by euro area firms, it follows that:*

$$\omega_{i,t} = \frac{MV_{i,t}(\mathcal{S}_{i,t} - AP) - \omega^*_{i,t}W^*_t}{W_t} \tag{24}$$

where $\omega_{i,t}$ is the portfolio share of bonds issued by euro area firms and held by investors resident in the euro area.

An increase in asset purchases acts like a drain in supply. For given demand (portfolio) shares, the market clearing condition remains valid if the valuation of the assets increases.

32 Note this could be easily extended to two types of investors in each market. For example for OFI and ICPF, the market condition would look like

$$MV_{i,t}\mathcal{S}_{i,t} = \omega^{ofi}_{i,t}W^{ofi} + \omega^{icpf}_{i,t}W^{icpf}_t + \omega^{ofi^*}_{i}W^{ofi^*}_t + \omega^{icpf^*}_{i,t}W^{icpf*}_t \tag{22}$$

This captures the essence of the local supply channel, namely the impact that monetary policy has on prices through the local market clearing condition.

As we describe in the appendix, using this market clearing condition and Taylor expansions we derive optimal portfolio share solution. [33].

Proposition 1. *Optimal portfolio shares read as follows:*

$$\omega_h = \frac{\mathcal{S}}{2} - \frac{1}{2} V_{xx}^{-1} V_{xD} \tag{25}$$

where the vector $V_{xx} = E((\hat{r}_t - \hat{r}_t^* - \hat{s}_{t+1} + \hat{s}_t)^2)$ *and* $V_{xD} = E(\{(\hat{y}_{t+1} - \hat{y}_{t+1}^*) + (\hat{w}_{t+1} - \frac{\hat{w}_t}{\beta}) - (\hat{w}_{t+1}^* - \frac{\hat{w}_t^*}{\beta})\}(\hat{r}_t - \hat{r}_t^* - \hat{s}_{t+1} + \hat{s}_t))$.

Proof. See Appendix E.3.

The above portfolio shares, despite being obtained in a dynamic and more complex model, behave much in line with classical ones derived under a simple mean variance optimization. In the standard mean/variance optimizations, portfolio shares increase when risk declines and increase when return increase. In our more complex case these share movements in responses to changes in the mean and variance of the return differential are tied down to the sign of V_{xD}.

Note that V_{xD} is a proxy for the covariance between the the wealth of the home investor relative to the foreign investor and the uncovered interest rate parity (home -foreign). If this value is negative it indicates that home investor expected to be wealthier when its home currency bond return declines in relative terms. In appendix E.4 we discuss how this condition captures a rebalance linked to arbitrage opportunities. This negative covariance has three important implications: home currency portfolio bias, risk rebalance and search for yields. Next we elaborate each of these.

First, it is clear to see from equation (E.23) that, since V_{xx} is always non-negative, a $V_{xD} < 0$ leads to a portfolio share higher than 50%. This is in line with the share of euro-denominated assets observed for ICPF. Next we show how this condition also leads

33 These methods were originally designed in Samuelson (1958) and Judd (1998) and latter applied to dynamic open economy models by Devereux and Sutherland (2011) and Tille and Van Wincoop (2010).

to the channels that drive the impact of monetary policy in portfolio shares.

Corollary 1. Risk Rebalance Channel. *The elasticity of the portfolio share in equation E.27 reads as follows* $\frac{\partial w_h}{\partial V_{xx}} = \frac{1}{2}\frac{V_{xD}}{V_{xx}^2}$ *and is negative when* V_{xD} *is negative.*

Proof. *See Appendix E.4.*

The above corollary captures the essence of the rebalance channel. When risk declines, due for instance to the decline in excess returns from the asset purchases, the share increases. This is consistent with the rise in shares observed in the data and induced by the asset purchase programmes. Interestingly this channel materializes when $V_{xD} < 0$ and investors rebalance.

Corollary 2. Search for yields. *The elasticity of the portfolio shares to the* $UIP = E_t[\hat{r}_t - \hat{r}_t^* + \hat{s}_t - \hat{s}_{t+1}]$ *is positive if and only if* $V_{xD} < 0$.

Proof. *See Appendix E.5.*

The above corollary captures the essence of the valuation or yield seeking channel that materializes when $V_{xD} < 0$. A decline in the euro-dollar returns differential induces a decline in the portfolio share of the lower yielding asset.

Channel Combination. The two channels described above have two implications. First, they extend to a dynamic portfolio optimization with general preferences the channels behind the classical mean-variance optimization. Portfolio shares decline with the returns and increase when risk declines. The type of shocks which materialized in our data, namely the drain in euro-denominated asset supply, induced at the same time a decline in the returns and in their risk. Based on the model the two channels would push the portfolio shares in opposite direction. Our estimation of the rebalance (see 5.4) however shows that shares of euro-denominated securities increased. This result can be reconciled with the model only if the risk rebalance channel prevails over the return seeking channel.

6. Conclusions

Leveraging on a unique confidential securities dataset we study the role of institutional investors' excess demand for the pricing of corporate bonds across currencies. The latter have far reaching consequences for asset safety and for global firms funding conditions. Motivated by a set of stylized facts showing a stark currency preference segmentation between insurance and mutual funds, we devise an econometric methodology that identifies investor demand contribution to the euro-dollar yield differential for the same type of security, issued by the same type of firms. To measure the responsiveness of investor demand we also exploit the large shock represented by the ECB asset purchase programme.

Over our sample period we find a decline in the average investor demand for euro-dollar return differential. This decline persists and is sizable even when we estimate swap contracts hedged differentials and provides a sign of the shift of convenience yield from the dollar to the euro. The sample period under consideration is particularly apt for spotlighting the channels underlying the dynamic of the investors' contributions to the yields. The asset purchase programme by the European Central Bank have engineered scarcity of euro-denominated securities issued by euro area firms, which were in high and rising demand by large investors such as insurance and pension funds. Excess demand induced a rise in the valuation of euro bonds and a decline in their yields. The ensuing fall in risk induced those investors to a further rebalance toward the euro securities.

The importance of our findings is broader than the specific shocks analyzed, as it speaks to the consequences of stable investor demand for bond pricing. It also provides insights on the determinants of the UIP and CIP deviations and of the asset safety.

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Internet Appendix

A. Euro Area Confidential Securities Data.

The Securities Holdings Statistics (SHS), collected on a security-by-security basis, provide information on securities held by selected categories of euro area investors, broken down by instrument type, issuer country and further classifications.

Securities holdings statistics 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 cover 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 Sector data provides information on holdings by investor types.

The SHS by investor provides aggregate information on the holdings of investor types in line with European regulation. We differentiate in this paper between the following investors: banks, government, money market funds, non-financial corporations, households, insurance companies, investment funds, other investors, pension funds, and non-European Monetary Union investors.

Securities holdings include holdings by (i) investors residing in the euro area, such as banks in Italy or households in France, and (ii) non-resident investors' holdings of euro area securities that are deposited with a euro area custodian, such as US investors' holdings of German securities deposited in Luxembourg. In addition, non-euro area EU countries (Bulgaria, the Czech Republic, Denmark, Hungary, Poland and Romania) also collect SHS investor type data.

The holding information is complemented 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.

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. We apply some standard cleaning following filters provided by SHSS (TPH filter and security status filter). In addition, securities which have not been redeemed yet, but have a negative residual maturity can still be reported in the investors holdings portfolio. Thus we do not include holdings for securities with negative residual maturity according to CSDB.

In terms of investors' types, the SHS defines 22 different types of investors, which they call "sectors." We group these "sectors" into 10 distinct investor types. Most investor types correspond to the definition in the original dataset. These include banks (e.g., commercial banks, savings banks), investment funds (e.g., open-ended investment funds, closed-ended investment funds, funds of funds, hedge funds), insurance companies, money market funds (MMFs), pension funds, and households (direct holdings). We group related and remaining sectors into the following four investor types: government, non-financial corporations, others (less prominent investors, e.g., non-profit, other financial institutions, or social security funds), and non-euro area investors.

B. Appendix: Data Trimming

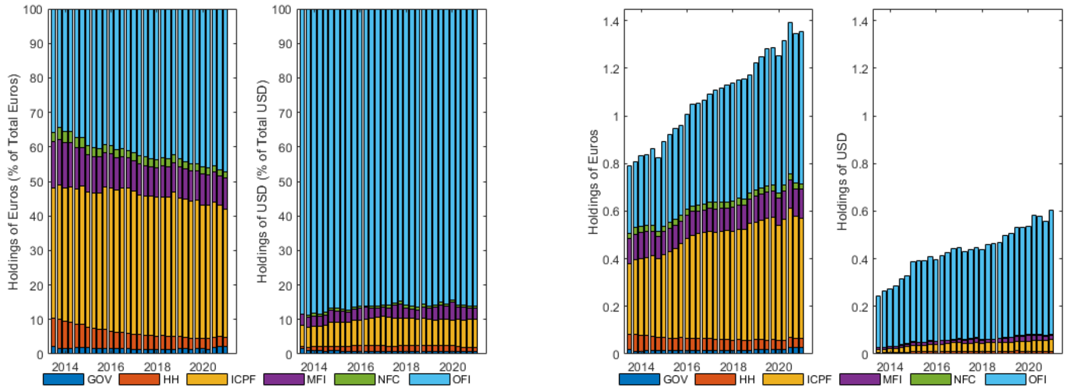
The dataset contains around 16000 unique different ISINs in 2013 Q3. Around 3000 ISINs have to be excluded because of missing pricing information and an additional 2000 ISINs are also excluded because firm FE drops all observations which appear only for one firm. The pattern is more or less the same for all quarters, but we have an increasing number of ISINs and less missing pricing information over time.

The data on the yield variable has been trimmed by dropping observations below 1% and 99% at each quarter to control for outliers. We performed manual checks on these and found that and the outliers exist primarily due to misreporting. This drops only around 10630 observations for the whole panel of about 533,000 observations – around 2% of the whole dataset.

Table A1
Summary Statistics of euro and dollar-denominated bonds by maturity

	Full Dataset		Euro Denominated		Dollar Denominated	
	Mean	Median	Mean	Median	Mean	Median
Residual maturity	7.2	4.1	3.6	1.0	10.0	6.0
Original Maturity	10.7	8.0	5.8	4.2	14.6	10.0

Figure C1
Currency Break down of all non-financial corporate debt securities - Type of Investors
Figure C1 shows a break down of all non-financial corporate debt securities in U.S. Dollars and euros and per type of investor, namely government (GOV), households (HH), insurance companies and pension funds (ICPF), monetary financial institutions (MFI), non-financial corporations (NFC) and other financial institutions (OFI). Left panel shows volumes, right panel shows shares. Sample period 2013 Q3 - 2021 Q1. Left panel shows shares denominated in euros and right panel shows shares denominated in Dollars.

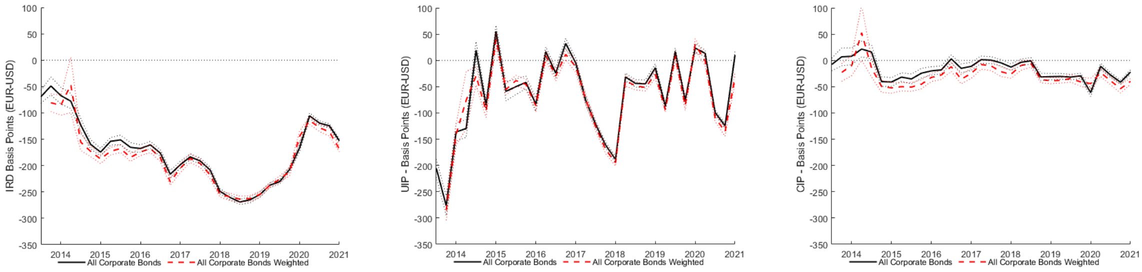


C. Other Tables and Figures

Figure C2, C5 and C4 replicate the equivalents in the main text, but considering all bonds with maturity above 6 months. Results remain robust.

Figure C2
Euro-dollar returns differential, UIP and CIP on SHSS sample

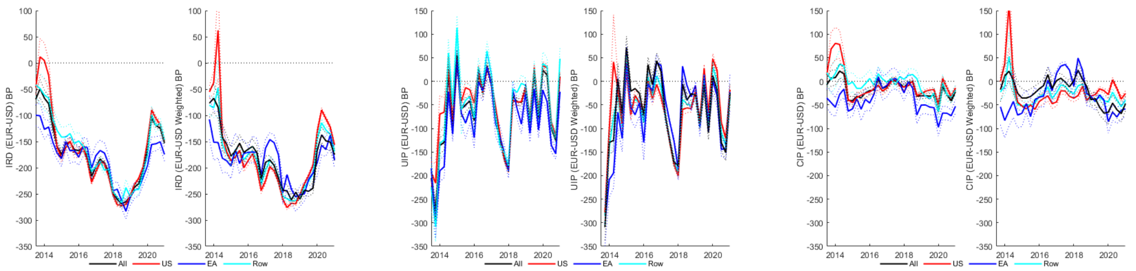
Figure C2 plots results for the un-hedged interest rate differential (left panel), the uncovered interest rate party (middle panel) and the covered interest rate parity (right panel), all estimated on the SHSS sample from 2013 Q3 - 2021 Q1, including all bonds with maturity above 6 months. Each panel compares the differentials weighted with portfolio weights (red and dashed line) with the un-weighted (black and solid line). Econometric specification is: $y_{i,t} = \alpha_t \mathcal{I}_{EUR,i} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t}$, where $y_{i,t}$ is the local currency yield for bond i traded in the secondary market at time t. 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. The regressions are estimated in the cross-section at each date t. Standard errors are clustered at the fixed effect variable.



(a) Returns Differentials **(b)** Uncovered interest parity **(c)** Covered Interest Rate Parity

Figure C3
Euro-dollar returns differential, UIP and CIP -Break down per investor type

Figure C5 plots results for the un-hedged interest rate differential (left panel), the uncovered interest rate party (middle panel) and the covered interest rate parity (right panel) for all bonds (black line), for the sub-samples of bonds issued by U.S. firms (red line), euro area firms (dark blu line) and rest of the world (light blu line). Sample period is 2013 Q3 - 2021 Q1 and samples included all bonds with maturity above 6 months. Each panel compares the differentials weighted with portfolio weights (red and dashed line) with the un-weighted (black and solid line). Econometric specification is: $y_{i,t} = \alpha_t \mathcal{I}_{EUR,i} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t}$, where $y_{i,t}$ is the local currency yield for bond i traded in the secondary market at time t. 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. The regressions are estimated in the cross-section at each date t. Standard errors are clustered at the fixed effect variable.

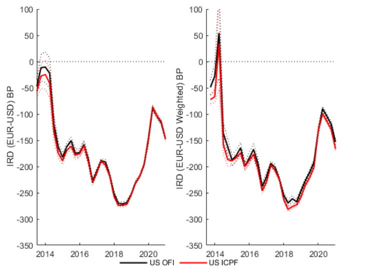


(a) Returns Differentials **(b)** Uncovered Interest Parity **(c)** Covered Interest Rate Parity

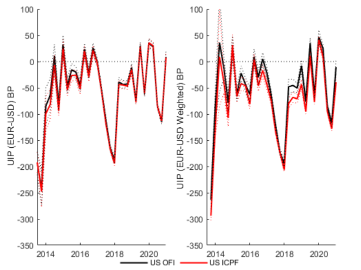
Figure C4

Euro-dollar returns differential, UIP and CIP - Break down per residence of issuer

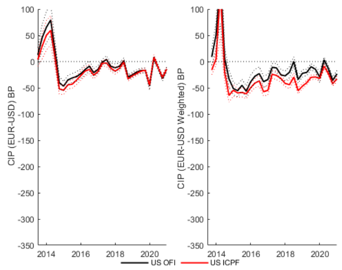
?? plots results for the un-hedged interest rate differential (left panel), the uncovered interest rate party (middle panel) and the covered interest rate parity (right panel) for the sub-samples of bonds held by OFI (black lines) and by ICPF (red line). Top three panels shows estimations on subsample of bonds issued by U.S. firms, bottom panels instead for firms from the rest of the world. Sample period is 2013 Q3 - 2021 Q1 and samples included all bonds with maturity above 6 months. Each panel compares the differentials weighted with portfolio weights (red and dashed line) with the un-weighted (black and solid line). Econometric specification is: $y_{i,t} = \alpha_t \mathcal{I}_{EUR,i} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t}$, where $y_{i,t}$ is the local currency yield for bond i traded in the secondary market at time t. 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. The regressions are estimated in the cross-section at each date t. Standard errors are clustered at the fixed effect variable.



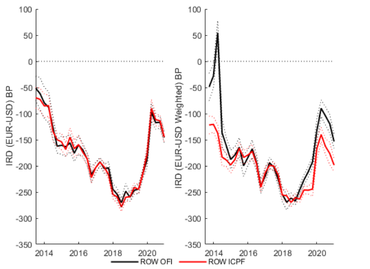
(a)
Returns Differentials - U.S. Firms



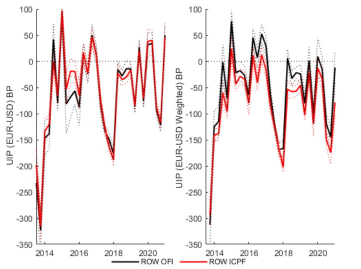
(b)
Uncovered Interest Parity - U.S. Firms



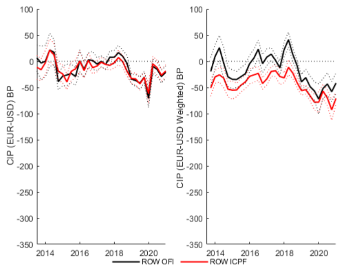
(c)
Covered Interest Rate Parity - U.S. Firms



(d)
Returns Differentials - R.o.W. Firms



(e)
Uncovered Interest Parity - R.o.W.. Firms

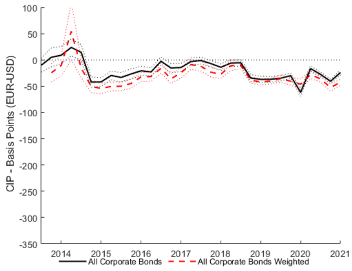


(f)
Covered Interest Rate Parity - R.o.W. Firms

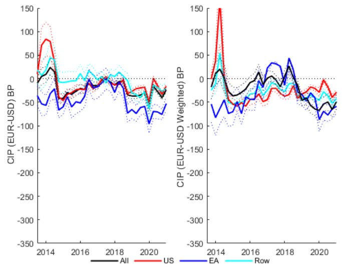
Figure C5

Euro-dollar returns differential, CIP using forward rates - All securities and sub-samples

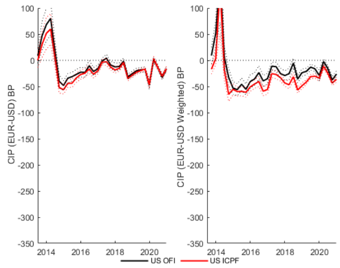
Figure C5 plots results for the hedged interest rate differential using forward rates. Each sub-panel plots results for different samples. Sample period is 2013 Q3 - 2021 Q1 and samples included all bonds with maturity above 1 year. Econometric specification is: $y_{i,t} = \alpha_t \mathcal{I}_{EUR,i} + \beta_{f,t} + \gamma_{m,t} + \delta_{r,t}$, where $y_{i,t}$ is the local currency yield for bond i traded in the secondary market at time t. 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. The regressions are estimated in the cross-section at each date t. Standard errors are clustered at the fixed effect variable.



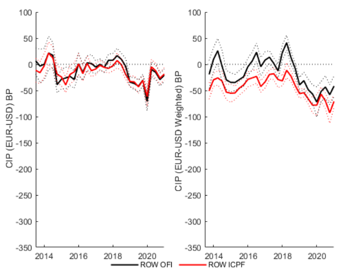
(a)
CIP All securities



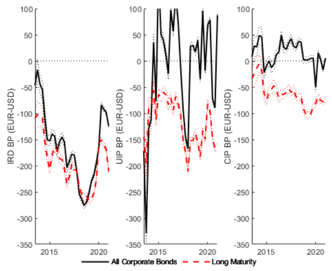
(b)
CIP per area of issuer



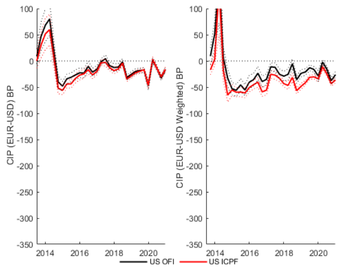
(c)
CIP per investor



(d)
CIP per investor



(e)
CIP for long maturity securities



(f)
CIP for long maturity securities weighted

D. Adjustment by Swap Rates

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

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:

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

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

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

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

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

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:

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

E. Model Derivations

This appendix contains intermediate derivations of results reported in the main text.

E.1. UIP Derivation from Asset and Firm Specific Risk.

Our empirical return differential specification contained also dummies for security and firm risk. We now show how to accommodate within the model those additional deviations in the return differentials.

Let us define $\Theta(e_{t-1}B_{f,t-1})$ as a loss given default that characterizes the security and captures firms' risk.[34] The budget constraint of the domestic investor now reads as follows:

$$P_tC_t + B_{h,t} + e_tB_{f,t} = (1 + i_{t-1})B_{h,t-1} + (1 + i^*_{t-1})\Theta(e_{t-1}B_{f,t-1})e_tB_{f,t-1} + P_tY_t$$

where E_t is the expectation operator with respect to the information set at time t, β is the time discount, P_t is the price level in the domestic economy, $B_{h,t-1}$ pay an interest $(1 + i_t)$ one period later, $B_{f,t-1}$ pay $(1 + i^*_t)$ one period later, where e_t is the nominal exchange

34 This cost is akin to the default premia or the portfolio adjustment costs introduced in Schmitt-Grohé and Uribe (2003).

rate and where Y_t is exogenous real income. In principle the default premium may apply to all bonds, but it will enter the UIP only to the extent that it applies asymmetrically between domestic and foreign bonds and between domestic and foreign investors. This captures the idea that redeploying abilities are typically different across investors and that foreign ones face more information asymmetries. Hence for notational convenience we introduce it only for foreign bonds. The cost then applies only to domestic investors. Hence the budget constraint of foreign investors remains the same as in the main text. First order conditions for the portfolio optimization problem of domestic investors now read as follows:

$$\frac{U_{c,t}}{P_t} = \beta E_t(1+i_t)\frac{U_{c,t+1}}{P_{t+1}}; \frac{U_{c,t}}{P_t}e_t = \beta E_t(1+i_t^*)e_{t+1}(\Theta(e_t B_{f,t})+\Theta_B(e_t B_{f,t})B_{f,t})\frac{U_{c,t+1}}{P_{t+1}} \quad \text{(E.1)}$$

where $U_{c,t}$ is the marginal utility of consumption, $\Theta_B(B_{f,t})$ is the derivative of the default premium with respect to foreign debt. Imposing arbitrage between bonds pricing conditions across countries and loglinearizing now delivers the following UIP:

$$E_t(\hat{u}_{c,t+1} - \hat{u}_{c,t} + \hat{s}_{t+1} - \hat{s}_t + \varepsilon\hat{b}_t) = E_t(\hat{u}^*_{c,t+1} - \hat{u}^*_{c,t}) \quad \text{(E.2)}$$

where all variables have been defined in the main text and where $\varepsilon\hat{b}_t = \frac{\gamma_1}{\gamma}(\hat{\theta}_B + \hat{b}_{f,t}) + (1 - \frac{\gamma_1}{\gamma})\hat{\theta}_t$, $\gamma_1 = \Theta_B(B_f)B_f$ and $\gamma = \Theta_B(B_f)B_f + \Theta(B_f)$ and represents the default risk of the bond. Or equivalently:

$$E_t(\hat{s}_{t+1} - \hat{s}_t) = E_t(\hat{m}^{\$}_{t,t+1} - \hat{m}^{euro}_{t,t+1} - \varepsilon\hat{b}_t) \quad \text{(E.3)}$$

where $E_t\hat{m}^{euro}_{t,t+1} = E_t(\hat{u}_{c,t+1} - \hat{u}_{c,t})$ and $E_t\hat{m}^{\$}_{t,t+1} = E_t(\hat{u}^*_{c,t+1} - \hat{u}^*_{c,t})$ are the loglinear expressions for the real SDFs. Finally using the loglinear expressions, $E_t\hat{r}_t = E_t(\hat{u}_{c,t} - \hat{u}_{c,t+1}) = -E_t\hat{m}^{euro}_{t,t+1}$ and $E_t\hat{r}^*_t = E_t(\hat{u}_{c^*,t} - \hat{u}_{c^*,t+1}) = -E_t\hat{m}^{\$}_{t,t+1}$ into E.3 delivers:

$$E_t(\hat{s}_{t+1} - \hat{s}_t) = E_t(\hat{r}_t - \hat{r}^*_t - \varepsilon\hat{b}_t) \quad \text{(E.4)}$$

Equation E.4 resembles our empirical specification, namely equation 1, in that the interest rate differential equates exchange rate deviations and a bond or firm risk premium. The latter maps the bond and firm fixed effects included in our empirical specification.

E.2. UIP Deviations: Loss-Averse Preferences.

A more general class of reference-dependent utilities is the one that foresee different risk-attitudes toward gains and losses. The class which includes loss aversion has been shown as particularly powerful in explaining asset price facts.[35] An expanding literature has shown that those preferences are successful in explaining a number of asset price facts[36] We therefore consider how they can affect international asset pricing and, hence the UIP deviations. So far, they have never been used in international asset pricing. Their advantage lies in providing a richer characterization of time varying risk-sensitivity, with increasing risk-tolerance in the gain domain and increasing risk-aversion in loss domain. For this reason they are often labelled as S-shaped preferences. They are well suited to capture the gradation of risk-sensitivity to small and large shocks.

The functional form for S-shaped preferences reads as follows $U(C_t, X_t) = \alpha U(C_t) + (1-\alpha)\mathcal{W}(C_t, X_t)$, where $U(C_t)$ is the standard CRRA utility and where:

$$\mathcal{W}(C_t, X_t) = \begin{cases} \frac{\left(\frac{(C_t)^{(1-\sigma)}}{1-\sigma} - \frac{(X_t)^{(1-\sigma)}}{1-\sigma}\right)^{1-\sigma}}{1-\theta}, & \text{if } C_t \geq X_t \\ -\Lambda \frac{\left|\frac{(C_t)^{(1-\sigma)}}{1-\sigma} - \frac{(X_t)^{(1-\sigma)}}{1-\sigma}\right|^{1-\sigma}}{1-\theta}, & \text{if } C_t < X_t, \end{cases} \tag{E.5}$$

The parameter Λ captures the degree of loss aversion and X_t is again a consumption reference level, such as past consumption.

Lemma A1. *The expected stochastic discount factor of S-shaped preferences reads as follows:*

$$\mathbb{E}_t\left\{\mathcal{M}_{t,t+1}\right\} = \frac{\beta}{k(y_t)} \exp\left\{-\sigma\mu + \frac{(\sigma\xi)^2}{2}\right\} \times \left[1 + (\Lambda - 1)F(\sigma\xi + \frac{(\kappa_{t+1} - \mu)}{\xi})\right]$$

where $\mu = E_t(\Delta(\hat{c}_{t+1}))$ and $\xi = Var(\Delta(\hat{c}_{t+1})$, where:

$$k(y_t) = \begin{cases} 1 & \text{if } y_t \geq 0 \\ \Lambda, & \text{if } y_t < 0, \end{cases} \tag{E.6}$$

with $Y_t = \frac{C_t}{X_t}$ being the consumption to habit ratio and all variables in small letters are in

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35 See Kahneman and Tversky (1979) for lab evidence. Kőszegi and Rabin (2009) introduced those preferences into a consumption-saving problem.

36 See Bordalo et al. (2018), Pagel (2016) and Curatola and Faia (2021).

logs. Under $\Lambda = 1$ and $\theta = 0$ the expected value of the logarithm of the expected SDF nests the one derived under CES

Proof.

The stochastic discount factor in this case is given by:

$$\mathcal{M}_{t+1} = \beta G_{t+1}^{\sigma} \frac{k(Y_{t+1})}{k(Y_t)} \tag{E.7}$$

where $G_{t+1} = C_{t+1}/C_t$ and $Y_{t+1} = C_{t+1}/X_{t+1}$ and:

$$k(Y_t) = \begin{cases} (\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{X_t^{1-\sigma}}{1-\sigma})^{-\theta} & for\ Y_t \geq 1 \\ \lambda \mid \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{X_t^{1-\sigma}}{1-\sigma} \mid^{-\theta} & for\ Y_t < 1 \end{cases} \tag{E.8}$$

The parameter θ, which has been found lower than one in the data[37] implies a rising risk-tolerance in the gain domain, $Y_t > 1$. Losses instead, $Y_t > 1$ resonate more than gains, when Λ is larger than one.[38] When $\theta = 0$, we have:

$$k_L(Y_t) = \begin{cases} 1 & for\ Y_t \geq 1 \\ \Lambda & for\ Y_t < 1 \end{cases} \tag{E.9}$$

Following Tallarini (2000) and Yogo (2008), log consumption growth, g_t, is modelled as a normal distribution $N(\mu, \xi^2)$ at any date t. Upon defining $\kappa_{t+1} = x_{t+1} - c_t$., where small letters indicate logs, if $\theta = 0$ it holds that:

$$\mathbb{E}_t \left[\exp(g_{t+1}) \mid g_{t+1} > \kappa_{t+1}\right] = \exp\left\{\mu + \frac{\xi^2}{2}\right\} \frac{F(-(\kappa_{t+1} - \mu - \xi^2)/\xi)}{F(-(\kappa_{t+1} - \mu)/\xi)} \tag{E.10}$$

$$\mathbb{E}_t \left[\exp(g_{t+1}) \mid g_{t+1} < \kappa_{t+1}\right] = \exp\left\{\mu + \frac{\xi^2}{2}\right\} \frac{F((\kappa_{t+1} - \mu - \xi^2)/\xi)}{F((\kappa_{t+1} - \mu)/\xi)} \tag{E.11}$$

where F is the cumulative conditional distribution of the standard normal distribution. The SDF in E.8 in logarithms reads as follows:

$$\mathcal{M}_{t,t+1} = \begin{cases} \frac{\Lambda\beta \exp\{-\sigma g_{t+1}\}}{k(y_t)} & \text{if } g_{t+1} < \kappa_{t+1}, \\ \frac{\beta \exp\{-\sigma g_{t+1}\}}{k(y_t)} & \text{if } g_{t+1} > \kappa_{t+1}, \end{cases} \tag{E.12}$$

37 See Yogo (2008) or Curatola and Faia (2021).
38 This is the value found in most experimental studies starting with Kahneman and Tversky (1979).

Given the above we can compute the first moment of $\mathcal{M}_{t,t+1}$ as follows:

$$\mathbb{E}_t\left\{\mathcal{M}_{t,t+1}\right\} = \frac{\beta}{k(y_t)}(F(-\frac{(\kappa_{t+1}-\mu)}{\xi})\mathbb{E}_t\left[\exp\left\{-\sigma g_{t+1}\right\} \mid g_{t+1} > \kappa_{t+1}\right] + \\ +\Lambda F(-\frac{(\kappa_{t+1}-\mu)}{\xi})\mathbb{E}_t\left[\exp\left\{-\sigma g_{t+1}\right\} \mid g_{t+1} < \kappa_{t+1}\right]) \quad \text{(E.13)}$$

Using formulas in E.10 and E.11 we can rewrite E.13 as follows:

$$\mathbb{E}_t\left\{\mathcal{M}_{t,t+1}\right\} = \frac{\beta}{k(y_t)}\exp\left\{-\sigma\mu + \frac{(\sigma\xi)^2}{2}\right\} \times \left[1 + (\Lambda-1)F(\sigma\xi + \frac{(\kappa_{t+1}-\mu)}{\xi})\right]$$

Setting $\Lambda = 1$ and $\theta = 0$ delivers the expected SDF under the standard CES preferences:

$$\mathbb{E}_t\left\{\mathcal{M}_{t,t+1}\right\} = \beta^{-1}\exp\left\{-\sigma\mu + \frac{(\sigma\xi)^2}{2}\right\} \quad \text{(E.14)}$$

Under CES preferences the risk-free rate is:

$$\hat{r}_t = -log(\mathbb{E}_t\left\{\mathcal{M}_{t,t+1}\right\}) = \sigma E_t(\Delta\hat{c}_{t+1}) - (\sigma)^2 Var(\Delta\hat{c}_{t+1}) = E_t(\hat{m}_{t+1}) - (\sigma)^2 Var(\Delta\hat{c}_{t+1}) \quad \text{(E.15)}$$

The above implies that under $\Lambda \neq 1$ and $\theta \neq 0$ the SDF features an additional premium which is given by the term $\frac{\beta}{k(y_t)}(\Lambda-1)F(\sigma\xi + \frac{(\kappa_{t+1}-\mu)}{\xi})$.

Remark. *Under S-shaped preferences and in presence of a Λ different than one, the model based investor residual features an additional premium given by $F(\gamma\sigma + \frac{(\kappa_{t+1}-\mu)}{\sigma})$..*

In this case too $\hat{r}_t = -log(E_t(\mathcal{M}_{t+1})$, however under $\Lambda \neq 1$ and $\theta \neq 0$ the required returns feature an additional premium, which is given by $\frac{\beta}{k(y_t)}(\Lambda-1)F(\sigma\xi + \frac{(\kappa_{t+1}-\mu)}{\xi})$. Once again we can accommodate different investor classes. Investors with larger Λ have time-varying premia, which respond more to large losses. Equally so investors whose preferences feature different θ have different degree of risk-tolerance in the gain domain, hence the sensitivity of their premia is larger in face of shocks that reduce consumption risk.

E.3. Proof of Proposition 1. Derivation Portfolio Shares.

We compute here portfolio shares employing the perturbation methods originally designed in Samuelson (1958) and Judd (1998) and latter applied to dynamic open economy models by Devereux and Sutherland (2011) and Tille and Van Wincoop (2010). The method consists in merging second order approximations of the Euler conditions and first order approximations of the budget constraints to obtain a solution for the portfolio share. We derive them in our model for the purpose of discussing the impact of the asset purchase.

The budget constraint of the domestic investors:

$$P_tC_t + B_{h,t} + e_tB_{f,t} = (1 + i_{t-1})B_{h,t-1} + (1 + i^*_{t-1})e_tB_{f,t-1} + P_tY_t$$

can be re-arranged in real terms as follows:

$$W_t = (r_{t-1} - r^*_{t-1})(B^R_{h,t-1}) + (1 + r^*_{t-1})W_{t-1} + Y_t - C_t + (1 + r^*_{t-1})(B^R_{f,t-1})(S_t - S_{t-1}) \quad \text{(E.16)}$$

where $W_t = B^R_{h,t} + S_tB^R_{f,t}$ is *real* wealth, $S_t = \frac{e_tP^*}{P_t}$ is the real exchange rate and where $B^R_{h,t} = \frac{B_{h,t}}{P_t}$ are real holdings by domestic investors of home currency bonds and $B^R_{f,t} = \frac{B_{f,t}}{P^*_t}$ are real holdings of foreign denominated bonds by domestic investors. Log-linearizing (E.16) delivers:

$$\overline{W^*}\hat{w}_t = \frac{1}{\beta}\overline{B}_h(\hat{r}_{t-1} - \hat{r}^*_{t-1}) + \frac{\overline{W}}{\beta}(\hat{w}_{t-1} + \hat{r}^*_{t-1}) + \overline{Y}\hat{y}_t - \overline{C}\hat{c}_t + \overline{SB}^R_f\frac{1}{\beta}(\hat{s}_t - \hat{s_{t-1}}) \quad \text{(E.17)}$$

where $\overline{W} = \overline{B}^R_h + \overline{SB}^R_f$ and $\hat{w}_t = \hat{b}^R_{h,t} + \hat{b}^R_{f,t} + \hat{s}_t$. Variables with bars indicate steady states and with hats indicate log-linear deviations from steady state. The above derivations subsumed the fact that the term $(\frac{1}{\beta} - \frac{1}{\beta})\hat{B}_{h,t} = 0$.

Likewise the budget constraint for the foreign investors can be reshuffled as follows:

$$W^*_t = (r_{t-1} - r^*_{t-1})\frac{B^{R*}_{h,t-1}}{S_t} + (1 + r^*_{t-1})W^*_{t-1} + Y^*_t - C^*_t + B^{R*}_{h,t-1}(1 + r^*_{t-1})(\frac{1}{S_t} - \frac{1}{S_{t-1}}) \quad \text{(E.18)}$$

where $W^*_t = \frac{B^{R*}_{h,t}}{S_t} + B^{R*}_{f,t}$ is *real* wealth, $B^{R*}_{h,t} = \frac{B^*_{h,t}}{P_t}$ are real holdings of domestic bonds by foreign investors and $B^{R*}_{f,t} = \frac{B^*_{f,t}}{P^*_t}$ are real holdings of foreign currency denominated bonds by foreign investors (which are home currency bonds for them). Log-linearizing this equation:

$$\overline{W}^*(\hat{w}_t^*) = \frac{1}{\beta \overline{S}}\overline{B}_h^*(\hat{r}_{t-1} - \hat{r}_{t-1}^*) + \frac{\overline{W}}{\beta}(\hat{w}_{t-1}^* + \hat{r}_{t-1}^*) + \overline{Y}^*\hat{y}_t^* - \overline{C}^*\hat{c}_t^* + \overline{B}_h^*\frac{1}{\beta \overline{S}}(\hat{s}_{t-1} - \hat{s}_t) \quad \text{(E.19)}$$

where $\overline{W}^* = \frac{\overline{B}_h^{R*}}{\bar{S}_t} + \overline{B}_f^{R*}$, $\hat{w}_t = \hat{b}_{h,t}^{R*} + \hat{b}_{f,t}^{R*} - \hat{s}_t$. For simplicity we assume the symmetric equilibrium steady state where $\overline{C} = \overline{Y} = \overline{C}^* = \overline{Y}^*$ and $\overline{W} = \overline{W}^* = 0$. Furthermore we assume in the real exchange rate is 1 in the steady state. Define $\hat{w}_t = \frac{W_t - \bar{W}}{C}$ and $\hat{w_t^*} = \frac{W_t^* - \bar{W}^*}{C^*}$. Also, we can express the bonds as shares as $\omega_h = \frac{B_h^R}{\beta C}$, and $\omega_h^* = \frac{B_h^{R*}}{\beta C^*}$, so that we can write home and foreign consumption as

$$\hat{c}_t = \hat{w}_t + \hat{y}_t - \frac{\hat{w}_{t-1}}{\beta} + \omega_h(\hat{r}_{t-1} - \hat{r}_{t-1}^* - \hat{s}_t + \hat{s}_{t-1}) \quad \text{(E.20)}$$

$$\hat{c}_t^* = \hat{w}_t^* + \hat{y}_t^* - \frac{\hat{w}_{t-1}^*}{\beta} + \omega_h^*(\hat{r}_{t-1} - \hat{r}_{t-1}^* - \hat{s}_t + \hat{s}_{t-1}) \quad \text{(E.21)}$$

Note that portfolio optimal conditions and non arbitrage imply that :

$$E_t[U_{c,t+1}(1 + r_t)] = E_t[U_{c,t+1}(1 + r_t^*)\frac{S_{t+1}}{S_t}] \quad \text{(E.22)}$$

For ease of exposition we will adopt the CES specification since now and frame all our results in terms of the standard risk-aversion parameter. The derivations can be generalized to other preferences.[39] Taking a second order Taylor expansion of equation (E.22) under CES utility specification delivers:

$$E_t[\hat{r}_t - \hat{r}_t^* + \hat{s}_t - \hat{s}_{t+1} + (\frac{\hat{r}_t^2}{2} - \frac{\hat{r}_t^{*2}}{2}) - \sigma\hat{c}_{t+1}(\hat{r}_t - \hat{r}_t^* + \hat{s}_t - \hat{s}_{t+1}) + (\frac{\hat{s}_t^2}{2} - \frac{\hat{s}_{t+1}^2}{2}) + \hat{s}_t\hat{r}_t - \hat{s}_{t+1}\hat{r}_t^*] = \text{"}o\text{"} \quad \text{(E.23)}$$

Repeating the same procedure for foreign investors and combining the two approximations delivers the following two implications :

$$E_t[(\sigma\hat{c}_{t+1} - \sigma\hat{c}_{t+1}^*)(\hat{r}_t - \hat{r}_t^* + \hat{s}_t - \hat{s}_{t+1})] = \text{"}0 + O(\varepsilon^3)\text{"} \quad \text{(E.24)}$$

39 For instance in the case of habit preferences the term $\sigma\hat{c}_{t+1}$ shall be replaced by $\sigma(\hat{x}_t - \hat{c}_t)$, where $\hat{x}_t$ is the log deviation of $X_t = \frac{C_t - H_t}{C_t}$.

$$E(\hat{r}_t - \hat{r}_t^* + \hat{s}_t - \hat{s}_{t+1}) = -\frac{1}{2}E[(\hat{r}_t + \hat{s}_t)^2 - (\hat{r}_t^* + \hat{s}_{t+1})^2] + \frac{\sigma}{2}E[(\hat{c}_{t+1} + \hat{c}_{t+1}^*)(\hat{r}_t - \hat{r}_t^* + \hat{s}_t - \hat{s}_{t+1})] + O(\varepsilon^3) \quad \text{(E.25)}$$

Note that for the more general class of preferences condition E.26 would read as follows:

$$E_t[(\hat{m}_{t+1} - \hat{m}_{t+1}^*)(\hat{r}_t - \hat{r}_t^* + \hat{s}_t - \hat{s}_{t+1})] = \text{"}0 + O(\varepsilon^3)\text{"} \quad \text{(E.26)}$$

The two conditions, E.26 and E.25, express portfolio optimality conditions for equilibrium portfolio holdings and excess return. Plugging in equations (E.20) and (E.21) into equation (E.26) and assuming that total supply of assets is equal to $\mathcal{S}$ it follows that $\omega_h^* = \mathcal{S}_t - \omega_h$. Solving for ω_h and assuming the same risk aversion for investors in different countries:

$$\omega_h = \frac{\mathcal{S}}{2} - \frac{1}{2}V_{xx}^{-1}V_{xD} \quad \text{(E.27)}$$

where the vector: $V_{xx} = E[(\hat{r}_t - \hat{r}_t^* - \hat{s}_{t+1} + \hat{s}_t)^2]$ and$V_{xD} = E[\{(\hat{y}_{t+1} - \hat{y}_{t+1}^*) + (\hat{w}_{t+1} - \frac{\hat{w}_t}{\beta}) - (\hat{w}_{t+1}^* - \frac{\hat{w}_t^*}{\beta})\}(\hat{r}_t - \hat{r}_t^* - \hat{s}_{t+1} + \hat{s}_t)]$. The corresponding (partial equilibrium) solution for excess returns is:

$$E(\hat{r}_t - \hat{r}_t^* - \hat{s}_{t+1} + \hat{s}_t) = -\frac{1}{2}V_{xx} + \frac{\sigma}{2}V_{xA} \quad \text{(E.28)}$$

where $V_{xA} = E[(\hat{r}_t - \hat{r}_t^* - \hat{s}_{t+1} + \hat{s}_t)(\hat{y}_{t+1} + \hat{y}_{t+1}^*)]$. Note that the portfolio allocation depends on the deviation from the uncovered interest rate parity, as the return differential captures exactly this differential. Specifically, $\hat{uip} = (\hat{r}_t - \hat{r}_t^* - \hat{s}_{t+1} + \hat{s}_t)$. Furthermore, notice that equations (E.27) and (E.28) are similar to the solution for asset holdings and expected excess returns that would emerge from a mean-variance model of portfolio allocation. Therefore the intuitions that apply to those models are applicable in this solutions. We discuss these next.

First note that the shares in equation (E.27) has two parts. The first part depends on the total supply of bonds and the second on moments of the excess return (UIP deviation). If V_{xD} is zero, then the share is simply half. Since V_{xx} is always positive and that we observe that the shares of euro-denominated bonds in euro investors portfolios is more than half, it is fair to assume that $V_{xD} < 0$, therefore the second part increases the shares. Next note that V_{xx} is equivalent, in a first order approximation, to the volatility and therefore risk of the excess return. As the asset purchases drop this variance, given the negative sign of V_{xD}, implies an increase in the shares. This captures the essence of the risk rebalance channel. As risk premia declines investors rebalance towards the home asset.

E.4. Corollary 1. Risk Rebalance Channel

Given the portfolio share derived in proposition 1:

$$w_h = -\frac{1}{2}V_{xx}^{-1}V_{xD} + \frac{\mathcal{S}}{2} + O(\varepsilon^3) \tag{E.29}$$

Note that from a first order approximation $E(\hat{uip}^2)$, hence:

$$V_{xx} = E(\hat{uip}^2) \tag{E.30}$$

and

$$V_{xD} = E(\{(y_{t+1} - y^*_{t+1}) + (w_{t+1} - \frac{w_t}{\beta}) - (w^*_{t+1} - \frac{w^*_t}{\beta})\}\hat{uip}) \tag{E.31}$$

The term V_{xD} is the correlation between the relative growth in wealth across countries and the return differentials. Under complete markets it would be zero as perfect insurance would neutralize cross country shocks. A positive correlation would indicate poor hedging opportunities. While a negative correlation indicates that investors are well equipped to rebalance their portfolio toward the security whose yields (returns) are expected to increase (decline). The sign of this correlation also affects the elasticities in the model. Our empirical observations suggest that its sign maybe negative in our data. ICPF's portfolios or euro securities are above above 50%. Based on equation E.29 this would be the case if the term $V_{xD} < 0$. This is also intuitively in line with the idea that large institutional investors are well equipped in their hedging capacity.

Given that our variables are in log deviation the elasticity of the portfolio share is given by:

$$\frac{\partial w_h}{\partial V_{xx}} = \frac{1}{2}\frac{V_{xD}}{V_{xx}^2} \tag{E.32}$$

The sign depends on the sign of the numerator. If elasticity is negative, shares increase when volatility drops. If V_{xD} negative, this elasticity is negative.

E.5. Corollary 2. Search for Yield.

The return condition derived before is:

$$E(uip) = -\frac{1}{2}V_{xx} + \frac{\sigma}{2}V_{xA} \tag{E.33}$$

where:

$$V_{xA} = E[\hat{uip}(y_{t+1} + y^*_{t+1})] \tag{E.34}$$

The term V_{xA} describes how the UIP changes with the average income shock of all investors. We can re-write the condition on expected return as:

$$V_{xx} = \sigma V_{xA} - 2E(uip) \tag{E.35}$$

Substituting this condition in the share, implies:

$$w_h = \frac{1}{2}\frac{V_{xD}}{[2E(uip) - \sigma V_{xA}]} + \frac{\mathcal{S}}{2} \tag{E.36}$$

Let us assume an MIT unexpected shock to the UIP, on impact:

$$\frac{\partial w_h}{\partial E(uip)} = -\frac{V_{xD}}{[2E(uip) - \sigma V_{xA}]^2} \tag{E.37}$$

The sign of the elasticity depend on the sign of V_{xD} again. If and only if $V_{xD} < 0$, the elasticity is positive. This implies that a larger decline in the UIP implies a larger decline in the portfolio share.