Market Segmentation and International Bond Prices: the Role of ECB Asset Purchases
Online Appendix

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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.

The SHS data on corporate bonds used in the present paper corresponds to the download of 23 November 2021. SHS revises systematically each quarter its last two quarters of data and each year up to approximately three years of data backwards. If we compare our SHS sample with a new vintage downloaded on 15 July 2023, we would find (euro and dollar-denominated) deviations of about 0.1-1% on average since 2018 (previous years are mostly unrevised) for ICPF and OFI sectors owing to data revisions. The SHS data vintage on government bonds corresponds to the download of end June 2023. Baseline regression results are based on data aggregated at the security level across all issuers; Sub-sample regressions with the investor dummies are based on data aggregated at security and sector (investor) level. Regression results are robust to different data aggregations.

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.

C. Other Tables and Figures

Summary Statistics and Other Data Facts.

Figure C3 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 the world is above 50% for a large part of the sample. This is likely due to the decline in the rate of return of those securities as result of the ECB asset purchase program.

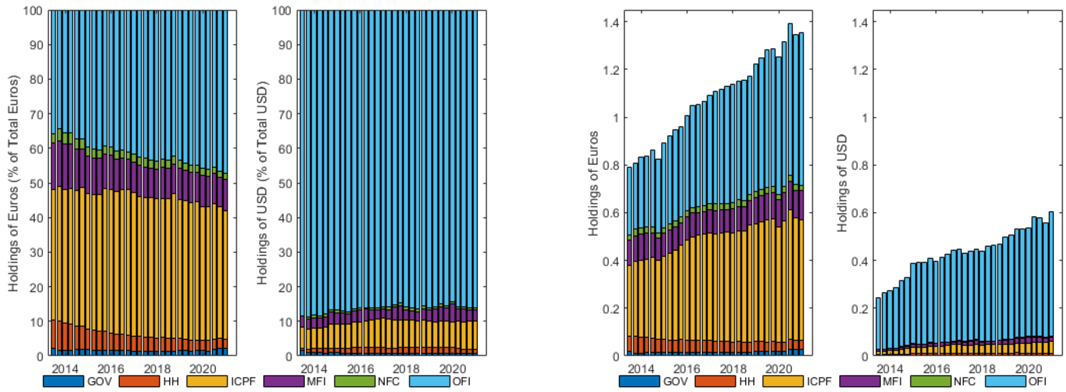
Portfolio Shares in Currencies Other than euro and U.S. Dollar. Figure C4 shows the break down of portfolio shares of corporate bonds for all other currencies. The left panel shows the averages over the time period 2013-2021 and the right panel shows the shares for ICPF and OFI. Interestingly ICPF hold much less of the other currencies compared to OFI.

Currency Denomination of Government Bond Portfolios Across ICPF and

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.



OFI. Figure C5 shows the break down by currency denomination, focusing on euro and U.S. dollars, and across major investors, for holdings of government bonds. Figure C.5, shows that for government bonds, ICPF also exhibit a preference for euro denomination and OFI for U.S. dollars denomination. Overall the holdings of euro denominated bond is much larger (between 20 times larger in 2014) than the holdings of dollar, although the difference in magnitude decreases over time (to 5 times larger in 2021).

Robustness Checks for Return Differentials. Figure C6 repeats the baseline regression shown in **??** by replacing maturity at each date with the Macaluy duration. Figure C7 repeats again the baseline regression by using bonds issued only by firms that issue in both currencies, euros and dollars. Figure C8 shows the return differentials across sub-samples.

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:

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

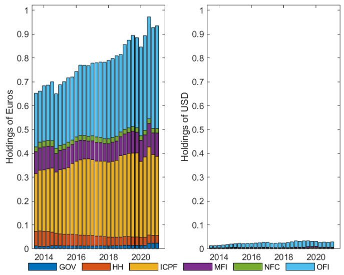
To do the swap adjustment, for short bonds we can proxy the currency premium in logs as:

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

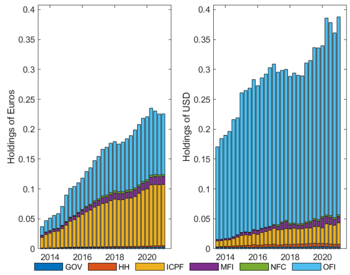
Figure C2

Debt in non-financial corporations by currency and investors

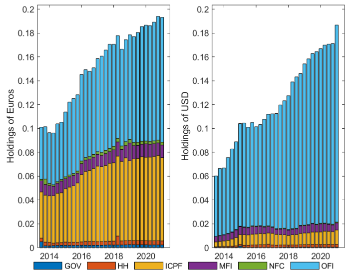
Figure C2 shows the breakdown (in levels) of debt in non-financial corporations by currency denomination, U.S. dollars (left sub-panels) versus euro (right sub-panels), and types of investor in different colors. Debt held by governments (GOV) is in blue, by households (HH) in orange, insurance corporations 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.



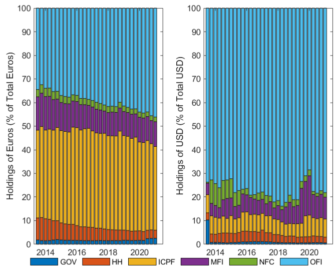
(a)
Euro area issuers



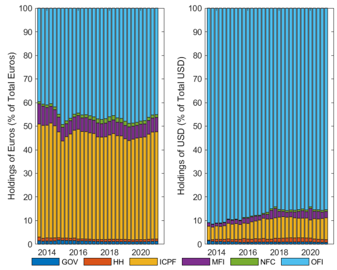
(b)
U.S. issuers



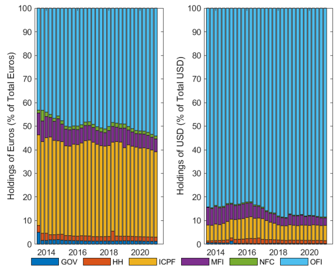
(c)
Rest of the World issuers



(d)
Euro area issuers



(e)
U.S. issuers

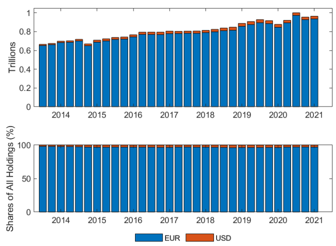


(f)
Rest of the World issuers

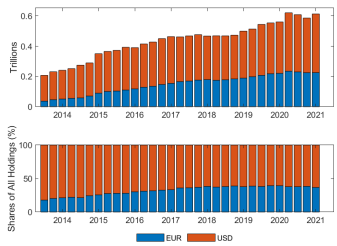
Figure C3

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

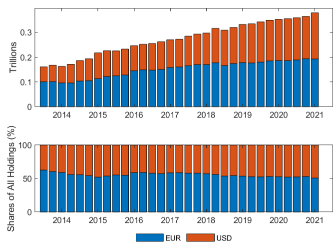
Figure C3 shows the breakdown of debt in non-financial corporations per currency denomination, U.S. dollars versus euro. Top left panels shows only securities issued by firms resident in euro area, the top right panels shows only securities for issuers resident in the U.S. and the bottom panels shows securities for issuers resident in the rest of the world.



(a)
Euro area issuers



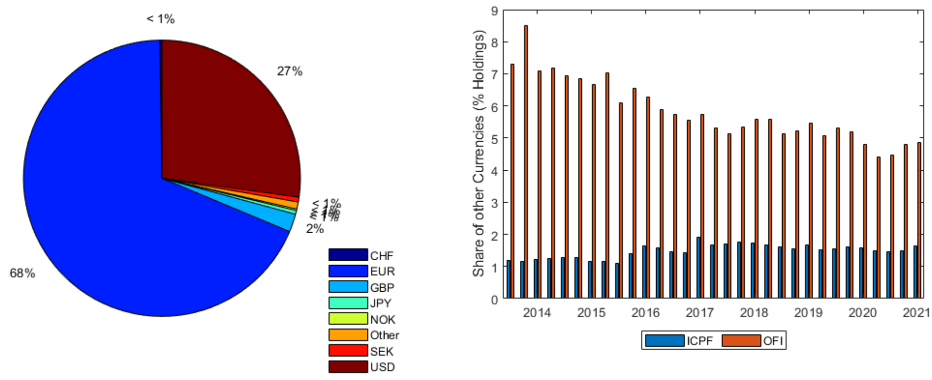
(b)
U.S. issuers



(c)
Rest of the World issuers

Figure C4
Other Currencies

Figure C4 shows the breakdown of debt in non-financial corporations over our time sample 2013-2021 for all other currencies other than euro and dollar.



(a)
Average Shares 2013-2021

(b)
Shares for ICPF and OFI

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. Derivation of Equation 16 in Main Draft

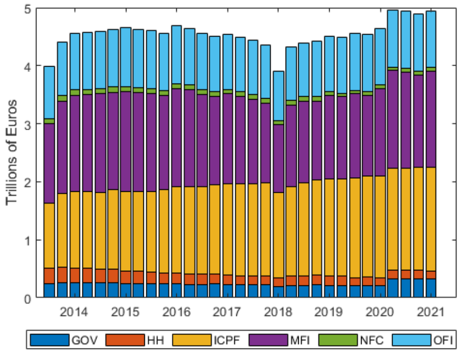
The UIP deviation is the expected excess return of an euro investor who borrows funds in dollars, converts them to euros, invests at the euro interest rate, and then converts the earnings to the dollar. The first order conditions in equations 13 and 14 in the main draft imply:

$$i_t = -logE_tM_{t+1} - cons_1 = -Em_{t+1} - \frac{1}{2}var_t(m_{t+1}) - cons_1 \tag{E.1}$$

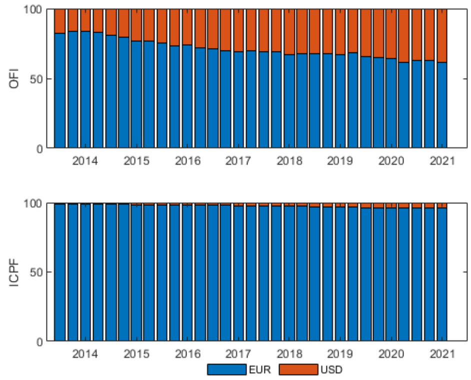
$$i^*_t = -logE_tM^*_{t+1} = -Em^*_{t+1} - \frac{1}{2}var_t(m^*_{t+1}) \tag{E.2}$$

Figure C5
Currency Denomination of Government Bond Holdings. ICPF vs. OFI.

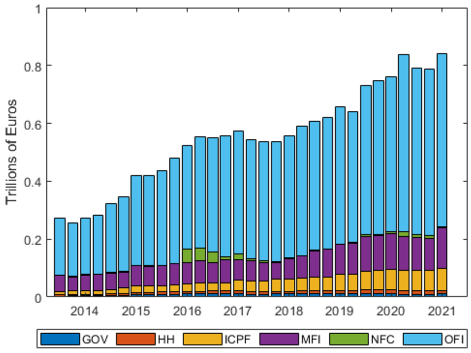
Figure C5 shows the breakdown for currency denomination of the government bond holdings of euro area investors focusing on OFI and ICPF over our time sample 2013-2021. Panel (a) shows the distribution of euro denominated bonds across all investors. Panel (c) shows the distribution of dollar denominated bonds (note scale difference across the (a) and (c)). Panel (b) shows the currency composition (in shares) of the government bond holdings of OFI and ICPF investors.



(a)
Euro bonds



(b)
OFI and ICPF Currency Composition



(c)
USD bonds

where $cons_1 = log(1 + \frac{\lambda_t(1-\kappa)}{U_{c,t}(1+i_t)E_t(M_{t+1})})$. If financial markets are complete, the SDF is unique, hence:

$$\frac{M_{t,t+1}}{M^*_{t,t+1}} + cons_2 = \frac{e_t}{e_{t+1}} \tag{E.3}$$

where $cons_2 = \frac{\lambda_t(1-\kappa)}{U_{c,t}M^*_{t,t+1}(1+i_t)} > 0$ if the constraint on the share of foreign holdings is binding. The expected change in exchange rate (in logs) is:

$$E(\Delta e_{t+1}) = Em^*_{t+1} - Em_{t+1} + cons_3 = -i^*_t + i_t - \frac{1}{2}var_t(m^*_{t+1}) + \frac{1}{2}var_t(m_{t+1}) + cons_4 \tag{E.4}$$

Figure C6

Euro-dollar yields differential, UIP and CIP controlling for duration.

Figure C6 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), time sample is from 2013 Q3 - 2021 Q1, including all bonds with Macaluy duration. 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, duration 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.

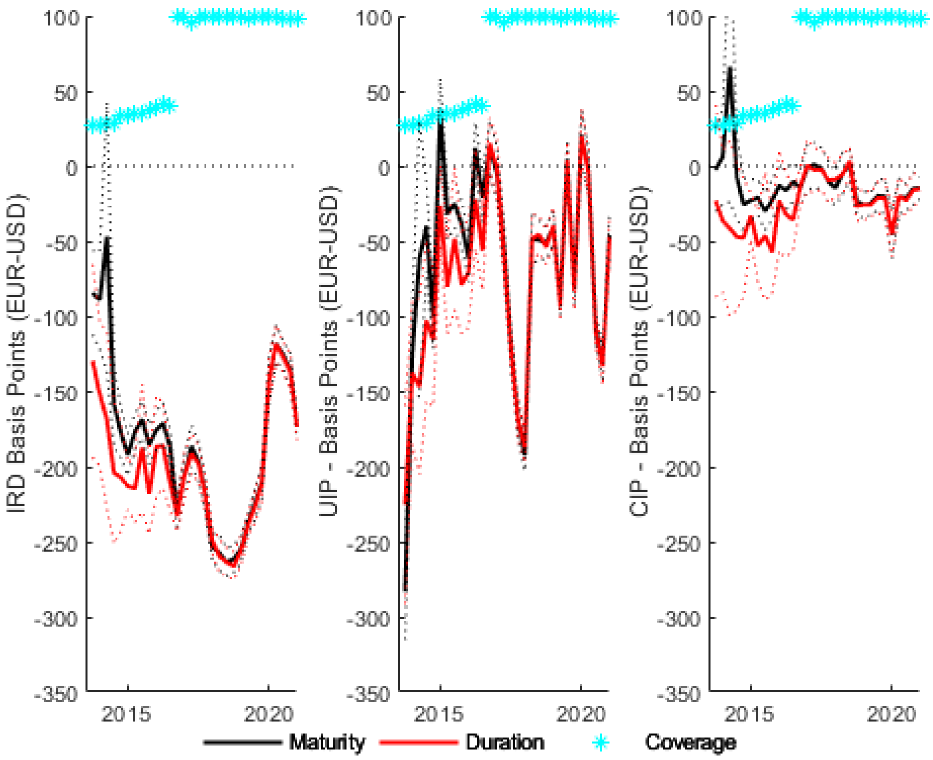
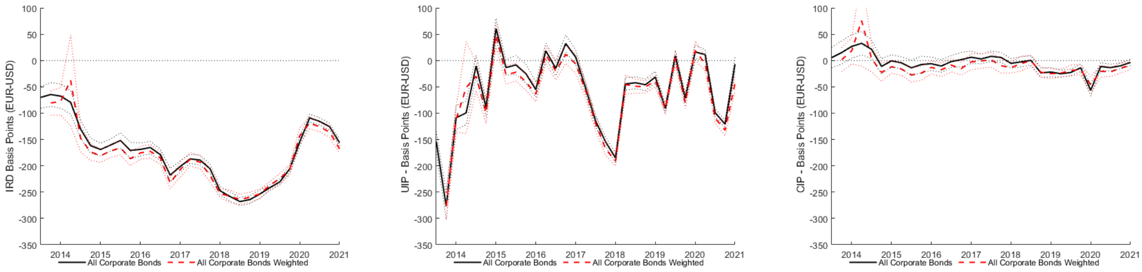


Figure C7
Euro-dollar yields differential, UIP and CIP for firms issuing in both currencies.

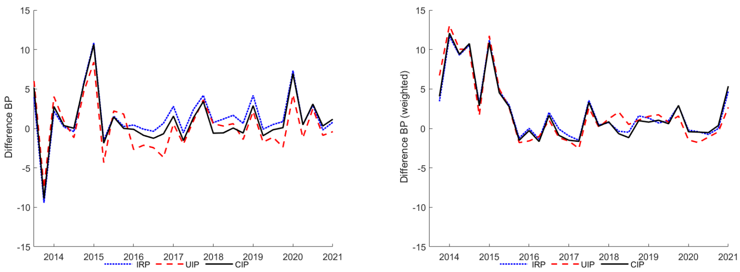
Figure C7 plots estimates for residual intercept for the raw specification (left panel), for the uncovered interest rate party (middle panel) and for the covered interest rate parity (right panel) using the corporate bonds from firms issuing in both, euros and dollars, time sample is from 2013 Q3 - 2021 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

Figure C8
Difference in Euro-dollar estimates between samples.

Figure C8 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

Figure C10

Euro-dollar yields differential, UIP and CIP controlling for Senior Unsecured bond.

Figure C6 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), time sample is from 2013 Q3 - 2021 Q1, with a dummy for senior unsecured bond. 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, duration 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.

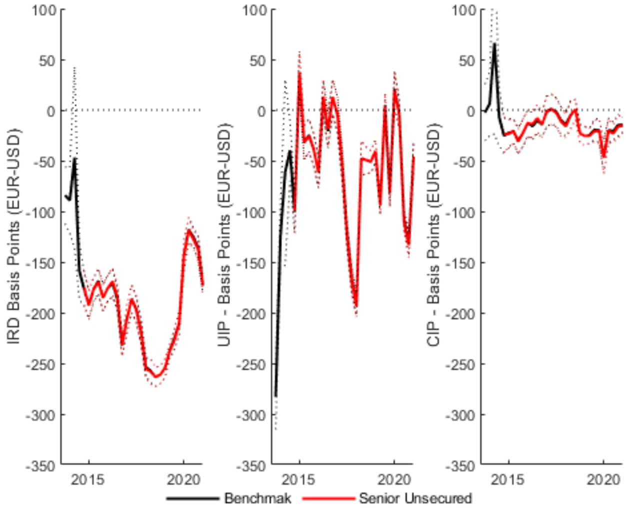


Figure C11

Euro-dollar yields differential, UIP and CIP controlling for bonds being callable.

Figure C6 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), time sample is from 2013 Q3 - 2021 Q1, with a dummy for bond being callable. 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, duration 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.

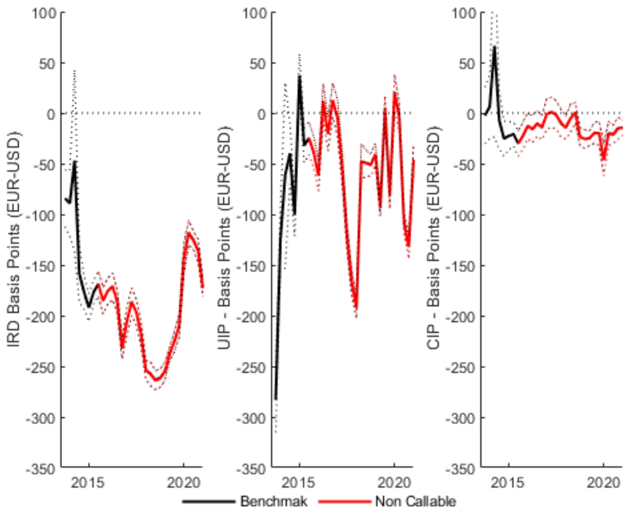
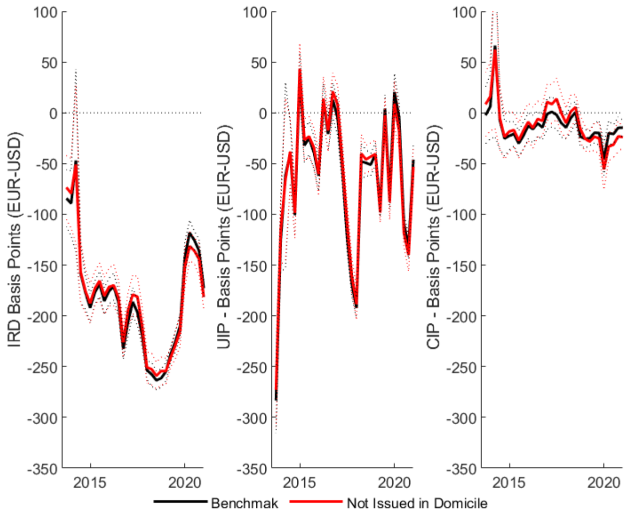


Figure C12

Euro-dollar yields differential, UIP and CIP controlling for Market of Issuance.

Figure C6 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), time sample is from 2013 Q3 - 2021 Q1, with a dummy if the bond is issued at a market different from the firm's domicile. 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, duration 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.



where $cons_3 = -E(log(1+\frac{\lambda_t(1-\kappa)}{U_{c,t}(1+i_t)M_{t,t+1}}))$ and $cons_4 = log(1+\frac{\lambda_t(1-\kappa)}{U_{c,t}(1+i_t)E_t(M_{t+1})}) - E(log(1+\frac{\lambda_t(1-\kappa)}{U_{c,t}(1+i_t)M_{t,t+1}}))$. As a result:

$$uip_{t+1} = \frac{1}{2}var_t(m^*_{t+1}) - \frac{1}{2}var_t(m_{t+1}) - cons \tag{E.5}$$

where $cons = log(1+\frac{\lambda_t(1-\kappa)}{U_{c,t}(1+i_t)E_t(M_{t+1})}) - E(log(1+\frac{\lambda_t(1-\kappa)}{U_{c,t}(1+i_t)M_{t,t+1}}))$.

Note that if the regulatory constraint on foreign holdings is not binding, we have that $cons = 0$. If the constraint is binding, Jensen's inequality implies that $cons > 0$. Hence, the market segmentation exemplified by the constraint implies a more negative deviation, as we observe in the data.

E.2. UIP from Second Order Approximations of the Euler

We now derive the UIP by taking second order approximations of the Euler conditions. We will derive it for both the case of CES utility and the case of a general utility function. Note that the first order conditions of the euro investors, coupled with non arbitrage, implies that:

$$E_t[U_{c,t+1}(1+i_t)] = E_t[U_{c,t+1}(1+i^*_t)\frac{e_{t+1}}{e_t}] \tag{E.6}$$

For the time being we assume that the regulatory constraint is not binding. This allows us to highlight the role of differences in investor preferences and demand first.

The second order approximation of $U_{c,t+1}$ delivers: $U_c + U_{cc}(C_{t+1} - C) + U_{ccc}\frac{(C_{t+1}-C)^2}{2} =$

$U_c(1+\frac{U_{cc}}{U_c}C_{t+1}\hat{C_{t+1}}+\frac{U_{ccc}}{U_c}C_{t+1}^2\hat{C_{t+1}}^2)$. The second order approximation of each return delivers: $i_t=I(1+\hat{i_t}+\frac{\hat{i_t}^2}{2})$, $i_t^*=I(1+\hat{i_t^*}+\frac{\hat{i_t^*}^2}{2})$. Finally the second order approximation of each exchange rate delivers: $e_t=E(1+\hat{e_t}+\frac{\hat{e_t}^2}{2})$ and $e_{t+1}=E(1+\hat{e_{t+1}}+\frac{\hat{e_{t+1}}^2}{2})$. Substituting these terms in equation (E.6) and dropping terms with order higher than the second delivers:

$$E_t(\hat{i_t}-\hat{i_t^*}+e_t-e_{t+1}+(\frac{\hat{i_t}^2}{2}-\frac{\hat{i_t^*}^2}{2})+\frac{U_{cc}}{U_c}C_{t+1}\hat{C_{t+1}}(\hat{i_t-i_t^*}+e_t-e_{t+1})+(\frac{\hat{e_t}^2}{2}-\frac{\hat{e_{t+1}}^2}{2})+\hat{e_t}\hat{i_t}-\hat{e_{t+1}}\hat{e_t^*}]=O(\varepsilon^3) \tag{E.7}$$

Merging the first order conditions of the foreign investors, coupled with non arbitrage, implies that:

$$E((1+i_t)U_{c^*,t+1}e_t)=E((1+i_t^*)U_{c^*,t+1}e_{t+1}) \tag{E.8}$$

Replicating the steps above in this case delivers:

$$E_t(\hat{i_t}-\hat{i_t^*}+e_t-e_{t+1}+(\frac{\hat{i_t}^2}{2}-\frac{\hat{i_t^*}^2}{2})+\frac{U^*_{cc}}{U_{c^*}}C^*_{t+1}\hat{C^*_{t+1}}(\hat{i_t-i_t^*}+e_t-e_{t+1})+(\frac{\hat{e_t}^2}{2}-\frac{\hat{e_{t+1}}^2}{2})+\hat{e_t}\hat{i_t}-\hat{e_{t+1}}\hat{i_t^*}]=O(\varepsilon^3) \tag{E.9}$$

Combining the two approximations delivers the following two implications:[1]

$$E((\frac{U^*_{cc}}{U_{c^*}}C^*_{t+1}\hat{C^*_{t+1}}-\frac{U_{cc}}{U_c}C_{t+1}\hat{C_{t+1}})(\hat{i_t-i_t^*}+\hat{e_t}-\hat{e_{t+1}}))=0+O(\varepsilon^3) \tag{E.10}$$

and

$$E_t((1+(\frac{U^*_{cc}}{2U_{c^*}}C^*_{t+1}\hat{C^*_{t+1}}+\frac{U_{cc}}{2U_c}C_{t+1}\hat{C_{t+1}})((\hat{i_t-i_t^*}+\hat{e_t}-\hat{e_{t+1}}))+\frac{1}{2}E\{(\hat{i_t}+\hat{e_t})^2-(\hat{i_t^*}+\hat{e_{t+1}})^2\}]=O(\varepsilon^3) \tag{E.11}$$

where this last equation can be re-written as:

$$E(\hat{uip})=-\frac{1}{2}E\{(\hat{i_t}+\hat{e_t})^2-(\hat{i_t^*}+\hat{e_{t+1}})^2\}-E[(\frac{U^*_{cc}}{2U_{c^*}}C^*_{t+1}\hat{C^*_{t+1}}+\frac{U_{cc}}{2U_c}C_{t+1}\hat{C_{t+1}})(\hat{uip})]+O(\varepsilon^3) \tag{E.12}$$

Under the CES preference specification the two implications boil down to:

$$E_t[(\sigma\hat{c}_{t+1}-\sigma^*\hat{c}^*_{t+1})(\hat{i}_t-\hat{i}^*_t+\hat{e}_t-\hat{e}_{t+1})]=\text{"}0+O(\varepsilon^3)\text{"} \tag{E.13}$$

and

$$E(\hat{i}_t-\hat{i}^*_t+\hat{e}_t-\hat{e}_{t+1})=-\frac{1}{2}E[(\hat{i}_t+\hat{e}_t)^2-(\hat{i}^*_t+\hat{e}_{t+1})^2]+E[(\frac{\sigma}{2}(\hat{c}_{t+1})+\frac{\sigma^*}{2}(\hat{c}^*_{t+1}))(\hat{i}_t-\hat{i}^*_t+\hat{e}_t-\hat{e}_{t+1})]+O(\varepsilon^3) \tag{E.14}$$

The two conditions in equations (E.13) and (E.14) express portfolio optimally conditions for equilibrium portfolio holdings and return differentials (UIP). These extend the results obtained by Devereux and Sutherland (2011), for a two asset endowment economy, to the case of different risk aversion across investors. We will use these approximations and CES functional form to derive optimal portfolio shares next.

1 The first implication is achieved by difference or the equation (E.7) and equation (E.9). The second is from adding up half of each of the conditions.

E.3. Optimal Portfolio Shares

We now compute optimal portfolio shares merging the budget constraint and the first order conditions. We rely on second order approximations following 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 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 as follows:

$$W_t = (i_{t-1} - i^*_{t-1})(B^R_{h,t-1}) + (1 + i^*_{t-1})W_{t-1} + Y_t - C_t + (1 + i^*_{t-1})(B^R_{f,t-1})(e_t - e_{t-1}) \quad \text{(E.15)}$$

where $W_{t-1} = B^R_{h,t-1} + e_tB^R_{f,t-1}$ is wealth. Log-linearizing (E.15) delivers:

$$\overline{W^*}\hat{w}_t = \frac{1}{\beta}\overline{B}_h(\hat{i}_{t-1} - \hat{i}^*_{t-1}) + \frac{\overline{W}}{\beta}(\hat{w}_{t-1} + \hat{i}^*_{t-1}) + \overline{Y}\hat{y}_t - \overline{C}\hat{c}_t + \overline{EB}^R_f\frac{1}{\beta}(\hat{e}_t - \hat{e_{t-1}}) \quad \text{(E.16)}$$

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:

$$W^*_t = (i_{t-1} - i^*_{t-1})\frac{B^{R*}_{h,t-1}}{S_t} + (1 + i^*_{t-1})W^*_{t-1} + Y^*_t - C^*_t + B^{R*}_{h,t-1}(1 + i^*_{t-1})(\frac{1}{e_t} - \frac{1}{e_{t-1}}) \quad \text{(E.17)}$$

where $W^*_{t-1} = \frac{B^{R*}_{h,t}}{e_{t-1}} + B^{R*}_{f,t-1}$ is wealth. Log-linearizing this equation:

$$\overline{W}^*(\hat{w}^*_t) = \frac{1}{\beta\overline{e}}\overline{B}^*_h(\hat{i}_{t-1} - \hat{i}^*_{t-1}) + \frac{\overline{W}}{\beta}(\hat{w}^*_{t-1} + \hat{i}^*_{t-1}) + \overline{Y}^*\hat{y}^*_t - \overline{C}^*\hat{c}^*_t + \overline{B}^*_h\frac{1}{\beta\overline{e}}(\hat{e}_{t-1} - \hat{e}_t) \quad \text{(E.18)}$$

where $\overline{W}^* = \frac{\overline{B}^{R*}_h}{\overline{e_t}} + \overline{B}^{R*}_f$, $\hat{w}_t = \hat{b}^{R*}_{h,t} + \hat{b}^{R*}_{f,t} - \hat{e}_t$. 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 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 $\omega_h = \frac{B^R_h}{\beta C}$, and $\omega^*_h = \frac{B^{R*}_h}{\beta C^*}$, so that we can write home and foreign consumption as

$$\hat{c}_t = \hat{w}_t + \hat{y}_t - \frac{\hat{w}_{t-1}}{\beta} + \omega_h(\hat{r}_{t-1} - \hat{r}^*_{t-1} - \hat{e}_t + \hat{e}_{t-1}) \quad \text{(E.19)}$$

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

The two conditions, E.13 and E.14, express portfolio optimality conditions for equilibrium portfolio holdings and excess return. For ease of exposition we employ them in the case in which the regulatory constraint does not bind. Plugging in equations (E.19) and (E.20) into equation (E.13) 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:

$$\omega_h = \frac{\sigma^* \mathcal{S}_t}{(\sigma + \sigma^*)} - \frac{1}{(\sigma + \sigma^*)} V_{xx}^{-1} V_{xD} \tag{E.21}$$

where the vector: $V_{xx} = E[(\hat{r}_t - \hat{r}_t^* - \hat{e}_{t+1} + \hat{e}_t)^2]$ and $V_{xD} = E[\{(\sigma y_{t+1} - \sigma^* y_{t+1}) + \sigma(w_{t+1} - \frac{w_t}{\beta}) - \sigma^*(w_{t+1}^* - \frac{w_t^*}{\beta})\}(\hat{r}_t - \hat{r}_t^* - \hat{e}_{t+1} + \hat{e}_t)]$.

The corresponding (partial equilibrium) solution for excess returns is:

$$E(\hat{r}_t - \hat{r}_t^* - \hat{e}_{t+1} + \hat{e}_t) = -\frac{1}{2} V_{xx} + \frac{1}{2} V_{xA} \tag{E.22}$$

where $V_{xA} = E[(\hat{r}_t - \hat{r}_t^* - \hat{e}_{t+1} + \hat{e}_t)(\sigma \hat{y}_{t+1} + \sigma^* \hat{y}_{t+1}^*)]$.

Note that the portfolio allocation depends on the deviation from the uncovered interest rate parity, as the return differential captures exactly this differential. Specifically, $\hat{uip} = (\hat{r}_t - \hat{r}_t^* - \hat{e}_{t+1} + \hat{e}_t)$. Furthermore, notice that equations (E.21) and (E.22) 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.21 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.
Risk Rebalance Channel. Given the portfolio share derived in proposition 1:

$$\omega_h = \frac{\sigma^* \mathcal{S}_t}{(\sigma + \sigma^*)} - \frac{1}{(\sigma + \sigma^*)} V_{xx}^{-1} V_{xD} \tag{E.23}$$

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

$$V_{xx} = E(\hat{uip}^2) \tag{E.24}$$

and

$$V_{xD} = E[\{(\sigma y_{t+1} - \sigma^* y_{t+1}^*) + \sigma(w_{t+1} - \frac{w_t}{\beta}) - \sigma^*(w_{t+1}^* - \frac{w_t^*}{\beta})\}(uip)] \tag{E.25}$$

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.24 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:

$$\frac{\partial w_h}{\partial V_{xx}} = \frac{1}{\sigma + \sigma^*} \frac{V_{xD}}{V_{xx}^2} \tag{E.26}$$

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.
Search for Yield. The return condition derived before is:

$$E(uip) = -\frac{1}{2}V_{xx} + \frac{1}{2}V_{xA} \tag{E.27}$$

where:

$$V_{xA} = E[\hat{uip}(\sigma y_{t+1} + \sigma^* y^*_{t+1})] \tag{E.28}$$

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:

$$V_{xx} = V_{xA} - 2E(uip) \tag{E.29}$$

Substituting this condition in the share, implies:

$$w_h = \frac{1}{\sigma + \sigma^*} \frac{V_{xD}}{[2E(uip) - \sigma V_{xA}]} + \frac{\sigma^{**}\mathcal{S}}{\sigma + \sigma^*} \tag{E.30}$$

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

$$\frac{\partial w_h}{\partial E(uip)} = -\frac{2V_{xD}}{(\sigma + \sigma^*)[2E(uip) - \sigma V_{xA}]^2} \tag{E.31}$$

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.

F. Relation between Deviations and Euro Share

In section 4.6 we discuss how investors' demand response to yield differentials affect the impact of the ECB purchases. Specifically, equation (8) shows that the smaller is the aggregated β_m, the higher is the impact of the ECB purchases in the euro-dollar yield differential.

In this section we estimate the following equation to get a proxy for those βs:

$$\Delta EuroShare_t = \alpha + \beta(\Delta\alpha_{t-1}) + \epsilon_t \tag{F.1}$$

We use the change in the euro share of all investors, ICPF and OFI and the aggregated yield differential of Figure 7. We lag the change in yields to attenuate endogeneity concerns.

The table below shows the results for our two main investors (ICPF and OFI) and for the portfolio that aggregates across all investors in the euro area.

Table A1

Regressing the portfolio share of euro denominated securities for ICPF over return differential. The regression is done with bootstrap standard errors. The econometric specification is $\Delta EuroShare_t = \alpha + \beta(\Delta\alpha_{t-1}) + \epsilon_t$. P-values indicated as: *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)
	ICPF	OFI	Total
ΔCIP_{t-1}	1.468***	3.156***	3.101***
	(0.347)	(0.676)	(0.757)
Constant	−0.174***	0.031	−0.224
	(0.051)	(0.189)	(0.159)
Observations	29	29	29
R-squared	0.322	0.263	0.295

The results show that, as expected in response to a drop in the euro-dollar yield differential, investors lower the share of euro denominated bonds. Importantly, ICPF investors are less elastic than OFI investors, lowering the overall response. This implies that ICPF investors, lower the denominator in equation (8) and magnifies the impact of ECB purchases on the change in the differential.

G. Full Firm Level Results

The table shows all the coefficient estimates for the firm-level specification (10) in section 4.4. The overall positive effect of investors' (weighted) demand elasticities on CIP decreases with purchases, becoming negative. Results are significant only for ICPF inventors.

References

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Table A2

Regressing the hedged return differentials onto the lagged firm-level corporate bonds purchases, interacted with the investor demand elasticity and weighted by the outstanding amount held by each investor type of the CSPP-purchased corporate bonds. The econometric specification reads as follows: $CIP_{i,t} = \kappa_{i,t} + \beta_0 w_{i,j,t}^T \eta_j + \beta_1 CSPP_{i,t-1} + \beta_2 w_{i,j,t}^T \eta_j CSPP_{i,t-1} + \epsilon_{i,j,t}$. Standard errors are bootstrapped. P-values indicated as: *** p<0.01, ** p<0.05, * p<0.1.

	ICPF	**OFI**
$w_{i,j,t}^T \eta_j$	0.03674**	0.01104
	(0.01451)	(0.01074)
$CSPP_{i,t-1}$	0.57993***	0.12750
	(0.19001)	(0.21080)
$w_{i,j,t}^T \eta_j CSPP_{i,t-1}$	-0.02712***	-0.00668
	(0.00793)	(0.00521)
Constant	-1.06686***	-0.54964
	(0.36123)	(0.46411)
Observations	439	439
R-squared	0.112	0.030