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INSPECTING THE MECHANISM OF QUANTITATIVE EASING IN THE EURO AREA

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ABSTRACT

Using security-level holdings for all euro-area investors, we study portfolio rebalancing during the quantitative easing program from March 2015 to December 2017. Foreign investors outside the euro area accommodated most of the Eurosystem's purchases. Duration, government credit, and corporate credit risk did not get concentrated in particular regions or investor sectors. We estimate a demand system for government bonds by instrumental variables to relate portfolio rebalancing to yield changes. Government bond yields decreased by 65 basis points on average, and this estimate varies from 38 to 83 basis points across countries.

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1. Introduction

Because of growing concerns about a prolonged period of low inflation, the European Central Bank (ECB) announced the expanded asset purchase program on January 22, 2015. Its objective was to increase inflation to a level below but close to 2%. The size of asset purchases was initially €60 billion per month from March 2015 to September 2016. The ECB subsequently expanded the size and the duration of asset purchases. Central banks in the United States, the United Kingdom, and Japan have implemented similar quantitative easing programs when their policy rate reached a level close to zero.

The goal of this paper is to understand how quantitative easing works by studying portfolio rebalancing, the dynamics of risk exposure, and asset prices in the euro area from 2013Q4 to 2017Q4. We use new security-level holdings data for all investor sectors (including banks, insurance companies, pension funds, and mutual funds) and all asset classes (i.e., government bonds, corporate bonds, asset-backed securities (ABS), covered bonds, and equities). We also use the security-level transactions data for the Eurosystem (i.e., the ECB and its member central banks), both from the expanded asset purchase program and earlier programs. We combine these holdings data with asset prices and characteristics. We document which investors sell to the Eurosystem, how portfolio rebalancing affects the distribution of risk exposure across regions and investors, how portfolio rebalancing affects government bond yields, and which regions and investors have the largest capital gains on their portfolios.

We first summarize the initial portfolio holdings and risk exposure from 2013Q4 to 2014Q4 prior to the expanded asset purchase program, updating Koijen et al. (2017). Because of data confidentiality requirements, we report aggregate results for two regions grouped as vulnerable countries (Cyprus, Greece, Ireland, Italy, Portugal, and Spain) and nonvulnerable countries (other euro-area countries), following Altavilla et al. (2017). All investors in vulnerable countries, including insurance companies, pension funds, and mutual funds, have a strong home bias in their government bond portfolios compared with those in nonvulnerable countries. Therefore, the feedback loop between the financial sector and governments, which received much attention among regulators, is not limited to banks but extends to institutions that safeguard long-term savings. Based on all euro-area portfolio holdings, we measure the duration, government credit, corporate credit, and equity risk exposure by region and investor sector.[1] We also measure the foreign risk exposure of euro-area investors through investments in assets issued outside the euro area or denominated in foreign

[1] In a related exercise, Begenau et al. (2015) measure U.S. banks' exposure to interest rate and credit risk. Our exercise is limited to the asset side of the balance sheet. However, we expand the scope of analysis to include government credit and equity risk and other investors such as insurance companies, pension funds, and mutual funds.

currencies. Through market clearing, we develop a risk accounting framework to measure the distribution of aggregate risks across regions and investors prior to the expanded asset purchase program.

We then measure how investors rebalance their portfolios during quantitative easing. Based on market clearing in first differences, we decompose the share of government bonds that each investor sells in response to the Eurosystem's purchases. In the order of importance, foreign investors sell €0.40, banks sell €0.20, and mutual funds sell €0.06 per euro purchased by the Eurosystem. Long-term investors such as insurance companies and pension funds do not sell and instead buy the same bonds as the Eurosystem. Net issuances account for the remaining purchases by the Eurosystem. Foreign investors sell government bonds issued by vulnerable and nonvulnerable countries in roughly the same proportion and do not reinvest elsewhere in the euro area.[2]

Using the same risk accounting framework in first differences, we examine how quantitative easing affects the distribution of risk exposures across regions and investors. We do not find evidence for large-scale rebalancing across asset classes or risk concentration in particular regions or investor sectors. If anything, quantitative easing appears to reduce duration risk mismatch for banks, insurance companies, and pension funds.

Starting with a traditional mean-variance portfolio, Koijen and Yogo (2019) derive an empirically tractable model of portfolio weights that is a logit function of asset prices, asset characteristics, and latent demand that represents heterogenous expectations or constraints that are not captured by the observed characteristics. Following their approach, we estimate a demand system for euro-area government bonds, modeling portfolio weights as a logit function of yields, bond characteristics, and latent demand. Because yields are jointly endogenous with latent demand, we exploit a unique institutional feature that makes the Eurosystem's government bond purchases proportional to each country's capital key, which is an equal-weighted average of gross domestic product (GDP) and population shares within the euro area.[3] Cross-sectional variation in the size of the Eurosystem's purchases relative to the size of each country's government bond market gives us exogenous variation in residual supply that is correlated with yields.

The first stage of the instrumental variables regression shows that government bond yields decreased by 65 basis points on average. This estimate varies from 38 to 83 basis points across

[2]Based on the U.S. Flow of Funds, Carpenter et al. (2015) find that the household sector, which includes hedge funds, is the primary seller in response to the Federal Reserve's quantitative easing program. Saito and Hogen (2014) find that foreign investors are the primary sellers in response to the Bank of Japan's quantitative easing program.

[3]Importantly, the capital key uses the level of GDP rather than GDP per capita. If one were concerned about endogeneity of GDP shares, we could instead use population shares only as an instrument, which we have done in an earlier version of this paper.

countries. The previous literature uses an event study methodology to estimate how asset prices respond to quantitative easing policy announcements [e.g., Gagnon et al. (2011) and Krishnamurthy and Vissing-Jørgensen (2011) for the United States and Krishnamurthy et al. (2017) for the euro area]. A potential drawback of this methodology is that investors could have partly anticipated the policy announcement due to the gradual flow of macroeconomic and financial market news. Our empirical strategy based on instrumental variables operates at a lower frequency and does not require us to isolate the precise dates when investor expectations adjust.

The second stage of the instrumental variables regression identifies the demand elasticities based on the changes in government bond yields. The demand elasticities are heterogeneous across investors with foreign investors having the most elastic demand and insurance companies and pension funds having the least elastic demand. Consistent with portfolio rebalancing, investors with high demand elasticities, particularly foreign investors, sell to the Eurosystem during quantitative easing. A new generation of asset pricing models emphasize the importance of intermediaries and their role in quantitative easing programs (He and Krishnamurthy, 2013; Brunnermeier and Sannikov, 2014, 2016). Based on our finding that investor heterogeneity matters for how demand shocks are absorbed, modeling meaningful heterogeneity across investors is an important direction for future research (e.g., Greenwood, Hanson and Vayanos, 2016; Coimbra and Rey, 2017; Koijen and Yogo, 2019).

Finally, we estimate how quantitative easing affects portfolio valuations by region and investor sector. We multiply the total duration of each investor's government bond portfolio by the cumulative impact of quantitative easing on yields. Institutional investors (i.e., banks, mutual funds, insurance companies, and pension funds) in nonvulnerable countries benefit more than those in vulnerable countries because they have larger portfolios with more duration risk. The total valuation effect is €415 billion, which is the sum of €179 billion for investors in nonvulnerable countries, €74 billion for investors in vulnerable countries, and €162 billion for foreign investors. An important caveat is that these valuation effects reflect only the asset side of the balance sheet because we do not have sufficient data on the liability side.

1.1. Theories of quantitative easing

Three classes of theories about quantitative easing guide our empirical work. First, Wallace (1981) and Eggertsson and Woodford (2003) derive irrelevance results similar to Modigliani and Miller (1958). If markets are complete, households can unwind any changes in risk exposure due to changes in the central bank's portfolio. Consequently, consumption, inflation, and asset prices are all unaffected by quantitative easing. Eggertsson and Woodford

(2003) is based on a representative investor. In a model with heterogeneous investors, the same economic mechanism implies that only investors that are exposed to the central bank's investment returns (through taxes and subsidies) should adjust their portfolios.

A second class of theories shows that quantitative easing can have a positive effect on asset prices and economic growth through several channels. Mussa (1981), Clouse et al. (2003), and Eggertsson and Woodford (2003) argue that quantitative easing could signal future monetary policy. By buying long-term bonds, the central bank could have an incentive to keep interest rates low until maturity to avoid large mark-to-market losses. Another channel that could affect asset prices is portfolio rebalancing. The central bank's purchases of government bonds reduce the amount of duration and government credit risk in investor portfolios, lowering the risk premia on government bonds (Vayanos and Vila, 2009; Greenwood and Vayanos, 2014; Greenwood et al., 2018). In response to a lower risk premia, investors rebalance their portfolios to other risky assets, lowering their risk premia as well. The degree to which investors substitute across asset classes or characteristics (such as maturity) affects the actual impact on risk premia (Krishnamurthy and Vissing-Jørgensen, 2011). Our risk accounting framework directly measures how the risk exposure of investor portfolios changes in response to quantitative easing.

Brunnermeier and Sannikov (2016) develop a model in which quantitative easing relaxes banks' financial constraints and increases lending, which ultimately affects inflation and economic growth. Grosse-Rueschkamp et al. (2020) study how the ECB's corporate sector purchase program relaxed banks' lending constraints. Based on government bond holdings, we estimate which regions and investors have the largest capital gains due to quantitative easing.

A third class of theories highlights concerns about financial stability as a result of quantitative easing. By lowering borrowing costs, investors can take on excessive leverage or credit and liquidity risks, leading to financial fragility (Woodford, 2011; Stein, 2014; Coimbra and Rey, 2017). Lowering borrowing costs to encourage risky lending is precisely an objective of quantitative easing. However, risks could get concentrated in particular regions or investor sectors, falling through the cracks of existing capital and risk regulation. Our risk accounting framework can be used to monitor risk concentration across regions and investor sectors.

2. Asset purchase programs in the euro area

We summarize the ECB's various asset purchase programs since 2009. The first covered bond purchase program was €60 billion from July 2009 to June 2010, followed by a second covered bond purchase program of €16.4 billion from November 2011 to October 2012. In the

securities markets program from May 2010 to September 2012, the Eurosystem purchased government bonds issued by vulnerable countries in secondary markets. The size of the Eurosystem's portfolio from the securities markets program peaked at around €210 billion. The government bonds purchased during the securities markets program are to be held until maturity, so they enter our sample as part of the Eurosystem's portfolio. In September 2014, the ECB added an ABS purchase program and a third covered bond purchase program, amounting to €10 billion per month.

In January 2015, the ECB announced the expanded asset purchase program, which is the main focus of this paper. Its objective was to stimulate economic activity by lowering the borrowing costs of firms and households in an environment where the effective policy rate was at the lower bound. Through the stimulus, the ECB intended to restore inflation to a level below but close to 2%.

The initial size of the expanded asset purchase program was €60 billion per month from March 2015 to September 2016. The program had three components: extending the ABS purchase program, extending the third covered bond purchase program, and adding a public sector purchase program. The purchases under the public sector purchase program were split into bonds issued by euro-area governments and supranational institutions.[4] Assuming that the ABS purchase program and the third covered bond purchase program remain at €10 billion per month, the additional purchases were expected to be €44 billion of government bonds and €6 billion of supranational bonds (Claeys et al., 2015). By the end of 2017, the Eurosystem had accumulated €1.14 trillion in assets, which is approximately 15% of the euro area's GDP.

The monthly purchases of €44 billion in government bonds are proportional to each country's capital key, which is an equal-weighted average of GDP and population shares in the euro area. The capital key adjusts every five years or whenever a new country joins the euro area. The national central banks hold approximately 80% of the purchased bonds, and the ECB holds the remaining 20%. The ECB's investment returns are shared by its member central banks according to the capital key.

The ECB established eligibility criteria for government and supranational bonds to be purchased under the public sector purchase program. First, the bond must be investment grade (i.e., a credit rating of at least BBB−) with additional criteria for countries operating under the economic adjustment program of the European Union and the International Monetary Fund (IMF). Second, the maturity must be 2 to 30 years. Across the maturity

[4]Supranational institutions 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. Bonds issued by some national agencies, such as the Landeskreditbank Baden-Württemberg Foerderbank, are also eligible.

distribution, the ECB intends to act as market neutral as possible, which we interpret as buying approximately in proportion to debt outstanding. Third, the yield must be above the deposit facility rate, which is the interest that banks earn on overnight deposits with the central bank. The deposit facility rate was −20 basis points at the start of the expanded asset purchase program. The ECB limited purchases to 33% of an issuer or 25% of an issue to ensure market function, to encourage price discovery, and to avoid becoming a dominant creditor of euro-area governments. The ECB has increased the issuer limit to 50% for bonds issued by international and supranational institutions in the euro area. Table 1 summarizes policy announcements related to the original expanded asset purchase program and its subsequent modifications.

3. Data description

3.1. Portfolio holdings

The security-level portfolio holdings of all euro-area investors are from Securities Holding Statistics. The securities are uniquely identified by an International Securities Identification Number. The security types include government and corporate bonds, equities, mutual fund shares, ABS, and covered bonds. The data are reported by custodian banks at a quarterly frequency, and our sample covers 2013Q4 to 2017Q4. The total holdings aggregate to approximately €27 trillion during our sample. We refer to European Central Bank (2012) for more information about the data.

Securities Holding Statistics reports portfolio holdings by country of domicile and investor sector, defined according to the 1995 European System of Accounts. Because of data confidentiality requirements, we split 19 countries in the euro area into two regions based on their exposure to the European sovereign debt crisis (Altavilla et al., 2017).

- Nonvulnerable countries: Austria, Belgium, Estonia, Finland, France, Germany, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Slovakia, and Slovenia.
- Vulnerable countries: Cyprus, Greece, Ireland, Italy, Portugal, and Spain.

As summarized in Table 2, the six investor sectors are monetary financial institutions, insurance companies and pension funds (ICPF), other financial institutions (including, for instance, mutual funds and hedge funds), households, general government, and nonfinancial corporations. For short, we refer to monetary financial institutions as "banks" and other financial institutions as "mutual funds," which are the largest representatives of these sectors. The sector-level holdings only include direct holdings, so all indirect holdings through mutual

funds are part of the mutual fund sector. We aggregate general government and nonfinancial corporations as "other investors" because they are not the main focus of this paper.

The investor sectors are heterogeneous along at least two important dimensions. First, some investors, like banks and insurance companies, are subject to risk regulation that constrains their portfolios. Second, investors have different maturity structure of liabilities. For example, banks have short-term liabilities that can be subject to runs, while insurance companies have long-term liabilities that cannot be withdrawn easily in most countries.[5] Insurance companies and pension funds have fairly inelastic demand for long-term bonds because of interest-risk hedging that arises from their long-term liabilities.

We combine the Securities Holding Statistics data with the Eurosystem's transactions from its asset purchase programs. We infer the Eurosystem's holdings by accumulating the purchases and assuming that the securities are held until maturity. While there are no legal restrictions to selling securities prior to maturity, the ECB indicated that it would not sell regularly and would only sell for technical reasons to stay within the purchase limits. The data are at the same level of detail and frequency as the Securities Holding Statistics data, providing a comprehensive view of both public and private investors in the euro area.

Since we observe the holdings of all euro-area investors and the Eurosystem, their complement are foreign investors outside the euro area. Thus, we construct the portfolio holdings of foreign investors as the difference between the total amount outstanding and the aggregate holdings of all euro-area investors and the Eurosystem.

We are aware of two shortcomings of the Securities Holding Statistics data. First, we do not observe euro-area investors' holdings through offshore investors outside the euro area. Offshore investors are a common problem for all cross-country holdings data, as discussed in Milesi-Ferretti et al. (2010) and Zucman (2013). Second, we do not observe derivatives positions. Abad et al. (2016) use new data on over-the-counter derivatives that can be combined with the Securities Holding Statistics data for a more comprehensive view of risk exposure, which we leave for future research.

3.2. Asset prices and characteristics

The Centralised Securities Database contains asset prices and characteristics for more than six million active debt and equity securities as well as mutual fund shares across global markets. The European System of Central Banks manages the database based on public and commercial sources (European Central Bank, 2010). The database contains market prices for traded securities. For a debt security that does not trade, its reference information is used to estimate price.

[5]France is an exception because its insurance liabilities are more similar to demand deposits.

We use the security type from the Eurosystem eligible assets database (if available) or the Centralised Securities Database. The security types are standard corporate bonds, medium-term notes, commercial paper, ABS, and covered bonds.[6] We omit commercial paper because the short end of the yield curve is not a focus of this paper.

We obtain credit ratings from Standard and Poor's, Moody's, Fitch, and DBRS Morningstar. The Eurosystem recognizes these rating agencies as external credit assessment institutions and publishes a mapping between the four rating scales. We follow the Eurosystem's priority rule of issue ratings over issuer or guarantor ratings. In the order of priority, we use the long-term issue rating, the short-term issue rating, the long-term issuer rating, and the short-term issuer rating. When ratings are available from multiple rating agencies, we follow the Eurosystem's guideline to use the second highest rating for ABS and the highest rating for all other securities.

3.2.1. Asset classes

We group securities into seven asset classes, as summarized in Fig. 1 and Table 2. We first distinguish euro-denominated securities issued in the euro area. This distinction is important for some of our calculations that require the total amount outstanding, which is not always available for foreign securities in the Centralised Securities Database. To clarify, we do observe the complete holdings for all euro-area investors, even on foreign securities.

Within euro-area securities, we separate debt and equity securities. We further separate debt securities into government bonds issued by general, central, state, and local governments versus nongovernment bonds issued by the remaining sectors. We distinguish government bonds based on their eligibility for the public sector purchase program, as summarized in Section 2. To determine eligibility, we use the asset characteristics from the Centralised Securities Database, supplemented by observations of Eurosystem purchases as part of the public sector purchase program.

We separate nongovernment bonds into corporate bonds and collateralized debt, which includes ABS and covered bonds. We further separate corporate bonds into high versus low grade based on credit ratings. High-grade bonds are investment grade, and low-grade bonds include unrated bonds.

[6]Standard corporate bonds have the code 01 in the Eurosystem eligible assets database or the codes D.1, D.11, D.15, D.16, D.164, or D.18 in the Centralised Securities Database. Medium-term notes have the code 02 in the Eurosystem eligible assets database or D.3 or D.32 in the Centralised Securities Database. Commercial paper has the code 03 in the Eurosystem eligible assets database or D.7, D.72, D.74, or D.742 in the Centralised Securities Database. ABS have the code 11 in the Eurosystem eligible assets database or D.2, D.21, D.22, D.23, or D.233 in the Centralised Securities Database. Covered bonds have the codes 9, 10, 12, or 13 in the Eurosystem eligible assets database or D.21, D.23, or D.233 in the Centralised Securities Database.

3.3. Measures of risk exposure

We estimate the portfolio's risk exposure by region and investor sector. The five measures of risk exposure are duration risk, euro-area government credit risk, euro-area corporate credit risk, euro-area equity risk, and foreign risk. We define each of these risk measures so that the portfolio's risk exposure is a weighted average of the risk measure over all relevant assets in the portfolio.

Duration risk measures the portfolio's interest rate risk from government bonds, corporate bonds, ABS, and covered bonds. We report two versions of duration risk, based on all bonds (i.e., asset classes 1–5 and 7) and euro-area bonds only (i.e., asset classes 1–5). We compute each bond's Macaulay duration in years, based on its yield, coupon rate, and coupon frequency. For floating-rate notes, we assume that the duration is zero.

Because of data confidentiality requirements, we use publicly available data to compute the Eurosystem's duration risk. For government bonds, we compute the weighted-average duration of government bonds outstanding in a one-year window around the publicly available weighted-average maturity of the Eurosystem's portfolio. For ABS and covered bonds, for which the maturity breakdown is unavailable, we assume that the Eurosystem's portfolio has the same duration as a market portfolio of these asset classes.

Government credit risk is based on the credit ratings of euro-area government bonds. For each government bond, we use the long-term issue rating (if available) or the long-term issuer rating. We map the credit rating to a five-year cumulative default probability for government bonds (Moody's Investors Service, 2015).

Corporate credit risk is based on the credit ratings of euro-area corporate bonds, ABS, and covered bonds. We map the credit rating to a five-year cumulative default probability for corporate bonds (Moody's Investors Service, 2015). An asset's credit rating reflects its default probability, but it does not distinguish systematic versus idiosyncratic risk. Because idiosyncratic risk diversifies, the portfolio's default probability need not be a weighted average of the default probability for individual assets in the portfolio. Therefore, corporate credit risk is a proper risk measure only under an additional assumption that an asset's default probability is proportional to its systematic risk.

For equity risk, we simply report the portfolio share of euro-area equities relative to total euro-area assets. Our measure of equity risk coincides with the portfolio's market beta if all equities have a market beta of one, and all bonds have a market beta of zero.

For foreign risk, we simply report the portfolio share of foreign assets relative to total assets. We do not report foreign risk for foreign investors because we do not observe their complete portfolio outside the euro area.

4. Initial portfolio holdings and risk exposure

We summarize the portfolio holdings and risk exposure by region and investor sector prior to the announcement of the expanded asset purchase program in January 2015.

4.1. Initial portfolio holdings

Table 3 reports the market values of holdings by region and investor sector, averaged over a quarterly sample from 2013Q4 to 2014Q4. The total assets of all investors in nonvulnerable countries are €12,594 billion, which is more than twice the total assets of all investors in vulnerable countries, which are €5,600 billion.

Banks are major investors in eligible government bonds in nonvulnerable countries, holding €818 billion. Banks are the largest investors in eligible government bonds in vulnerable countries, holding €550 billion. In both regions, banks are the largest investors in ABS and covered bonds. Banks tilt their corporate bond portfolio towards high-grade bonds in nonvulnerable countries, while the opposite is true in vulnerable countries.

In nonvulnerable countries, mutual funds are the largest investors in euro-area equity and foreign assets. Similarly, mutual funds are the largest investors in foreign assets in vulnerable countries. Thus, mutual funds serve an important role in providing global diversification for euro-area institutions and households.

Insurance companies and pension funds invest a large share of their portfolios in government and corporate bonds. They are the largest investors in eligible government bonds in nonvulnerable countries, holding €918 billion. Insurance companies and pension funds are major investors in eligible government bonds in vulnerable countries, holding €346 billion. In both regions, insurance companies and pension funds tilt their corporate bond portfolio towards high-grade bonds, consistent with asset-liability management.

Foreign investors mostly invest in euro-area government bonds and equity. They own €2,261 billion in eligible government bonds and €1,632 billion in ineligible government bonds. Ineligible government bonds include bonds with a maturity of less than two years or a yield below the deposit facility rate (e.g., some German government bonds).

The Eurosystem owns a small portfolio of government and covered bonds from the earlier purchase programs, namely the covered bond purchase program and the securities markets program. The Eurosystem owns a small amount of ineligible government bonds because a previously eligible government bond can become ineligible when its yield or remaining maturity changes. Prior to 2015, the Eurosystem did not own corporate bonds.

The first column of Table 4 reports the market values of eligible government bond holdings by region and investor sector. The second column reports the percent of the investor's

portfolio in eligible government bonds. In both regions, insurance companies and pension funds invest a larger share of their government bond portfolios in eligible bonds, compared with other investor sectors.

The third column of Table 4 reports the home bias, which is the percent of the investor's eligible government bond portfolio in own country. All investors in vulnerable countries have a stronger home bias, compared with the same investor sector in nonvulnerable countries. Banks invest 85%, mutual funds invest 66%, and insurance companies and pension funds invest 86% of their eligible government bond portfolio in own country.

The banking literature raises a concern that government credit risk can adversely affect banks that own large amounts of government bonds; that risk then feeds back to the real economy and the government's fiscal position in a "doom loop" (Altavilla et al., 2017). However, our findings suggest that this concern should extend to the financial sector more broadly. Mutual funds, insurance companies, and pension funds intermediate retirement savings and provide long-term capital. Therefore, government credit risk could have implications for financial stability and economic growth through these institutional investors.

Acharya and Steffen (2015) discuss three reasons why banks in vulnerable countries have a strong home bias in their government bond portfolio. First, banks could be attracted to the carry trade, in which they borrow cheaply from the ECB and invest in high-yield government bonds. The carry trade is considered riskless under the Basel regulations because all government bonds have a zero risk weight. However, the carry trade does not explain home bias for mutual funds that are entirely equity financed and not subject to the same risk regulation. Second, institutional investors with limited liability could find it optimal to invest in own country government bonds to align their default risk with their government's default risk (Diamond and Rajan, 2011). However, this explanation does not account for home bias for mutual funds that are entirely equity financed and not subject to default. Third, governments can encourage or force institutional investors in their own country to hold government bonds in a financial repression (Becker and Ivashina, 2017; Ongena et al., 2019). Because most banks in the euro area offer mutual funds, this theory applies to mutual funds in the euro area. Governments can pressure banks to tilt their mutual fund portfolios to own country government bonds.

The distribution of eligible government bonds across investors plays an important role in theories in which quantitative easing relaxes financial constraints (Brunnermeier and Sannikov, 2016). In Section 6.4, we estimate which regions and investors have the largest capital gains due to quantitative easing.

4.2. Initial risk exposure

Table 5 reports the portfolio's risk exposure by region and investor sector, averaged over a quarterly sample from 2013Q4 to 2014Q4. Section 3.3 defines the risk measures in the table. The two versions of duration risk based on all bonds and euro-area bonds generally coincide because foreign bonds are a small share of the portfolio. The only exception is mutual funds in vulnerable countries.

Insurance companies and pension funds have the highest duration risk. In nonvulnerable countries, the euro-area duration risk for insurance companies and pension funds is 7.2 years, compared with 3.2 years for banks. In vulnerable countries, the euro-area duration risk for insurance companies and pension funds is 5.4 years, compared with 2.4 years for banks. The euro-area duration risk for institutional investors in vulnerable countries is lower than that in nonvulnerable countries, which partly reflects the differences in the maturity structure of debt outstanding across regions.

Investors in vulnerable countries have higher government credit risk than those in nonvulnerable countries. For example, the average five-year default probability for banks is 1.5% in vulnerable countries and 0.4% in nonvulnerable countries. This is because investors have a strong home bias, and governments in vulnerable countries have higher credit risk. The Eurosystem has an average five-year default probability of 1.5%, which comes from purchases of government bonds in vulnerable countries as part of the securities markets program.

Corporate credit risk is also higher for investors in vulnerable countries than in nonvulnerable countries, but the difference is less extreme than government credit risk. Banks in nonvulnerable countries have low corporate credit risk with an average five-year default probability of 0.5%. The Eurosystem, whose only exposure to corporate credit risk comes from covered bonds at this point, also have a low average five-year default probability of 0.6%.

In both regions, households and other investors have the highest portfolio share in equities. In nonvulnerable countries, households have an equity portfolio share of 52%, and other investors have an equity portfolio share of 66%. In both regions, mutual funds have the highest portfolio share in foreign assets. Mutual funds have a foreign portfolio share of 49% in nonvulnerable countries and 58% in vulnerable countries.

4.3. Initial distribution of risk exposure

For each of the risk measures in Section 3.3, we define total risk exposure as a weighted sum of the risk measure over all relevant assets in the portfolio. Table 6 reports the percent of total risk exposure held by each investor, where the column total is 100% for each risk

measure. This table is different from Table 5 in that the size distribution of investors, in which larger investors bear a higher share of the total risk exposure, is now important.

Nonvulnerable countries have higher euro-area duration risk than vulnerable countries. Nonvulnerable countries bear 48%, vulnerable countries bear 19%, and foreign investors bear 32% of the duration risk. In nonvulnerable countries, insurance companies and pension funds bear the most duration risk with 21%, followed by banks with 13%, and mutual funds with 11%. Banks have a surprisingly high risk exposure because of their size, even though their portfolios have a relatively short average duration.

Vulnerable countries have higher government credit risk than nonvulnerable countries, consistent with the home bias of government bond portfolios in Table 4. Nonvulnerable countries bear 22%, vulnerable countries bear 47%, and foreign investors bear 28% of the government credit risk. Banks in vulnerable countries bear 23% of the government credit risk despite being much smaller than banks in nonvulnerable countries, which bear only 8%.

Corporate credit risk is more equally distributed across regions than duration and government credit risk. Nonvulnerable countries bear 47%, vulnerable countries bear 36%, and foreign investors bear 16% of the corporate credit risk. However, corporate credit risk is concentrated in vulnerable countries with banks bearing 22%. Thus, banks bear a high concentration of both government and corporate credit risks in vulnerable countries. In nonvulnerable countries, corporate credit risk is more evenly distributed across institutional investors.

Nonvulnerable countries bear 40%, vulnerable countries bear 12%, and foreign investors bear 48% of the equity risk. Thus, foreign investors are important for equity risk.

Nonvulnerable countries bear 75%, and vulnerable countries bear 25% of the foreign risk. In both regions, mutual funds bear the most foreign risk with 48% in nonvulnerable countries and 16% in vulnerable countries.

Prior to the expanded asset purchase program, the Eurosystem has a relatively small portfolio and does not bear much risk. The Eurosystem bears only 1% of the duration risk and 3% of the government credit risk. As we show in the next section, the Eurosystem's risk exposure increases significantly during quantitative easing.

5. Portfolio rebalancing and the dynamics of risk exposure

We document portfolio rebalancing and the dynamics of risk exposure during the expanded asset purchase program from 2015Q1 to 2017Q4. In particular, the security-level portfolio holdings allow us to tell which investors sell to the Eurosystem.

5.1. Portfolio rebalancing

Let $Q_{i,t}(n)$ be the total face value of security n held by investor i at time t, and let $P_t(n)$ be its price. We measure investor i's rebalancing of security n from time $t-1$ to t as

$$D_{i,t}(n) = (Q_{i,t}(n) - Q_{i,t-1}(n))P_t(n). \tag{1}$$

By holding the price constant, this measure of rebalancing is unaffected by capital gains. We aggregate rebalancing by region, investor sector, and asset class. In Table 7, we report the cumulative rebalancing from 2015Q1 to 2017Q4. As a point of reference, Table A.1 in Appendix A reports the average rebalancing per quarter from 2013Q4 to 2014Q4 prior to the expanded asset purchase program.

From 2015Q1 to 2017Q4, the Eurosystem purchased €1,876 billion in government bonds. The Eurosystem's purchases were offset by investors who collectively sold €1,335 billion and net issuances of €541 billion.[7] Quite strikingly, foreign investors were the most important sellers, accounting for €927 billion. Prior to the expanded asset purchase program, foreign investors were net buyers of euro-area government bonds, as shown in Table A.1 in Appendix A.

The finding that foreign investors are important is surprising from the perspective of the irrelevance theorem, which predicts that only investors that are exposed to the central bank's investment returns should adjust their portfolios. Foreign investors are not directly exposed to the Eurosystem's portfolio, and exchange rates are unaffected under the irrelevance theorem. However, our finding is consistent with Saito and Hogen (2014), who show that foreign investors sell in response to the Bank of Japan's quantitative easing program. A possible interpretation is that foreign investors' demand is more price elastic than euro-area investors. As quantitative easing lowers government bond yields, foreign investors rebalance to other regions or asset classes with a more attractive risk-return tradeoff. Euro-area investors with euro-denominated liabilities have less elastic demand for euro-area government bonds.

Table 8 further breaks down foreign investors' rebalancing of government bonds, corporate bonds, ABS, and covered bonds by issuer region. For ease of comparison across regions, the last column reports rebalancing as a percent of the initial holdings in 2015Q2 prior to the expanded asset purchase program. Across all asset classes, foreign investors sell a similar share of their initial holdings across the two regions. If foreign investors were leaving the euro-area because of fears about credit risk, we would have expected the rebalancing to be concentrated in vulnerable countries.

[7] Although government bond issuances primarily depend on fiscal policy and other macroeconomic factors, the Eurosystem's purchases could have affected the timing and the maturity distribution of issuances.

As reported in Table 7, banks in nonvulnerable countries sell €275 billion in government bonds, and banks in vulnerable countries sell €195 billion. Mutual funds in nonvulnerable countries sell €70 billion in government bonds, and mutual funds in vulnerable countries sell €57 billion. In contrast, insurance companies and pension funds in nonvulnerable countries buy €102 billion in government bonds, and insurance companies and pension funds in vulnerable countries buy €181. They have inelastic (or even upward-sloping) demand in order to hedge the interest rate risk of their long-term liabilities, especially in a low interest rate environment (Domanski et al., 2017).

From 2015Q1 to 2017Q4, the Eurosystem purchased €130 billion in corporate bonds. However, their purchases are smaller than the large net reduction in corporate bonds during the same period, amounting to €384 billion. Banks, households, and foreign investors sell to accommodate the net reduction in corporate bonds.

The net reduction in corporate bonds predates and is not necessarily related to the expanded asset purchase program. Fig. 2 reports corporate debt outstanding for banks, nonbank financial firms, and nonfinancial firms in the euro area since 1990. These data include bonds issued in foreign currency, but the secular trends hold for euro-denominated bonds only. Following the European sovereign debt crisis in 2012, banks have dramatically reduced debt outstanding. This deleveraging of the banking sector predates the expanded asset purchase program, but the program could have accelerated deleveraging. In contrast to banks, other financial firms have kept relatively constant debt outstanding, and nonfinancial firms have slightly increased debt outstanding since the European sovereign debt crisis.

From 2015Q1 to 2017Q4, the Eurosystem purchased €184 billion in ABS and covered bonds. However, its purchases are smaller than the large net reduction in ABS and covered bonds, amounting to €293 billion. Banks and foreign investors sell to accommodate the net reduction in ABS and covered bonds. Similar to corporate bonds, the reduction in ABS and covered bonds predates and is not necessarily related to the expanded asset purchase program.

There is some evidence that mutual funds rebalance from euro-area bonds to equities and foreign assets. Mutual funds in nonvulnerable countries buy €167 billion in equities and €542 billion in foreign assets. Mutual funds in vulnerable countries buy €370 billion in foreign assets. For other investor sectors, there is little evidence of rebalancing from euro-area bonds to equities and foreign assets. Di Maggio et al. (2016) find related evidence on limited rebalancing across asset classes during the Federal Reserve's quantitative easing program.

5.2. Which investors sell to the Eurosystem?

We examine portfolio rebalancing in further detail to see which investors sell eligible government bonds to the Eurosystem. Starting with eq. (1), for rebalancing at the security level, we aggregate rebalancing of eligible government bonds by investor region, investor sector, and issuer country. Let $D_{i,t}(c)$ be investor i's rebalancing of eligible government bonds issued by country c at time t, and let $D_{\text{ECB},t}(c)$ be the Eurosystem's rebalancing.

Let $S_t(n)$ be the total face value outstanding of security n at time t, and let $P_t(n)$ be its price. We measure net issuance from time $t-1$ to t as

$$I_t(n) = (S_t(n) - S_{t-1}(n))P_t(n). \tag{2}$$

By holding the price constant, this measure of net issuance is unaffected by capital gains. We aggregate net issuance of eligible government bonds by investor region, investor sector, and issuer country. Let $I_t(c)$ be net issuance of eligible government bonds issued by country c at time t.

In first differences, market clearing of eligible government bonds issued by country c at time t is

$$I_t(c) = \sum_{i=1}^{I} D_{i,t}(c) + D_{\text{ECB},t}(c), \tag{3}$$

where foreign investors are one of the investor sectors. This equation implies a variance decomposition of the Eurosystem's purchases of eligible government bonds:

$$\frac{\text{Cov}(I_t(c), D_{\text{ECB},t}(c)) - \sum_{i=1}^{I} \text{Cov}(D_{i,t}(c), D_{\text{ECB},t}(c))}{\text{Var}(D_{\text{ECB},t}(c))} = 1. \tag{4}$$

The Eurosystem's purchases must be offset by the sum of net issuances and investor sales.

We estimate the variance decomposition through a pooled ordinary least squares regression from 2015Q2 to 2017Q4. The regression equations are

$$I_t(c) = \alpha_I + \beta_I D_{\text{ECB},t}(c) + \epsilon_t(c), \tag{5}$$

$$D_{i,t}(c) = \alpha_i + \beta_i D_{\text{ECB},t}(c) + \epsilon_{i,t}(c). \tag{6}$$

Then, eq. (4) is equivalent to $\beta_I - \sum_{i=1}^{I} \beta_i = 1$. To minimize the impact of outliers, we use a sample of the ten largest countries by total government debt outstanding: Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal, and Spain.

For each investor sector, the first bar in Fig. 3 reports the variance decomposition. For

each euro of eligible government bonds that the Eurosystem purchases, foreign investors sell €0.40, banks sell €0.20, and mutual funds sell €0.06. Insurance companies and pension funds do not sell and instead buy the same bonds as the Eurosystem. Euro-area governments issue €0.39 in eligible government bonds.

To show that the variance decomposition is consistent with the cumulative rebalancing in Table 7, we compute a simple measure of average rebalancing:

$$\text{AverageRebalancing}_i = \frac{\sum_{t=2015\text{Q2}}^{2017\text{Q4}} D_{i,t}(c)}{\sum_{t=2015\text{Q2}}^{2017\text{Q4}} D_{\text{ECB},t}(c)}. \tag{7}$$

This is investor i's cumulative rebalancing from 2015Q1 to 2017Q4 as a ratio of the Eurosystem's cumulative rebalancing over the same period. For each investor sector, the second bar in Fig. 3 reports the average rebalancing, which aligns with the variance decomposition.

We draw two important policy lessons related to the role of foreign investors in quantitative easing. First, foreign investors accommodate most of the Eurosystem's purchases, which suggests that they have more elastic demand than domestic investors with hedging demand for euro-denominated liabilities. This fact implies that the demand elasticity of foreign investors is particularly important for understanding the yield impact. Because the yield impact decreases with the weighted average demand elasticity across investors, it is smaller when more elastic foreign investors hold a larger share of government debt. As foreign investors leave the euro area, the weighted average demand elasticity decreases, and the yield impact of quantitative easing could become larger.

Second, Table 7 shows that foreign investors do not reinvest in the euro area after selling government bonds. This fact implies that government bond purchases have limited impact on other asset classes through portfolio rebalancing if foreign investors substitute outside the euro area.

5.3. Dynamics of risk exposure

Table 9 reports how the distribution of euro-area duration risk, government credit risk, and corporate credit risk changed during the expanded asset purchase program. For each risk measure, we normalize the total risk exposure to 100% in 2014Q4. Thus, a total risk exposure of 110% means that the level of risk is 10% higher than in 2014Q4.

Panel A of Table 9 reports euro-area duration risk. As yields decreased, the total duration risk increased from 100% in 2014Q4 to 118% in 2017Q4. During the expanded asset purchase program, the Eurosystem's duration risk increased from 1% in 2014Q4 to 22% in 2017Q4, more than offsetting the overall increase in duration risk. The duration risk remained stable

for most investors. However, the duration risk of insurance companies and pension funds slightly increased, which is consistent with interest-risk hedging that arises from their long-term liabilities.

Panel B of Table 9 reports government credit risk. Total government credit risk increased from 100% in 2014Q4 to 132% in 2016Q2, then decreased to 115% in 2017Q4. This hump shape is due to decreasing yields and changing credit ratings, which we aggregate from issue ratings that are more variable than issuer country ratings. The Eurosystem as well as banks, insurance companies, and pension funds in vulnerable countries bear the increase in government credit risk from 2014Q4 to 2016Q2. The Eurosystem's government credit risk increased from 3% in 2014Q4 to 12% in 2016Q2. The government credit risk of insurance companies and pension funds in vulnerable countries increased from 10% in 2014Q4 to 15% in 2017Q4. However, foreign investors' government credit risk decreased from 26% in 2014Q4 to 23% in 2017Q4.

Panel C of Table 9 reports corporate credit risk. Because of the reduction in bank debt outstanding shown in Fig. 2, total corporate credit risk decreased rapidly from 100% in 2014Q4 to 71% in 2017Q4. The corporate credit risk of banks in nonvulnerable countries decreased from 14% in 2014Q4 to 10% in 2017Q4. Perhaps surprisingly, the corporate credit risk of banks in vulnerable countries decreased from 18% in 2014Q4 to 9% in 2017Q4. Similarly, foreign investors' corporate credit risk decreased from 17% in 2014Q4 to 7% in 2017Q4. In contrast, the Eurosystem's corporate credit risk increased from 0% in 2014Q4 to 7% in 2017Q4.

As banks reduce debt outstanding in Fig. 2, they also reduce their portfolios' corporate credit risk in Panel C of Table 9. This finding points to the importance of cross-holdings of corporate bonds in the banking sector. To support this point, Fig. 4 shows that banks in vulnerable countries have a strong home bias in their corporate bond holdings of other financial firms, even more so than insurance companies, pension funds, and mutual funds. Quantitative easing appears to reduce the potential feedback loop that can arise from cross-holdings of corporate bonds in the banking sector.

6. Relation between portfolio rebalancing and yield changes

We estimate a demand system for government bonds to relate portfolio rebalancing to yield changes. We use instrumental variables that exploit a unique institutional feature of the public sector purchase program that makes the Eurosystem's purchases proportional to each country's capital key. Consistent with portfolio rebalancing, investors with high demand elasticities, particularly foreign investors, sell to the Eurosystem during quantitative easing.

Finally, we estimate how quantitative easing affects portfolio valuation by region and investor sector.

6.1. A demand system for government bonds

Since our key findings on portfolio rebalancing in Table 7 are by investor sector, we aggregate government bond holdings by investor sector across all countries. Let $B_{i,t}(n)$ be the market value of government bonds issued by country n held by investor i at time t. Let $B_{i,t}(0)$ be the market value of other assets held by investor i at time t, which we call the outside asset. The portfolio weight in government bonds issued by country n held by investor i at time t is

$$w_{i,t}(n) = \frac{B_{i,t}(n)}{B_{i,t}(0) + \sum_{m=1}^{N} B_{i,t}(m)} = \frac{\delta_{i,t}(n)}{1 + \sum_{m=1}^{N} \delta_{i,t}(m)}, \tag{8}$$

where $\delta_{i,t}(n) = B_{i,t}(n)/B_{i,t}(0)$. The portfolio weight in the outside asset is $w_{i,t}(0) = 1 - \sum_{m=1}^{N} w_{i,t}(m)$.

Koijen and Yogo (2019) derive an empirically tractable model of portfolio weights from traditional portfolio theory, based on three assumptions. First, investors have preferences such that the optimal portfolio is a mean-variance portfolio (Markowitz, 1952). Second, returns have a factor structure, which is especially relevant in the context of government bond returns. Third, both expected returns and factor loadings depend only on an asset's own prices and characteristics. Under these assumptions, we can write the portfolio weight (8) as a logit function of the yield $y_t(n)$ and a vector of characteristics $\mathbf{x}_t(n)$:

$$\log(\delta_{i,t}(n)) = \alpha_i + \beta_{0,i} y_t(n) + \beta_{1,i}' \mathbf{x}_t(n) + \beta_{2,i} \log(B_{i,2014Q4}(n)) + \epsilon_{i,t}(n). \tag{9}$$

We construct the yield as a weighted average over each issuer country's government debt outstanding. The bond characteristics capture key sources of risk. To capture uncertainty in interest rates (i.e., the level factor), we construct a weighted average maturity of each issuer country's government debt outstanding. We capture government credit risk through the issuer country's credit rating, which we map to a five-year cumulative default probability. We include log GDP per capita to capture changing macroeconomic conditions. We capture persistent unobserved characteristics through the market value of investor i's holdings in 2014Q4 (i.e., $\log(B_{i,2014Q4}(n))$. By conditioning on initial holdings, our identification comes from time-series variation within an issuer country during quantitative easing. Alternatively, we obtain similar estimates with issuer country fixed effects. Latent demand $\epsilon_{i,t}(n)$ in eq. (9) represents unobserved (to the econometrician) characteristics that capture differences in

beliefs about expected returns and risk across investors.

If the outside asset were observed, eq. (9) becomes an estimation equation by substituting $\delta_{i,t}(n) = B_{i,t}(n)/B_{i,t}(0)$. Unfortunately, we do not observe foreign investors' government bond holdings outside the euro area. For euro-area investors, we would like an empirical specification that is not too sensitive to the definition of the outside asset. Although time fixed effects would be the most general specification, they would preclude us from using time-series variation to identify demand elasticities. Therefore, we take a middle ground and parametrically specify the outside asset as $\log(B_{i,t}(0)) = \phi_i + \beta_{3,i} y_t^{\$}$, where $y_t^{\$}$ is the ten-year U.S. Treasury yield (Gürkaynak et al., 2007). We essentially assume that the U.S. Treasury yield captures investment opportunities outside the euro area. Under this assumption, eq. (9) becomes

$$\begin{aligned}\log(B_{i,t}(n)) =& \log(\delta_{i,t}(n)) + \log(B_{i,t}(0)) \\ =& (\alpha_i + \phi_i) + \beta_{0,i} y_t(n) + \beta_{1,i}' \mathbf{x}_t(n) + \beta_{2,i} \log(B_{i,2014Q4}(n)) + \beta_{3,i} y_t^{\$} + \epsilon_{i,t}(n). \quad (10)\end{aligned}$$

We anticipate that $\beta_{3,i} < 0$ because investors (especially foreign) substitute out of euro-area government bonds when outside investment opportunities improve.

6.2. Capital key as an instrument

To identify government bond demand (10), we start with a strong assumption that all bond characteristics are exogenous to latent demand in the spirit of asset pricing in endowment economies. However, we allow government bond yields to be jointly endogenous with latent demand. That is, a correlated positive demand shock to an investor sector can lower yields.

We construct an instrument for government bond yields by using the predicted government bond purchases under the public sector purchase program. Table 10 summarizes changes in the remaining duration and the monthly purchase rate. We define total announced purchases as the amount already purchased plus future purchases equal to the monthly purchase rate times the remaining duration. We then assume that predicted government bond purchases are equal to 73% of total announced purchases (i.e., €44 billion of every €60 billion), as we discussed in Section 2. Although some of the time-series variation in total purchases could be correlated with changing macroeconomic conditions, we do control for the issuer country's GDP per capita and the U.S. Treasury yield.

The distribution of purchases across issuer countries is proportional to the capital key, which is plausibly exogenous. The capital key for country n is an equal-weighted average of

its GDP and population weights within the euro area:

$$K(n) = \frac{1}{2}\left(\frac{\text{GDP}(n)}{\sum_{m=1}^{N}\text{GDP}(m)} + \frac{\text{Population}(n)}{\sum_{m=1}^{N}\text{Population}(m)}\right). \tag{11}$$

We use the capital key in 2014Q4 prior to the public sector purchase program.

Let A_t be predicted government bond purchases, based on the most recent announcement up to time t. The instrument is the predicted purchase as a share of government debt outstanding:

$$z_t(n) = \min\left\{\frac{A_t K(n)}{M_{2014Q2}(n)}, 0.33\right\}, \tag{12}$$

where $M_{2014Q2}(n)$ is the issuer country n's government debt outstanding in 2014Q2. We measure government debt outstanding prior to the public sector purchase program to exclude a potentially endogenous response of government debt issuance. We cap the instrument at 33% to account for the Eurosystem's issuer share limit, which binds for a few countries with small government bond markets. Fig. 5 reports the realized instrument for Germany from 2014Q2 to 2017Q4. Table 11 reports the value of the instrument for all countries in 2017Q4, which highlights the cross-sectional variation that arises from the capital key.

The first column of Table 12 reports the first stage of instrumental variables demand estimation for foreign investors. The coefficient on the yield is -2.504 with a standard error of 0.330, implying a very strong instrument (Stock and Yogo, 2005). The magnitude of the coefficient implies that a 10% purchase of the government debt outstanding lowers the yield by 25 basis points.

Table 11 quantifies the yield impact of quantitative easing by multiplying this estimate by the value of the instrument in 2017Q4. There is significant heterogeneity in the yield impact, ranging from -38 basis points in Belgium to -83 basis points in countries that reach the 33% purchase limit (i.e., Finland, Ireland, Latvia, Lithuania, Portugal, Slovakia, and Slovenia). We estimate the average impact to be 65 basis points. This estimate is fairly close to 45 basis points for the ten-year government bond yield, based on an event study methodology (Andrade et al., 2016).

6.3. Estimated government bond demand system

Table 12 reports the estimated government bond demand (10) by investor sector. All investors, except for insurance companies and pension funds, have a positive coefficient on the yield, which means that their demand is downward sloping with respect to price. Foreign

investors have the highest coefficient on the yield, which means that their demand is the most price elastic.

Insurance companies and pension funds have a preference for longer maturity bonds compared with other investors. Foreign investors have a preference for government bonds with the lowest default risk (or highest credit quality). For all investors, their holdings in 2014Q4 have a coefficient near one, implying persistence in their government bond portfolio. The coefficient on the U.S. Treasury yield is negative, which means that the demand for euro-area government bonds is lower when outside investment opportunities are better. This effect is strongest for foreign investors, followed by mutual funds and banks.

Following Koijen and Yogo (2019), we define investor i's demand elasticity for government bonds issued by country n as

$$-\frac{\partial \log(Q_{i,t}(n))}{\partial \log(P_{i,t}(n))} = 1 + 100\frac{\beta_{0,i}}{m_t(n)}(1 - w_{i,t}(n)), \tag{13}$$

where $m_t(n)$ is the weighted average maturity of country n's government debt outstanding. A higher coefficient $\beta_{0,i}$ on the yield implies a higher demand elasticity with respect to price. This calculation depends on the definition of the outside asset through the portfolio weight $w_{i,t}(n)$. We assume that the outside asset is the portfolio of corporate bonds, ABS, and covered bonds.

Table 13 reports summary statistics for demand elasticities by investor sector, pooled across issuer countries and over time. Foreign investors have the highest demand elasticity, consistent with the fact that they rebalance out of euro-area government bonds in Table 7. Among institutional investors, mutual funds have more elastic demand than banks, and insurance companies and pension funds have upward-sloping demand. In the last row of Table 13, the average elasticity across all investors is 3.21, weighted by their government bond holdings in 2014Q2. In comparison, Chang et al. (2015) report a demand elasticity close to one in the cross section of U.S. stocks. The higher elasticity that we find implies that the cross section of euro-area government bonds are closer substitutes than the cross-section of U.S. stocks.

To relate the demand elasticities to the yield impact of quantitative easing, we consider a simple back-of-the-envelope calculation. As reported in Table 11, the Eurosystem purchased 26% of government debt outstanding. The weighted average demand elasticity is 3.21, which implies a yield impact of $26\%/3.21 = 8.1\%$. Assuming an average duration of ten years, the yield falls by 81 basis points, which is close to our actual estimate of 65 basis points in Table 11.

6.4. Impact of quantitative easing on portfolio valuation

We estimate how quantitative easing affects portfolio valuation by region and investor sector. We first compute total euro-area duration in 2015Q1 by region and investor sector, based only on the euro-area government bond holdings. We focus on government bond holdings to provide a conservative lower bound, ignoring the potential impact of quantitative easing on other asset classes like corporate bonds. Assuming a parallel shift in the yield curve, the capital gain is equal to total duration times the yield impact of 65 basis points from quantitative easing, reported in Table 11.

As reported in Table 14, the total valuation effect is €415 billion, which is the sum of €179 billion for investors in nonvulnerable countries, €74 billion for investors in vulnerable countries, and €162 billion for foreign investors. Because institutional investors in nonvulnerable countries are larger than their counterparts in vulnerable countries, they have greater duration risk. Therefore, they experience larger valuation effects from quantitative easing. In both regions, insurance companies and pension funds have large valuation effects because of the high average duration of their portfolios. A caveat to this finding is that insurance companies and pension funds also have long-term liabilities, so we cannot assess the overall impact on their equity positions.

In interpreting the valuation effects in Table 14, it is important to distinguish short- versus long-run benefits. In the short run, the valuation effect is positive and could relax financial constraints, insofar as they are not entirely offset by liabilities. In particular, foreign investors fully realize their capital gains by selling their government bond holdings in response to the declining yields. If investors hold onto the government bonds until maturity and roll them over to newly issued government bonds, their reinvestment yield will be lower. Thus, the capital gains on their existing portfolio could be partly offset by deteriorating investment opportunities in the long run.

7. Conclusion

We use new security-level holdings data for all euro-area investors to study the impact of quantitative easing on portfolio rebalancing, the dynamics of risk exposure, and asset prices. We find that foreign investors outside the euro area accommodated most of the Eurosystem's purchases through 2017Q4. We examine how the investors' exposure to duration, government credit, corporate credit, and equity risk changes during quantitative easing. We do not find evidence for large-scale rebalancing across asset classes or risk concentration in particular regions or investor sectors.

We estimate a demand system for euro-area government bonds by instrumental variables

to relate portfolio rebalancing to yield changes. We find that foreign investors have the most elastic demand, which is consistent with the fact that they accommodated most of the Eurosystem's purchases. Foreign investors' relatively elastic demand also implies that their presence dampens the impact of quantitative easing on government bond yields. Finally, we estimate how quantitative easing affects portfolio valuation by region and investor sector. The total valuation effect is €415 billion, which is the sum of €179 billion for investors in nonvulnerable countries, €74 billion for investors in vulnerable countries, and €162 billion for foreign investors.

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Table 1. Policy announcements related to the expanded asset purchase program.

Date	Policy announcement
9/4/2014	The deposit facility rate is decreased to −20 basis points on 9/10/2014.
1/22/2015	Expanded asset purchase program (EAPP) is announced with monthly purchases of €60 billion from 3/9/2015 to September 2016. Eligible bonds must have a maturity of 2 to 30 years and a yield above the deposit facility rate. Issuer and issue share limits are 33% and 25%, respectively.
7/16/2015	List of eligible government agencies is expanded.
9/3/2015	Issue share limit is increased to 33% on 11/10/2015, except for bonds with specific collective action clauses.
12/3/2015	(1) The deposit facility rate is decreased to −30 basis points on 12/9/2015. (2) EAPP is extended to March 2017. (3) Principal repayments are to be reinvested for as long as necessary. (4) List of eligible bonds is expanded to include euro-denominated marketable debt issued by regional and local governments in the euro area.
3/10/2016	(1) The deposit facility rate is decreased to −40 basis points on 3/16/2016. (2) Monthly purchases are increased to €80 billion on 4/1/2016. (3) Corporate sector purchase program (CSPP) is announced as part of the combined monthly purchases starting in June 2016. (4) The issuer and issue share limits for bonds issued by eligible international organizations and multilateral development banks are increased to 50%.
4/21/2016	Technical details on CSPP are published.
12/8/2016	(1) Monthly purchases are decreased from €80 billion to €60 billion in April 2017. (2) EAPP is extended to December 2017. (3) The minimum maturity for eligibility is decreased to one year. (4) Purchases below the deposit facility rate are permitted as necessary.
1/19/2017	Technical details on purchases below the deposit facility rate are published.
10/26/2017	(1) Monthly purchases are to continue at €30 billion from January to September 2018. (2) Additional information about redemptions, reinvestments, and the role of private sector purchase programs is published.
6/14/2018	Monthly purchases are decreased to €15 billion from September to December 2018 and will end thereafter.
12/3/2018	Quinquennial adjustment of the capital key.
12/13/2018	Reinvestments are to be based on the new capital key.

Table 2. Investor sectors and asset classes.

Asset classes 1 to 6 consist of euro-denominated securities issued in the euro area.

Investor sectors	
Sector	Description
1	Banks: Monetary financial institutions
2	Insurance companies and pension funds
3	Mutual funds: Other financial institutions including hedge funds
4	Households
5	Other investors: General government and nonfinancial corporations
6	Foreign investors
7	Eurosystem
Asset classes	
Class	Description
1	Eligible government bonds
2	Ineligible government bonds
3	High-grade corporate bonds and medium-term notes
4	Low-grade corporate bonds and medium-term notes
5	Asset-backed securities and covered bonds
6	Equity
7	Foreign assets: Non-euro-area issuer or non-euro denominated

Table 3. Portfolio holdings by region and investor sector.

This table reports the market values of portfolio holdings in billion euros, averaged over a quarterly sample from 2013Q4 to 2014Q4. Nonvulnerable countries are Austria, Belgium, Estonia, Finland, France, Germany, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Slovakia, and Slovenia. Vulnerable countries are Cyprus, Greece, Ireland, Italy, Portugal, and Spain. ABS/CB refers to asset-backed securities and covered bonds, and ICPF refers to insurance companies and pension funds.

Investor	Government		Corporate		ABS/CB	Equity	Foreign	Total
	Eligible	Ineligible	High	Low				
Panel A: Nonvulnerable countries								
Banks	818	482	433	153	702	126	624	3,338
Mutual funds	568	239	266	248	190	890	2,324	4,725
ICPF	918	214	348	215	191	137	456	2,479
Households	20	17	94	150	12	462	137	892
Other	122	88	32	47	26	763	82	1,160
Total	2,446	1,040	1,173	813	1,121	2,378	3,623	12,594
Panel B: Vulnerable countries								
Banks	550	397	131	229	587	72	258	2,224
Mutual funds	164	132	37	49	25	155	786	1,348
ICPF	346	93	66	49	38	29	63	684
Households	175	75	114	242	5	196	66	873
Other	114	43	11	24	2	240	37	471
Total	1,349	740	359	593	657	692	1,210	5,600
Panel C: Foreign investors and the Eurosystem								
Foreign	2,261	1,632	235	475	359	2,869		7,831
Eurosystem	114	17	0	0	30	0		161

Table 4. Eligible government bond holdings by region and investor sector.

This table reports the market values of eligible government bond holdings in billion euros, the percent of the investor's portfolio in eligible government bonds, and the percent of the investor's eligible government bond portfolio in own country. Each statistic is an average over a quarterly sample from 2013Q4 to 2014Q4. Nonvulnerable countries are Austria, Belgium, Estonia, Finland, France, Germany, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Slovakia, and Slovenia. Vulnerable countries are Cyprus, Greece, Ireland, Italy, Portugal, and Spain. ICPF refers to insurance companies and pension funds.

Investor	Holdings (billion €)	% eligible	% own country
Panel A: Nonvulnerable countries			
Banks	818	25	60
Mutual funds	568	12	20
ICPF	918	37	55
Households	20	2	72
Other	122	11	74
Total	2,445	19	49
Panel B: Vulnerable countries			
Banks	550	25	85
Mutual funds	164	12	66
ICPF	346	51	86
Households	175	20	97
Other	114	24	97
Total	1,349	24	85
Panel C: Foreign investors and the Eurosystem			
Foreign	2,261	29	
Eurosystem	114	83	

Table 5. Risk exposure by region and investor sector.

Section 3.3 defines the risk measures. Duration risk is in years. Government and corporate credit risk are five-year cumulative default probabilities shown as a percentage. Equity and foreign risk are portfolio shares shown as a percentage. Each statistic is an average over a quarterly sample from 2013Q4 to 2014Q4. Nonvulnerable countries are Austria, Belgium, Estonia, Finland, France, Germany, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Slovakia, and Slovenia. Vulnerable countries are Cyprus, Greece, Ireland, Italy, Portugal, and Spain. ICPF refers to insurance companies and pension funds.

Investor	Duration		Government credit	Corporate credit	Equity	Foreign
	All	Euro				
Panel A: Nonvulnerable countries						
Banks	3.2	3.2	0.4	0.5	4	19
Mutual funds	5.2	5.1	0.6	1.2	19	49
ICPF	6.8	7.2	0.4	1.0	6	18
Households	2.6	2.7	0.5	1.6	52	15
Other	4.1	4.3	0.2	1.2	66	7
Panel B: Vulnerable countries						
Banks	2.4	2.4	1.5	1.4	3	12
Mutual funds	5.7	3.8	1.3	1.9	11	58
ICPF	5.3	5.4	1.3	1.6	4	9
Households	3.6	3.6	1.3	2.1	23	7
Other	4.8	4.8	1.6	2.1	51	8
Panel C: Foreign investors and the Eurosystem						
Foreign		4.9	0.5	1.2	37	
Eurosystem	3.7	3.7	1.5	0.6	0	

Table 6. Distribution of risk exposure by region and investor sector.

This table reports the percent of total risk exposure held by each investor sector, where the column total is 100% for each risk measure. Section 3.3 defines the risk measures. Each statistic is an average over a quarterly sample from 2013Q4 to 2014Q4. Nonvulnerable countries are Austria, Belgium, Estonia, Finland, France, Germany, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Slovakia, and Slovenia. Vulnerable countries are Cyprus, Greece, Ireland, Italy, Portugal, and Spain. ICPF refers to insurance companies and pension funds.

Investor	Euro duration	Government credit	Corporate credit	Equity	Foreign
Panel A: Nonvulnerable countries					
Banks	13	8	14	2	13
Mutual funds	11	7	14	15	48
ICPF	21	6	13	2	9
Households	1	0	5	8	3
Other	2	1	2	13	2
Total	48	22	47	40	75
Panel B: Vulnerable countries					
Banks	7	23	22	1	5
Mutual funds	2	6	3	3	16
ICPF	5	9	4	0	1
Households	4	5	7	3	1
Other	1	4	1	4	1
Total	19	47	36	12	25
Panel C: Foreign investors and the Eurosystem					
Foreign	32	28	16	48	
Eurosystem	1	3	0	0	

Table 7. Portfolio rebalancing by region and investor sector.

This table reports the cumulative rebalancing from 2015Q1 to 2017Q4 in billion euros. In the last row, total rebalancing across all investors and the Eurosystem equals net issuance. The second to last column reports the initial government bond holdings in 2015Q2 in billion euros. The last column reports the cumulative government bond rebalancing as a percent of the initial government bond holdings. Nonvulnerable countries are Austria, Belgium, Estonia, Finland, France, Germany, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Slovakia, and Slovenia. Vulnerable countries are Cyprus, Greece, Ireland, Italy, Portugal, and Spain. ABS/CB refers to asset-backed securities and covered bonds, and ICPF refers to insurance companies and pension funds.

Investor	Government	Corporate	ABS/CB	Equity	Foreign	Initial holdings	% of initial holdings
Panel A: Nonvulnerable countries							
Banks	-275	-140	-177	-15	-63	1,281	-21
Mutual funds	-70	55	-51	167	542	849	-8
ICPF	102	-9	-33	-1	130	1,193	9
Households	-14	-69	-4	2	10	29	-48
Other	13	-6	-7	66	14	210	6
Panel B: Vulnerable countries							
Banks	-195	-97	-40	11	-11	930	-21
Mutual funds	-57	32	-9	20	370	304	-19
ICPF	181	48	-9	14	109	473	38
Households	-63	-182	-3	15	-26	210	-30
Other	-29	-13	-4	-13	19	148	-20
Panel C: Foreign investors and the Eurosystem							
Foreign	-927	-134	-140			3,817	-24
Eurosystem	1,876	130	184			326	575
Total (net issuance)	541	-384	-293				

Table 8. Foreign investors' portfolio rebalancing by issuer region.

This table reports foreign investors' cumulative government bond rebalancing from 2015Q1 to 2017Q4 in billion euros. The second to last column reports the initial government bond holdings in 2015Q2 in billion euros. The last column reports the cumulative government bond rebalancing as a percent of the initial government bond holdings. Nonvulnerable countries are Austria, Belgium, Estonia, Finland, France, Germany, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Slovakia, and Slovenia. Vulnerable countries are Cyprus, Greece, Ireland, Italy, Portugal, and Spain. ICPF refers to insurance companies and pension funds.

Asset class	Rebalancing	Initial holdings	% of initial holdings
Panel A: Nonvulnerable countries			
Government bonds	-675	2,957	-23
Corporate bonds	-118	548	-22
ABS and covered bonds	-70	168	-42
Panel B: Vulnerable countries			
Government bonds	-252	860	-29
Corporate bonds	-16	130	-12
ABS and covered bonds	-70	121	-58

Table 9. Dynamics of risk exposure by region and investor sector.

This table reports the percent of total risk exposure held by each investor sector, where the column total is 100% for each risk measure in 2014Q4. The risk exposure in other periods is reported as a percent of the total risk exposure in 2014Q4. Section 3.3 defines the risk measures. Nonvulnerable countries are Austria, Belgium, Estonia, Finland, France, Germany, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Slovakia, and Slovenia. Vulnerable countries are Cyprus, Greece, Ireland, Italy, Portugal, and Spain. ICPF refers to insurance companies and pension funds.

Investor	2013	2014				2015				2016				2017			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Panel A: Euro-area duration risk																	
Nonvulnerable countries																	
Banks	12	12	12	12	12	12	11	11	11	12	12	12	11	11	11	11	11
Mutual funds	9	10	11	11	12	13	12	12	12	13	13	14	12	12	13	13	12
ICPF	18	18	19	20	21	22	20	21	20	23	24	24	22	22	23	23	23
Households	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Other	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Vulnerable countries																	
Banks	6	6	7	7	7	7	7	7	6	7	8	7	7	8	8	7	7
Mutual funds	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2
ICPF	4	4	5	5	5	5	5	5	6	7	8	8	8	8	8	8	8
Households	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2
Other	1	1	1	1	1	2	1	1	1	2	2	2	1	1	1	1	1
Foreign investors and the Eurosystem																	
Foreign	26	28	30	31	32	34	30	30	29	30	30	29	25	24	25	25	25
Eurosystem	1	1	1	1	1	2	3	5	6	9	12	15	16	18	20	21	22
Total	84	89	94	96	100	107	99	101	100	110	116	117	111	111	115	117	118
Panel B: Government credit risk																	
Nonvulnerable countries																	
Banks	8	8	8	8	8	8	8	8	7	8	8	8	7	7	7	6	6
Mutual funds	7	7	8	8	8	9	8	9	9	9	10	10	8	8	9	9	9
ICPF	6	6	7	7	7	8	7	8	8	9	9	9	8	8	8	8	8
Households	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vulnerable countries																	
Banks	25	27	22	22	22	20	19	19	19	20	28	23	20	21	20	20	18
Mutual funds	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	5	5
ICPF	8	9	9	10	10	10	10	10	11	12	14	15	14	14	15	15	15
Households	5	5	5	5	5	4	4	4	4	4	4	4	4	4	4	4	4
Other	4	4	4	4	4	4	4	4	3	4	9	8	7	7	6	6	8
Foreign investors and the Eurosystem																	
Foreign	28	31	28	28	26	26	25	26	25	24	30	28	23	22	23	23	23
Eurosystem	3	3	3	3	3	4	5	6	8	9	12	14	14	16	17	19	19
Total	102	107	100	102	100	101	96	102	100	106	132	126	111	114	115	115	115
Panel C: Corporate credit risk																	
Nonvulnerable countries																	
Banks	15	15	15	15	14	13	13	13	12	13	12	12	11	11	11	11	10
Mutual funds	14	15	15	15	15	12	12	11	10	11	12	12	12	12	12	12	12
ICPF	14	14	15	15	14	13	13	13	12	13	13	13	13	13	13	13	12
Households	5	5	5	5	5	3	3	3	3	3	3	3	3	3	2	2	2
Other	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
Vulnerable countries																	
Banks	31	25	23	21	18	14	14	13	12	12	23	16	14	12	11	10	9
Mutual funds	3	3	3	3	3	2	2	2	2	2	2	3	3	3	3	3	3
ICPF	5	5	5	5	5	4	4	4	3	4	4	5	5	5	5	5	4
Households	8	8	7	7	6	5	5	5	3	3	3	3	3	3	2	2	2
Other	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0
Foreign investors and the Eurosystem																	
Foreign	20	19	17	17	17	10	9	9	8	8	8	7	7	7	7	7	7
Eurosystem	0	0	0	0	0	1	1	1	1	1	2	3	4	5	6	6	7
Total	118	111	107	105	100	80	77	76	68	73	84	77	75	74	72	72	71

Table 10. Changes in the expanded asset purchase program.

Announcement date	1/22/2015	12/3/2015	03/10/2016	12/8/2016	10/26/2017
Start date	3/2015	10/2016	4/2016	4/2017	1/2018
End date	9/2016	3/2017	3/2017	12/2017	9/2018
Remaining duration (months)	19	6	12	9	9
Monthly purchase rate (billion €)	60	60	80	60	30

Table 11. Instrumental variables and the yield impact of quantitative easing.

This table reports the instrument in 2017Q4, which is the predicted cumulative government bond purchase as a share of government debt outstanding in 2014Q2. The yield impact comes from the first stage of instrumental variables in government bond demand estimation. The quarterly sample from 2014Q2 to 2017Q4 includes all euro-area countries except Cyprus, Estonia, Greece, Luxembourg, and Malta.

Country	Instrument	Yield effect (%)
Austria	0.18	-0.45
Belgium	0.15	-0.38
Finland	0.33	-0.83
France	0.18	-0.45
Germany	0.24	-0.60
Ireland	0.32	-0.80
Italy	0.16	-0.40
Latvia	0.33	-0.83
Lithuania	0.33	-0.83
The Netherlands	0.20	-0.50
Portugal	0.33	-0.83
Slovakia	0.33	-0.83
Slovenia	0.33	-0.83
Spain	0.21	-0.53
Mean	0.26	-0.65

Table 12. Estimated government bond demand by investor sector.

The first column reports the first stage of government bond demand estimation for foreign investors. The remaining columns report instrumental variables estimates of government bond demand (10) by investor sector. The instrument is the predicted cumulative government bond purchase as a share of government debt outstanding in 2014Q2. The quarterly sample from 2014Q2 to 2017Q4 includes all euro-area countries except Cyprus, Estonia, Greece, Luxembourg, and Malta. Robust standard errors clustered by time are reported in parentheses. ICPF refers to insurance companies and pension funds.

Variable	First stage	Banks	Mutual funds	ICPF	Households	Other	Foreign
Yield		0.073	0.131	-0.344	0.014	0.013	0.428
		(0.051)	(0.046)	(0.030)	(0.047)	(0.096)	(0.032)
Instrument	-2.504						
	(0.330)						
Log GDP per capita	-0.073	0.049	-0.017	-0.013	0.148	-0.004	0.151
	(0.037)	(0.015)	(0.035)	(0.025)	(0.042)	(0.046)	(0.026)
Maturity	0.019	-0.021	0.020	0.044	-0.086	-0.044	-0.044
	(0.014)	(0.008)	(0.005)	(0.005)	(0.016)	(0.011)	(0.006)
Default probability	48.060	-0.757	-2.041	23.182	19.587	-0.636	-20.828
	(4.994)	(2.323)	(1.998)	(2.676)	(7.062)	(4.432)	(3.786)
Log holdings in 2014Q4	-0.034	0.975	1.004	0.989	0.958	0.981	0.978
	(0.012)	(0.010)	(0.003)	(0.004)	(0.008)	(0.010)	(0.008)
U.S. Treasury yield	0.367	-0.104	-0.130	0.078	-0.038	-0.077	-0.247
	(0.093)	(0.028)	(0.028)	(0.025)	(0.044)	(0.052)	(0.038)
Observations	210	210	210	210	210	210	210

Table 13. Estimated demand elasticity by investor sector.

The demand elasticity (13) is estimated for each investor sector, issuer country, and time. This table reports summary statistics over a quarterly sample from 2014Q2 to 2017Q4, pooled across issuer countries and over time. The weighted average elasticity in the last row uses the asset weights in the last column, which are based on the market values of government bond holdings in 2014Q2. ICPF refers to insurance companies and pension funds.

Investor	Mean	Standard deviation	Min	Max	Asset weight (%)
Banks	2.08	0.22	1.71	2.99	23
Mutual funds	2.93	0.40	2.28	4.57	12
ICPF	-4.04	1.11	-8.37	-2.30	17
Households	1.21	0.04	1.13	1.37	3
Other	1.20	0.04	1.13	1.37	4
Foreign	7.19	1.31	5.17	12.67	41
Total	3.21				100

Table 14. Asset valuation effects by region and investor sector.

This table reports the market value, total duration, and average duration of euro-area government bond holdings in 2015Q1. The capital gain is total duration times 65 basis points for the average yield impact of quantitative easing. ICPF refers to insurance companies and pension funds.

Investor	Holding	Duration		Gain
	(billion €)	Total	Average	(billion €)
Panel A: Nonvulnerable countries				
Banks	1,346	6,694	5.0	44
Mutual funds	895	6,795	7.6	44
ICPF	1,284	12,622	9.8	82
Households	32	137	4.3	1
Other	217	1,297	6.0	8
Total	3,774	27,545	7.3	179
Panel B: Vulnerable countries				
Banks	963	3,919	4.1	25
Mutual funds	333	1,700	5.1	11
ICPF	493	3,288	6.7	21
Households	232	1,477	6.4	10
Other	162	1,039	6.4	7
Total	2,183	11,423	5.2	74
Panel C: Foreign investors				
Foreign	4,114	24,912	6.1	162

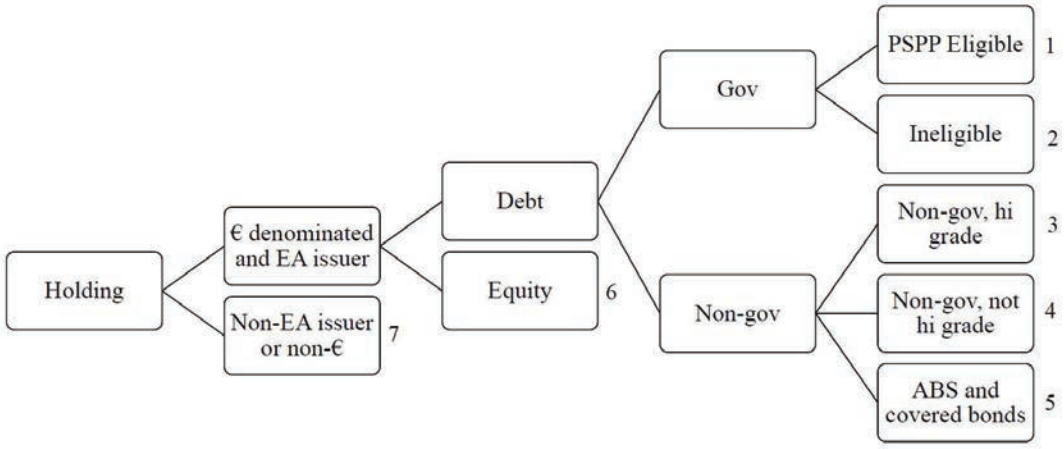

Fig. 1. Summary of asset classes.

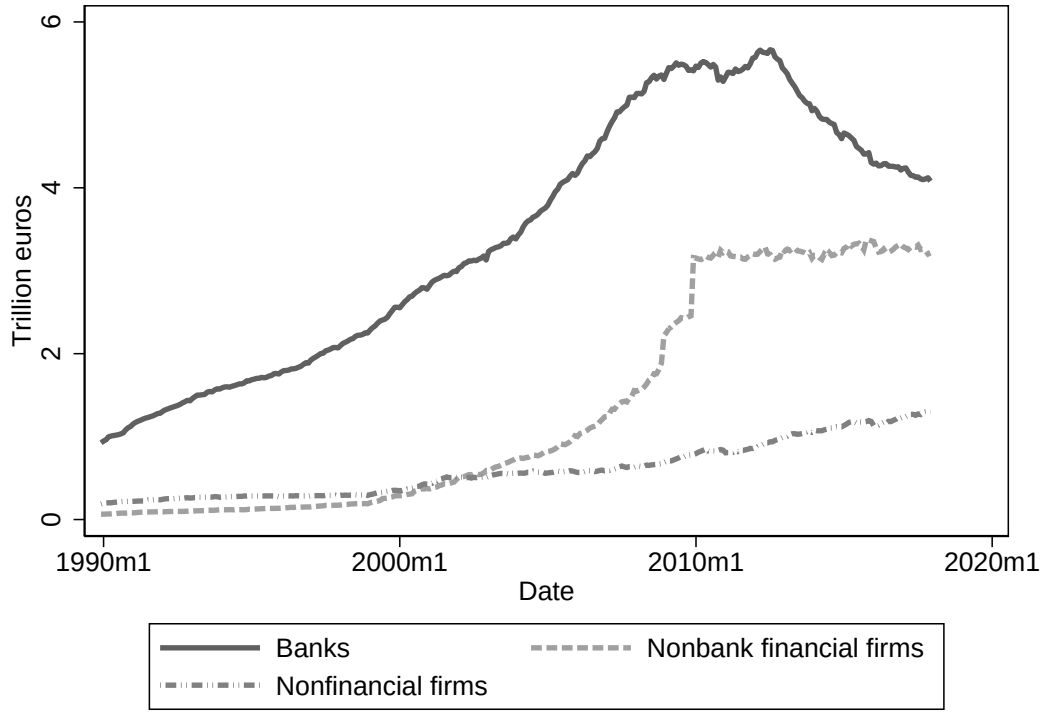

Fig. 2. Corporate debt outstanding. This figure reports the face value of corporate debt outstanding for banks, nonbank financial firms, and nonfinancial firms in the euro area from January 1990 to December 2017. The data source is the European Central Bank's Statistical Data Warehouse.

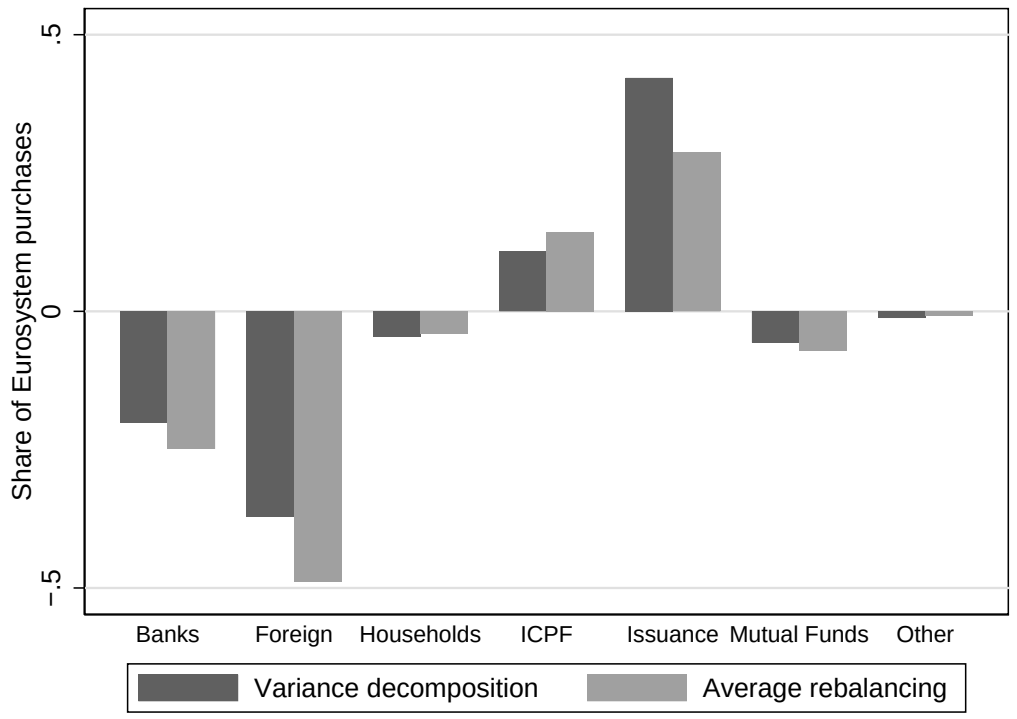

Fig. 3. Variance decomposition of the Eurosystem's purchases. The first bar represents the variance decomposition of the Eurosystem's purchases of eligible government bonds, based on eq. (4). The second bar represents average rebalancing of eligible government bonds, based on eq. (7). The quarterly sample period is 2015Q2 to 2017Q4.

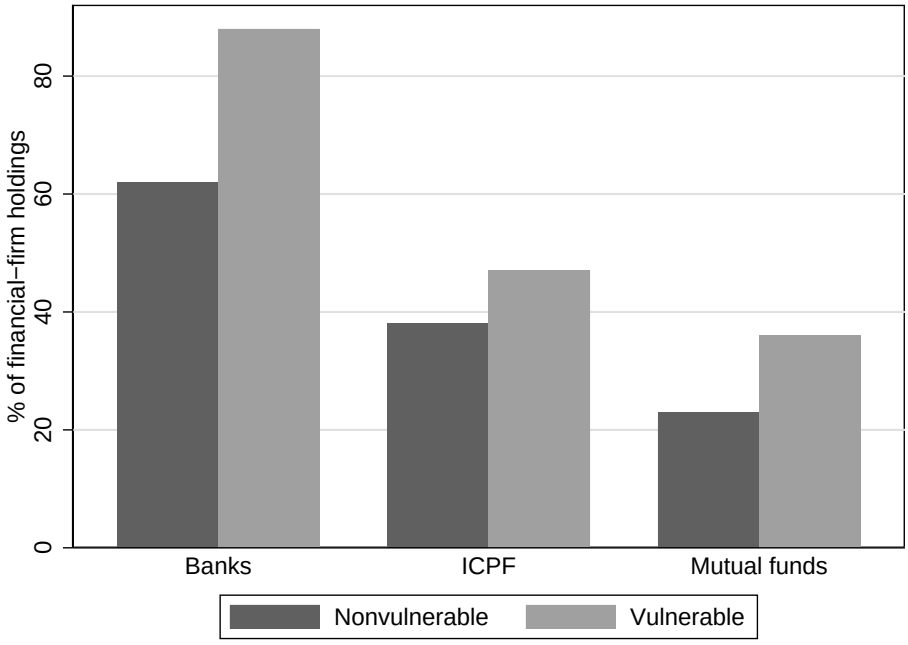

Fig. 4. Home bias within bonds issued by financial firms.

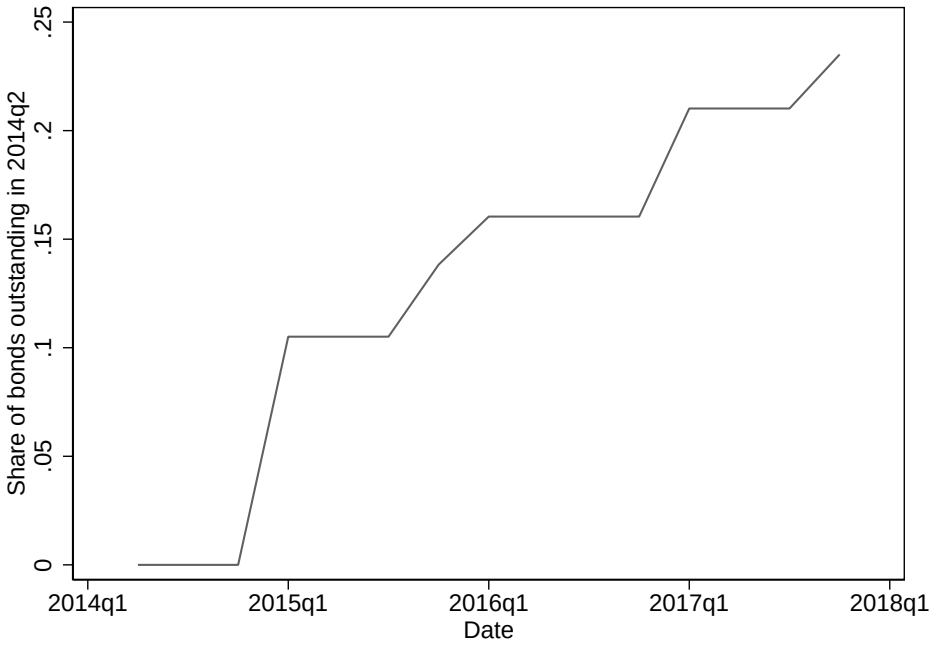

Fig. 5. Instrument for German government bonds.

Appendix A. Additional tables

Table A.1. Portfolio rebalancing prior to the expanded asset purchase program.

This table reports the average rebalancing per quarter from 2013Q4 to 2014Q4 in billion euros. In the last row, total rebalancing across all investors and the Eurosystem equals net issuance. Nonvulnerable countries are Austria, Belgium, Estonia, Finland, France, Germany, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Slovakia, and Slovenia. Vulnerable countries are Cyprus, Greece, Ireland, Italy, Portugal, and Spain. ABS/CB refers to asset-backed securities and covered bonds, and ICPF refers to insurance companies and pension funds.

Investor	Government	Corporate	ABS/CB	Equity	Foreign
Panel A: Nonvulnerable countries					
Banks	7	-10	-10	4	7
Mutual funds	9	5	-3	19	59
ICPF	5	2	-2	1	8
Households	-1	-6	-1	3	1
Other	1	0	-1	-2	0
Panel B: Vulnerable countries					
Banks	-3	-28	-16	-3	6
Mutual funds	8	4	0	11	21
ICPF	8	0	0	1	2
Households	-6	-18	0	1	0
Other	-1	-1	0	1	-3
Panel C: Foreign investors and the Eurosystem					
Foreign	-32	-14	-10		
Eurosystem	0	0	6		
Total (net issuance)	-6	-67	-37		