Quantitative Easing in the Euro Area: The Dynamics of Risk Exposures and the Impact on Asset Prices*

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October 2016

Preliminary and Incomplete: Comments Welcome

Abstract

We use new data on security-level portfolio holdings of institutional investors and households in the euro area to understand the impact of the ongoing asset purchase programme of the European Central Bank (ECB) on the dynamics of risk exposures and on asset prices. We develop a tractable measurement framework to quantify the dynamics of euro-area duration, sovereign and corporate credit, and equity risk exposures as the programme evolves. We propose an instrumental-variables estimator to identify the impact of central bank purchases on sovereign bonds on sovereign bond yields. Our results suggest that the foreign sector sells most in response to the programme, followed by banks and mutual funds, while the purchases of insurance companies and pension funds are positively related to purchases by the ECB.

Keywords: Quantitative Easing, Flow of Risk, Portfolio Rebalancing, Risk Concentration.

*First version: March 2016. Working papers reflect the opinions of the authors and do not necessarily express the views of the Banque de France or the Eurosystem. Koijen acknowledges financial support from the European Research Council (grant 338082). For comments and discussions, we thank Francisco Gomes, Gregor Matvos, Emanuel Moench, Benoit Mojon, Lubos Pastor, Hélène Rey, Harald Uhlig, and conference and seminar participants at the Banque de France, the European Central Bank, Chicago Booth, the 12th CSEF-IGIER Symposium on Economics and Institutions. Fric'16: Conference on Financial Frictions, and London Business School. We also thank Imène Rahmouni-Rousseau, Emmanuel Gervais, and colleagues at the Banque de France and the ECB for their comments and help with the data.

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In response to growing concerns about a prolonged period of low inflation, the European Central Bank (ECB) announced the expanded asset purchase programme on January 22, 2015. The objective is to increase inflation to a level close to, but below, 2%. The initially announced size of the purchase programme was €60 billion per month until September 2016, starting in March 2015. The programme has subsequently been extended until March 2017 and its size has been increased to €80 billion per month.

Central banks in Japan, the United Kingdom, and the United States, among others, have implemented similar quantitative easing (QE) programmes when interest rates reached levels close to zero. The recent literature has explored various channels through which unconventional policy can affect asset prices, inflation, and economic growth more broadly. To analyze and test the importance of various channels, the literature has mostly focused on event studies by looking at the response of asset prices around key policy announcements. [1]

We extend this literature by looking at prices and portfolio holdings jointly. We use a new micro-level data set from the Eurosystem, which contains security-level portfolio holdings for all major investor sectors, including banks, insurance companies and pension funds, and mutual funds, and for all countries in the euro area. For each sector, we observe the quarterly holdings of government bonds, corporate bonds, asset-backed securities (including covered bonds), and equities, both in and outside of the euro area. We link these data to detailed information on prices and security characteristics. Lastly, we have security-level purchase data of the ECB, both from the ongoing asset purchase programme as well as the legacy holdings from earlier programmes that have been implemented by the ECB. By combining these data, we analyze which investors are more likely to sell in response to the purchase programme and what they buy instead by focusing on the distribution of financial risk exposures across investors.

Our sample is from 2013Q4 until 2015Q4.[2] We first summarize the properties of portfolio holdings in the euro area prior to the announcement of the asset purchase programme using data from 2013Q4 to 2014Q4. We develop a tractable framework to measure the distribution of risk exposures across investors. For all securities in an investor's portfolio, we measure the euro-area duration, sovereign and corporate credit, and equity risk exposure. In addition, we summarize the holdings by euro-area investors of foreign, that is, non-euro-area assets. Starting from market clearing, our framework measures how aggregate risks are shared across investors and hence the initial conditions going into the programme.

We then measure how investors rebalance their portfolios when the programme is im-

[1] See for instance Gagnon, Raskin, Remache, and Sack (2011) and Krishnamurthy and Vissing-Jørgensen (2011) for the United States and Krisnamurthy, Nagel, and Vissing-Jorgensen (2014) for Europe.

[2] We plan to update our results regularly as data become available, which is typically with a lag of about three months.

plemented. We provide a simple regression framework, starting from the market clearing condition in changes, to measure which investors sell in response to the purchase programme. Second, we are interested in what investors buy instead. To answer this question, we use the same risk accounting framework, but now applied in changes, to understand how the programme affects the distribution of risk exposures across investors.

Although our data are at the level of the holder country and investor sector, we often aggregate countries into broad regions to which we refer as vulnerable countries (Italy, Spain, Portugal, Greece, Cyprus, and Ireland) and non-vulnerable countries (all other countries).

In the final part of the paper, we estimate the impact of the programme on bond yields. We focus on the announcement period as the programme was modified during the purchase period, which confounds the measurement of the actual purchases with the announcement of the programme extension. The challenge in estimating the impact of asset purchase programmes on bond yields is generally that the announcement of a programme depends on economic conditions, which also affect bond yields directly. The solution in the literature is to select a small set of days on which important programme announcements have been made, and to measure the price response on those days. We will refer to this as a high-frequency, single-difference estimator.

One potential drawback of this empirical strategy is that investors may anticipate (parts of) the purchase programme and that expectations adjust gradually in response to the flow of macro-economic and financial news. Instead, we use a particular feature of the purchase programme to identify the impact on yields. The ECB[3] buys bonds across countries according to the capital key. The weight of a country in the capital key is an average of a country's GDP and population shares. Although GDP may be affected by economic conditions, population size is not (at least, not in the medium run). This provides us exogenous variation in purchases across countries using variation in population size. Second, within a country, the ECB intends to act as "market neutral" as possible, which we interpret as purchasing bonds according to the maturity distribution of outstanding bonds. Using the maturity distribution before the programme was announced gives us variation across bonds within a given country. By interacting the exogenous component of the capital key with the maturity distribution, we obtain exogenous variation in purchases across countries and maturities. We relate this to changes in bond yields from 2014Q2 until 2015Q1. We refer to this as a low-frequency, difference-in-difference estimator that complements the high-frequency, single-difference estimates.

Based on our current data, which includes 10 months, or €600 billion, of purchases, we

[3]In practice, bonds are purchased by national central banks as we explain below. For simplicity, we often refer to the ECB implementing the programme.

document the following six initial facts:

Initial conditions

1. All institutions in vulnerable countries, including insurance companies, pension funds, and mutual funds, have a strong home bias in their fixed income portfolios compared to the same institutions in non-vulnerable countries. Of all variation in home bias across countries and institutional types, 75% (25%) is explained by country (institutional-type) fixed effects. This implies that the sovereign-bank feedback loop, which received a lot of attention among regulators, is not limited to banks, but extends to institutions that safeguard households' long-term savings.

2. Although banks in vulnerable countries are about a third smaller than banks in non-vulnerable countries, they hold more than three times as much of the aggregate sovereign risk and almost twice as much of the overall corporate credit risk as the banks in non-vulnerable countries.

Dynamics in risk exposures

3. The response to asset purchases is very heterogenous across institutional types: Foreign (that is, non-euro-area) investors are most elastic, followed by banks and mutual funds. Long-term investors, like insurance companies and pension funds, if anything, buy the same bonds as the ECB.

4. The ECB buys approximately 1.5% per quarter of all euro-area duration and sovereign risk. However, in particular for duration risk, the purchase programme appears to *reduce* mismatch risk.

5. There has been a large reduction in corporate credit risk in the euro area, which is due to a reduction in the amount of debt issued by the banking sector. We find that these bonds were primarily held by the foreign sector and by banks in vulnerable countries. We show that banks in vulnerable countries also have a strong home bias in their portfolio of corporate debt of financial firms, which can further complicate the bank-sovereign feedback loop.

Impact on asset prices

6. Our low-frequency, difference-in-difference estimate implies that bond yields decline (on average) by -13bp, although there is significant heterogeneity across countries and maturity groups.

In addition to improving our understanding of the mechanics of asset purchase programmes, our findings have broader implications for asset pricing models. Traditional asset pricing models do not explicitly model institutional investors. In recent years, also in response to the financial crisis, a new generation of asset pricing models explore the role of institutional frictions and some of these models are also used to think about the impact of asset purchase programmes.[4] Most models feature one class of intermediaries, which are perhaps best interpreted as banks. Our results highlight the heterogeneity across institutions, and the importance of the rich institutional architecture to absorb demand shocks.[5]

Theories of Quantitative Easing: The Dynamics of Risk Exposures and Asset Prices

We can relate our empirical results to three broad groups of theories. First, Wallace (1981) and Eggertsson and Woodford (2003) derive irrelevance results similar to Modigliani and Miller (1958) for corporate capital structure. If markets are complete, households can unwind any exposures coming from changes in the central bank's portfolio. As a result, consumption, inflation, and asset prices are unaffected by the QE programme.

Eggertsson and Woodford (2003) develop a model with a representative household. However, in the presence of heterogeneous investors, the same economic mechanism suggests that only the investors that are exposed to the trading profits and losses of the central bank (through taxation) should adjust their portfolios.[6]

QE can have a positive effect on asset prices and growth through various channels. Eggertsson and Woodford (2003) argue that the QE programme can be helpful if it can be used to signal future monetary policy commitments.[7] For instance, by buying long-term bonds, the central bank may have an incentive to keep interest rates low until maturity to avoid large mark-to-market losses. The second channel through which prices and portfolio change is the "portfolio balance channel." If the ECB purchases government bonds, it reduces the amount of duration risk in the hands of investors, which can lower the term premium Vayanos and Vila (2009).[8] In response to the lower term premium, investors may substitute to other assets and increase prices (and lower risk premia) of other risky assets. Depending on how investors substitute across various risk factors or characteristics (such as maturity), other

[4]See for instance He and Krishnamurthy (2013), Brunnermeier and Sannikov (2014), and Brunnermeier and Sannikov (2016).

[5]See Coimbra and Rey (2016), Koijen and Yogo (2016), and Greenwood, Hanson, and Liao (2016) for models with richer heterogeneity across institutions.

[6]In the United States, Carpenter, Demiralp, Ihrig, and Klee (2013) show using data from the Flow Funds that the household sector (which includes hedge funds) is an important group selling to the Fed. In Japan, Saito and Hogen (2014) document that the foreign sector sells in response to QE programme.

[7]See also Mussa (1981) and Clouse, Henderson, Orphanides, Small, and Tinsley (2000).

[8]See also Greenwood and Vayanos (2014) and Greenwood, Hanson, and Vayanos (2015).

asset prices are affected (Krishnamurthy and Vissing-Jørgensen (2011)). We use our risk accounting framework to measure directly how investors change their exposures to key risk factors.

A central insight of the model of Brunnermeier and Sannikov (2016) is that it matters which institutions own the securities that are purchased by the central bank. In the presence of financial frictions, an increase in the prices of assets held by compromised institutions relaxes their financial constraints and increases lending activity, which in turn affects inflation and economic growth in their model. We use our detailed holdings data to map out how eligible securities are distributed across investor sectors and geographically.

The third category of theories points to the potential financial stability concerns as a result of asset purchase programmes. If such programmes are successful, the yields of safe assets and the funding costs of intermediaries decrease and investors may decide to take on (excessive) levels of leverage, leading to financial fragility (Woodford, 2011, Coimbra and Rey, 2016). In addition to leverage, investors may take on additional forms of risk, such as liquidity and credit risks (Stein, 2012). Of course, in part, this is precisely the objective of the QE programme. However, risks may get concentrated in certain sectors, which may lead to financial instability. Although such risk shifting incentives are perhaps best addressed through capital and risk regulation of banks and insurance companies, regulation may be slow to adjust. Our risk accounting framework can be used to monitor the dynamics of risk exposures and risk concentration across countries and institutional sectors.

1. Asset Purchase Programmes in the Euro Area

We briefly summarize the asset purchase programmes that the ECB implemented since the euro crisis in the fall of 2009. The first covered bond purchase programme (CBPP1) of €60 billion was implemented from July 2009 until June 2010. From November 2011 to October 2012, the ECB implemented a second covered bond purchase programme (CBPP2) of €16.4 billion. The securities markets programme (SMP) was implemented from May 2010 until September 2012 and was used to buy mostly sovereign bonds through secondary markets. The size of the SMP portfolio at its peak was around €210 billion. The securities purchased as part of these programmes will be held until maturity and we observe the legacy holdings of the SMP. In September 2014, the ECB added a purchase program for asset-backed securities (ABSPP) and the third covered bond purchase programme (CBPP3).

In January 2015, the ECB announced the extended asset purchase programme (APP), which is our main focus. The APP contains three programmes: it extends the ABSPP and CBPP3 and adds the public sector purchase programme (PSPP). The PSPP will purchase

bonds of euro-area governments, agencies, and European institutions.

The combined purchases were announced to be €60 billion per month starting in March 2015. The initial programme was supposed to end in September 2016. The programmes would lead to Eurosystem purchases of €1.14 trillion, which is about 15% of the total GDP in the euro area. The objective of the purchase programme is to stimulate economic activity by lowering the borrowing costs of firms and households in an environment where the main policy rates are close to their effective lower bound. Ultimately, this should help restoring inflation at a level close to, but below, 2%.

Before the start of the PSPP, the purchases as part of the ABSPP and CBPP3 amount to €10 billion a month. In addition, the ECB announced that the PSPP was split into purchasing debt of supranational institutions[9] located in the euro area (12%) and governments (88%). Assuming that the ABSPP and CBPP3 purchases continue at the same pace, this corresponds to €6 billion purchases of supranational debt and €44 billion of government debt (Claeys, Leandro, and Mandra, 2015). The €44 billion of purchases are allocated to bonds issued by euro-area governments according to each country's share of the ECB's capital, the so-called capital key. The capital key reflects the GDP and population share of each member state. These two determinants have equal weighting so that countries with a large population and high GDP, such as for instance Germany, have a relatively high share (25%) relative to smaller countries (we provide further details in Section 5).[10] The purchases are held both by national central banks and the ECB. For 20% of the asset purchases as part of the PSPP, there is loss sharing via the ECB. Profits and losses on ECB holdings are shared among national central banks according to the capital key. Throughout the paper, we refer to ECB purchases as the sum of purchases by Eurosystem central banks.

The ECB specified a set of eligibility criteria for bonds that are purchased as part of the PSPP. The bonds need to be investment grade (corresponding to a credit rating of BBB or better), with additional criteria for countries operating under an EU/IMF Eligible Asset Rating adjustment program. The bond maturities need to be between 2 and 30 years, and up to 33% (25%) of an issuer (issue) can be purchased.[11] In addition, the yield to maturity has to be above the deposit facility rate, which was equal to -20bp at the launch of the programme. The deposit facility rate is the interest banks receive for depositing money with the central bank overnight.

[9]Supranational institutions in the euro area include the European Financial Stability Facility, the European Investment Bank, the European Stability Mechanism, the European Union, the European Atomic Energy Community, the Council of Europe Development Bank, and the Nordic Investment Bank.

[10]The ECB adjusts the shares every five years and whenever a new country joins the EU. The adjustment is made on the basis of data provided by the European Commission.

[11]These limits are imposed to avoid that the ECB has a blocking minority in a debt restructuring involving collective action clauses.

Debt of certain national agencies is also eligible, such as for instance the debt of the Landeskreditbank Baden-Württemberg Foerderbank. Across maturities, the ECB intends to act as "market neutral" as possible, which we interpret as buying (approximately) in proportion to the outstanding maturity distribution between 2 and 30 years.

The PSPP has been modified twice. First, in December 2015, the end date of the programme was extended from September 2016 until March 2017 and the deposit facility rate was lowered to -30bp. Second, in March 2016, the size of the programme was scaled up from €60 billion to €80 billion per month and the deposit facility rate was lowered further to -40bp. In addition, investment-grade corporate bonds are now considered to be eligible as well. In future versions of this paper, we plan to analyze the portfolio rebalancing in response to these purchases.

2. Data Description

2.1. Portfolio Holdings and Asset Characteristics

We use data on security-level portfolio holdings of euro-area investors from the Securities Holding Statistics (SHS).[12] Securities in our sample are identified by a unique International Securities Identification Number (ISIN). The data are collected on a quarterly basis from custodian banks in the euro area since 2013Q4, which is the first quarter of our sample. The last available quarter at the time of writing is 2015Q4. Updates of our data are available with a lag of approximately three months and we plan to update our paper as the programme evolves.

Investors in the SHS are defined by sector and by country of domicile. There are six aggregate sectors: households, monetary and financial institutions (MFI), insurance companies and pension funds (ICPF), other financial institutions (OFI), general government, and non-financial corporations.[13] OFI includes important intermediaries such as mutual funds and hedge funds. We will refer to MFI as banks and to OFI as mutual funds, which are the largest subgroups. We group non-financial corporations and general government as a sector labeled "Other" as we mostly focus on banks, mutual funds, insurance companies and pension funds, the ECB, and the foreign sector. The countries are the 19 member states of the euro area.[14] The holdings reported in the SHS correspond to approximately €27 trillion for each quarter. The assets covered include both government and corporate debt, equities, mutual fund shares, asset-backed securities (ABS), and covered bonds.

[12] We refer to EU Regulation 1011/2012 for more information on SHS.

[13] The sector definitions follow the European System of Accounts 1995 (ESA 95) standard.

[14] The list of countries is Belgium, Germany, Ireland, Greece, Spain, France, Italy, Cyprus, Luxembourg, Malta, The Netherlands, Austria, Portugal, Slovenia, Slovakia, Finland, Estonia, Latvia, and Lithuania.

We merge the SHS with data on the securities held by the ECB as part of the SMP, the CBPP3, and the PSPP. Holdings are observed at the same level of detail and frequency as the SHS so that the combined data sources provide a unique overview of the portfolios of public and private investors in the euro area.

To avoid that we display confidential data, we compute the duration risk held by the ECB, we use publicly available data on holdings of the ECB. If the weighted average maturity is available, we select a sample of government bonds with maturity in a one year window around that of the ECB and compute the weighted average duration of these bonds, which we assign as the duration of the ECB. For covered bonds and ABS, we take the average market duration.

We link the holdings data to asset characteristics. The main source for data on characteristics is the Centralised Securities Database (CSDB). The CSDB contains information on more than six million alive debt securities, equities, and mutual fund shares issued by both companies residing in the euro area and outside. The data are from both public and commercial sources and is managed by the ESCB (ECB, 2010). A key variable used in CSDB is price, where market prices are used when available. For debt securities for which the price is unavailable (for instance, when a bond does not trade), the price is estimated using the reference information of the security.

We complement the CSDB with data on credit ratings from Datastream and from the Eurosystem collateral database. We use the ratings given by Standard and Poor's, Moody's, Fitch, and DBRS. These are the four rating agencies recognized as "External credit assessment institutions" by the Eurosystem, which publishes also a mapping between the different rating scales. We use the long-term asset-level credit rating. If this rating is unavailable, then we use, in order of priority, the short-term asset level credit rating, the long-term issuer rating or the short-term issuer rating.

In assigning ratings, we follow the priority rule used by the Eurosystem.[15] When we have ratings from multiple agencies, we apply the rules defined in the guidelines (first-best rating for non-ABS securities and the second-best rating for ABS).

2.2. Security Types

We study the direct holdings of debt instruments and equities. Therefore, we exclude indirect holdings, for instance via holdings of mutual fund shares, to avoid double-counting. We group securities into broad categories as summarized in Figure 1. We use the CSDB

[15]Guideline 2015/510 of the ECB on the implementation of the Eurosystem monetary policy framework, Art.82/83/84 "The Eurosystem shall consider ECAI issue ratings in priority to ECAI issuer or ECAI guarantor ratings."

characteristics to classify securities, unless mentioned otherwise.

First, we distinguish "euro-area" and "non-euro-area" securities. Euro-area securities are defined as euro-denominated securities issued in the euro area. It is useful to make this distinction for some of our calculations as we do not always have data on the total amount of debt outstanding for non-euro-area securities (at both face and market value). However, we always have accurate data on holdings of euro-area investors for both euro-area and non-euro-area securities.

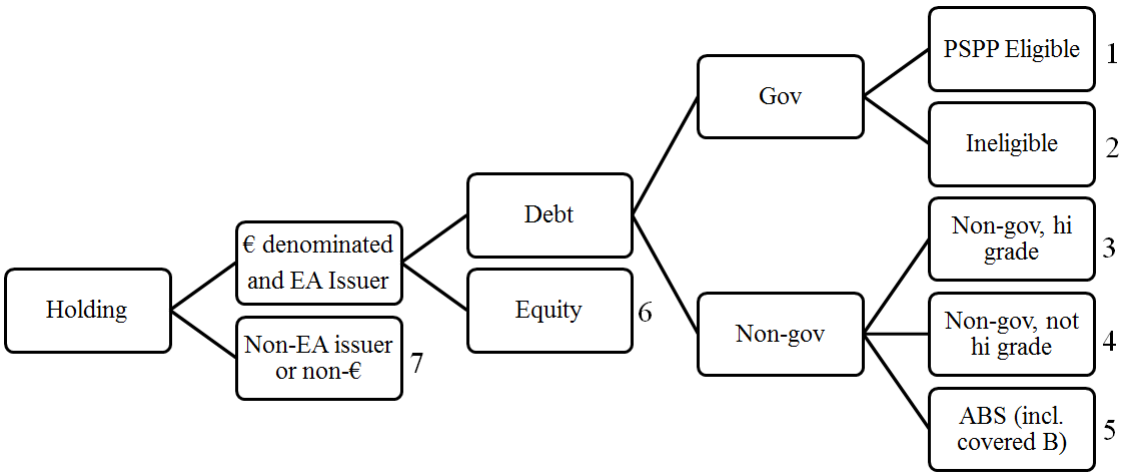


Figure 1: Summary of security types.

Within euro-area securities, we separate equity and fixed income securities, and we consider a finer breakdown of debt securities. We define government debt as debt issued by the general, central, state or local government sectors. Non-government debt is issued by the remaining issuer sectors. We divide government debt into "PSPP eligible" and "PSPP ineligible," depending on whether a bond satisfies the eligibility criteria outlined in Section 1. In addition, we also classify a bond as PSPP eligible if the Eurosystem purchase data show that a bond is purchased as part of the PSPP.

We split non-government debt into corporate bonds and collateralized debt, which includes ABS and covered bonds. To distinguish standard corporate bonds from ABS, covered bonds, medium-term notes, and commercial paper, we use data on asset type from the Eurosystem collateral database. If this information is missing, we use information on debt type from the CSDB.[16] We omit commercial paper as we do not focus on the very short end of the yield curve.

[16]Standard bonds are defined as debt types D.1, D.11, D.15, D.16, D.164, D.18. Covered bonds correspond to asset types 9, 10, 12 and 13 in the ECB collateral database and debt types D.21, D.23 and D.233 in CSDB. Medium term notes are asset types 02 in the collateral database or debt types D.3 and D.32 in CSDB. Commercial paper is asset type 03 in the collateral database and debt types D.7, D.72, D.74 and D.742 in CSDB.

We use data on credit ratings to group corporate bonds into investment grade and speculative grade. If bonds are unrated, we classify them as speculative grade. Panel A of Table B.1 summarizes the definitions of the asset categories.

2.3. Investor Types

We do not have direct data on the portfolio holdings of non-euro-area investors, to which we refer as the "foreign sector." We compute their holdings as the difference between the total amount outstanding of a given security from the CSDB and the aggregate holdings of euro-area investors. Combined with the holdings data from SHS and the data on Eurosystem purchases, we consider in total seven investor types as summarized in Panel B of Table B.1.

Investor types differ at least along two dimensions. First, several sectors are subject to some form of risk regulation, such as banks and insurance companies. Second, investors differ in terms of the maturity structure of their liabilities. For instance, banks have short-term liabilities that may be subject to runs, while insurance companies have long-term liabilities that cannot be withdrawn easily in most countries.[17] The combination of long-term liabilities and risk regulation leads insurance companies and pension funds to hold long-term bonds, in particular when interest rates are low (Domanski, Shin, and Sushko (2015)).

For some of the calculations, we separate countries into two groups based on the extent to which countries were affected by the euro crisis (following Altavilla, Pagano, and Simonelli (2016)). The first group includes the more vulnerable countries, namely Italy, Spain, Portugal, Greece, Cyprus, and Ireland. The second group consists of relatively non-vulnerable countries, namely Austria, Germany, France, the Netherlands, Estonia, Luxembourg, Latvia, Slovakia, Finland, Malta, Slovenia, Belgium, and Lithuania.

2.4. Potential Shortcomings of the Data

We are aware of two potential shortcomings of our data. First, as is common in measuring cross-border holdings, we cannot measure securities positions of euro-area institutions that are held through offshore institutions, such as those domiciled in the Cayman Islands (see Milesi-Ferretti, Strobbe, and Tamirisa (2010) and Zucman (2013) for further discussions). However, we do know direct holdings in mutual funds that are domiciled in tax-favoured countries within the euro-area, such as Luxembourg.[18]

Second, we have accurate holdings of cash securities, but we do not observe derivatives positions. Abad, Aldasoro, Aymanns, D'Errico, Rousova, Hoffmann, Langfield, and Roukny

[17] France is an exception in the euro area where insurance liabilities are more similar to demand deposits.
[18] Our holdings account for roughly €2.7 trillion of the €3.5 trillion mutual fund sector in Luxembourg.

(2016) use new data on OTC derivatives in the euro area that can potentially be merged with our data to get the full picture based on both cash and derivatives positions.

3. Heterogeneity in Institutional Portfolios in the Euro Area

We summarize the heterogeneity in portfolio characteristics of institutional portfolios before the announcement and implementation of the PSPP programme.

3.1. Securities Holdings

In Table I, we report the holdings by sector and holder country group for each asset category. We compute the average market value of portfolio holdings from 2013.Q4 to 2014.Q4, that is, before the announcement of the PSPP programme. These holdings therefore summarize the initial heterogeneity in institutional portfolios across geographies and sectors.

The top panel summarizes the holdings by sector for non-vulnerable countries and the middle panel for vulnerable countries. The bottom panel summarizes the holdings of the ECB and the foreign sector. Each of the columns corresponds to an asset category. The final column reports the total value of the portfolio of marketable securities, which reveals that the sectors in low debt-to-GDP countries are significantly larger than the sectors in high debt–to-GDP countries.

Insurance companies and pension funds invest a large fraction of their portfolio in fixed-income instruments and in particular in eligible government bonds. In terms of corporate bonds, their portfolios are tilted towards investment-grade corporate bonds. This allocation is consistent with the long-maturity liabilities of these institutions.

Banks also invest a large share of their portfolios in eligible government debt and are also the largest investor in ABS and covered bonds. The corporate bond portfolios in non-vulnerable countries are tilted towards investment-grade corporate bonds, while the opposite is true in vulnerable countries. We explore this fact in more detail below.

Mutual funds invest a large fraction of their assets in equity and in particular foreign, that is, non-euro-area securities. This suggests that mutual funds play an important role in providing global diversification benefits for euro-area households and institutions. The foreign sector mostly holds government bonds and euro-area equity. About one-third of the allocation to government bonds is invested in ineligible bonds, which includes short-maturity bonds (residual maturities shorter than two years) but also bonds with yields that are below the deposit facility rate (for instance, in Germany).

The ECB holds a small portfolio of government bonds and covered bonds due to the earlier purchase programmes, namely the SMP and the CBPP, before the start of the PSPP.

Table I: Holdings by investor sector, holder country group, and asset category.

The table reports the average market value of holdings, computed before the announcement of the PSPP programme, from 2013Q4 until 2014Q4. The asset categories are defined as: Elig. Govt. - PSPP eligible government bonds, Inelig. Govt. - PSPP ineligible government bonds, IG-Corp. - Investment grade corporate bonds, SG-Corp. - Speculative grade corporate bonds, ABS&CB - ABS and covered bonds, Equity - Euro area equity, and Foreign - Non-euro area assets. The top panel reports the holdings for investor sectors in non-vulnerable countries and the bottom panel for vulnerable countries. The classification of vulnerable and non-vulnerable countries follows Altavilla et al. (2016).

		Asset category							
Riskiness	Sector	Elig. Govt.	Inelig. Govt.	IG Corp.	SG Corp.	ABS &CB	Equity	Foreign	Total
Non-vulnerable	ICPF	933	122	395	215	191	137	490	2,483
	Banks	815	325	535	154	702	127	681	3,339
	Mutual funds	577	175	296	250	189	900	2,422	4,809
	Households	19	12	98	150	12	465	148	904
	Other	125	76	36	47	26	767	90	1,167
	Total	2,469	709	1,360	817	1,121	2,396	3,830	12,702
Vulnerable	ICPF	341	80	79	49	38	29	67	683
	Banks	508	343	190	233	588	72	292	2,226
	Mutual funds	161	120	48	50	25	156	809	1,369
	Households	174	61	123	241	5	199	75	878
	Other	113	41	12	25	2	257	39	489
	Total	1,296	647	452	598	658	713	1,281	5,645
	Foreign	2,290	1,272	414	564	359	2,852	0	7,751
	ECB	114	17	0	0	30	0	0	161

During this period, the ECB does not invest in corporate bonds or equity. The position in ineligible government bonds is a consequence of a bond's residual maturity dropping below two years at some point or the yield-to-maturity falling below the deposit facility rate, which renders it ineligible.

The holdings of eligible government debt across institutions play a central role in theories that point out that asset purchase programmes can relax financial constraints of compromised institutions by increasing the value of their assets (Brunnermeier and Sannikov, 2016). Moreover, the holdings of sovereign debt by banks in the same country has been highlighted as an important concern for financial stability in the euro area (Altavilla et al., 2016). We extend this literature by studying the home bias in sovereign debt across institutions, which differ for instance in terms of their risk regulation.

We report the holdings of PSPP-eligible debt by holder country group and investor sector in Table II. Each panel contains three columns. The first column reports the market value of holdings in euros. The second column reports the share (in percent) of an investor's portfolio invested in eligible government debt. The third column reports the share (in percent) of the investment in eligible debt for which the holder and issuer country coincide. The third column therefore measures the home bias in the allocation to eligible debt.

Table II: Holdings of PSPP-eligible government debt by sector and country group.

The table reports for each investor sector and country group three statistics on the holdings of PSPP-eligible debt. The first columns reports the market value of the holdings in billions of euros. The second column reports the share of sector's portfolio invested in PSPP-eligible government debt (in %). The third column reports the share of a sector's portfolio invested in PSPP-eligible debt of the same country (in %), which is the home bias. Each statistic is an average from 2013Q4 until 2014Q4. The classification of vulnerable and non-vulnerable countries follows Altavilla et al. (2016).

Riskiness	Sector	Holdings	Share in PSPP-eligible debt	Home bias
Non-vulnerable	ICPF	933	38	52
	Banks	815	24	56
	Mutual funds	577	12	19
	Households	19	2	69
	Other	125	11	72
	Total	2,469	19	46
Vulnerable	ICPF	341	50	85
	Banks	508	23	90
	Mutual funds	161	12	65
	Households	174	20	96
	Other	113	23	97
	Total	1,296	23	87
	Foreign	2.290	–	–
	ECB	114	83	–

In both regions, insurance companies and pension funds invest a larger share of their portfolios in eligible government debt than the other sectors. The main insight from Table II is, however, that all institutions in vulnerable countries have a stronger home bias, compared to non-vulnerable countries. Even mutual funds invest 65% of their sovereign debt portfolio in their own sovereign. Using data at the country level, we find that 75% of the home bias in institutional portfolios can be explained by country fixed effects and only 25% by institutional-type fixed effects.

Acharya and Steffen (2015) discuss various reasons why banks in peripheral countries

invest heavily in sovereign debt. One explanation is based on the fact that banks can borrow cheaply from the ECB and invest in high-yielding sovereign bonds, hence earning the "carry." As sovereign bonds have zero risk weights under Basel II regulations, this trade is riskless from the perspective of regulators. However, as any sovereign bond has a zero risk weight, this explanation does not necessarily imply a home bias. More importantly, mutual funds are not subject to the same risk weights, yet their portfolios have a similar home bias as the portfolios of regulated institutions such as banks, insurance companies, and pension funds.

Alternatively, financial institutions may internalize the fact that in case of a sovereign default, the banking sector will default or experience runs as well. With limited liability, it may be optimal for financial institutions to invest in sovereign bonds of their own country as in states in which these bonds pay off, the institutions are likely to survive as well (Diamond and Rajan, 2011).

Financial repression provides a third possible explanation of the home bias in peripheral countries, where financial institutions are encouraged or forced to buy bonds of their own government to lower sovereign borrowing costs, see Becker and Ivashina (2014) and Ongena, Popov, and Horen (2016) in the context of banks in the euro area. Although one may be inclined to conclude that this theory cannot explain the home bias of mutual funds, it is important to keep in mind that most mutual funds in the euro area are offered through banks. The pressure on banks may therefore incentivize mutual funds to tilt their portfolios towards sovereign debt of their own country.

These findings are also important from a financial stability concern. Most of the policy discussion so far focuses on the bank-sovereign feedback loop. Given that insurance companies, pension funds, and mutual funds play a central role in saving for retirement, the failure of a sovereign would not only have an adverse affect on the banking sector, but also on the accumulation of retirement savings.

3.2. Risk Exposures of Investment Portfolios: Measurement

In addition to summarizing portfolio holdings and flows in response to the asset purchase programme, we are interested in measuring the distribution and dynamics of risk exposures to euro-area financial market risks across investors. To this end, we distinguish five dimensions of risk: (i) euro-area duration risk, (ii) euro-area sovereign credit risk, (iii) euro-area corporate credit risk, (iv) euro-area equity risk, and (v) foreign risk.

For each of these risks, we define linear risk measures to measure exposures. For euro-area interest rate risk, we use duration risk. We measure the duration of government bonds, both eligible and ineligible, corporate bonds, ABS, and covered bonds.[19] To compute duration,

[19] We assume that the duration of floating-rate bonds is zero.

we need to know the yield-to-maturity, the coupon rate, and the payment frequency of the coupons. We have this information for 83% of the securities (in terms of market value) and there is no noticeable trend in coverage during our sample period.

For sovereign credit risk, we measure the risk exposure using the credit rating of all eligible and ineligible government bonds. The rating is not necessarily the same for all bonds in a given country, as some of the bonds are issued by local governments or government agencies. The actual sovereign risk exposure is measured by the probability of default, which relates non-linearly to a bond's rating. To account for this non-linear relationship, we map each rating to the 5-year cumulative default probability using estimates in Moody's (2015). We report the value-weighted average default probability. We observe the rating of government bonds for 98% of securities (in terms of market value) and there is no noticeable trend in coverage during our sample period.

We follow a similar procedure to measure corporate credit risk exposure. In this case, we aggregate holdings across all corporate bonds, ABS, and covered bonds. We map the ratings to default frequencies using estimates for 5-year cumulative corporate default probabilities reported in Moody's (2015). In interpreting the numbers, it is important to keep in mind that a bond's rating can be low because of its exposure to either aggregate or idiosyncratic risk (or both). As we do not have the information required do decompose risk exposures, we assume that a bond's exposure to aggregate corporate credit risk is linear in its default probability. We observe the rating of credit instruments for 68% of securities (in terms of market value) and there is no noticeable trend in coverage during our sample period.

For equity risk, we report the total investment in equities as a share of the overall portfolio value. This assumes that the equity exposure of fixed income securities, once we control for rating and duration, is zero and that all stocks have a beta equal to one. Analogously, for foreign risks, we measure the portfolio share. In all cases, we report the average risk measures from 2013Q4 until 2014Q4.

3.3. Portfolio Risk Exposures

We report the risk exposures by holder country group and sector in Table III. In the first column we report the duration of the overall portfolio, which also accounts for fixed-income securities issued outside of the euro area or denominated in a currency other than euros. The second column reports the euro-area duration risk. By comparing both columns, we find that these numbers generally coincide other than for mutual funds in vulnerable countries and the foreign sector. The difference for the foreign sector is consistent with euro-area firms issuing debt in, for instance, U.S. dollars, which is held primarily by non-euro-area investors.

Across institutional sectors, we find that insurance companies and pension funds hold the

Table III: Risk Exposures of Investors' Portfolios

The table reports the average risk characteristics from 2013Q4 until 2014Q4. Duration and euro-area duration are expressed in years. The sovereign and corporate risk exposure is measured by the 5-year cumulative probability of default for either sovereigns or firms as reported in Moody's (2015). For equity and foreign risk exposure, we report the fraction in percent of an investor's portfolio invested in either asset category. The top panel reports the risk exposures for investor sectors in non-vulnerable countries and the middle panel for investors in vulnerable countries. The bottom panel reports the risk exposures of the portfolios of the foreign sector and the ECB (as so far as related to purchase programmes). ECB duration risk is imputed from public data on maturity and duration data on representative bond portfolios. The classification of vulnerable and non-vulnerable countries follows Altavilla et al. (2016).

Riskiness	Sector	Dur.	EA Dur.	Sovereign	Corporate	Equity	Foreign
Non-vulnerable	ICPF	6.83	7.20	0.34	0.98	6	20
	Banks	3.22	3.26	0.38	0.52	4	20
	Mutual funds	5.18	5.13	0.58	1.20	19	50
	Households	2.61	2.64	0.51	1.66	51	16
	Other	4.15	4.25	0.23	1.21	66	8
Vulnerable	ICPF	5.34	5.45	1.33	1.59	4	10
	Banks	2.42	2.47	1.67	1.39	3	13
	Mutual funds	5.72	3.84	1.28	1.81	11	59
	Households	3.61	3.62	1.35	2.14	23	9
	Other	4.79	4.85	1.61	2.08	53	8
	Foreign	6.19	4.92	0.49	1.09	–	–
	ECB	3.10	3.10	1.54	0.56	0	0

longest duration portfolios. The duration for insurers and pension funds is about twice as large as for banks. The euro-area duration is lower for banks, mutual funds, and insurance companies and pension funds in vulnerable countries compared to non-vulnerable countries.

Home bias combined with higher sovereign risk exposures of debt in vulnerable countries explains the difference in sovereign risk exposures across vulnerable and non-vulnerable countries. The foreign sector tends to invest in non-vulnerable countries, leading to a low sovereign risk exposure. The ECB, by contrast, purchased debt of vulnerable countries as part of the SMP, which leads to a legacy sovereign exposure.

The corporate credit risk exposure is also higher for institutions in vulnerable countries, although the difference is less extreme than for sovereign risk. The ECB's portfolio, which only includes covered bonds during our sample, is safest across all institutions, followed by banks. As discussed before, mutual funds invest a large fraction of their portfolio in foreign

securities.

3.4. The Distribution of Risk Exposures

The results so far illustrate the difference in portfolios and size across investors. In this section, we propose a risk accounting framework to summarize how risk exposures are distributed across investors. We focus on the same risk factors as in the previous section.[20] Ideally, we would observe the entire balance sheet of institutions and measure risk mismatch between assets and liabilities. Unfortunately, these data are not available for most of the institutions and we therefore focus on the narrower question of understanding the distribution of risk exposures of cash securities and how the distribution of risk exposures changes in response to the asset purchase programme.

The results are presented in Table IV for all five risk factors that we consider. The final column reports the size of a given sector per country group. By definition, each of the columns (excluding the subtotals) aggregates to 100.

Insurance companies and pension funds bear 26% of all euro-area duration risk, while the foreign sector is exposed to another 31%. Banks are the third-largest holder of duration risk and are exposed to 20% of all the risk. This may be surprising given the short duration of their liabilities.

As expected, vulnerable countries are most exposed to sovereign risk, which reflects the home bias of these institutions. Banks in vulnerable countries alone already bear 23% of all the risk, while they only bear 7% of the duration risk. Compared to banks in non-vulnerable countries, which are 50% larger than banks in vulnerable countries, banks in vulnerable countries bear more than three times as much sovereign risk. We estimate that the ECB is exposed to 1% of euro-area duration risk and 3% of all sovereign risk as a result of the earlier SMP.

The exposure to corporate credit risk is more equally split across country groups, with sectors in non-vulnerable countries bearing 47% of all risk and sectors in vulnerable countries bearing 37%. The foreign sector is exposed to 18% of all euro-area credit risk. However, the risk exposures in vulnerable countries are concentrated in the banking sector (22% of 37%), while the risk exposures are almost equally split among banks, mutual funds, and insurance companies and pension funds in non-vulnerable countries. Hence, both sovereign and corporate credit risks are concentrated in the banking sector in vulnerable countries.

[20] Although we focus on univariate risk measures, it may be interesting to explore the risk of the overall portfolio, which depends on the covariance of various risk factors. This is potentially important as the correlation between, for instance, equity and government bond returns in Germany tends to be negative, while it is significantly higher in Italy. Combined with home bias, this implies that holding a portfolio of stocks and bonds is riskier for Italian institutions than for German institutions.

Table IV: The Distribution of Risk Exposures

The table shows the distribution of risks across investors, normalized to 100 for the total risk outstanding. We report the average from 2013Q4 until 2014Q4. The top panel reports the risks for investor sectors in non-vulnerable countries and the middle panel for investors in vulnerable countries. The bottom panel reports the risks of the portfolios of the foreign sector and the ECB. ECB duration risk is imputed from public data on maturity and duration data on representative bond portfolios. The classification of vulnerable and non-vulnerable countries follows Altavilla et al. (2016).

Riskiness	Sector	EA Dur.	Sovereign	Corporate	Equity	Foreign	Size
Non-vulnerable	ICPF	21	6	13	2	10	2,483
	Banks	13	7	14	2	13	3,339
	Mutual funds	11	7	13	15	47	4,809
	Households	1	0	5	8	3	905
	Other	2	1	2	13	2	1,167
	Total	48	21	47	40	75	12,703
Vulnerable	ICPF	5	9	4	0	1	683
	Banks	7	23	22	1	6	2,226
	Mutual funds	2	6	3	3	16	1,370
	Households	4	5	7	3	1	878
	Other	2	4	1	4	1	489
	Total	19	47	37	11	25	5,646
	Foreign	31	28	18	48	–	7,751
	ECB	1	3	0	0	–	136

The picture is quite different in terms of exposures to euro-area equity risk and foreign risk. The foreign sector bears almost half of all euro-area equity risk and institutions in non-vulnerable countries bear another 40%, where mutual funds account for the largest share (15% of 40%). For foreign risk, we normalize the overall holdings to 100% for all euro-area investors as we do not observe the holdings of foreign investors in foreign securities. As expected, non-vulnerable countries are most exposed to foreign risk (75% versus 25%) and in both country groups, most of the risk is concentrated in the mutual fund sector.

4. Portfolio Rebalancing and the Dynamics of Risk Exposures

In this section, we study portfolio flows and the dynamics of risk exposures during the PSPP programme from 2015Q2 until 2015Q4. We plan to update this part of the paper as new waves of data become available.

4.1. Portfolio Rebalancing Across Asset Categories

We start by reporting the average portfolio rebalancing across sectors and holder country groups for each of the asset categories. For investor i and security n, we measure rebalancing

at time t, T_{int}, as

$$T_{int} = (Q_{int} - Q_{in,t-1})\, P_{nt}, \tag{1}$$

where Q_{int} denotes the number of securities and P_{nt} the price. This definition ensures that portfolio rebalancing is not driven by price effects. We then aggregate the rebalancing for each asset category in a given quarter. In Table V, we report the average rebalancing per quarter in billions of euros. As a point of reference, Table B.2 summarizes the average rebalancing during the quarters before the PSPP from 2013Q4 until 2014Q4.

Table V: Portfolio Rebalancing During the PSPP

The table reports average portfolio rebalancing from 2015Q2 until 2015Q4. The asset categories are defined as: Elig. Govt. - PSPP eligible government bonds, Inelig. Govt. - PSPP ineligible government bonds, IG-Corp. - Investment grade corporate bonds, SG-Corp. - Speculative grade corporate bonds, ABSCB - ABS and covered bonds, Equity - Euro area equity, and Foreign - Non-euro area assets. The top panel reports the rebalancing for investor sectors in non-vulnerable countries and the second panel for investors in vulnerable countries. The third panel reports the rebalancing of the foreign sector and the ECB. The bottom panel reports net issuances. The flows are reported in billions of euros. The classification of vulnerable and non-vulnerable countries follows Altavilla et al. (2016).

		Asset category						
Riskiness	Sector	Elig. Govt.	Inelig. Govt.	IG Corp.	SG Corp.	ABS &CB	Equity	Foreign
Non-vulnerable	ICPF	2	1	-10	-3	-4	1	5
	Banks	-32	17	-32	-4	-32	-1	-13
	Mutual Funds	-8	9	-10	-5	-9	35	4
	Household	-1	0	-6	-5	-1	3	-1
	Other	-1	3	-1	-1	-2	7	-3
Vulnerable	ICPF	15	5	1	6	-1	1	5
	Banks	-15	-2	-7	9	-33	2	-1
	Mutual Funds	-9	-1	-2	-1	-1	6	13
	Household	-8	1	-7	-14	0	3	-4
	Other	-6	1	-1	0	0	-3	1
	ECB	135	22	0	0	26	0	0
	Foreign	-123	7	-36	-19	-19	–	–
	Issuer	-52	62	-110	-37	-76	–	–

We first focus on eligible government bonds, where the ECB buys on average €135 billion per quarter, which is approximately equal to $3 \times$ €44 billion = €132 billion. The flows suggest that it is mostly the foreign sector selling eligible government bonds during this period with €-123 billion on average per quarter.

This finding is surprising from the perspective of the neutrality theorems, which suggest

that sectors that are affected by changes in the timing or risk exposures of the central bank's portfolio (through taxation or adjustments in subsidies) should rebalance their portfolios.[21] However, it is consistent with estimates of the impact of asset purchase programmes in Japan based on aggregate statistics from the Flow of Funds (Saito and Hogen (2014)). One possible interpretation is that markets are somewhat segmented and that foreign investors are more global than euro-area investors. In response to lower yields in the euro area due the asset purchase programme, as we show below, foreign investors rebalance their portfolio towards more attractive investment opportunities outside of the euro area.

The banking sector sells another €-47 billion on average per quarter and mutual funds €-19 billion. Insurance companies and pension funds do not sell at all and in fact buy €17 billion. The inelastic demand, or even upward-sloping demand, of insurance companies and pension funds may be due to their desire to hedge the interest rate risk of the liabilities (Domanski et al., 2015). On the supply side, net issuances are negative at approximately €-52 billion per quarter. By market clearing, the sum of the flows across investor sectors equals net issuances.

If we compare these flows to earlier quarters, as reported in Table B.2, then net issuances were positive at approximately €60 billion per quarter on average. The reduction in net issuances suggests that government produce less duration risk, which, all else equal, helps the PSPP in lowering bond yields. In earlier quarters, all major sectors (banks, insurance companies and pension funds, mutual funds, and the foreign sector) were purchasing government bonds. During the PSPP, by contrast, all institutions sell government bonds, with the exception of insurance companies and pension funds.

If we look beyond eligible government bonds, then flows to ineligible government bonds are largely driven by bonds that mature or yields falling below the deposit rate, and these bonds become ineligible as a result. Hence, it is not the case that the ECB purchases ineligible bonds.

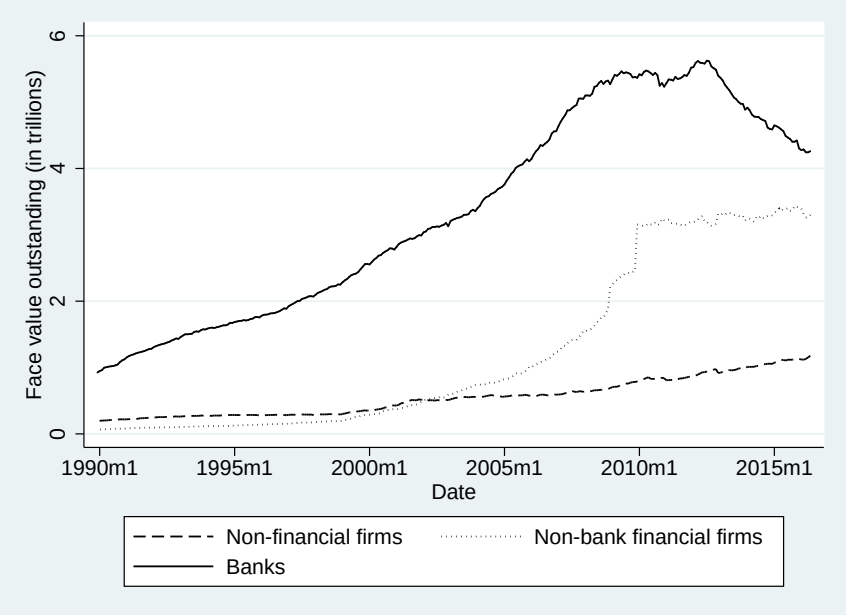
Second, we see large negative net issuances for corporate bonds, both before and during the PSPP. The reduction is absorbed by the foreign sector and in particular banks. To understand the supply-side dynamics of the corporate bond market in the euro-area, we use data from the ECB's Statistical Data Warehouse. In Figure 2, we plot the total amounts outstanding for corporate bonds issued by non-financial firms, financial firms excluding banks, and banks. These data also include bonds issued in foreign currencies, which is a broader definition than we use, but the trends are comparable. Following the crisis in the euro area in 2012, banks have reduced the amount of debt outstanding dramatically from €5.6 tril-

[21] Since the consumption plans are unaffected by asset purchase programmes if the neutrality theorems apply, the exchange rate should not be affected either.

lion in July 2012 to €4.3 trillion in May 2016. Given the timing, this is unrelated to the PSPP programme, although lower yields may help banks to reduce their leverage. The debt dynamics for banks is strikingly different than for other financial firms, for which the debt outstanding is stable since the financial crisis, and non-financial firms, for which debt has been increasing gradually over time.

Figure 2: Corporate Debt Dynamics.

The figure displays the total face value of debt outstanding from January 1990 until May 2016 for non-financial firms (dashed line), financial firms excluding banks (dotted line), and banks (solid line).



Third, the ECB also purchases on average €26 billion of covered bonds per quarter. Since net issuances are negative as well, there are large negative flows from banks, in both vulnerable and non-vulnerable countries, as well as the foreign sector. Again, these flows are similar to the flows before the PSPP and may be due to banks deleveraging instead of being caused by the PSPP.

Lastly, equity and foreign asset flows are relatively small compared to the flows in fixed income markets, other than for mutual funds. Hence, most of the rebalancing, in euro terms, happens within fixed income markets.[22]

4.2. Which Sectors Sell to the ECB: Evidence from Micro Data

In the previous section, we report the average rebalancing across different asset categories. However, the portfolio rebalancing that we observe may be unrelated to the ECB's asset

[22]See also Di Maggio, Kermani, and Palmer (2016) for evidence of limited rebalancing in U.S. mortgage markets in response to the QE programmes in the U.S.

purchases. We now use our micro data to quantify the portfolio-rebalance channel directly.

To this end, we start from the market clearing condition in changes for security n at time t

$$\sum_i T_{int} + T_{Foreign,nt} + T_{ECB,nt} = I_{nt}, \tag{2}$$

where $T_{Foreign,nt}$ and $T_{ECB,nt}$ denotes the rebalancing of the foreign sector and the ECB, respectively, which are defined analogously to T_{int} in (1). I_{nt} corresponds to net issuances, which is defined as

$$I_{nt} = (S_{nt} - S_{n,t-1})P_{nt}, \tag{3}$$

where S_{nt} denotes the total supply of security n at time t.

To measure portfolio rebalancing, we compute a variance decomposition of (2) by regressing each of the terms on $T_{ECB,nt}$ across securities and time. To avoid lots of zeroes in these regressions, we aggregate the securities within a country into maturity brackets where the residual maturity is in $[2, 5]$, $[5, 7.5]$, $[7.5, 10]$, $[10, 15]$ or $[15, 30]$. We estimate the coefficient separately for every investor sector and holder country.

However, differences in country size and the fact that investors are home biased (see Table II), may lead to counter-intuitive estimates. To see this, consider two countries that differ in size, say Germany and Malta. If investors in both countries are perfectly home biased, German investors hold all German debt and Maltese investors hold all Maltese debt. The ECB follows the capital key to buy debt across countries, which implies that the ECB buys a lot of German debt and much less Maltese debt. If German and Maltese investors sell the same share of their portfolios to accommodate the ECB's purchases, then the regression of T_{German} on T_{ECB} results in a slope coefficient larger than one, while a regression of T_{Malta} on T_{ECB} leads to a coefficient that is negative. After all, Maltese investors sell no German debt, of which the ECB buys a lot, and do sell Maltese debt, of which the ECB buys very little. Appendix A provides a simple two-country example formalizing this intuition.

Given the differences in initial portfolios, we are interested in studying whether investors sell the same fractions of their initial portfolios to accommodate ECB purchases. We first compute the aggregate holdings across all investor sectors, excluding the ECB, $S^{\star}_{int}$,

$$S^{\star}_{in,t-1} = \sum_i Q_{in,t-1} + Q_{Foreign,n,t-1}. \tag{4}$$

We then compute the rebalancing of each investor if ECB purchases are accommodated by

each investor selling the same fraction of its portfolio,

$$T_{ECB,nt} \quad = \quad \sum_{h,s} \frac{Q_{in,t-1}}{S^{\star}_{in,t-1}} T_{ECB,nt} + \frac{Q_{Foreign,n,t-1}}{S^{\star}_{in,t-1}} T_{ECB,nt}.$$

We define rebalancing adjusted for ECB purchases as

$$T^{\star}_{int} = T_{int} + \frac{Q_{in,t-1}}{S^{\star}_{in,t-1}} T_{ECB,nt}, \tag{5}$$

and analogously for the foreign sector. The market clearing condition in changes now can be written as

$$\sum_{i} T^{\star}_{int} + T^{\star}_{Foreign,nt} = I_{int}. \tag{6}$$

We regress each of the terms on $T_{ECB,nt}$ across issuer countries, maturity brackets, and quarters. The market clearing condition then implies

$$\sum_{i} \beta^{\star}_{i} + \beta^{\star}_{Foreign} = \beta_{I}. \tag{7}$$

If all investors rebalance in proportion to their initial holdings and if supply does not respond to the asset purchase programme, then we have $\beta^{\star}_{hs} = \beta_I = 0, \forall i$. Economically, when $\beta^{\star}_{i} < 0$, investor sector i sells more than proportionally in response to purchases by the ECB. When $\beta^{\star}_{i} > 0$, the investor sector is less elastic.

We rewrite (5) to

$$T_{int} = T^{\star}_{int} - \frac{Q_{in,t-1}}{S^{\star}_{in,t-1}} T_{ECB,nt} = \left(\beta^{\star}_{i} - \frac{Q_{in,t-1}}{S^{\star}_{in,t-1}} \right) T_{ECB,nt} + \epsilon_{int}, \tag{8}$$

where ϵ_{int} is the regression error from regressing $T^{\star}_{int}$ on $T_{ECB,nt}$ and $E(\epsilon_{int} \mid T_{ECB,nt}) = 0$.

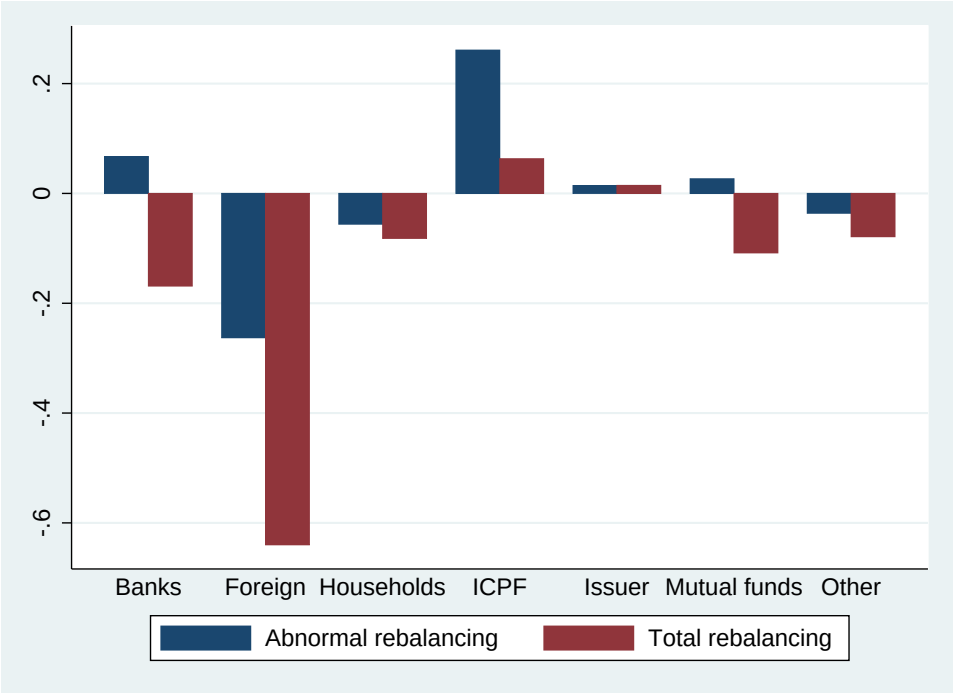
We aggregate the right-hand side for a given investor and divide by total ECB purchases to assess which investors sell in response to a €1 of assets purchases. We compute the average response across the three quarters for which we have purchases, 2015Q2 until 2015Q4.

Figure 3 reports the results. The first bar for each sector corresponds to abnormal rebalancing, $\beta^{\star}_{i}$. It measures how investors rebalance beyond simply scaling back their initial holdings in proportion to ECB purchases. The sum of these bars equals zero. The second bar for each sector measures total rebalancing, see (8). The sum of these bars equals one.

The first set of bars shows that the foreign sector sells to the ECB, while insurance companies and pension funds tend to buy bonds with similar maturities as the ECB. Long-

Figure 3: Portfolio Rebalancing in Response to ECB Purchases.

The figure reports the rebalancing by different investor sectors in response to ECB purchases. The first bar for each sector corresponds to abnormal rebalancing ($\beta_i^\star$). It measures how investors rebalance beyond simply scaling back their initial holdings in proportion to ECB purchases. The sum of these bars equals zero. The second bar for each sector measures total rebalancing, which subtracts the rebalancing due to initial holdings. The sum of these bars equals one. The coefficients are estimated from 2015Q2 until 2015Q4. The classification of vulnerable and non-vulnerable countries follows Altavilla et al. (2016).



term investors therefore amplify the asset purchase programme. The second set of bars allows us to answer the question how a €1 purchase of assets is accommodated by different investors. We find that the foreign sector sells €0.64, banks sell €0.17, and mutual funds €0.11. Insurance companies and pension funds do not sell and in fact buy €0.06. Changes on the supply side, as measured by the issuer sector, are virtually unrelated to ECB purchases.

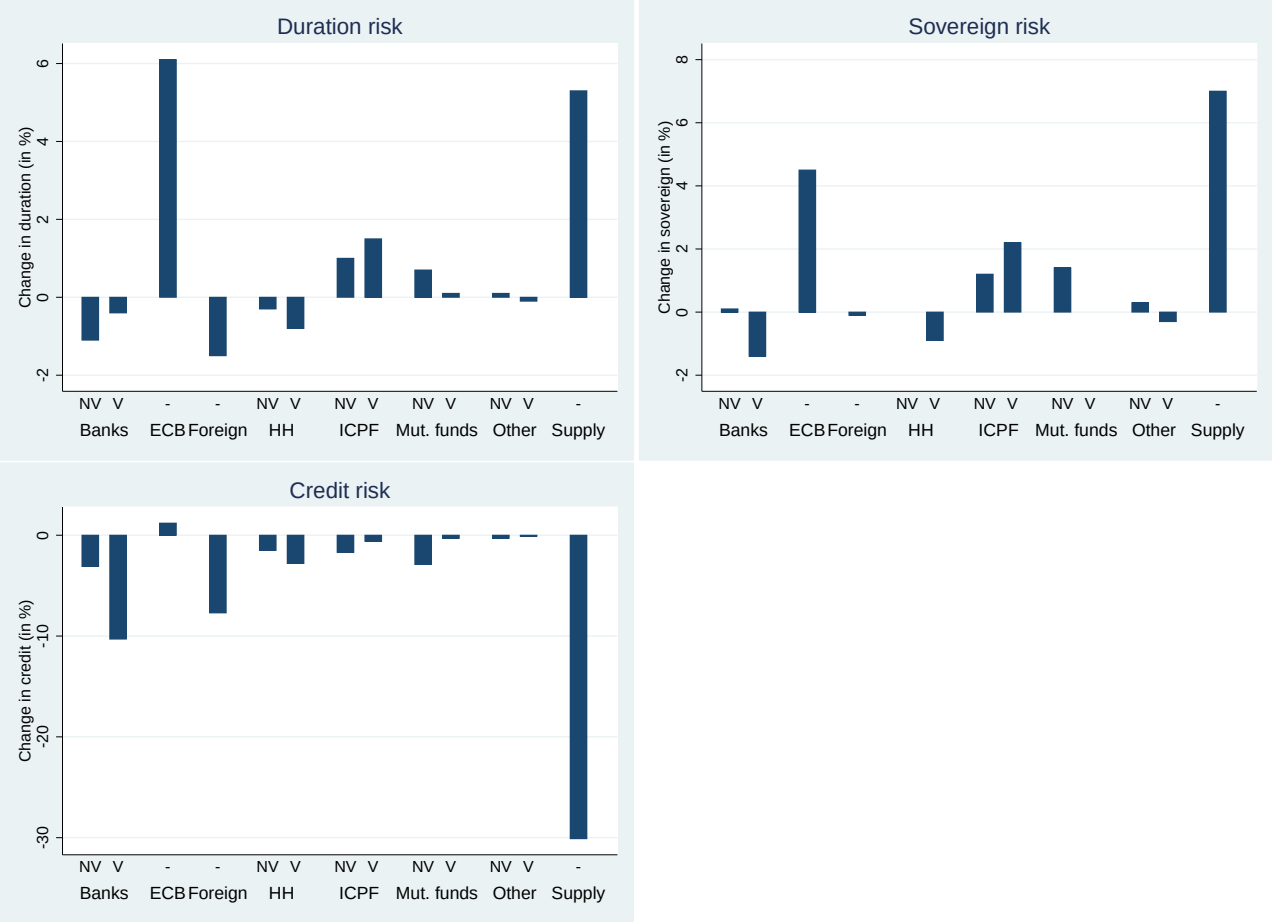
4.3. The Dynamics of Risk Exposures

In the previous sections, we focus on portfolio rebalancing and the flow of funds. However, the theories we discuss in the introduction have direct predictions in terms of changes in risk exposures, and not necessarily the flow of funds.

In Figure 4, we report the dynamics of duration risk exposures (top left panel), sovereign risk exposures (top right panel), and credit risk exposures (bottom left panel). To compute the dynamics of risk exposures, we compute the distribution of risk exposures as in Table IV. We scale the total supply of exposures in 2014Q4, which is the quarter before the

Figure 4: The Dynamics of Risk Exposures.

The figure summarizes the dynamics of risk exposures from 2014Q2 to 2015Q4. The top left panel shows the dynamics of duration risk exposures, the top right panel of sovereign risk exposures, and the bottom left panel of credit risk exposures. The two bars for each sector (other than Foreign, ECB, and Supply) correspond to the dynamics of risk exposures for investors in non-vulnerable ("NV") and vulnerable ("V") countries. The dynamics of risk exposures are expressed in percentage points. The classification of vulnerable and non-vulnerable countries follows Altavilla et al. (2016).



announcement and the start of the implementation of the purchase programme, to 100. We then track how the total exposure changes before and after 2014Q4 and how it is distributed across investors. We define the dynamics of risk exposures as the difference between the exposure share of a given institution in 2015Q4 relative to the share in 214Q2. The detailed data, by quarter, institution, and holder country group, are reported in Table VI.

We first discuss duration risk exposures. The aggregate duration risk in the economy increased by 5.2% from 2014Q2 until 2015Q4. This increase is not driven by sovereigns or the private sector issuing more debt, but this increase is to a large extent a valuation effect. As interest rates decreased during this period, in part due to the asset purchase programme as we discuss in the next section, the total amount of duration risk increases. Second, we

estimate that the ECB increases its share of duration risk exposure from 0.9% to 7.0%, an increase of 5.9%. Hence, the ECB currently buys about 1.5% of all euro-area duration risk exposure per quarter.

For each of the other sectors, we split the dynamics of risk exposures by vulnerable and non-vulnerable countries. As before, we find that insurance companies and pension funds increase their exposure to duration risk, and mutual funds to a smaller extent as well, while the share of duration risk borne by banks and in particular the foreign sector declines.

These results suggest that the foreign sector and banks are the most price elastic. One possible interpretation is that the demand for long-term bonds is driven by a component that depends on the risk-return trade-off offered by bonds (that is, the traditional mean-variance or speculative demand) and a hedging demand, which is inelastic. As a result of the asset purchase programme, the risk premium on long-term bonds falls and the speculative demand becomes less important. In this case, the distribution of duration risk exposures across institutions is driven to a larger extent by hedging demands. Insurance companies and pension funds have hedging demands coming from their long-term liabilities, while (bond) mutual funds may have an incentive to match the duration of the bonds in their performance benchmarks (Basak and Pavlova, 2013). A direct consequence of this mechanism is that risk mismatch, at least in terms of the risks purchased by central banks, is reduced as a result of asset purchase programmes. This mechanism may also have implications for price effects across countries. The foreign sector tends to focus on non-vulnerable countries. Their more elastic demand may lead to smaller price effects for non-vulnerable countries than for vulnerable countries.

In terms of sovereign risk exposures, the supply side is more volatile and follows a U-shaped pattern in the amount of sovereign risk in financial markets. Sovereign risk falls by about 10% from 2013Q4 until 2014Q3 and subsequently increases by 6% by 2015Q4. This pattern can be attributed to two factors. The first are changes in the relative value of risky and non-risky bonds. However, part of the U-shaped pattern remains even if we use the bonds' face values. The second factor consists of changes in the credit rating of some countries during our sample, in particular, the upgrade of Greece in late 2013 and early 2014 and the downgrade of France in 2015.

Sovereign risk exposures increase for insurance companies and pension funds in both vulnerable and non-vulnerable countries. This comes from the fact that these institutions buy more government bonds as discussed before. Given that French insurance companies are particularly large, the share of sovereign risk increases somewhat. As with duration risk, the ECB stands out in terms of removing sovereign risk from financial markets and purchases the equivalent of approximately 1.5% of all euro-area sovereign risk per quarter.

Table VI: The Distribution and Dynamics of Risk Exposures.

The table reports the distribution and dynamics of duration (Panel A), sovereign (Panel B), and credit risk (Panel C) exposures. The dynamics of risk exposures is defined as the difference in risk distributions in 2015Q4 and 2014Q2, before the announcements and discussions of the asset purchase programme. The distribution of risk exposures is normalized to 100 in 2014Q4. ECB duration risk is imputed from public data on maturity and duration data on representative bond portfolios. The classification of vulnerable and non-vulnerable countries follows Altavilla et al. (2016).

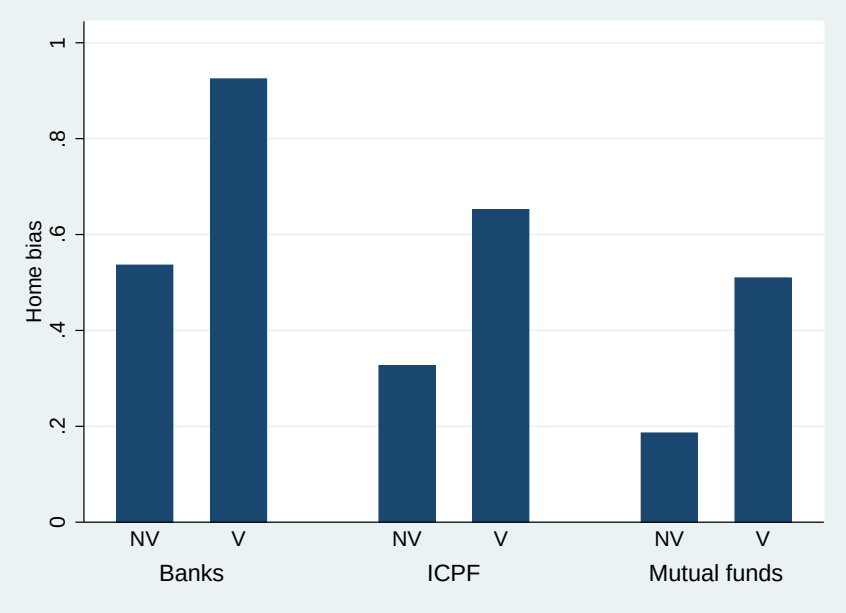
Panel A: Duration risk exposures											
		2013	2014				2015				Flow of
Riskiness	Sector	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	risk
	ICPF	17.6	18.1	19.3	20.1	21.2	22.5	20.5	21.0	20.3	1.0
	Banks	11.7	11.6	11.9	11.7	11.9	12.5	11.2	11.2	10.8	-1.1
Non-vulnerable	Mutual funds	9.2	10.1	10.9	11.3	11.7	12.9	11.6	11.9	11.6	0.7
	Households	1.1	1.1	1.1	1.1	1.0	1.0	0.9	0.9	0.8	-0.3
	Other	1.7	1.8	1.8	1.9	2.0	2.2	2.0	2.0	1.9	0.1
	ICPF	3.9	4.5	4.8	4.9	5.2	5.5	5.3	5.4	6.3	1.5
	Banks	6.0	6.6	6.9	7.1	7.2	7.3	7.2	7.1	6.5	-0.4
Vulnerable	Mutual funds	1.5	2.0	2.1	2.2	2.4	2.6	2.5	2.4	2.2	0.1
	Households	3.0	3.4	3.4	3.3	3.2	3.1	2.7	2.7	2.6	-0.8
	Other	1.2	1.4	1.4	1.4	1.5	1.6	1.4	1.4	1.3	-0.1
	Foreign	25.9	27.7	29.9	30.4	31.7	33.8	29.9	29.5	28.4	-1.5
	ECB	0.9	0.9	0.9	0.8	1.0	1.7	3.4	5.2	7.0	6.1
	Total	83.7	89.2	94.4	96.2	100.0	106.7	98.6	100.7	99.7	5.3
Panel B: Sovereign risk exposures											
	ICPF	5.6	5.6	6.3	6.4	6.6	7.5	7.0	7.6	7.5	1.2
	Banks	6.9	7.1	7.2	7.3	7.1	7.9	7.4	8.0	7.3	0.1
Non-vulnerable	Mutual funds	6.4	7.1	7.5	7.7	7.8	9.1	8.4	9.0	8.9	1.4
	Households	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0
	Other	0.7	0.7	0.7	0.8	0.9	1.1	1.0	1.0	1.0	0.3
	ICPF	8.5	9.4	9.5	9.7	10.2	10.6	10.2	10.5	11.7	2.2
	Banks	24.7	26.5	22.0	22.3	22.3	21.9	20.5	21.1	20.6	-1.4
Vulnerable	Mutual funds	6.0	5.8	5.9	6.3	6.3	6.7	6.1	6.0	5.9	0.0
	Households	5.0	5.1	4.8	4.7	4.6	4.5	4.0	4.0	3.9	-0.9
	Other	4.3	4.4	4.0	4.0	4.1	4.2	3.8	3.9	3.7	-0.3
	Foreign	28.1	31.1	28.5	28.5	26.4	30.5	27.1	27.5	28.4	-0.1
	ECB	3.3	3.2	3.4	3.5	3.5	4.0	5.2	6.7	7.9	4.5
	Total	99.8	106.3	100.0	101.4	100.0	108.2	100.9	105.5	107.0	7.0
Panel C: Credit risk exposures											
	ICPF	13.4	13.5	13.8	13.9	14.1	13.9	13.3	13.3	12.1	-1.7
	Banks	15.0	14.8	15.1	14.8	13.9	13.1	13.0	12.8	12.0	-3.1
Non-vulnerable	Mutual funds	13.7	14.2	14.3	14.4	14.3	13.9	13.0	12.6	11.4	-2.9
	Households	5.1	5.1	5.0	4.7	4.4	4.0	4.0	3.9	3.5	-1.5
	Other	1.9	1.7	1.7	1.8	1.7	1.6	1.5	1.5	1.4	-0.3
	ICPF	4.7	4.7	4.7	4.7	4.6	4.4	4.0	4.0	4.1	-0.6
	Banks	30.2	24.9	22.7	21.4	17.9	16.0	14.1	13.5	12.4	-10.3
Vulnerable	Mutual funds	3.0	3.1	3.2	3.3	3.4	3.2	3.2	3.1	2.9	-0.3
	Households	8.2	7.9	7.1	6.5	6.3	5.5	5.6	5.8	4.3	-2.8
	Other	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.6	-0.1
	Foreign	19.9	20.2	18.5	18.6	18.5	16.9	14.7	14.4	10.8	-7.7
	ECB	0.0	0.0	0.0	0.0	0.4	0.8	1.0	1.2	1.2	1.2
	Total	115.9	110.9	106.8	104.8	100.0	94.0	88.1	86.8	76.7	-30.1

The third risk factor that we consider is corporate credit risk. The dynamics of credit risk exposures is much larger than the dynamics of either duration risk or sovereign risk exposures. For starters, the supply of credit risk declines from 116% in 2013Q4 to 77% in 2015Q4 (see the final line of Table VI). This finding resonates with Figure 2, where we find that the amount of corporate debt issued by banks rapidly declines since the euro crisis. Given the secular decline in the amount of credit risk, this appears to be unrelated to the asset purchase programme.

However, our risk distribution framework is useful in this context to quantify how corporate credit exposures change across institutions. Perhaps surprisingly, we find the largest reduction exposure to corporate credit risk for banks in vulnerable countries with 17.8% from 2013Q4 to 2015Q4. As a point of reference, the share of credit risk held by banks in non-vulnerable countries reduces by only 3.0%. The foreign sector also reduces the share of credit risk substantially from 19.9% in 2013Q4 to 10.8% in 2015Q4, a reduction of 9.1%.

Hence, the results suggests that banks reduce their holdings of financials and the supply of bonds. This points to cross-holdings of corporate debt in the banking sector. To make this point more precise, we report the home bias in the holdings of financial firms in Figure 5. Consistent with the dynamics of risk exposures, we find that banks in vulnerable countries have a strong home bias in their holdings of corporate bonds issued by banks. These cross-holdings are important also in considering the sovereign-bank feedback loop, as this has to be evaluated across the system instead of per bank.

Figure 5: Home Bias in Bonds of Financial Firms across Institutions.



5. The Impact of Asset Purchases on Government Yields

In this section, we estimate the impact of the PSPP on the yield curve. In general, the challenge in identifying the impact on prices is that the announcement of an asset purchase programme is endogenous to broader economic conditions that also affect yields. To address this concern, the standard approach in the literature is to identify the key event days and to measure the yield curve response on those days, see Andrade, De Fiore, Karadi, Tristani (2016) for a review. This high-frequency single-difference estimator relies on identifying the correct event days and ideally that the announcement is largely unexpected, which may be problematic when expectations about the programme evolve gradually over time, for instance, in response to the flow of macro-economic news.

Instead, we propose a low-frequency difference-in-difference estimator to estimate the impact of the PSPP programme on government bond yields. We focus on the period from 2014Q2-2015Q1, which includes the period when the programme is announced. It also includes three weeks of PSPP purchases as the actual purchases started on March 9th. We use features of the purchase programme that generate exogenous variation across countries and maturity brackets to try and estimate the causal impact on yields.[23]

As discussed before, the ECB purchases bonds across countries according to the capital key. The weight of a country c in the capital key is given by

$$K_c = \frac{1}{2}\left[\frac{GDP_c}{\sum_c GDP_c} + \frac{Pop_c}{\sum_c Pop_c}\right],$$

where GDP_c denotes a country's GDP and Pop_c a country's population. The capital is revised infrequently and we use the capital key in 2014Q4. Within a country, the rules are less strict, and the ECB intends to act in a "market-neutral" way, which we interpret as buying according to the maturity distribution of bonds outstanding. We denote the fraction of bonds (measured in terms of face value) in a given maturity range τ by $\mu_{c,\tau}$, where we use the distribution in 2014Q4. This is the maturity distribution before the programme was announced.

As the programme was announced to last for 19 months during which the ECB buys €44 billion per month, the predicted purchases for country c in maturity bracket τ equals

$$\Pi_{c,\tau} = 19 \times 44 \times \mu_{c,\tau} \times K_c.$$

In theory, the price effects depend on the reduction in residual supply. We therefore scale

[23] One can potentially use other features of the purchase programme, such as the rule that bonds with a yield-to-maturity below the deposit facility rate cannot be purchased.

the purchases by the size of the market in a given country, as measured in face value. We denote the scaled purchases by $\pi_{c,\tau}$.

To estimate the impact on yields, we consider the following regression

$$\Delta y_{c,\tau} = a + b\pi_{c,\tau} + \gamma' X_{c,\tau} + \epsilon_{c,\tau}, \tag{9}$$

where $\Delta x = x(2015Q1) - x(2014Q2)$ and $X_{c,\tau}$ are other factors that may drive the yield changes in a country, such as maturity, sovereign risk, and economic conditions. We use the probability of default as before to capture differences in exposure to aggregate shocks that may have caused a decline in yields during this period. We measure economic conditions by the logarithm of GDP per capita, but consider various alternative economic indicators as well. We include dummy variables for the maturity brackets as $[2, 5]$, $[5, 7.5]$, $[7.5, 10]$, $[10, 15]$, and $[15, 30]$.

One possible concern is that the capital key depends on GDP, which reflects a country's economic conditions. To alleviate this concern, we also consider an IV estimator. We use the population share multiplied by the maturity distribution in a given country, scaled by the country's bond market, as an instrument for PSPP purchases. As an alternative approach to alleviating this concern, we consider specifications in which we directly control for GDP and GDP scaled by the size of the bond market.

Figure 6: Instrument Versus Expected Purchases.

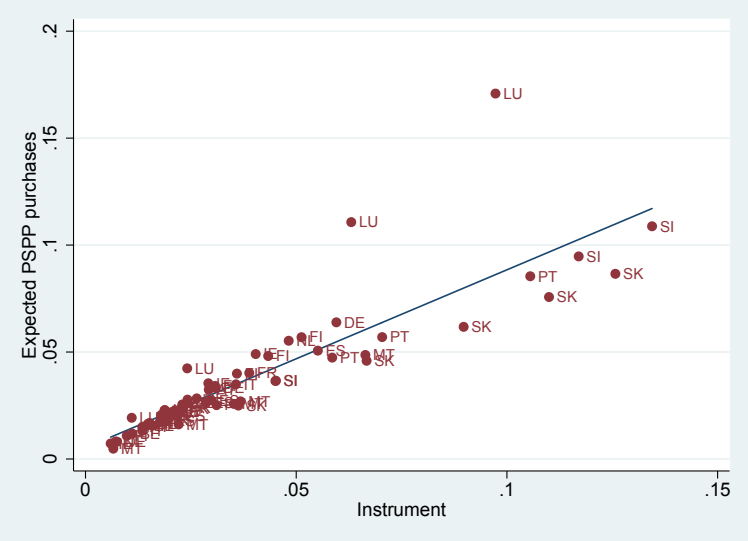


Figure 6 displays a scatter plot of expected PSPP purchases and our instrument. Although we find some deviations as GDP per capita is relatively high in, for instance, Germany and Luxembourg and relatively low in Slovenia and Portugal, the instrument and expected

purchases are highly positively correlated.

The estimation results of (9) are reported in Table VII. The first column reports the first stage regression of the IV estimation, the second column the second stage regression, and in the final column we report the results when we estimate the model using OLS. As is obvious from the first stage regression, consistent with Figure 6, the instrument is strongly related to expected purchases and we have a near perfect fit with an R-squared of 92%. Consequently, the IV estimate and the OLS estimate are virtually identical at -3.3 and -3.5, respectively. In terms of the controls, we find that the yields fall more for longer-maturity bonds. For instance, bonds with residual maturities between 15 and 30 years fall by 1.3 percentage points compared to only 0.4 percentage points for bonds with residual maturities between 5 and 7.5 years. Moreover, yields fall more for countries with lower levels of GDP per capita and higher levels of sovereign risk, implying that yields fall more in vulnerable countries.

To interpret the coefficient of -3.5, we multiply the coefficient with expected purchases and average across all countries and maturity groups. The average decline in yields equals -13bp. However there is significant heterogeneity and the predict change in yields ranges from -2bp to -60bp.

In Table B.3, we explore various alternative specifications in which we control for GDP per capita (in levels and logs), growth in GDP per capita, the GDP share of a country, and the GDP share normalized by the size of the bond market in a given country. The coefficient on PSPP purchases is always statistically significant at the 5% level and the point estimates vary between -2.5 and -4.0. In Table B.4, we consider a placebo test by studying the yield changes from 2013Q4-2014Q2, which is before the PSPP programme was announced and discussed. We find that the coefficient is positive (2.8) and statistically insignificant ($t = 1.25$). We also estimate the same regressions for each maturity group maturity group, implying that we only use cross-country information to identify the coefficients. The point estimates range from -1.7 to -4.5.

6. Conclusions

We use new data on security-level portfolio holdings of institutional investors and households in the euro area to understand the impact of the ongoing asset purchase programme of the European Central Bank on the dynamics of risk exposures and on asset prices. We develop a tractable measurement framework to quantify the dynamics of euro-area duration, sovereign and corporate credit, and equity risk exposures as the programme evolves. We propose an instrumental-variables estimator to identify the impact of central bank purchases on

Table VII: Expected Purchases and Yield Changes.

The first column reports the first-stage regression of expected purchases on the instrument that depends on population size and the size of the government bond market in a given country. The controls are dummy variables for (residual) maturity brackets, the probability of default, and log GDP per capita. The second column reports the second-stage of regression of changes in yields on expected purchases. The final column reports the estimates of an OLS regression of yield changes on expected PSPP purchases. We measure the yield changes from 2014Q2 until 2015Q1. We report the standard errors in parentheses.

	(1)	(2)	(3)
	Expected purchases	2014Q2-2015Q1	2014Q2-2015Q1
Instrument	0.999***		
	(0.0440)		
Maturity [5,7.5]	0.00428	-0.372***	-0.373***
	(0.00344)	(0.0554)	(0.0591)
[7.5,10]	0.00361	-0.804***	-0.808***
	(0.00355)	(0.0588)	(0.0625)
[10,15]	0.000436	-1.123***	-1.128***
	(0.00372)	(0.0603)	(0.0640)
[15,30]	0.000148	-1.304***	-1.310***
	(0.00376)	(0.0629)	(0.0666)
Country risk (PD)	0.190*	-12.31***	-12.28***
	(0.0991)	(1.664)	(1.776)
Log GDP per capita	0.0298***	0.158***	0.159***
	(0.00314)	(0.0516)	(0.0551)
Expected purchases		-3.346***	-3.504***
		(0.722)	(0.732)
R^2	0.917	0.917	0.917
Observations	67	65	65

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

sovereign bonds on sovereign bond yields. Our results suggest that the programme reduced duration mismatch risk and that it lowered bond yields.

In ongoing work, we are estimating demand elasticities for sovereign debt across institutions. This will allow us to connect the portfolio rebalancing results directly to the price effects we documented in the final section. In addition, as new waves of data become available, we plan to update the dynamics of risk exposures.

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A. Home Bias, Country Size, and Measuring Rebalancing

Consider two countries that are symmetric in terms of portfolios, other than that one country is larger than the other country. Countries are indexed by $c = 1, 2$. Each country has a single institution. The assets are denoted by A_c. We assume $A_1 = xA_2 = xA$, where $x > 1$. The portfolio weights of country 1 are given by $w_1 = (\xi, 1-\xi)$. The portfolio weight of country 2 by $(1-\xi, \xi)$, where $\xi \in (0.5, 1)$. Hence, each country is home biased.

Market clearing implies that supply satisfies

$$S_1 = \xi A_1 + (1-\xi)A_2 = (x\xi + 1 - \xi)A, \tag{10}$$

$$S_2 = (1-\xi)A_1 + \xi A_2 = (x(1-\xi) + \xi)A, \tag{11}$$

implying that $S_1 > S_2$. We normalize $A = 1$.

Suppose the ECB buys a fraction $\theta \in (0, 1-\xi)$ of each country's supply. Hence, T_{ECB} can be computed as

$$T_{ECB} = \begin{pmatrix} \theta(x\xi + 1 - \xi) \\ \theta(x(1-\xi) + \xi) \end{pmatrix}. \tag{12}$$

Assume that both investors sell a fraction θ of their portfolios. The rebalancing in response to the ECB purchases are equal to

$$T_1 = \begin{pmatrix} -\theta x\xi \\ -\theta x(1-\xi) \end{pmatrix} \tag{13}$$

and

$$T_2 = \begin{pmatrix} -\theta(1-\xi) \\ -\theta\xi \end{pmatrix}. \tag{14}$$

Assuming supply remains constant, the market clearing condition in changes holds. The slope for the institution in country 1 is

$$\beta_1 = \frac{-x\xi + x(1-\xi)}{(x\xi + 1 - \xi) - (x(1-\xi) + \xi)} = \frac{x(1-2\xi)}{(1-x)(1-2\xi)} = \frac{x}{1-x} < -1, \tag{15}$$

and for country 2

$$\beta_2 = 1 - \beta_1 = \frac{1-2x}{1-x} > 0. \tag{16}$$

With this measure of rebalancing, we get the counterintuitive result that $\beta_2 > 0$, while both investors accommodate QE by scaling their portfolios in proportion. Intuitively, the ECB buys a lot Country 1 and less of Country 2. The investor in Country 2 sells a lot of Country 2 and little of Country 1, which suggests it amplifies the effect of the QE programme.

Next, we consider an alternative way to measure rebalancing. We start from the market clearing condition in changes

$$\Delta Q_{ECB} P = -\Delta Q_1 P - \Delta Q_2 P, \tag{17}$$

where the products of vectors are to be interpreted as element-by-element multiplication. The idea is that the ECB purchases may need to be "attributed" to different investors in proportion to their initial portfolios. That is,

$$\Delta Q_{ECB} = \frac{Q_1}{S}\Delta Q_{ECB} + \frac{Q_2}{S}\Delta Q_{ECB}. \tag{18}$$

We can then rewrite the market-clearing condition as

$$0 = \left(\Delta Q_1 + \frac{Q_1}{S}\Delta Q_{ECB}\right) P + \left(\Delta Q_2 + \frac{Q_2}{S}\Delta Q_{ECB}\right) P. \tag{19}$$

This is similar as before, other than that we add a "fixed effect" to each country's rebalancing based on their initial portfolios. Define

$$T_i^\star = \left(\Delta Q_i + \frac{Q_i}{S}\Delta Q_{ECB}\right) P, \tag{20}$$

and T_{ECB} is the same as before. We now consider the regressions

$$T_i = \alpha_i^\star + \beta_i^\star T_{ECB} + \epsilon_i, \tag{21}$$

where the market clearing condition implies

$$\beta_1^\star + \beta_2^\star = 0. \tag{22}$$

Importantly, in step 2, we now measure the rebalancing induced by the ECB as

$$-\frac{Q_i}{S}\Delta Q_{ECB} + \beta_i \Delta Q_{ECB}. \tag{23}$$

If we apply this alternative framework to the example above, then

$$T_1^\star = \begin{pmatrix} -\theta x \xi \\ -\theta x (1-\xi) \end{pmatrix} + \begin{pmatrix} \frac{\xi x}{\xi x + 1 - \xi} \theta (\xi x + 1 - \xi) \\ \frac{(1-\xi) x}{x(1-\xi) + \xi} \theta (x(1-\xi) + \xi) \end{pmatrix} = 0_{2\times 1}. \tag{24}$$

Hence, $\beta_1^\star = \beta_2^\star = 0$, and the rebalancing is in proportion to the ECB purchases.

B. Additional tables and figures

Table B.1: Definitions of asset categories and investor sectors.

Panel A: Definition asset categories

Category	Description
1	PSPP-eligible government bonds, € denominated, and euro-area issuer.
2	PSPP-ineligible government bonds, € denominated, and euro-area issuer.
3	High-grade corporate debt (incl. medium-term notes), € denominated, and euro-area issuer.
4	Low-grade corporate debt (incl. medium-term notes), € denominated, and euro-area issuer.
5	Asset backed securities (incl. covered bonds), € denominated, and euro-area issuer.
6	Equity, € denominated, and euro-area issuer.
7	Non-euro-area issuer or in a currency other than euros.

Panel B: Definition investor sectors

Sector	Description
1	Household sector (HH).
2	Insurance companies and pension funds (ICPF).
3	Monetary financial institutions, such as banks (MFI).
4	Other financial institutions, such as mutual funds (OFI).
5	Foreign investors.
6	Other (General government and Non-Financial Corporations).
7	Eurosystem holdings in the framework of the PSPP, CBPP, and the SMP.

Table B.2: Rebalancing Before the PSPP

The table reports average portfolio rebalancing from 2013Q4 until 2014Q4. The asset categories are defined as: Elig. Govt. - PSPP eligible government bonds, Inelig. Govt. - PSPP ineligible government bonds, IG-Corp. - Investment grade corporate bonds, SG-Corp. - Speculative grade corporate bonds, ABSCB - ABS and covered bonds, Equity - Euro area equity, and Foreign - Non-euro area assets. The top panel reports the rebalancing for investor sectors in non-vulnerable countries and the second panel for investors in vulnerable countries. The third panel reports the rebalancing of the foreign sector and the ECB. The bottom panel reports net issuances. The flows are reported in billions of euros.

		Asset category						
Riskiness	Sector	Elig. Govt.	Inelig. Govt.	IG Corp.	SG Corp.	ABS &CB	Equity	Foreign
Non-vulnerable	ICPF	1	7	-2	4	-2	2	11
	Banks	8	5	-18	3	-12	5	-25
	Mutual Funds	8	3	-3	9	-4	22	97
	Household	-2	0	-5	-3	-1	4	3
	Other	4	-3	0	0	-1	-2	0
Vulnerable	ICPF	7	4	-1	0	-1	1	1
	Banks	15	-9	-20	-22	-20	-4	4
	Mutual Funds	9	1	2	3	0	14	31
	Household	-5	-1	-13	-10	0	2	-13
	Other	-2	0	0	-1	0	1	-4
	ECB	-6	6	0	0	8	0	0
	Foreign	22	-42	2	-26	-12	–	–
	Issuer	61	-30	-60	-44	-45	–	–

Table B.3: ECB expected purchases and yield changes (OLS).

	(1) 2014Q2-2015Q1	(2) 2014Q2-2015Q1	(3) 2014Q2-2015Q1	(4) 2014Q2-2015Q1	(5) 2014Q2-2015Q1	(6) 2014Q2-2015Q1
Expected purchases	-3.306***	-3.930***	-3.504***	-2.502***	-2.627***	-4.043***
	(0.773)	(0.791)	(0.732)	(0.566)	(0.742)	(1.028)
Maturity [5,7.5]	-0.362***	-0.378***	-0.373***	-0.354***	-0.353***	-0.374***
	(0.0626)	(0.0607)	(0.0591)	(0.0450)	(0.0578)	(0.0635)
[7.5,10]	-0.784***	-0.815***	-0.808***	-0.770***	-0.769***	-0.808***
	(0.0658)	(0.0647)	(0.0625)	(0.0473)	(0.0608)	(0.0691)
[10,15]	-1.116***	-1.143***	-1.128***	-1.089***	-1.093***	-1.143***
	(0.0677)	(0.0663)	(0.0640)	(0.0488)	(0.0629)	(0.0720)
[15,30]	-1.276***	-1.319***	-1.310***	-1.263***	-1.258***	-1.307***
	(0.0696)	(0.0695)	(0.0666)	(0.0501)	(0.0644)	(0.0750)
Country risk (PD)	-15.46***	-13.14***	-12.28***	-14.82***	-14.94***	-14.55***
	(1.478)	(1.735)	(1.776)	(1.067)	(1.373)	(1.695)
GDP per capita		3.462**				
		(1.477)				
Log GDP per capita			0.159***			
			(0.0551)			
Growth in GDP per capita				-0.0687***		
				(0.00924)		
GDP share					0.748***	
					(0.224)	
GDP share / Size of the bond market						0.296
						(0.273)
R^2	0.905	0.913	0.917	0.952	0.921	0.907
Observations	65	65	65	65	65	65

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B.4: ECB expected purchases and yield changes (separate regressions for each maturity group) and placebo regression using yield change from 2013q4 to 2014q2

	(1)	(2)	(3)	(4)	(5)	(6)
	2014Q2-2015Q1	2014Q2-2015Q1	2014Q2-2015Q1	2014Q2-2015Q1	2014Q2-2015Q1	Placebo
Expected purchases	-4.482**	-3.639***	-1.742	-3.892	-4.004	2.757
	(1.616)	(0.837)	(2.565)	(3.059)	(3.730)	(2.199)
Country risk (PD)	-12.47***	-16.39***	-17.10***	-22.26**	-13.22***	26.85***
	(2.535)	(2.408)	(4.356)	(7.304)	(2.350)	(4.244)
Maturity [5,7.5]						0.332*
						(0.180)
[7.5,10]						0.340*
						(0.184)
[10,15]						0.299
						(0.194)
[15,30]						0.174
						(0.196)
R^2	0.814	0.845	0.608	0.517	0.796	0.432
Observations	13	14	13	13	12	67

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$