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Investor heterogeneity and large-scale asset purchases

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Abstract

Large-Scale Asset Purchases can impact the price of securities directly, when securities are targeted by the central bank, or indirectly through portfolio re-balancing of private investors. We quantify both the direct and the portfolio re-balancing impact, emphasizing the role of investor heterogeneity. We use proprietary security-level data on asset holdings of different investors. We measure the direct impact on security level, finding that it is smaller for securities predominantly held by more price-elastic investors, funds and banks. Comparing a security at the 90th percentile of the investor elasticity distribution to a security at the 10th percentile, the price impact is only two-thirds as large. To assess the portfolio re-balancing effects, we construct a novel shift-share instrument to measure investors' quasi-exogenous exposure to central bank purchases, based on investors' holdings of eligible securities before the QE program was announced. We show that funds and banks sell eligible securities to the central bank and re-balance their portfolios towards ineligible securities, with investors ex-ante more exposed to central bank purchases re-balancing more. Using detailed holdings data of mutual funds, we estimate that for each euro sold to the central bank, the average fund allocates 88 cents to ineligible assets and 12 cents to other eligible assets that the central bank does not buy in that time period. The price of ineligible securities held by more exposed funds increases compared to those held by less exposed funds, underscoring the portfolio re-balancing channel at work.

Keywords: financial intermediaries, mutual funds, central bank, asset pricing
JEL Classification: E52, E58, G11, G12, G23

Non-technical summary

To combat the Great Recession following the 2008 financial crisis and the more recent Pandemic Recession, central banks around the globe purchased unprecedented quantities of securities. Largely as a result of asset purchases (also known as Quantitative Easing or QE), balance sheets of major central banks ballooned in size, constituting - at the peak - between 40% (US Federal Reserve, Bank of England) and 130% of their country's GDP (Bank of Japan). By purchasing large quantities of assets, the central banks aim to affect asset prices throughout the economy. Indeed, according to the so-called portfolio re-balancing channel, QE operates well beyond the effect on prices the central bank purchases directly: it also affects other asset prices as investors selling assets to the central bank re-balance into other securities not eligible for central bank purchases. At the same time, the effectiveness of QE as a policy is the subject of intense dispute among economists as it is difficult to separate the effects of QE from other contemporaneous events and policy measures. The identification and quantification of the particular channels through which QE operates is subject to several challenges, as the decisions of investors to sell securities to the central bank and to re-balance their portfolios are affected by a host of factors.

In this paper, we set out to deal with these challenges and to quantify both the direct and indirect effects of large-scale asset purchases. We use proprietary security-level data on asset holdings of major investors (banks, insurances, pension funds, mutual funds) to analyze how different investors adjust their holdings of the same security in the same time period, in response to central bank purchases. We argue that QE effects depend crucially on the composition of investors selling assets to the central bank. Our data allows us to measure the direct effects on security level and we show that central bank purchases have smaller effects on yields for securities predominantly held by more price-elastic investors - mutual funds and banks. Comparing a security at the 90th percentile of the investor elasticity distribution to a security at the 10th percentile, the price impact is only two-thirds as large.

To assess the portfolio re-balancing effects, we construct a novel shift-share instrument to measure investors' quasi-exogenous exposure to central bank purchases. The instrument is based on investors' holdings of securities eligible for purchases before the QE program was announced. We show that funds and banks – major investors in the bond markets - sell eligible securities to the central bank and re-balance their portfolios towards ineligible securities, with investors ex-ante more exposed to central bank purchases re-balancing more. In contrast, insurance companies and pension funds are less elastic, and respond less to central bank purchases, and therefore contribute less to the portfolio re-balancing channel. Using detailed holdings data of mutual funds, we estimate that for each euro sold to the central bank, the average fund allocates 88 cents to ineligible assets and 12 cents to other eligible assets that the central bank does not buy in that time period. The prices of ineligible securities held by funds more exposed to central bank purchases increase compared to those held by less exposed funds, underscoring the portfolio re-balancing channel at work.

We reach these conclusions by analyzing purchases conducted by the European Central Bank (ECB) from 2015 to 2022. Our sample encompasses two major programs: the Asset Purchase Program (APP) and the Pandemic Emergency Purchase Program (PEPP), which combined amounted to nearly 5 trillion euros of purchases (60 percent of euro area GDP) by the end of 2022. Assets targeted under these programs include government bonds, corporate bonds, asset-backed securities, and covered bonds. We use Securities Holdings Statistics (SHS), an administrative database of portfolio holdings of private investors collected by the ECB. Portfolio holdings are reported at the security (ISIN), quarter, and investor-type level. In addition, we merge SHS with confidential information on ECB purchases at the security level. To study spillover effects, we also employ detailed mutual fund-level portfolio holdings data provided by Lipper, a market data provider.

1 Introduction

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In the first part of the paper, we assess the importance of investor heterogeneity for the direct effects of central bank purchases. Large-scale asset purchases are isomorphic to negative changes in supply, as they effectively reduce the supply of bonds available to private investors in the market. In a demand-supply framework, the effect of a given purchase on the

[1] To arrive at this split, we take the re-balancing coefficients from our regression analysis for both eligible assets not purchased and ineligible assets. We weigh the estimates by the portfolio composition (number of securities held) of the respective asset types for the average fund.

price of one security depends on the slope of the demand curve for that asset. In a setting with investors with different price-elasticity, this slope can depend on the composition of investors holding the bond. Empirically, to estimate the slope of the demand curve, we need a plausibly exogenous supply shock. However, in our setting, supply changes are not necessarily randomly allocated, as purchases could be correlated with asset characteristics.

To address this challenge, we isolate a random component of purchases and, with that, estimate the price elasticity of each type of investor. Our identification strategy compares central government bonds purchased by the ECB issued by the same country and with similar residual maturity. By including security fixed effects and quarter - country - residual maturity fixed effects, we absorb variation in ECB purchases that could be correlated with security characteristics. Even when comparing purchased bonds to very close substitutes, purchases by the ECB reduce yields. We use this supply shock generated by the ECB purchases to estimate investor-type level price elasticity. For each investor type, we regress the security holdings on that security's yield, instrumenting the yield with ECB purchases. Investors outside of the euro area, along with euro area banks and mutual funds, exhibit a positive price-elasticity statistically different from zero. In contrast, insurance companies and pension funds are relatively more inelastic.

Given the estimated investor elasticities, we construct a security-level measure of the price elasticity of the investor base. For each security, we compute a weighted average of the investor-type level elasticity estimates, where the weights are the shares of the amount outstanding held by each investor type. Investor composition might be endogenous to asset purchases. To address this concern, we exploit quasi-exogenous cross-sectional variation in investor base composition across securities, measuring the share held by each investor type prior to the announcement and implementation of asset purchases. The weighted elasticity measure is by construction higher for assets held ex-ante more by more elastic investors. With this measure, we can finally test how investor composition affects the direct impact of central bank purchases.

We find that the effects of purchases on prices are smaller for securities that are predominantly held by more elastic investors, but also that the effects of purchases are non-linear: they increase as the stock of a particular security held by the central bank increases. Our regressions of bond yields on ECB purchases interacted with the weighted elasticity measure show that ECB purchases reduce yields but less so for securities with higher weighted elasticity. Furthermore, we show that the higher the stock of a given security the ECB holds, the lower the elasticities of the remaining investors holding that security are and the larger the price impact of an additional ECB purchase is. These results highlight that heterogeneous price elasticities of investors matter for asset prices. Quantitatively, sorting securities by the price elasticity of their investor base, we find that the direct effects of central bank purchases for a security at the 90th percentile of the investor elasticity distribution are only two-thirds as large as for a security at the 10th percentile.

In the second part of the paper, we examine the indirect effects of large-scale asset purchases: how the prices of ineligible assets are affected by portfolio re-balancing. Intuitively, as the price of eligible securities increases, private investors may re-balance their portfolio towards ineligible assets, generating spillover effects. We first focus on quantity re-balancing at the investor-security level and then show the effects on prices of ineligible securities. In this part of the analysis, we focus on mutual funds, one investor type we estimated to be elastic. The advantage of zooming in mutual funds is having fund-level portfolio holdings data.

Since mutual funds could endogenously choose to hold a portfolio highly exposed to central bank purchases, we construct a shift-share instrument of mutual funds' exposure. For each fund, in each quarter, we construct a measure of predicted exposure to ECB purchases. This variable depends on how much the ECB buys of each security in each quarter and how much each fund owned of that security at the end of 2014 (before the beginning of the central bank purchase program). The exogeneity of the instrument relies on the ex-ante shares to be quasi-exogenous. We use this predicted exposure to instrument for the amount of eligible securities the funds sell. Between 2015 and 2022, we estimate that the average fund sells 0.5% of its eligible portfolio holdings due to central bank purchases. At the same time, we estimate substantial heterogeneity across funds. We exploit the cross-sectional heterogeneity across funds in exposure and portfolio allocation of ineligible securities to estimate spillover effects.

For the same ineligible security in the same quarter, funds ex ante more exposed to large-scale asset purchases re-balance their portfolios more towards such security. We regress the portfolio weight of each ineligible security each fund holds on the fund's exposure measure, instrumented by the predicted exposure. One concern is that ineligible securities held by more-exposed funds could differ from ineligible securities held by less-exposed funds: to address this, we use a within-security estimator based on Khwaja and Mian (2008), including security by time fixed effects in our analysis. Intuitively, by "holding the security fixed" at each point in time, we ensure that security-time-varying factors do not drive re-balancing. We estimate that for each euro sold to the central bank, an average fund allocates 88 cents to ineligible assets and 12 cents to other eligible assets that the central bank does not buy in that time period.

Next, we study the price impact of the estimated quantity re-balancing. Since we find that funds with higher exposure re-balance more, we test whether the prices of securities held by more exposed funds increase compared to securities held by less exposed funds. The intuition behind this hypothesis is that funds are more likely to re-balance towards existing securities in their portfolio, so heterogeneity in preferences that generate heterogeneous portfolio allocations across private investors influences the pass-through of the policy.

To identify the causal effect of ECB asset purchases on the price of ineligible securities, we construct a shift-share instrument of the amount purchased of each ineligible security by funds. We compute the predicted change in the nominal amount for each security based on the interaction of two terms: the portfolio weight of each ineligible security for each fund and the quasi-exogenous exposures of funds to central bank purchases. The exogeneity of the shift-share instrument, in this case, relies on the "shifter", the exposure of funds, being exogenous. The intuition behind this instrument is that we use a predicted version of how much ineligible securities would be impacted by second-round purchase flows if funds were re-balancing according to pre-existing portfolio weights.

In our analysis, we also include quarter-by-security characteristics fixed effects to address the potential sorting between funds and securities. In other words, we seek not to compare securities for which we expect price dynamics to differ. In the assessment of quantity re-balancing, we use a within-security estimator to address this issue. To study the effects on prices, we identify a set of observable characteristics that yield similar results to the within-security estimator (Khwaja and Mian (2008) , Chodorow-Reich (2014b)) and include those as controls in the estimation of effects on prices. Given this strategy, we estimate the effect on prices of ineligible securities of second-round demand shocks induced by central bank purchases.

We find evidence of spillover effects as the prices of securities that more exposed funds hold increase compared to those held by less exposed funds. Quantitatively, the price impact on ineligible assets is smaller but on the same order of magnitude as the price impact on eligible assets. This result shows that central bank purchases have the potential to affect the prices of securities that they do not directly target. This insight can help assess the calibration and targeting of asset purchase programs by central banks based on their objective function. Our results show that private investors' preferences mediate the propagation of the policy. Since our estimation relies on revealed preferences by measuring investors' ex-ante portfolio allocation, our methodology can be used to predict the effects of purchases across ineligible assets for a given set of targeted assets.

Related Literature. This paper relates to several strands of literature on unconventional monetary policy, intermediary and demand-system asset pricing.

First, we relate to the literature on large-scale asset purchases in the Euro Area, studying announcement effects of purchases (Andrade et al. (2016), Altavilla et al. (2015)) and portfolio re-balancing (Bergant et al. (2020), Albertazzi et al. (2021)), and estimating price elasticities (Koijen and Yogo (2019), De Santis and Holm-Hadulla (2020)). In the context of the Federal Reserve operations, D'Amico and King (2013) study flow and stock effects of purchases, Lu and Wu (2023) study portfolio re-balancing due to traditional interest rate policy, and Acharya et al. (2022) study how Fed purchases induced long-duration IG-focused investors to rebalance their portfolios towards higher-yielding IG bonds. We contribute to this literature by estimating spillover effects on assets that are not eligible for central bank purchases while emphasizing the role of investor heterogeneity and developing a novel identification methodology.

We share with Koijen et al. (2021) the focus on investor heterogeneity. Koijen et al. (2021) study the direct effects of QE and estimate demand elasticities of investors for different national issuers of government bonds in the euro area (e.g., German Bunds, French government bonds etc.), following the approach of Koijen and Yogo (2019). They find that demand elasticities are heterogeneous across investors, with foreign investors having the most elastic demand, and insurance companies and pension funds having the least elastic demand. We estimate the direct effects of purchases on a security - rather than national-issuer - level and we show that the direct effects of QE are non-linear, and become larger as the stock of a given security held by the central bank increases.

Second, this paper contributes to the intermediary asset pricing literature (Greenwood and Vayanos (2010), Greenwood and Vayanos (2014), Vayanos and Vila (2021)) and growing work on demand system asset pricing (Koijen and Yogo (2019), Gabaix and Koijen (2021)) that has highlighted the role of investors' preferences in determining equilibrium asset prices Coppola (2021). Our contribution to this literature is to analyze the role of investors' preferences for the propagation of large scale asset purchases.

Finally, we relate to a broader literature in monetary policy (Friedman and Kuttner (2010) Eggertsson and Woodford (2003) Stein (2012) studying large scale asset purchases as a policy tool (Bernanke (2020), Vissing-Jorgensen and Krishnamurthy (2011) Chodorow-Reich (2014a) Woodford (2016)) and their relationship to traditional interest rate policy (Greenwood et al. (2023)).

The remainder of the paper is organized as follows. In section 2, we provide a stylized supply and demand model for one asset and K heterogeneous investors, which we subsequenly extend to N assets. In section 3, we describe the data we use in the empirical sections. In section 4, we test how investors' composition matters for the direct effects of purchases. In section 5, we study spillover effects driven by portfolio re-balancing of mutual funds. In section 6, we analyze portfolio re-balancing of heterogenous investor types beyond mutual funds.

2 A theoretical framework

2.1 A stylized 1 asset model with K heterogeneous investors

In this section, we present a simple one asset model to think about the effects of purchases on prices when an asset is held by multiple investors. There is one bond in fixed supply S, the price of the bond is denoted by p. There are K investors in measures μ_k. Assume the demand function for investor type k is of the following form:

$$x_k = \alpha_k - p\beta_k.$$

Then the aggregate demand curve for the asset is

$$\sum_k \mu_k x_k = \sum_k \mu_k(\alpha_k - p\beta_k)$$

where μ_k is the share of investor k in the market.

By adding market clearing ($S = \sum_k \mu_k x_k$) we can derive that the price of the asset takes the following form:

$$p = \frac{\sum_k \mu_k \alpha_k}{\sum_k \mu_k \beta_k} - \frac{S}{\sum_k \mu_k \beta_k}.$$

We model purchases by the central bank as a negative supply shock, since purchases are effectively reducing the net supply of the bond available for private investors: $\Delta ECB = -\Delta S$.

It follows that the effect of purchases on the price of the asset is:

$$\Delta p = \frac{1}{\underbrace{\sum_k \mu_k \beta_k}_{\text{B}}} \Delta ECB.$$

We define $B = \sum_k \mu_k \beta_k$ as the aggregate elasticity, which in this stylized model is a weighted sum of investors' elasticities. The aggregate elasticity is a combination of potentially heterogeneous investors' elasticities: in this paper we investigate how in the cross-section of securities the effects on the price can vary as the weighted elasticity varies. The extent to which B varies across assets depends empirically on the relative dispersion of investor elasticities β_k and of the shares of investors μ_k across assets.

2.2 A portfolio choice model with N assets and K investors

In this section we propose a more general model with K investors and N assets to think about the direct effect and spillover effect of purchases. Following Greenwood and Vayanos (2014) and Hanson (2014) we assume the representative investor has mean-variance preferences over N assets. We denote by $\mathbf{d}_t$ the $Nx1$ vector of demand for each asset. $E_t[\mathbf{rx}_{t+1}]$ and $\text{Var}_t[\mathbf{rx}_{t+1}]$ correspond respectively to the $Nx1$ vector of expected returns and NxN variance-covariance matrix of returns. $1/\tau$ is a risk-aversion coefficient. The representative investor solves the following portfolio allocation problem:

$$\max_{\mathbf{d}_t} \left\{ (\mathbf{d}_t)' E_t[\mathbf{rx}_{t+1}] - \frac{1}{2\tau} (\mathbf{d}_t)' \text{Var}_t[\mathbf{rx}_{t+1}] (\mathbf{d}_t)' \right\}.$$

The demand function for each asset is of the following form:

$$\mathbf{d}_t = \tau \left(\text{Var}_t[\mathbf{r}_{t+1}]\right)^{-1} E_t[\mathbf{rx}_{t+1}].$$

In this paper we are interested in highlighting the role of heterogenous investors with different price-elasticities. We introduce β_k to allow investors' demand functions to differ from the representative investor:

$$\mathbf{d}_{t,k} = \beta_k \tau \left(\text{Var}_t[\mathbf{r}_{t+1}]\right)^{-1} E_t[\mathbf{rx}_{t+1}].$$

As in the previous section we define the share of investor k in the market as μ_k, the vector $\boldsymbol{\mu} = [\boldsymbol{\mu}_k, \boldsymbol{\mu}_{k'}, ...\boldsymbol{\mu}_K]$ is $Kx1$. We denote by $\mathbf{S}_t$ the $Nx1$ vector of total supply, or amount outstanding of each security. We denote with $\mathbf{D_t} = [\mathbf{d}_{t,k}, \mathbf{d}_{t,k'}, ...\mathbf{d}_{t,K}]$ the NxK matrix of demand of each investor type for each security. Total demand from investors in the market is in equilibrium equal to total supply, due to market clearing: $\mathbf{D}_t\boldsymbol{\mu} = \mathbf{S}_t$.

For simplicity assume 2 assets with variance equal to 1 and covariance equal to ρ:

$$E_t\left[\mathbf{rx}_{t+1}\right] = \begin{bmatrix} rx_1 \\ rx_2 \end{bmatrix}$$

and

$$\mathrm{Var}_t\left[\mathbf{rx}_{t+1}\right] = \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}.$$

Assume risk aversion equal to 1; then demand for each security by each investor k is of the following form:

$$\begin{bmatrix} d_{1,k} \\ d_{2,k} \end{bmatrix} = \begin{bmatrix} \beta_k \\ \beta_k \end{bmatrix} \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}^{-1} \begin{bmatrix} rx_1 \\ rx_2 \end{bmatrix}$$

$$d_{1,k} = \beta_k c(rx_1 - \rho rx_2)$$

$$d_{2,k} = \beta_k c(rx_2 - \rho rx_1)$$

where $c = (1 - \rho^2)^{-1}$.

Market clearing implies:

$$\sum_k \mu_k d_{1,k} = S_1.$$

We can derive the price effect for a change in supply for each security. In the first part of the paper, we study direct effects of the policy. The expression for the own-price effect in this framework is

$$\frac{\Delta rx_1}{\Delta S_1} = \frac{1}{\sum_k \mu_k \beta_k c}.$$

As in the stylized model in the previous section, the effect of purchases depends on the weighted demand elasticity of different investors, where the weights correspond to holding shares.

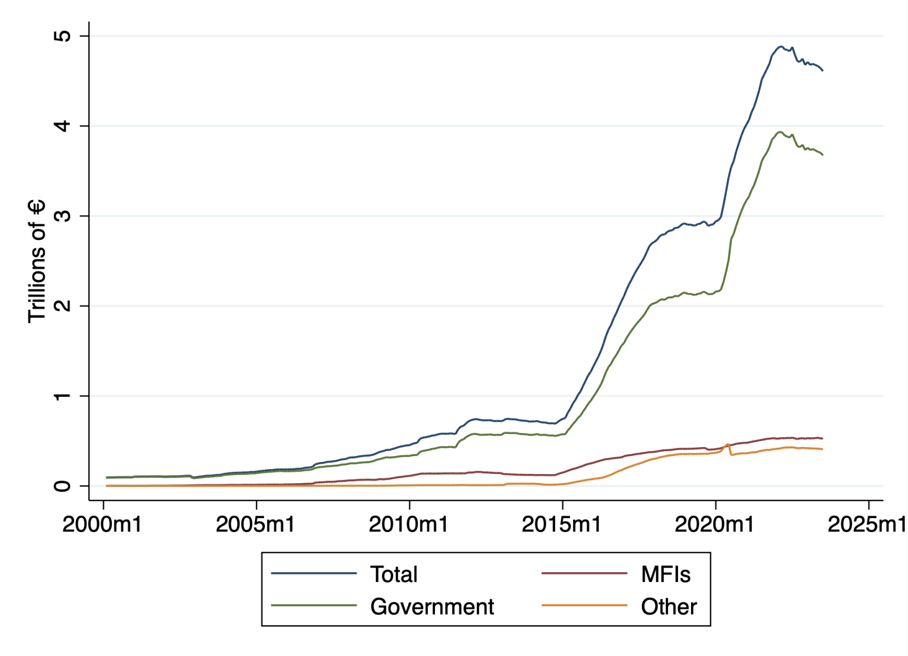
In the second part of the paper, we study indirect effects of the policy, the expression for the cross-price effect in this framework is

$$\frac{\Delta r x_2}{\Delta S_1} = \frac{\rho}{\sum_k \mu_k \beta_k c}.$$

3 Data and Institutional Framework

We use two main sources of portfolio holdings information. The first dataset is Securities Holdings Statistics by investor type provided by the ECB. Securities Holdings Statistics has been collected on a security-by-security, at the ISIN (CUSIP) level (based on Regulation ECB/2012/24), quarterly, since the fourth quarter of 2013. Financial institutions report positions of both their direct investment and indirect investment as custodians of non-reporting agents. The SHS Sector module provides information on the holdings of institutional sectors resident in individual countries within the Euro Area. The type of security reported are debt security, listed shares, and investment funds shares. The advantage of this database is to provide very comprehensive information of Euro Area residents holdings. However, the database does not provide individual investors' portfolio holdings. We therefore use portfolio holdings data also from a second data source: Refinitiv's Lipper for Investment Management. We retrieve mutual fund-level information on portfolio holdings at a quarterly frequency. We observe portfolio holdings at market valuation and also as shares of total fund holding. Lipper sources the portfolio holdings directly from the fund management companies. We merge holdings information from SHS and Lipper with the Centralized Securities Database (CSDB) that contains security level characteristics such as price, yield, issuer country, issuer sector, nominal currency, instrument type.

Figure 1: Debt securities held by the ECB



Note: The figure reports the amount of debt securities held by the Eurosystem issued by euro area residents in trillions of Euros. The blue line corresponds to the total amount held. The green line corresponds to the amount held of debt securities issued by the government sector. The red line corresponds to the amount held of debt securities issued by the monetary and financial institutions. The yellow line corresponds to the residual amount. Source: ECB Data portal, series key BSI.M.U2.N.C.A30.A.1.U2.0000.Z01.E (Total) - BSI.M.U2.N.C.A30.A.1.U2.1000.Z01.E(MFIs) - BSI.M.U2.N.C.A30.A.1.U2.2100.Z01.E (General Government) - BSI.M.U2.N.C.A30.A.1.U2.2200.Z01.E (Non-MFIs excl. general gov.)

We analyze the effects of purchases conducted by the European Central Bank starting from 2015q1 under the Asset Purchase Program (APP) and the Pandemic Emergency Purchase Program (PEPP). These two programs account for a substantial share of the balance sheet expansion of the ECB and combined amounted to nearly 5 trillion euros of purchases (60 percent of euro area GDP) by end 2022 (see Figure 1).

The amount of quarterly ECB purchases was announced overtime at the press conferences and allocation of this amount across countries was pre-determined by the so-called “capital key” rule (shares ownership by national central banks in the ECB’s capital). Public sector purchases are only on the secondary market, in line with European regulation that prohibits sovereign debt financing. The ECB aims to be market neutral as stated from this quote from the ECB website: “In its implementation of the public sector purchase programme (PSPP), the Eurosystem conducts purchases in a gradual and broad-based manner, aiming to achieve market neutrality in order to avoid interfering with the market price formation mechanism." (ECB website).

4 Direct effects and investor heterogeneity

In this section we study the following research question: do effects of asset purchases depend on investor composition?

In order to answer this question, we test how purchases affect yields and how these effects vary as investor composition changes. In other words, our goal is to empirically estimate the following stylized regression:

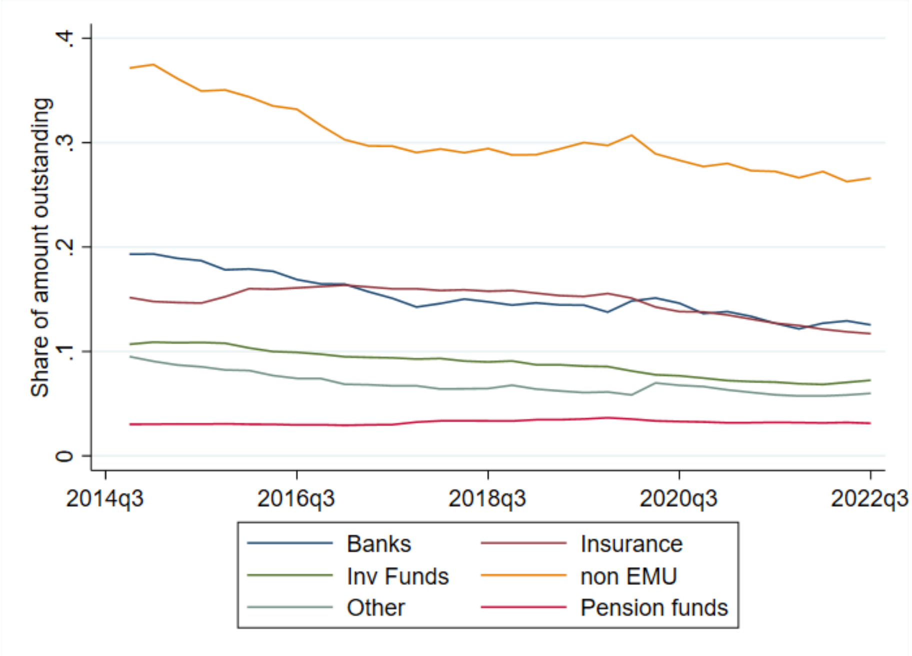
$$Yield = \beta ECBPurchase * Investorcomp. + ECBPurchase + Investorcomp.$$

where β is the coefficient of interest.

Given that *ECB purchases* and *Investor composition* are not necessarily randomly assigned across securities and overtime, we face an identification challenge. Our empirical strategy consists of three steps. First, we isolate a random component of ECB purchases by interacted fixed effects, assuming that, conditional on certain characteristics purchases are "as good as random". Second, we use the ECB purchase shock to estimate the demand elasticities of different types of investors. Third, we measure investor composition by exploiting quasi-random variation in ex-ante investor composition.

For identification reasons, since we want to compare bonds "holding the issuer fixed", we restrict our analysis of direct effects to sovereign bonds. In Figure 2, we report the share of amount outstanding of Euro Area sovereign bonds held by each investor type. We group private investors into six types: Non EMU (European Monetary Union) corresponds to investors outside of the Euro Area, whereas the remaining five types comprise euro area investors - banks, mutual funds, insurance companies, pension funds, and "other", which corresponds to smaller residual investors (government, households).

Figure 2: Share of amount outstanding of sovereign debt



Note: The figure reports the share of amount outstanding of sovereign debt issued by Euro Area countries held by different type of investors across time. The “nonEMU” category corresponds to investors outside of the European Monetary Union.

In Table 1, we report security-level summary statistics, including the share of each security held by the ECB and by each investor type, as well as price, yield, original and residual maturity. There is considerable cross-sectional variation across securities in the share of amount outstanding held by each investor type. For instance, insurance companies hold on average 19% of a security total supply, but this value goes from 2% at the 10th percentile of distribution to 45% at the 90th percentile. In the next section we will investigate how this security-level heterogeneity in investor composition matters for the effects of asset purchases.

Table 1: Government bonds - Summary statistics

	count	mean	sd	p10	p50	p90
Holdings as a fraction of Amount Outstanding						
ECB	9330	0.235	0.139	0.030	0.259	0.418
Banks	9330	0.179	0.178	0.003	0.146	0.398
Insurance	9330	0.189	0.188	0.015	0.130	0.450
Investment funds	9330	0.093	0.080	0.018	0.075	0.179
Non EMU	9330	0.213	0.175	0.016	0.167	0.461
Pension funds	9330	0.040	0.064	0.002	0.017	0.092
Other	9330	0.068	0.106	0.002	0.036	0.155
Security characteristics						
Price	9330	114.900	18.014	99.400	109.228	143.740
Yield	9330	0.458	0.827	-0.460	0.271	1.673
Orig Mat	9330	14.951	8.974	5.249	10.504	31.014
Resid Mat	9330	8.531	7.045	1.964	6.295	19.248

Note: This table reports summary statistics of sovereign government bonds purchased by the ECB. The top part of the table reports holdings as a fraction of the amount outstanding for each investor type in the dataset. The bottom part of the table reports static and dynamic security level characteristics

4.1 Direct effects of purchases

Our strategy is to use fixed effects to control for multiple bond characteristics to identify the effect of purchases on yields. Specifically, we run the following specification:

$$Yield_{n,t} = \theta_n + \delta_{t,c,m} + \frac{1}{B} ECBshare_{n,t} + \nu_{n,t} \qquad (1)$$

where θ_n corresponds to the security FE and $\delta_{t,c,m}$ corresponds to the interaction of quarter, issuer country and maturity FE. Introducing these controls in the regression allows us to compare bonds issued by the same country, in the same quarter and with similar residual maturity.

In Table 2 we report results of the specification above where the outcome variable is the yield of the bonds. In table Table 18 in the appendix we test the effects on log prices rather than yields.

Table 2: Purchase effect: Yield

	(1) Yield	(2) Yield	(3) Yield	(4) Yield	(5) Yield
ECB Share	-0.487**	-0.591***	-0.154**	-0.206***	-0.177**
	(-3.36)	(-4.48)	(-3.24)	(-3.79)	(-3.48)
Observations	9329	9329	9030	7468	5844
R^2	0.901	0.915	0.987	0.987	0.989
F	11.28	20.05	10.48	14.40	12.14
Isin_FE	Yes	Yes	Yes	Yes	Yes
Quarter_FE	Yes				
QuarterXMaturity_FE		Yes			
QuarterXIssuerXMaturity_FE			Yes	Yes	Yes

Note: The table reports regressions of the form $Yield_{n,t} = \theta_n + \delta_{t,c,m} + \frac{1}{B} ECBshare_{n,t} + \nu_{n,t}$. ECB Share is the fraction of amount outstanding held by the ECB. Column (1) reports the result of the baseline panel regression only with quarter and security (Isin) fixed effects. In column (2) we interact quarter and maturity groups, so that comparisons are only made between securities in the same quarter and maturity group. In column (3-5) we add an additional interaction with country, in order to compare only bonds in the same quarter and maturity group issued by the same country. In column (1-2-3), the residual maturity variable is discretized in 4 bins: 1-2 years, 2-5 years, 5-10 years, above 10 years. In column (4) and (5) every bin has, respectively, a size of 2 years and 1 year residual maturity. t statistics are reported in parentheses. Standard errors are two-way clustered at the security and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

Column 1 reports the result of the baseline panel regression only with quarter and security fixed effects. In column 2, we interact quarter and maturity groups, so that comparisons are only made between securities in the same quarter and maturity group. In columns 3-5 we add an additional interaction with country, in order to compare only bonds in the same quarter and maturity group issued by the same country. The residual maturity variable is discretized into 4 bins in column 1-2-3 (1-2 years, 2-5 years, 5-10 years, above 10 years). In column 4 and 5, every bin has, respectively, a size of 2 years and 1 year residual maturity. Therefore in column 5, the comparison is across bonds in the same quarter, issued by the same country and with a very similar residual maturity (at most 1 year difference). The coefficient of interest in column 5, the specification with more granular maturity fixed effects is similar, and even smaller, in size compared to column 3, which implies that controlling for residual maturity at a less granular level is conservative. Therefore, we consider column 3 our preferred specification, since it allows us to retain more observations. We use this specification as a first-stage for the next part of the analysis.

In terms of magnitude, the coefficient in column 3 is equal to -0.15 which implies that if the ECB buys 100% of a sovereign bond (the share goes from zero 0 to 1), the yield will decrease on average by 15 basis points. This effect is computed relative to other assets that are very similar, and are likely to be close substitutes: in other words since SUTVA may not apply in this set-up, we consider this estimate a lower bound on the overall effect of purchases. Intuitively, we expect investors to substitute towards close substitutes that are purchased less by the ECB, driving the yield of those securities closer to the one of securities that are purchased more. The coefficient in column 1 and 2 is about 3 times larger than in the following columns, suggesting that the country dimension matters when it comes to evaluate sovereign bonds substitutability.

4.2 Demand elasticities of investors

In this section we investigate how different investor types react to Large Scale Asset Purchases (LSAPs). In particular we're interested in understanding how elastic they are with respect to the purchases, and which ones accommodate the purchases more. In the previous section, we estimated the sensitivity of yields to ECB purchases. In a supply and demand framework, we can think of large-scale asset purchases as a negative supply shock, since the central bank is effectively taking part of the supply of government bonds out of the market. In this section, we want to use this supply shock to trace out the demand curves of different investor types. As in the previous section, the identification strategy relies on comparing similar securities using interacted fixed effects. In the following specification, we regress the share that each investor type owns of a specific bond on the yield of the bond where the the yield is instrumented by the ECB share. The First Stage of this regression corresponds to column 3 of Table 2 in the previous section.

In Table 3 we report the Two Stages Least Square results and estimate the demand sensitivity of each investor type to changes in yields: Non EMU, banks and mutual funds have a sensitivity statistically different from zero, while insurance companies and pension funds are more inelastic. These results are in line with previous research by Koijen et al. (2021), as well as prior literature showing that insurance companies and pension funds tend to hold bonds to maturity and are less responsive to changes in prices (Coppola (2021) Chodorow-Reich et al. (2021)).

$$ShareInvestor_{n,t} = \theta_n + \delta_{t,c,m} + \beta \hat{Yield}_{n,t} + \nu_{n,t} \quad (2)$$

where $\hat{Yield}_{n,t}$ has been instrumented by $ECBShare_{n,t}$

Table 3: Investors' type elasticity: Yield - 2SLS regression

	(1) NonEMU	(2) Invfunds	(3) Banks	(4) Insurance	(5) Pension	(6) Other
Yield	2.188**	0.863**	1.464**	0.120	0.167	0.554**
	(3.25)	(3.00)	(2.78)	(0.82)	(1.85)	(2.83)
Observations	9030	9030	9030	9030	9030	9030
Isin	Yes	Yes	Yes	Yes	Yes	Yes
QuarterXIssuerXMaturity	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table reports two stages least square regressions of the form $ShareInvestor_{n,t} = \theta_n + \delta_{t,c,m} + \beta \hat{Yield}_{n,t} + \nu_{n,t}$. *ShareInvestor* is the fraction of amount outstanding held by each investor type. $\hat{Yield}$ is instrumented by *ECB Share*. The first stage is reported in Table 2. The residual maturity variable is discritized in 4 bins: 1-2 years, 2-5 years, 5-10 years, above 10 years. t statistics are reported in parentheses. Standard errors are two-way clustered at the security and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

In Table 4 we report regression results of the reduced form version of Equation 2. Each coefficient corresponds to how much each investor type sells in quantity terms when the ECB purchases one unit of the security. 33% of the purchases are accommodated by investors outside of the Euro area, 22% by banks and 13% by mutual funds. Koijen et al. (2021) find that foreign investors outside the euro area accommodated most of the Eurosystem's purchases. Our result is qualitatively in line with them, but quantitatively the importance of foreign investors in our estimation is relatively lower. This could be because in our estimation strategy we control for granular fixed effects and/or because we analyze a longer time-series.

Table 4: Investors' type selling: Quantity - Reduced form

	(1) NonEMU	(2) Invfunds	(3) Banks	(4) Insurance	(5) Pension	(6) Other	(7) Res
ECB Share	-0.337***	-0.133***	-0.226***	-0.0185	-0.0258*	-0.0855***	-0.174***
	(-12.41)	(-7.16)	(-5.19)	(-0.89)	(-2.28)	(-4.63)	(-4.35)
Observations	9030	9030	9030	9030	9030	9030	9030
R^2	0.955	0.891	0.936	0.982	0.930	0.946	0.901
Isin	Yes	Yes	Yes	Yes	Yes	Yes	Yes
QuarterXIssuerXMat.	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table reports regressions of the form $ShareInvestor_{n,t} = \theta_n + \delta_{t,c,m} + \beta ECBShare + \nu_{n,t}$. *ShareInvestor* is the fraction of amount outstanding held by each investor type while ECB Share is the fraction of amount outstanding held by the ECB. The residual maturity variable is discritized in 4 bins: 1-2 years, 2-5 years, 5-10 years, above 10 years. t statistics are reported in parentheses. Standard errors are two-way clustered at the security and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

4.3 Direct effects: The role of investor heterogeneity

In this section we investigate if the composition of investors is affecting the effects of purchase flows. As highlighted in the previous section, different investor types have different elasticities: foreign investors, mutual funds, banks have relatively high elasticity, while insurance companies and pension funds tend to be more inelastic. Given these heterogeneous elasticities, we test whether the effects of purchases on yields are smaller in magnitude for securities held more by more elastic investors.

We exploit quasi-exogenous cross-sectional variation in the investor base composition. In particular, we measure the holding composition for each security before asset purchases (APP) were announced and implemented by the ECB. We measure holdings at the end of 2014 and, based on these holding shares and the elasticities estimated in Table 3, we construct a security-level weighted elasticity measure. We also use ex-ante share as an instrument for the evolution of shares overtime and construct an instrumented weighted elasticity.

$$\text{Ex-ante Weighted Elasticity: } B_{n,2014q4} = \sum_k \mu_{n,k,2014q4}\beta_k \tag{3}$$

where β_k are the elasticities calculated in Table 3 and $\mu_{n,k,2014q4}$ is the share of the asset n held by investor k in 2014q4.

$$\text{Instrumented Weighted Elasticity: } \hat{B}_{n,t-1} = \sum_k \hat{\mu}_{n,k,t-1}\beta_k \quad (4)$$

where $\hat{\mu}_{n,k,t-1}$ is the share of the asset n held by investor k at t-1 instrumented by $\mu_{n,k,2014q4}$.

In Table 5 we report the first stage to calculate the instrumented weighted elasticity: we regress shares over time on ex-ante shares. First stage results are statistically different from zero, as investors' shares are highly predictable from ex-ante shares.

$$\mu_{n,t} = \delta_{t,c,m} + \alpha\mu_{n,2014q4} + \nu_{n,t}$$

Table 5: Shares of investors - First stage

	(1) Banks	(2) Insurance	(3) Invfunds	(4) NonEMU	(5) Pensionfunds	(6) Other
Ex-ante Share	0.738***	0.994***	0.490***	0.696***	0.578***	0.908***
	(11.22)	(32.74)	(6.66)	(10.61)	(14.09)	(6.71)
N	3886	3886	3886	3886	3886	3886
R^2	0.863	0.963	0.827	0.895	0.879	0.907
QuarterXIssuerXMatur.	Yes	Yes	Yes	Yes	Yes	Yes
F	125.9	1072.2	44.41	112.6	198.5	44.97

Note: The table reports regressions of the form $\mu_{n,t} = \delta_{t,c,m} + \alpha\mu_{n,2014q4} + \nu_{n,t}$. μ is the fraction of amount outstanding held by each investor type. μ_{2014q4} is the fraction of amount outstanding held by each investor type at the end of 2014. The residual maturity variable is discritized in 4 bins: 1-2 years, 2-5 years, 5-10 years, above 10 years. t statistics are reported in parentheses. Standard errors are two-way clustered at the security and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

Given the weighted elasticity measures we estimate the following regression:

$$Yield_{n,t} = \delta_{t,c,m} + \frac{1}{B}ECBshare_{n,t} + \gamma W.Elasticity_n + \beta ECBshare_{n,t} * W.Elasticity_n + \nu_{n,t} \quad (5)$$

The coefficient of interest is β which is the coefficient on the interaction term of the elasticity measure and the purchase shock. In Table 6 we report regression results of the specification above: the coefficient on the interaction term is positive which implies that when securities are held by more elastic investors the effects on yields are dampened. Table 20 reports similar results also on log prices.

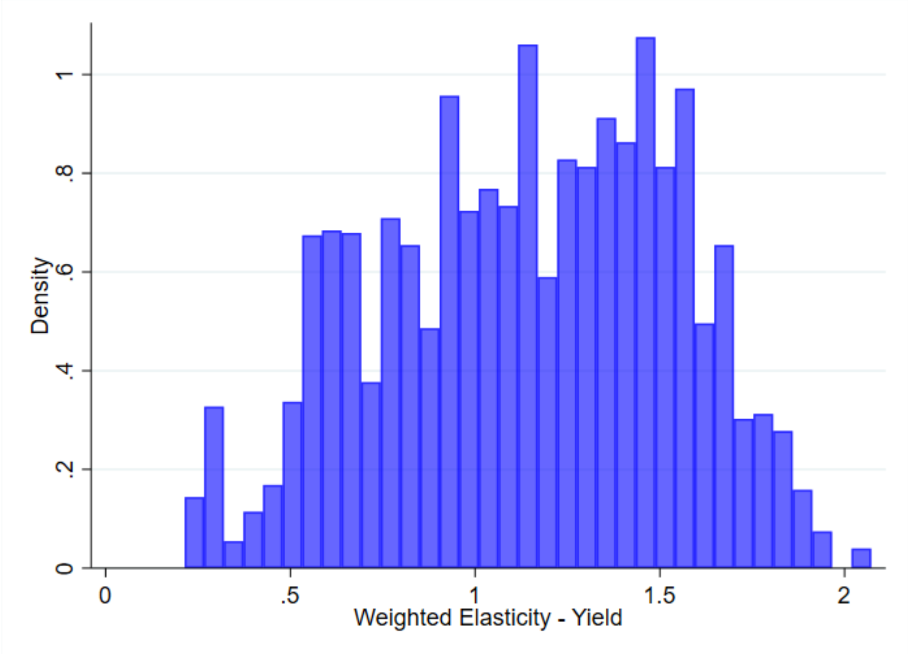
The effects on yields are dampened roughly by a third when the weighted elasticity goes up by one. In order to understand the magnitude of the effect, it is useful to look at the density of the elasticity measure. In Figure 3 we report the density of the weighted elasticity that corresponds to column 1 of Table 6. The interaction term corresponds to a change in weighted elasticity equal to one: that implies that comparing two securities at the 10th and 90th percentile of the holding composition distribution, the direct effects of quantitative easing are reduced by 1/3.

Table 6: Heterogenous effects of QE - Yield

	(1) Yield	(2) Yield
ECB Share	-1.307***	-1.353***
	(-4.80)	(-4.33)
ExAnte Weighted Elasticity	-0.158*	
	(-2.38)	
ECB Share × $ExAnteWeightedElasticity$	0.420*	
	(2.07)	
$\hat{W}eightedElasticity$		-0.216*
		(-2.14)
ECB Share × $\hat{W}eightedElasticity$		0.570+
		(1.86)
Observations	3886	3886
R^2	0.964	0.964
QuarterXIssuerXMaturity_FE	Yes	Yes

Note: The table reports regressions of the form $Yield_{n,t} = \delta_{t,c,m} + \frac{1}{B} ECBshare_{n,t} + \gamma W.Elasticity_n + \beta ECBshare_{n,t} * W.Elasticity_n + \nu_{n,t}$. ECB Share is the fraction of amount outstanding held by the ECB. In column (1) $Ex-anteWeightedElasticity$ is computed using as weights ex-ante shares. In column (2) $Weighted\hat{E}lasticity$ is computed using as weights shares instrumented in Table 5. The residual maturity variable is discritized in 4 bins: 1-2 years, 2-5 years, 5-10 years, above 10 years. t statistics are reported in parentheses. Standard errors are two-way clustered at the security and quarter level. +,*,**,*** indicate significance at the 10%, 5%, 1%, 0.1% level, respectively.

Figure 3: Density of the Weighted elasticity variable



Note: The figure reports the density of the Weighted Elasticity variable. This variable is computed according to the following equation: $B_{n,2014q4} = \sum_k \mu_{n,k,2014q4}\beta_k$ where β_k are the elasticities calculated in Table 3 and $\mu_{n,k,2014q4}$ is the share of the asset n held by investor k in 2014q4.

What is driving differences in investor composition across securities? In table Table 7 we report results from a cross-sectional regression of the weighted elasticity on bond characteristics. We control for issuer by maturity fixed effects in order to compare government bonds issued by the same country and in a similar maturity range. Bonds with a higher weighted elasticity have a lower original maturity and a "higher" year of issuance. This means that when comparing two similar bonds, the one held by more inelastic investors (insurance companies and pension funds) is a bond that was issued with a higher original maturity and further back in time. Intuitively, insurance companies and pension funds tend to buy long term bonds and hold them to maturity.

Table 7: Determinants of Investor composition

	(1) Weighted Elasticity	(2) Weighted Elasticity	(3) Weighted Elasticity
Original Maturity	-0.0228***		
	(-5.18)		
Year of issuance		0.0238***	
		(5.27)	
Residual Maturity			-0.0327
			(-0.84)
Observations	208	208	208
R^2	0.744	0.746	0.701
IssuerXMaturity	Yes	Yes	Yes

Note: The table reports regressions of the form $WeightedElasticity_n = \delta_{c,m} + \alpha Covariates_{n,2014q4} + \nu_n$. Original and residual maturity are measured in years. Year issuance corresponds to the year of issuance of each security. As a fixed effect, the residual maturity variable is discritized in 4 bins: 1-2 years, 2-5 years, 5-10 years, above 10 years. t statistics are reported in parentheses. Standard errors are two-way clustered at the security and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

Finally, we show that the direct effects of purchases are non-linear and depend on the stock of a particular security the central bank holds. To arrive at this result, we first show that, as the stock of a given security the ECB holds increases, the remaining investor base holding that security is less elastic (Table 20). We then document that the price impact of an additional unit of that security purchased by the ECB is larger. Quantitatively, comparing a security in the 90th percentile of ECB holdings on security level to a security at the 10th percentile of holdings, the price impact of an additional purchase is 20 basis points higher (see Figure 5).

5 Spillover effects to ineligible securities

5.1 Funds' exposure and portfolio rebalancing

In this section we study the effect of purchases on ineligible assets. Indeed, central banks general objective is to ease financing conditions for a broad class of assets, potentially beyond the ones specifically targeted by purchases. The extent to which a demand shock on specific securities can affect other non-targeted securities depends on the degree to which investors substitute treated assets with untreated ones. Our goal is to estimate the effect on prices of second-order demand shocks due to investors re-balancing their portfolio towards ineligible securities.

We will first zoom in on the mutual fund sector, one of the investor types that we estimated to be relatively elastic and for which we have portfolio data at the fund level. For each fund we define an *Exposure* index calculated as the amount each fund sells in a given quarter of securities purchased by the ECB in that quarter. This index measures how much each fund is selling of securities purchased by the ECB.

$$Exposure_{f,t} = \frac{\sum_n \Delta Amount_{f,t,n}}{TotPortfolio}$$

if n is purchased by the ECB at time t.

This quantity could be endogenously chosen by the fund and be correlated with specific funds' investment strategy: for instance a fund could choose to sell a high share of their portfolio to the ECB in order to invest in other securities. Therefore, we construct an instrument to address this endogeneity concern. We define the instrument as *Predicted Exposure*, this variable measures how much a fund can potentially sell to the ECB based on their portfolio allocation at the end of 2014 (before QE was announced).

$$PredExposure_{f,t} = \frac{\sum_n Share_{f,2014q4,n} * \Delta ECBAmount_{t,n}}{TotPortfolio}$$

For each security, we calculate how much the ECB buys in a given quarter, and we predict how much each fund would sell based on the share of amount outstanding that they held of the security at the end of 2014. By summing over securities for each fund, we get a predicted exposure index whose variation across funds is driven by quasi-exogenous exposure to QE due to variation in ex-ante portfolio allocation. In the language of shift-share designs, we claim that $Share_{f,2014q4,n}$, the ex-ante exposure, is uncorrelated with unobserved determinants of the outcome variable, as in Goldsmith-Pinkham et al. (2020). Both exposure measures are normalized by the total portfolio amount held by each fund.

The first stage of our analysis is to test whether predicted exposure is a good predictor of funds' exposure to ECB purchases.

$$Exposure_{f,t} = \gamma_t + \omega PredExposure_{f,t} + \nu_{t,f}$$

In Table 8 we report first stage results. The estimated coefficient implies that a fund that has a 1pp higher ex-ante exposure to purchases, sells 0.9pp more of its portfolio compared to a less exposed fund. One way of interpreting the coefficient ω in this specification is a measure of funds' sector demand sensitivity to supply shocks, since it indicates how much a fund is selling for a given purchase by the ECB.

Table 8: Funds' exposure - first stage

	Exposure
Pred Exposure	0.904***
	(8.02)
Observations	29231
R^2	0.063
Quarter	Yes
F	64.27

Note: The table reports regressions of the form $Exposure_{f,t} = \gamma_t + \omega PredExposure_{f,t} + \nu_{t,f}$. Exposure is calculated as the amount each fund sells in a given quarter of securities purchased by the ECB in that quarter. Predicted Exposure is a shift-share instrument that measures how much a fund can potentially sell to the ECB based on their portfolio allocation at the end of 2014. t statistics are reported in parentheses. Standard errors are two-way clustered at the fund and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

In Table 26 we report summary statistics for the sample of mutual funds we study. The average fund in the average quarter holds 3 billions of Euros and is predicted to sell 0.02% of its portfolio because of purchases by the ECB. In Table 27 we report the distribution of the exposures measures cumulated over time: the "endogenous" exposure, the predicted exposure and the "instrumented exposure", which is the predicted value from the first stage regression in Table 8. The average fund in the sample sells 0.5% of its portfolio due to central bank purchases between 2015 and 2022. There is substantial heterogeneity in exposure across funds. In the next section we will study this heterogeneity in exposure to understand how the price of ineligible securities is affected.

Given this first stage, we now turn to our main specification, which tests whether more exposed funds re-balanced more towards non-treated assets. The left hand side variable $\Delta Weight$ corresponds to the change in portfolio weight of securities that are not purchased by the ECB (ineligible assets). The hypothesis we test is whether funds that are more exposed to purchases re-balance their portfolio more towards ineligible assets. In Table 9 we report regression results of the following specification:

$$\Delta Weight_{n,t,f} = \alpha_{n,t} + \beta Exposure_{f,t} + \nu_{n,t,f}$$

Column 1 and 2 report OLS results, while in column 3 and 4 2SLS results, where we use predicted exposure as an instrument for the right-hand-side variable.

Table 9: Funds' rebalancing

	(1) (OLS) $\Delta Weight$	(2) (OLS) $\Delta Weight$	(3) (2SLS) $\Delta Weight$	(4) (2SLS) $\Delta Weight$
Exposure	0.00127***	0.00122***	0.00517**	0.00466**
	(4.71)	(4.42)	(3.45)	(3.07)
Observations	17389158	17389158	17384902	17385061
R^2	0.111	0.011		
QuarterXIsin	Yes		Yes	
QuarterXControls		Yes		Yes
Y Mean	-0.00252	-0.00252	-0.00252	-0.00252

Note: The table reports regressions of the form $\Delta Weight_{n,t,f} = \alpha_{n,t} + \beta Exposure_{f,t} + \nu_{n,t,f}$. $\Delta Weight$ corresponds to the change in portfolio weight of ineligible assets. Column (1-2) report OLS results. Column (3-4) report 2SLS results, where Exposure is instrumented by Predicted Exposure as in Table 8. Column (1) and (3) we control for quarter by security fixed effects. Column (2) and (4) we control for quarter interacted with the following control variables: Issuer country, Issuer sector, Asset type, Currency. t statistics are reported in parentheses. Standard errors are two-way clustered at the fund and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

In column 1 and 3 we control for quarter by security fixed effects. These controls are important to make sure we identify re-balancing towards ineligible securities that is driven only by exposure to QE rather than other factors. Indeed one of the identification threats in this exercise is potential non random assignment of funds and securities, in other words funds more exposed could be holding securities that are different from the ones held by less exposed funds. By introducing quarter by security fixed effects, we are holding the security fixed in each point in time and testing whether funds that are more exposed re-balance more towards the same security with respect to funds that are less exposed. The security fixed effects control for any observable and unobservable security time-varying factor that could be correlated with the error term $\nu_{n,t,f}$. In the next section of the paper, we assess the effects on prices of ineligible assets. Since prices are a security by quarter characteristic, in the price analysis we have to drop quarter by security fixed effects. Our strategy is to identify a set of observable controls that can be a good proxy for security fixed effects. In column 2 and 4 we substitute quarter by security fixed effects with quarter interacted with a set of control variables: Issuer country, Issuer sector, Asset type, Currency. The coefficient in column 3 and 4 is relatively stable, this implies that observable controls are a good proxy for security fixed effects since funds re-balancing behaviour is not different whether conditioning on security or control based fixed effects.

A similar identification strategy has been used in the context of bank lending to address potential sorting across borrowers and lenders by Khwaja and Mian (2008) and Chodorow-Reich (2014b).

Quantitatively, the coefficient of the 2SLS specification imply that a fund that is 1 pp more exposed to QE increases the portfolio weight of the average ineligible security in their portfolio by 0.5 basis points. This effects is low in absolute terms but not in relative terms since the average change in portfolio weight at the security level is -0.2 basis points as reported in Table 9.

5.2 Effect on prices of ineligible securities

In this section we study whether purchase flows induced by QE via re-balancing have effect on prices of assets not targeted by the central bank. In order to do so we want to measure how much funds purchase ineligible securities due to re-balancing.

First, we define the change in nominal amount that funds in our sample hold of each security. This variable quantifies how much each security is purchased by funds in our sample.

$$\Delta log(NomAmount)_{n,t} = \Delta log \sum_f NomAmount_{n,f,t}$$

Second, we define an instrument that isolate the change in quantity that is driven by funds re-balancing due to central bank purchases.

We calculate *Predicted Flow* as the predicted quantity change for each ineligible security by each fund due to exposure to quantitative easing.

$$PredictedFlow_{n,f,t} = (\sum_n Share_{f,2014q4,n} * \Delta ECBAmount_{t,n}) * Weight_{n,f,t-1}$$

where

$$PredExposure_{f,t} = \frac{\sum_n Share_{f,2014q4,n} * \Delta ECBAmount_{t,n}}{TotPortfolio}$$

This is a shift-share instrument where the shifter is the numerator of "Predicted exposure" computed previously and the shares are portfolio weights of ineligible securities in the previous quarter we consider the shifter quasi-exogenous (Borusyak et al. (2022)). Intuitively, we predict funds to distribute liquidity from QE according to their previous portfolio allocation.

We use these predicted flows at the security-flow level to calculate predicted change in nominal amounts held by funds.

$$\Delta log(PredNomAmount)_{n,t} = \Delta log \sum_f (NomAmount_{n,f,t-1} + PredictedFlow_{n,f,t})$$

We use the predicted demand flow measure as an instrument for the purchase flow measure.

$$\Delta log(NomAmount)_{n,t} = \gamma_t * Controls_n + \beta \Delta log(PredNomAmount)_{n,t} + \nu_{n,t}$$

In table Table 10 we report the first-stage result. Predicted demand flows are a good predictor of realized purchase flows. For a 1% increase in demand, there is an increase in holdings of 0.89%.

Table 10: Flows' predictability

	$\Delta log(NomAmount)$
$\Delta log(PredNomAmount)$	0.894^{***}
	(67.89)
Observations	653027
R^2	0.713
QuarterXControls	Yes

Note: The table reports regressions of the form $\Delta log(NomAmount)_{n,t} = \gamma_t * Controls_n + \beta \Delta log(PredNomAmount)_{n,t} + \nu_{n,t}$. $\Delta log(NomAmount)$ corresponds to the change in nominal amount of each security held by funds. $\Delta log(PredNomAmount)$ corresponds to the predicted change in nominal amount of each security. t statistics are reported in parentheses. Standard errors are two-way clustered at the security and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

Finally, we test how these second order purchase shock impacted prices with the following specification.

$$\Delta \log(P)_{n,t} = \gamma_t * Controls_n + \beta \Delta log(NomAmount)_{n,t} + \nu_{n,t} \tag{6}$$

In Table 11 we report regression results for Equation 6: in column 1 we run an OLS regression while in column 2 the 2SLS specification. In both specifications we include security by controls fixed effects so that securities that are more exposed because in the hands of more exposed funds are comparable to the less exposed ones. The control variables are the ones selected in the previous section: Issuer country, Issuer sector, Asset type, Currency.

Table 11: Effect on prices of indirect demand shock

	(OLS)	(2SLS)
	$\Delta log(P)$	$\Delta log(P)$
$\Delta log(NomAmount)$	0.00139***	0.00193***
	(5.65)	(6.32)
Observations	665787	653002
R^2	0.301	
QuarterXControls	Yes	Yes

Note: The table reports regressions of the form $\Delta \log(P)_{n,t} = \gamma_t * Controls_n + \beta \Delta log(NomAmount)_{n,t} + \nu_{n,t}$. $\Delta log(NomAmount)$ corresponds to the change in nominal amount of each security held by funds. In column (1) we report OLS results. In column (2) we report 2SLS results where the first stage is reported in Table 10 t statistics are reported in parentheses. Standard errors are two-way clustered at the security and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

The coefficient in Table 11 implies that for a 1% increase in demand by funds due to re-balancing, the price of ineligible assets increases by 0.2 basis points.

We compare the magnitude of this effect to the magnitude of the direct effects (an increase in price due to an increase in demand by the ECB). We run a similar specification but on eligible securities and having on the right hand side the change in demand by the ECB. As in the first part of the paper we use interacted fixed effects to isolate the "random" component of purchases.

$$\Delta \log(P)_{n,t} = +\alpha_n + \gamma_{t,c,m} * Controls_n + \beta \Delta log(ECBAmount)_{n,t} + \nu_{n,t} \tag{7}$$

The coefficient in Table 12 is in the same order of magnitude although about 1.5 times larger then the coefficient estimated in table Table 11. This suggests that the effect on prices of purchases are larger for eligible securities than ineligible ones.

Table 12: Effect on prices of direct demand shock

	(1)	(2)	(3)	(4)	(5)
	$\Delta log(P)$	$\Delta log(P)$	$\Delta log(P)$	$\Delta log(P)$	$\Delta log(P)$
$\Delta log(ECBAmount)$	0.00624*	0.00384**	0.00334**	0.00327***	0.00318***
	(2.76)	(3.22)	(3.59)	(7.35)	(7.35)
Observations	8200	8200	7919	6442	4969
R^2	0.488	0.765	0.919	0.965	0.966
Quarter FE	Yes				
QuarterXMaturity FE		Yes			
QuarterXIssuerXMatur. FE			Yes	Yes	Yes

Note: The table reports regressions of the form $\Delta \log(P)_{n,t} = +\alpha_n + \gamma_{t,c,m} * Controls_n + \beta \Delta log(ECBAmount)_{n,t} + \nu_{n,t}$. ECB Amount is the nominal amount of a security held by the ECB. Column (1) reports the result of the baseline panel regression only with quarter and security fixed effects. In column (2) we interact quarter and maturity groups, so that comparisons are only made between securities in the same quarter and maturity group. In column (3-5) we add an additional interaction with country, in order to compare only bonds in the same quarter and maturity group issued by the same country. The residual maturity variable is discritized in 4 bins in column (1-2-3): 1-2 years, 2-5 years, 5-10 years, above 10 years. While in column (4) and (5) every bin has, respectively, a size of 2 years and 1 year residual maturity. t statistics are reported in parentheses. Standard errors are two-way clustered at the security and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

6 Spillover effects and investor heterogeneity

6.1 Investors' exposure and portfolio rebalancing

In the previous section we focus the analysis on one subset of investors, mutual funds, for which we have detailed holdings data at the portfolio level. In order to assess spillover effects on the market in a more complete way, in this section we use Securities Holdings Statistics (SHS) data that we describe in section 3. In this data we can observe security level holdings of investors categories rather than at the individual level, but it allow us to broadly cover holdings of securities in the Euro Area by every type of investor. Including holdings data from the 19 Euro Area countries and the different investor types we end up with 184 portfolios.

The identification strategy and regression analysis mirrors the one in the previous section. We construct exposure measures in an analogous way and estimate re-balancing to ineligible securities of investors.

In the first stage of the analysis, we check whether *Predicted Exposure* is a good instrument for the amount investors sell of eligible securities.

$$Exposure_{k,t} = \gamma_t + \omega PredExposure_{k,t} + \nu_{k,t}$$

Table 13: Investors' exposure - first stage

	Exposure
Pred Exposure	0.318*
	(2.41)
Observations	4505
R^2	0.058
Isin	No
Quarter	Yes
Y Mean	0.0283
F	5.811

Note: The table reports regressions of the form $Exposure_{k,t} = \gamma_t + \omega PredExposure_{k,t} + \nu_{k,t}$. Exposure is calculated as the amount each investor sells in a given quarter of securities purchased by the ECB in that quarter. Predicted Exposure is a shift-share instrument that measures how much each investor can potentially sell to the ECB based on their portfolio allocation at the end of 2014. t statistics are reported in parentheses. Standard errors are two-way clustered at the investor and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

In section 4 we estimated heterogeneity in elasticity across investor types based on how price-elastic they were to ECB purchases. In the following specification, we text whether for a given exposure more elastic investors sell more of eligible securities. Intuitively, this first stage is an alternative way of estimating elasticities of investors.

$$Exposure_{k,t} = \gamma_t + \omega PredExposure_{k,t} * Investortype + \nu_{k,t}$$

Table 14: Investors' exposure - first stage

	Exposure
Banks × Pred Exposure	0.519*
	(2.06)
Insurance × Pred Exposure	0.434
	(1.72)
Inv funds × Pred Exposure	0.869**
	(2.88)
Pension funds × Pred Exposure	-0.194
	(-0.31)
Other × Pred Exposure	-0.0760
	(-0.23)
Observations	4505
R^2	0.066
Quarter	Yes

Note: The table reports regressions of the form $Exposure_{k,t} = \gamma_t + \omega PredExposure_{k,t} * Investortype + \nu_{k,t}$. Exposure is calculated as the amount each investor sells in a given quarter of securities purchased by the ECB in that quarter. Predicted Exposure is a shift-share instrument that measures how much investor each can potentially sell to the ECB based on their portfolio allocation at the end of 2014. t statistics are reported in parentheses. Standard errors are two-way clustered at the investor and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

Mutual funds and banks that are predicted to sell (based on ex-ante holdings of eligible securities) do sell eligible securities, while pension funds and insurance companies for a given predicted exposure do not sell eligible securities. These results are in line with Table 3, where we estimate heterogeneity in elasticity across investor types. This is reassuring, since in the first part of the paper we estimate elasticities based on interacted fixed effects while in this part of the project we do that with a shift-share instrument. Moreover for identification in section 4 we focus only on sovereign bonds while in this part of the paper we keep all the securities purchased by the ECB under the APP and PEPP program. Additionally, the result on mutual funds is in line with Table 8 where we estimated the same regression but on a different dataset (Lipper).

Given this first stage we now turn to our main specification, which tests whether investors that were more exposed re-balanced more towards non-treated assets. In Table 15 we report regression results: column 1 and 2 report OLS results from the following specification, in column 3 and 4 results from 2SLS where we use predicted exposure as an instrument for the right hand side variable.

$$\Delta Weight_{n,t,k} = \alpha_{n,t} + \beta Exposure_{k,t} + \nu_{n,,t,k}$$

Table 15: Investors' rebalancing

	(1) (OLS) $\Delta Weight$	(2) (OLS) $\Delta Weight$	(3) (2SLS) $\Delta Weight$	(4) (2SLS) $\Delta Weight$
Exposure	0.000757***	0.000720***	0.00512*	0.00491+
	(5.46)	(4.99)	(2.08)	(2.03)
Observations	85889995	82595800	85889995	82595800
R^2	0.109	0.010	-0.003	-0.003
QuarterXIsin	Yes		Yes	
QuarterXControls		Yes		Yes
Y Mean	-0.000694	-0.000713		

Note: The table reports regressions of the form $\Delta Weight_{n,t,k} = \alpha_{n,t} + \beta Exposure_{k,t} + \nu_{n,,t,k}$. $\Delta Weight$ corresponds to the change in portfolio weight of ineligible assets measured in basis points. Column (1-2) report OLS results. Column (3-4) report 2SLS results, where Exposure is instrumented by Predicted Exposure as in Table 13. Column (1) and (3) we control for quarter by security fixed effects. Column (2) and (4) we control for quarter interacted with the following control variables: Issuer country, Issuer sector, Asset type, Currency. t statistics are reported in parentheses. Standard errors are two-way clustered at the investor and quarter level. +,*,**,*** indicate significance at the 10%, 5%, 1%, 0.1% level, respectively.

In column 1 and 3 we control for quarter-by-security fixed effects, by holding the security fixed in each point in time we test whether investors that are more exposed purchase more of the same security with respect to less exposed once. In column 2 and 4 we substitute quarter-by-security fixed effects with quarter interacted with a set of control variables: Asset Class, Issuer country, Issuer sector, Currency. Since the coefficient in column 3 and 4 is stable we assume that observable characteristics of the security are a good proxy for the un-observable ones. Quantitatively, for an increase in exposure of 1 percentage point the change in security weight of the average security (expressed in basis points for convenience) increases by 0.005 bp.

6.2 Investor heterogeneity and effect on prices of ineligible securities

In the previous section we show that, for a given exposure, different investor types have different elasticities. So for a given exposure we expect ineligible securities in the hands of elastic investors to be purchased more. This means that when we evaluate the pass-through of purchases from the ECB to non-eligible assets, there are two important margins to consider: exposure and elasticity. Intuitively, consider an inelastic investor type like pension funds, even if they are highly exposed they may not sell eligible securities and therefore re-balance towards ineligible securities.

As we did in section 5 for mutual funds, we now measure how much investors purchase ineligible securities due to re-balancing.

First, we define the change in nominal amount that investors in our sample hold of each security. This variable quantifies how much each security is purchased by investors in our sample.

$$\Delta log(NomAmount)_{n,t} = \Delta log \sum_f NomAmount_{n,f,t}$$

Second, we define an instrument that isolate the change in quantity that is driven by investors re-balancing due to central bank purchases. We construct an instrument analogous to the one contructed for funds.

We calculate *Predicted Flow* as the predicted quantity change for each ineligible security by each investor due to exposure to quantitative easing.

$$PredictedFlow_{n,f,t} = (\sum_n Share_{f,2014q4,n} * \Delta ECBAmount_{t,n}) * Weight_{n,f,t-1}$$

where

$$PredExposure_{f,t} = \frac{\sum_n Share_{f,2014q4,n} * \Delta ECBAmount_{t,n}}{TotPortfolio}$$

In this section we want to explore how the investor composition base can shape the effects on ineligible securities. To measure investor composition base heterogeneity we construct security-level *Weighted elasticity* as we did in section 4.

$$\text{Weighted Elasticity: } B_{n,t-1} = \sum_k \hat{\mu}_{n,k,t-1}\beta_k \tag{8}$$

where $\hat{\mu}_{n,k,t-1}$ is the share of the asset n held by investor k at t-1 and β_k are the elasticities of investor types estimated in section 4.

In Table 16 we use predicted demand flow measures as an instrument for realized purchase flows. We add an interaction term with the *Weighted elasticity* variable to test whether ineligible securities held by more elastic investors receive higher purchase flows for a given exposure. Intuitively, in the previous section, we show that elastic investor types are selling more eligible securities, as a consequence we expect ineligible securities in the hands of more elastic investors to be purchased more.

$$\Delta log(NomAmount)_{n,t} = \gamma_t * Controls_n + \beta\Delta log(PredN)_{n,t} * W.Ela_{n,t-1} + \alpha\Delta log(PredN)_{n,t} + \omega W.Ela_{n,t-1} + \nu_{n,t}$$

Table 16: Second order purchase flows

	$\Delta log(NomAmount)$
$\Delta log(PredNomAmount)$	0.133^{*}
	(2.07)
$\Delta log(PredNomAmount)\times$ L.Weighted Ela	0.0562^{**}
	(3.37)
L.Weighted Ela	0.000704^{***}
	(20.77)
Observations	3046584
R^2	0.129
QuarterXControls	Yes

Note: The table reports regressions of the form $\Delta log(NomAmount)_{n,t} = \gamma_t * Controls_n + \beta\Delta log(PredN)_{n,t} * W.Ela_{n,t-1} + \alpha\Delta log(PredN)_{n,t} + \omega W.Ela_{n,t-1}\nu_{n,t}$. $\Delta log(NomAmount)$ corresponds to the change in nominal amount of each security held by investors. $\Delta log(PredNomAmount)$ corresponds to the predicted change in nominal amount of each security. t statistics are reported in parentheses. Standard errors are two-way clustered at the security and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

Finally, we test how prices of ineligible securities are affected by second order purchase flows and how investor composition base matter for those. In Table 17 we find that for a given purchase flow the price of ineligible securities increases, but increases by less when they are held predominantly by more elastic investors. This result is in line with what we found in the first part of the paper for direct effects of purchases: effects on prices are smaller for securities held more by more price elastic investors.

$$\Delta\log(P)_{n,t} = \gamma_t * Controls_n + \beta\Delta log(NomAm)_{n,t} * W.Ela_{n,t-1} + \alpha\Delta log(NomAm)_{n,t} + \omega W.Ela_{n,t-1} + \nu_{n,t}$$

Table 17: Price impact

	(2SLS) $\Delta log(P)$
$\Delta log(Nomamount)$	1.038***
	(9.25)
$\Delta log(Nomamount)\times$ L. Weighted Ela	-0.372***
	(-8.88)
L.Weighted Ela	-0.000438***
	(-5.47)
Observations	2994675
QuarterXControls	Yes

Note: The table reports regressions of the form $\Delta\log(P)_{n,t} = \gamma_t * Controls_n + \beta\Delta log(NomAm)_{n,t} * W.Ela_{n,t-1} + \alpha\Delta log(NomAm)_{n,t} + \omega W.Ela_{n,t-1} + \nu_{n,t}$. $\Delta log(NomAmount)$ corresponds to the change in nominal amount of each security held by investors. We report 2SLS results where the first stage is reported in Table 16. t statistics are reported in parentheses. Standard errors are two-way clustered at the security and quarter level. *,**,*** indicate significance at the 5%, 1%, 0.1% level, respectively.

These findings highlight that when it comes to indirect effects the role of elastic vs inelastic investors is non-trivial. On the one hand, securities held by more elastic investors receive more second-order purchase flows. On the other hand, for a given flow the effect on prices is lower for securities held by more elastic investors.

7 Conclusion

In this paper, we examine the role of investor heterogeneity for both direct and indirect effects of central bank purchases. For assets eligible for central bank purchases, we provide evidence that the direct effects of central bank purchases on prices are smaller when securities are held predominantly by more elastic investors. We show that ineligible assets are also impacted through portfolio re-balancing, and that the propagation of the central bank shock depends on investors' portfolio allocations. Our findings show substantial heterogeneity in exposure to large-scale asset purchases across mutual funds. Funds that hold a portfolio with high exposure to central bank purchases tend to re-balance more towards ineligible securities. The prices of ineligible securities held by funds with greater exposure increases relative to those held by less-exposed ones. These results imply that large-scale asset purchases do influence the prices of ineligible assets and that the impact of large-scale asset purchases fundamentally depends on the preferences of market participants.

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A Direct effects - Additional tables

Table 18: Purchase effect: Log price

	(1) log(P)	(2) log(P)	(3) log(P)	(4) log(P)	(5) log(P)
ECB Share	0.115***	0.122***	0.107***	0.0966***	0.111***
	(4.73)	(6.33)	(5.52)	(5.07)	(5.47)
Observations	9329	9329	9030	7468	5844
R^2	0.910	0.957	0.975	0.978	0.978
F	22.41	40.09	30.48	25.67	29.93
Isin_FE	Yes	Yes	Yes	Yes	Yes
Quarter_FE	Yes				
QuarterXMaturity_FE		Yes			
QuarterXIssuerXMaturity_FE			Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 19: Investors' type elasticity: Log price - IV regression

	(1) NonEMU	(2) Invfunds	(3) Banks	(4) Insurance	(5) Pension	(6) Other
log(P)	-3.142***	-1.239***	-2.102**	-0.172	-0.240	-0.796**
	(-5.55)	(-4.90)	(-3.65)	(-0.83)	(-1.99)	(-3.42)
Observations	9030	9030	9030	9030	9030	9030
Isin	Yes	Yes	Yes	Yes	Yes	Yes
QuarterXIssuerXMaturity	Yes	Yes	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 20: Heterogenous effects of QE - Log Price

	(1) log(P)	(2) log(P)
ECB Share	0.517**	0.614**
	(3.07)	(3.13)
WeightedElasticity	0.0715	
	(1.73)	
ECB Share × WeightedElasticity	-0.439**	
	(-3.09)	
$\hat{W}eightedElasticity$		0.109
		(1.75)
ECB Share × $\hat{W}eightedElasticity$		-0.672**
		(-3.14)
Observations	3886	3886
R^2	0.715	0.716
QuarterXIssuerXMaturity_FE	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 21: Investors' type elasticity: Yield - OLS regression

	(1) NonEMU	(2) Invfunds	(3) Banks	(4) Insurance	(5) Pension	(6) Other
Yield	0.0183*	0.00536	0.0114	-0.00308	0.00760	0.00355
	(2.31)	(0.73)	(0.70)	(-0.56)	(1.70)	(0.64)
Observations	9030	9030	9030	9030	9030	9030
R^2	0.948	0.886	0.933	0.982	0.929	0.945
Isin	Yes	Yes	Yes	Yes	Yes	Yes
QuarterXIssuerXMaturity	Yes	Yes	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 22: Investors' type elasticity: Log price - OLS regression

	(1) NonEMU	(2) Invfunds	(3) Banks	(4) Insurance	(5) Pension	(6) Other
log(P)	-0.151*	-0.200***	-0.0615	0.127**	0.0535*	-0.130**
	(-2.76)	(-3.72)	(-0.87)	(3.50)	(2.67)	(-3.35)
Observations	9030	9030	9030	9030	9030	9030
R^2	0.949	0.889	0.933	0.982	0.930	0.946
Isin	Yes	Yes	Yes	Yes	Yes	Yes
QuarterXIssuerXMaturity	Yes	Yes	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 23: ECB Purchases correlation with security characteristics

	ECB Share	ECB Share	ECB Share	ECB Share
Residual Maturity	0.000394**			-0.00939**
	(3.15)			(-3.07)
Original Maturity		0.000156		0.00976**
		(1.51)		(3.20)
Year of issuance			0.000368*	0.0101***
			(2.08)	(3.31)
Observations	10160	10160	10160	10160
R^2	0.312	0.312	0.312	0.313
QuarterXIssuerCountryFE	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 24: Weighted elasticity correlation with security characteristics

	Weighted Ela	Weighted Ela	Weighted Ela	Weighted Ela
Residual Maturity	-0.0240***			-0.224*
	(-6.01)			(-2.40)
Original Maturity		-0.0315***		0.201*
		(-10.45)		(2.16)
Year of issuance			0.0518***	0.252**
			(9.32)	(2.70)
Observations	463	463	463	463
R^2	0.515	0.579	0.561	0.601
IssuerCountryFE	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

B Dynamic Implications

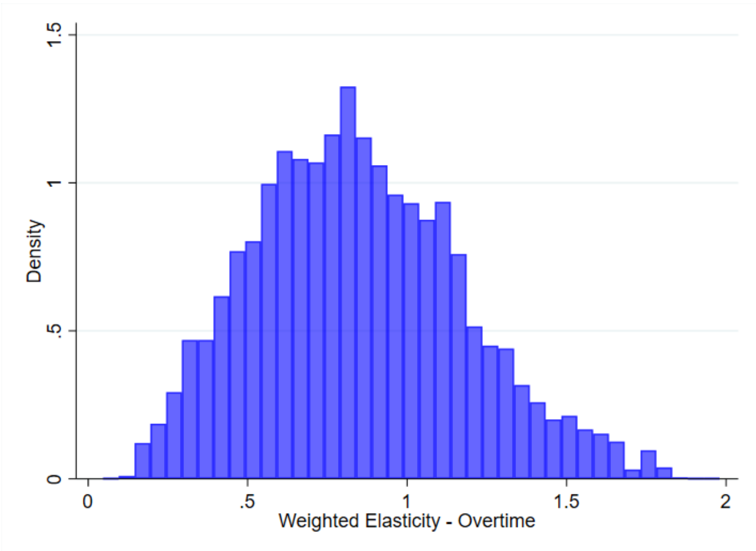
In section 4 we established that different investor types react differently to ECB purchase flows and taking into account their heterogenous elasticities we found that assets held more by more elastic investors tend to react less to purchase flows. Because of this heterogeneity, there could be interesting dynamic implications as purchases cumulate overtime. If the investors selling the most are the more elastic ones, overtime, the market will become more inelastic, since the residual investor composition will be more skewed towards inelastic investors.

B.1 Is the market more inelastic as a result of QE?

In this section we explore whether as a result of purchases assets are more in the hands of inelastic investors. To test this we construct an ex-post weighted elasticity variable, which is similar to the weighted elasticities constructed in the previous section, but where we allow the shares of investors to endogenously change overtime.

Ex-post Weighted Elasticity: $B_{n,t} = \sum_k \mu_{n,k,t}\beta_k$ where β_k are the elasticities calculated in Table 3 (elasticities are in absolute value, so that a high value corresponds intuitively to high elasticity) and $\mu_{n,k,t}$ is the share of the asset n held by investor k at time t.

Figure 4: Density of Ex-post Weighted Elasticity



In the following regression we test whether this ex-post elasticity decreases as the ECB Share increases. Notice that the variation in the ex-post weighted elasticity is driven by endogenous changes in the holding shares. This is coherent with previous results showing heterogeneity in investors' reactions to purchase flows.

$$B_{n,t} = \theta \ ECBshare_{n,t} + \nu_{n,t}$$

Table 25 reports that as the ECB shares increases the residual investors composition becomes more inelastic. Intuitively by controlling for interacted fixed effects, we compare similar bonds, and the weighted elasticity of bonds that have been purchased more, ceteris paribus, goes down by more. Column 1 has both security as well as quarter and interacted fixed effects, column 2 looks only at time series variation within a security, column 3 only at cross-sectional variation across securities within a quarter, country and maturity bucket. Column 4 tests also whether there's a reduction in elasticity as in column 1 but in a first difference specification.

Table 25: Evolution of investor composition

	(1) Weighted Ela	(2) Weighted Ela	(3) Weighted Ela	(4) D.Weighted Ela
ECB Share	-1.434***	-1.211***	-0.526**	
	(-26.81)	(-30.20)	(-3.49)	
D.ECB Share				-1.523***
				(-21.44)
Constant	1.198***	1.144***	0.976***	0.00448***
	(91.59)	(114.49)	(22.75)	(5.14)
Observations	8041	8320	8066	7384
R^2	0.977	0.955	0.548	0.549
Isin_FE	Yes	Yes		
QuarterXIssuerXMaturity_FE	Yes		Yes	Yes

t statistics in parentheses

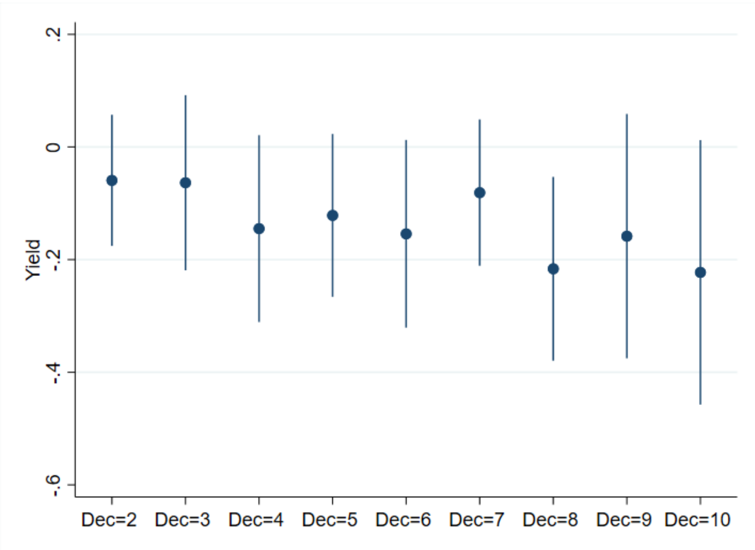
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Next, we test whether the effects of purchases on yields are higher when the level of purchases is already higher. In other words, we test whether the effects of purchase flows are non-linear, in particular we are interested in understanding whether the change in investors composition that we just identified has an impact on the effects of purchase flows.

In the following specification, we interact ECB Share with deciles of the ECB Share computed at the quarter level. The coefficients of the interaction terms estimate the difference of the purchase effect in each decile with respect to the purchase of the same security in the first decile.

$$Yield_{n,t} = \beta ECBshare_{n,t} + \gamma ECBshare_{n,t} * Decile_{n,t} + \alpha Decile_{n,t} + \theta_n + \delta_t + \nu_{n,t}$$

Figure 5: Purchase effect as a function of ECB Share



C Indirect effects - Mutual funds

Table 26: Funds' exposure - Summary statistics

	Lipper funds					
	mean	sd	p10	p50	p90	count
Exposure	.0282546	.244895	-.004492	0	.0450343	29231
Pred Exposure	.0215704	.0631107	0	0	.0660356	29231
Tot Assets(€Bil)	3.1503	50.63812	.0133468	.1496025	1.75567	28548

Note: The table reports summary statistics of mutual funds from the Lipper database. Exposure is calculated as the amount each fund sells in a given quarter of securities purchased by the ECB in that quarter. Predicted Exposure is a shift-share instrument that measures how much a fund can potentially sell to the ECB based on their portfolio allocation at the end of 2014. Total assets corresponds to the total amount held by each fund in each quarter in billions of Euro.

Table 27: Funds' exposure - Cumulative Summary statistics

	Lipper funds Cumulative					
	mean	sd	p10	p50	p90	count
Exposure	.4954473	1.338743	-.1300437	0	1.999211	1667
Pred Exposure	.3782398	.6377053	0	.0503986	1.240951	1667
Instr Exposure	.4954473	.685765	.0887019	.1428988	1.423176	1667

Note: The table reports cumulative (from 2015 to 2022) summary statistics of mutual funds from the Lipper database. Exposure is calculated as the amount each fund sells of securities purchased by the ECB. Predicted Exposure is a shift-share instrument that measures how much a fund can potentially sell to the ECB based on their portfolio allocation at the end of 2014. Instrumented exposure corresponds to the predicted value of Exposure based on the instrument Predicted Exposure as estimated in Table 8.

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