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ECB MONETARY POLICY AND DISTRIBUTION OF WEALTH

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Preface

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List of abbreviations

ABS : Asset-Backed Securities

APP : Asset Purchase Program

ADL : Autoregressive Distributed Lag model

BIS : Bank for International Settlements

ECB : European Central Bank

GLS: Generalized Least Squares estimator

HFCS : Household Finance and Consumption Survey

LSAP : Large-Scale Asset Purchase

NLS : Non-linear Least Squares estimator

OLS : Ordinary Least Squares estimator

OMT : Outright Monetary Transactions

PSPP : Public Sector Purchase Programme

QE : Quantitative Easing

TLTRO : Targeted Longer-Term Refinancing Operation

VAR : Vector AutoRegression model

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1 Introduction

The monetary policy stance has become an important decision parameter for financial markets and households during the last decade.[1] As governments have had to put their budgets in order, there has been an unprecedented focus on monetary policy to support aggregate demand. The European Central Bank (ECB) has pursued its price stability mandate[2] by setting the policy rate.[3] This monetary policy signal is then transmitted through the financial system, influencing financing conditions and, ultimately, aggregate output. Since the onset of the 2008 financial crisis (Brunnermeier, 2009), the ECB and all other major central banks have extended their conventional frameworks with a number of non-standard monetary policy measures (Praet, 2017). This unconventional monetary policy toolkit typically consist of: (i) policy rate at zero lower bound, (ii) quantitative easing[4] (QE), and (iii) forward guidance. In addition, the negative

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[1] Monetary policy attempts to influence broad financial and macroeconomic conditions in order to achieve the goals that the central bank has been tasked with in its mandate. This is done by varying the monetary policy stance (i.e. the contribution monetary policy makes to economic, financial and monetary developments).

[2] The Governing Council clarified in 2003 that in the pursuit of price stability it aims to maintain inflation rates below, but close to, 2% over the medium term. (source: https://www.ecb.europa.eu/mopo/strategy/pricestab/html/index.en.html)

[3] i.e. the price for central bank reservers. For example, the Taylor rule (Taylor, 1993) is a simple monetary policy rule mechanically linking the level of the central bank's policy rate to deviations of inflation from its target and of output from its potential (output gap) through fixed reaction coefficients.

[4] i.e. asset purchases financed by central bank money. For exmaple, Friedman's k-percent rule (M. Friedman & A. Schwartz, 1963) is a fixed monetary policy rule proposing the money supply (M) should be increased by the central bank by a constant growth rate every year in order to achieve it's price (P) stability target. The reasoning is based on a monetarist interpretation (Quantity theory of money) of the Fisher equation $M . V = P . T$ assuming the velocity of money (V) and the number of transactions per unit of time (T) constant.

interest rate on the deposit facility has brought overnight rates down to negative levels and contributed to flattening the yield curve.[5] The purchases program of private and public sector securities has helped further compressing the term structure of the interest rates by extracting risk premia out along the yield curve. Besides lower interest rates for debtors, banks have a stronger incentive to provide loans to the real economy. Lower interest rates encourage banks to rebalance their portfolios towards assets with higher risk-adjusted returns (e.g. loans). The incentive to invest in higher-yielding assets is further intensified by the excess cash reserves created by asset purchases and negative interest rates.

Monetary policy is commonly thought of at the macroeconomic level. However, monetary policy is not only working to ease financing conditions for firms and households in order to ensure a sustained recovery of the economy, but also entails specific implications for financial markets and household wealth. More specifically, financial markets face asset valuation challenges while households are confronted with a potential redistribution of their wealth.

The paper has two objectives. First, we examine the impact of monetary policy shocks on the evolution of return on assets and cost of debt in the Eurozone. Second, we infer wealth implications for households using the ECB Household Finance and Consumption Survey (HFCS).

[5] A yield curve is a representation of the relationship between market remuneration rates and the remaining time to maturity of debt securities. A yield curve can also be described as the term structure of interest rates. The yield curve estimated by the ECB is released on a daily basis and available at http://www.ecb.europa.eu/stats/money/yc/html/index.en.html

The first part of the paper reviews the theory on monetary transmission as well as channels through which monetary policy might affect the distribution of household wealth. Hence, implications for financial markets and household are discussed. The second part of the paper presents an econometric study analyzing European market data from October 2008 to December 2017. Finally, a general conclusion is provided.

1.1 The monetary transmission mechanism

Mishkin (1995) distinguishes four main channels that constitute the monetary transmission mechanism. These channels are considered in more detail below with Figure 1 providing a simple pictorial representation. The traditional Keynesian *interest rate channel* entails that accommodative monetary policy leads to declining real interest rates, which stimulates investing, and thereby causing a rise in aggregate demand and output. In addition, the *exchange rate channel* points out that lower domestic interest rates imply capital outflow leading to a depreciation of the domestic currency. Consequently, domestic goods become less expensive relative to foreign goods, hence net exports and thus aggregate output rises. Taking a Monetarist perspective, monetary transmission also runs through the *asset price channel* via both the Tobin's Q effect and real wealth effects. First off all, accommodative monetary policy might fuel asset prices (P) (e.g. equities) through discount rate (r) and cash flow (CF) effects.

$$P = \sum_{i=1}^{n} \frac{CF_i}{(1+r)^i} \tag{1}$$

Tobin's (1969) theory on the valuation of equities explains the positive correlation between Tobin's Q[6] and investments leading to higher output. Another channel for monetary transmission through asset prices occurs through wealth effects on household consumption. Modigliani's (1971) life-cycle model emphasizes that households do consumption smoothening over life following permanent income. When equity prices rise, the value of their financial wealth increases, thus increasing their permanent income so consumption should rise. Finally, the *credit channel* comprises two basic channels that arise from agency problems (adverse selection and moral hazard) in credit markets: the balance-sheet channel and the bank-lending channel. First, the balance sheet channel provides a further rationale for asset price effects emphasized in monetarist thinking. Higher assets prices due to accommodative monetary policy cause an amelioration of the firm's balance sheet because it increases cash flow. This lowers the risk of adverse selection and moral hazard problems implying lower risk premia. The idea behind the adverse selection problem is that lower interest rates attract more good borrowers (and push off bad borrowers that would be willing to pay high interest rates to finance low quality projects) and therefore determine the default risk a creditor bears. This risk decreases when the net value of the firm is higher since creditors will have more collateral behind their loans resulting in lower expected returns and risk premia. The same applies to moral hazard problems which are typically lower when the net value of the firm is higher.

[6] Tobin's Q is defined as the market value of the firm divided by the replacement cost of capital. A high Q-ratio indicates that the market price of the firm is high relative to the replacement cost of capital. Companies can then issue equity at low cost relative to the cost of the plant and equipment they are buying. Consequently, investment spending will rise.

Such a business environment characterized by less external sources of funding relative to equity discourages debtor risk taking and subsequently lowers creditor risk premia.[7] As a result, lower adverse selection and moral hazard problems stimulate lending, investment and output. Second, the bank-lending channel runs through the normal intermediation activity of banks.[8] Accommodative monetary policy increases bank reserves and deposits so more loans can be issued to corporates and households. This allows more investment spending and increases aggregate output.

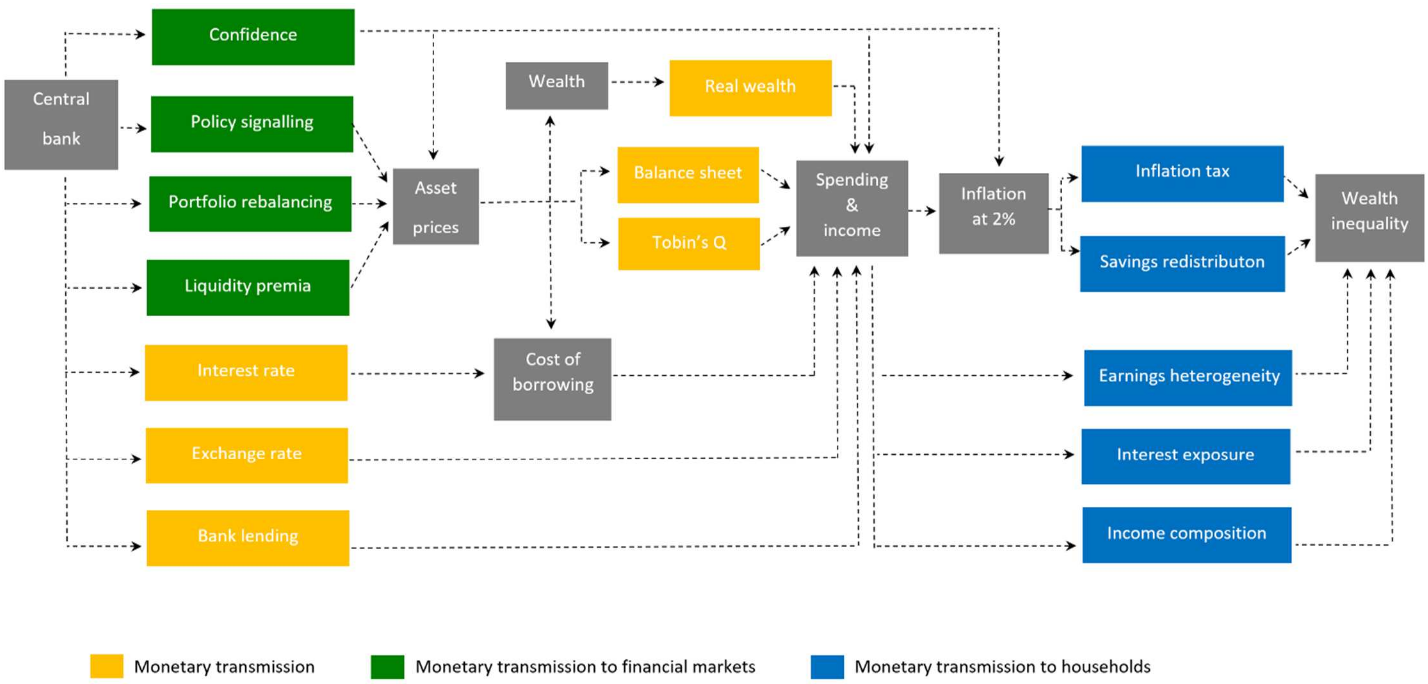


Figure 1: Monetary transmission channels (adapted from Joyce, Tong, & Woods (2011))

[7] Note that the same logic applies to household assets and consumption.

[8] The bank-lending channel is especially relevant for small enterprises and households as large firms can also finance themselves directly on the capital market.

1.2 Monetary transmission to financial markets

There are a number of potential channels through which monetary policy might affect financial markets (see Figure 1) (Joyce, Tong, et al., 2011). The *policy signaling channel* includes anything economic agents learn about the likely path of future monetary policy from the current policy stance. For example, both the pace and timeline of asset purchases has fueled market participants' expectations for policy rates to remain low for long. The *portfolio rebalancing channel* is based on the idea that accommodative monetary policy will push up asset prices. Sellers will have excess money and may attempt to rebalance their portfolios by buying other assets that are better substitutes for money. This process will raise the prices of assets until a new equilibrium is reached (i.e. when investors, in aggregate, are willing to hold the overall supplies of assets and money). While the policy signaling channel primarily affects expected policy rates,[9] accommodative monetary policy transmitted through the portfolio rebalancing channel reduces term premia[10] and equity risk premia.[11] The theoretical underpinnings of this channel date back to the 1960s (Brunner & Meltzer, 1973; M. Friedman & A. J. Schwartz, 1963; Tobin, 1961). On the condition that accommodative monetary policy will generate more trade, liquidity will rise resulting in lower liquidity premia (*liquidity premia channel*). Following equation (1), asset prices should rise.

[9] The expectations theory of the term structure of interest rates assumes that the long-term interest rate equals the average of the current and expected short-term interest rates (Heylen, 2004).

[10] Term premium can be defined as the amount by which the yield-to-maturity of a long-term bond exeeds that of a short-term bond.

[11] Equity risk premium can be defined as the excess return investors demand to hold equities compared to the risk free rate.

The *confidence channel* describes how monetary policy may have broader confidence effects beyond the effects generated by the other channels. For example, an accommodative monetary policy shock might directly boost consumer confidence and thus people's willingness to spend. As a result, lower uncertainty is translated in higher asset prices due to reduced risk premia.

1.3 Monetary policy in the Eurozone

Peersman and Smets (2001) showed that the interest rate channel was the most important transmission channel in the Eurozone. However, the balance sheet channel played a crucial role during the 2008 financial crisis as the willingness to give loans evaporated which leaded to an amplification of the crisis. In addition, the bank-lending channel was activated automatically during the crisis. The supply of loans dropped because of bank's liquidity problems and a completely dried up interbank market due to high risk premia (Brunnermeier, 2009).

In "normal" times the monetary policy stance is signalled by the policy rate for main refinancing operations and the standing facility rates (i.e. marginal lending facility and deposit facility).[12] In that way, the composition and size of the central bank balance sheet contain limited information on the degree of monetary easing. In response to the Eurocrisis, the ECB began to implement a range of unconventional monetary measures. Since September

[12] https://www.ecb.europa.eu/stats/policy_and_exchange_rates/key_ecb_interest_rates/html/index.en.html

and November 2014 the purchases of covered bonds and asset-backed securities (ABS) respectively were implemented.[13] From that moment on, the use of the Eurosystem balance sheet has evolved from a relatively passive approach to more active management of balance sheet assets in order to preserve a suistained recovery of the euro area economy (ECB, 2015a). Especially under credit easing policies,[14] the central bank may take a more activist role on determining the composition of its balance sheet. The monetary authority can ease conditions in specific markets via asset purchases by altering market spreads paid by debtors. Given the zero lower bound of short-term nominal interest rates, central banks have embarked on large-scale asset purchases to facilitate monetary transmission. In tandem with all major central banks,[15] the ECB expanded the size of its balance sheet[16] drastically since the 2008 crisis (Figure 2).

[13] A concise overview of the ECB's monetary policy is provided in a recent speech by Peter Praet (2017) titeled "The ECB's monetary policy: past and present". More detailed information can be found on the ECB website: https://www.ecb.europa.eu/mopo/implement/html/index.en.html

[14] In the case of "pure credit easing", the central bank finances the acquisition of specific assets through sales of other assets, changing the composition of the asset side of the balance sheet but leaving its size unaffected.

[15] Caution is required when comparing central bank balance sheets across jurisdictions and also within jurisdictions over time. The ECB notes that a unit of liquidity will have very different economic effects depending on the financial structures, the central bank operating procedures, and the specific use of the central bank balance sheet (ECB, 2015a).

[16] A breakdown of the recent Eurosytem balance sheet can be found in Appendix 2. More details are provided in "*The role of the central bank balance sheet in monetary policy*, ECB Economic Bulletin, Issue 4, 2015."

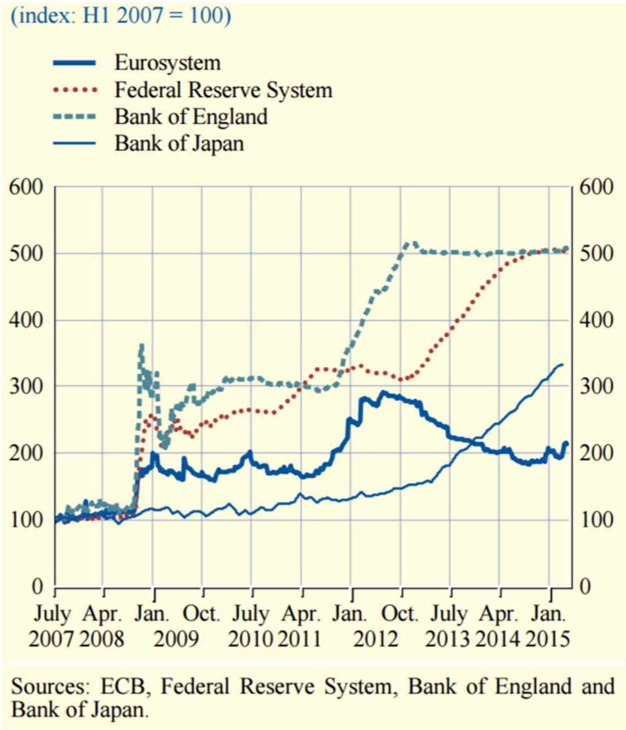


Figure 2: Central bank balance sheets since the crisis: total assets (ECB, 2015a)

These large-scale asset purchases are thought to affect financial markets via two main channels: policy signaling and portfolio rebalancing. Past studies have found that the contribution of the policy signaling channel is highly uncertain (Bauer & Rudebusch, 2014; Christensen & Rudebusch, 2012). First, it can trigger a downward revision of market expectations for future short-term rates. Second, it may increase inflation expectations so that long-term rates will be lower, thereby supporting investment and consumption. The effects in the Eurozone are considered to be moderate (ECB, 2015b). For example, Altavilla et al. (2015) studied transmission channels of the APP program by focusing on one- and two-day window changes in the OIS forward rates at short and medium maturities. The authors estimated the signaling channel to contribute at most 10 basis points at two-year horizon, idicating that it explains only part of the decline in long-term yields (see section 1.5). A prominent example of policy signalling is the ECB's Outright Monetary Transactions (OMTs). Although the OMT program has never been put into practice, since it's announcement governments spreads converged back to normal levels. The portfolio balance channel emphasises the importance of quantities of securities for the pricing of assets. Therefore, the empirical importance of the portfolio rebalancing channel has been studied through quantitative easing policies (ECB, 2015b). The idea is that newly generated liquidity is passed from one market to another (ECB, 2015a). Most studies have found evidence supporting the relevance of this channel (Altavilla et al., 2015; Gagnon, Raskin, Remache, & Sack, 2011; Joyce, Lasaosa, Stevens, & Tong, 2011).

1.4 Channels through which monetary policy affects the distribution of wealth

Depending on the transmission channel active, accommodative monetary policy may potentially increase or decrease wealth inequality (Amaral, 2017). In addition, the impact of some channels also depends on households' asset-liability structure and sources of income.

The *inflation tax*[17] *channel* assumes that increases in expected inflation erode the purchasing power of households. Especially low-income households typically rely more on cash to conduct their transactions (Erosa & Ventura, 2002). In that way, expected inflation acts as a regressive consumption tax, increasing inequality.[18] In turn, the *savings redistribution channel* implies that accommodative monetary policy is likely to decrease inequality (Coibion, Gorodnichenko, Kueng, & Silvia, 2012). Increases in unexpected inflation decreases the real value of nominal debt, making debtors better off at the expense of creditors. Consequently, the effect on inequality depends on the way debt is distributed across households. Doepke and Schneider (2006) showed that middle class households experience larger net wealth increases because these tend to hold fixed-rate mortgages.[19] On the other hand, richer households would lose the most, as they tend to be net savers. The effects of accommodative monetary policy through the *earnings heterogeneity channel* can go two ways. This channel describes how the position of a household in the earnings distribution determines how monetary policy affects labor earnings. A study showed that earnings at the top of the distribution are mainly driven by changes in wages, while earnings at the bottom are mainly driven by changes in hours worked and unemployment rate (Heathcote, Perri, & Violante, 2009). Monetary policy will thus produce

[17] The inflation tax concept refers to the fact that low-income households are more vunerable to inflation because of the relatively higher volumes of cash they tend to hold.

[18] The Erosa and Ventura (2002) paper discusses the differences in transaction patterns of low- and high-income households in more detail to explain why low-income households hold more cash as a fraction of their total consumption.

[19] The Doepke and Schneider (2006) paper provides an historical analysis of the redistributive effects of inflation in the U.S. by investigating the nominal asset positions both across sectors (i.e. households, government and foreign investors) and within the household sector.

redistributed income effects, to the extent that it affects these drivers differently. For the next channel, it is essential to know how both assets and liabilities, and importantly, their respective durations, are distributed across the population in order to be able to infer the impact of a monetary policy change on inequality. The *interest rate exposure channel* is based on the discount rate effect described in equation (1). Net creditors whose wealth is concentrated in short-duration assets (e.g. 3M T-bills) and net debtors that hold long duration liabilities (e.g. fixed-rate mortgages) benefit from accommodative monetary policy, to the extent that it decreases real interest rates. Mutatis mutandis, net creditors whose wealth is concentrated in long-duration assets (e.g. 10Y Government bonds) and net debtors that hold short duration liabilities (e.g. adjustable-rate mortgages) are disadvantaged if the monetary policy stance turns accomodative. In case of the *income composition channel,* the sources of income as a share of household income are crucial as each of these may respond differently to changes in monetary policy (Coibion et al., 2012). Households at the low, median and upper part of the income distribution typically rely more on respectively transfer (e.g. unemployment benefits), labor (e.g. wages) and capital income (e.g. dividends). However, inferring implications from this channel is not straightforward. Note that the *asset price channel* predicts a positive relation between accommodative monetary policy and stock prices (equation (1)) which is of course beneficial for market participants with stock positions.

A recent US study by Coibion et al. (2017) found that labor earnings inequality was only little affected by monetary policy compared to the effect for consumption and total expenditures inequality. This finding points to a small role for the earnings heterogeneity channel in the United States. On the other hand, the income composition channel plays an important role. In particular, the fact that labor earnings are a much higher fraction of total income at upper quintiles, compared to the bottom quintiles, where transfer income is more prevalent. As transfer income is relatively stable over the business cycle, labor earnings will be more important to account for changes in inequality following monetary policy shocks.

1.5 Implications for financial markets and households

In general, the impact of monetary policy on financial markets is threefold. First, accommodative monetary policy aims to stimulate growth so expected cash flows increase. Second, the risk-free rate[20] drops when the central bank lowers the policy rate. Finally, the required risk premium also drops when expected returns are lower due to lower uncertainty. Following equation (1), asset prices should rise. Changing monetary policy is thus an important decision parameter for financial markets because equity risk premia and expected equity returns vary over time (Campbell & Diebold, 2009; Cochrane, 2005). For example, when financial markets consider accommodative monetary policy to be good news for the economy, uncertainty will be low while risk appetite is high. This leads to lower equity risk premia and expected equity returns, which translates the monetary policy stance directly into market prices. In addition, changing monetary policy entails market timing

[20] For example, a 3M T-bill is considered a risk free security.

opportunities and implications for portfolio rebalancing (NBIM, 2012). Long-term investors are likely to benefit from rebalancing to weights that take into account the time variation in risk premia[21]. Evidence shows that the historical performance of equity markets is not related to economic growth, but that expected business conditions predict subsequent stock returns (Campbell & Diebold, 2009). This emphasizes the role of forward guidance by the central bank and economic forecasts in the context of tactical asset allocation. Furthermore, Norges Bank Investment Management showed that on a five-year time horizon, several valuation metrics (i.e. P/E ratio[22], cyclically adjusted P/E ratio[23], dividend yield[24], and Tobin's Q[25]) outperform even perfect knowledge of three-year-ahead GDP growth for this timeframe. This finding is consistent with the view that variation in equity returns reflect changes in expected returns and equity risk premia, rather than rational changes is expected fundamentals. The authors conclude that current valuations are more important in forecasting future long-term equity returns than future economic growth. Note that markets might react differently to monetary policy (Andersen, Bollerslev, Diebold, & Vega, 2007). In addition to their susceptibility for term premia, bond markets have a one-

[21] i.e. increasing exposure to risky assets when premia are perceived to be high and reducing them when premia are perceived to be low.

[22] P/E ratio refers to price-earnings ratio and is defined as asset price divided by asset return. A higher P/E ratio reflects higher trust of financial markets in the underlying return of a stock.

[23] Cyclically adjusted P/E is often labeled as CAPE ratio or Shiller P/E. For example, a P/E 10 ratio is defined as asset price devided by average of ten years of asset earnnings adjusted for inflation. The cyclically adjusted P/E is used to gauge whether a stock is undervalued or overvalued by comparing its current market price to its inflation adjusted historical earnings record.

[24] Dividend yield is defined as asset dividend divided by asset price. Next to P/E multiple growth and earnings per share (EPS) growth, it is one of the major drivers of equity returns (Ritter, 2005).

[25] See footnote 6.

factor exposure: i.e. the outlook for monetary policy, which basically comes down to inflation expectations in case of a credible central bank. In addition to equity risk premia, equities have a two-factor exposure: i.e. monetary policy via the discount rate effect and economic growth via the cash flow effect. Furthermore, evidence shows that the correlation between equities and bonds depends on the business cycle. Anyhow, the distribution of these financial assets across households is decisive for distributional consequences within the population.

Macroeconomist often think from the perspective of a “representative household”, but in reality, households have a very different composition of assets and liabilities. Therefore, monetary policy can generate distributional effects between households.

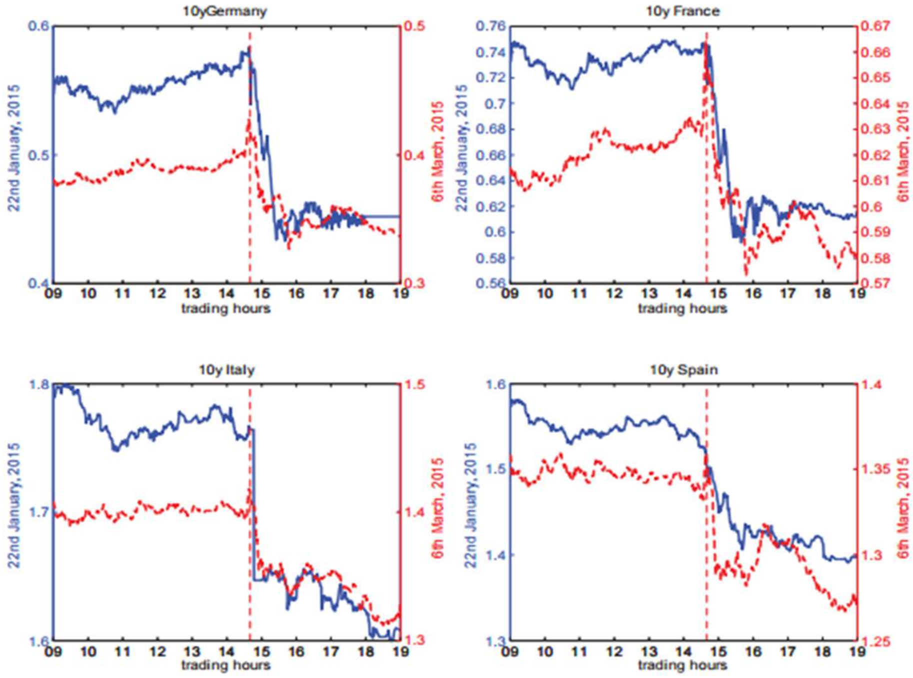
The Bank of England (2012) distinguishes four implications for households. First, the ‘income effect’ refers to the fact that accommodative monetary policy reduces both the interest income creditors receive on their savings and the interest payments made by debtors. In addition, there is also a ‘substitution effect’, as lower interest rates encourages household spending instead of saving. Third, the ‘wealth effect’ takes asset prices into account. As these are typically rising when the monetary policy stance is accomodative, households holding assets in their portfolio will benefit relatively more. Finally, ‘exchange rate effects’ are possible. The currency is expected to depreciate due to lower interest rates on the capital market, raising the price of imports and reducing the price of exports. All of these effects would tend to raise spending in the economy in the near term, but especially income and wealth effects may generate distributional effects on households. Of course, the benefits from these wealth effects are larger for those households with more financial assets. Therefore, it is essential to take the distribution of assets across households into account when inferring the joint impact of income and wealth effects.

1.6 Empirical findings on the impact of monetary policy on financial markets and households

Altavilla et al. (2015) evaluated the effects on asset prices of the ECB asset purchase programme (APP) announced in January 2015. The study shows that the APP has significantly lowered yields for a broad set of market segments. Notably, effects generally rise with maturity and riskiness of assets. For example, long-term sovereign bonds yields with a 10-year maurity declined by about 30-50 basis points within a two-day window and by roughly twice as much in member countries that involve a higher default risk (i.e. Italy and Spain). The effects tend to be more persistent for 20-year govenment bonds with changes ranging from 30 basis points in Germany to 80 basis points in Spain. The Euro Stoxx market index was up by 1 to 5 percent (depending on the approach used) at the announcement dates. Another event study considered macroeconomic news for the euro area and the four largest euro area economies over a sample period from the beginning of January 2014 to the end of March 2015 (ECB, 2015b). The results confirm that the non-standard measures implemented since June 2014 have significantly lowered yields and put upward pressure on stock prices. For example, the ten-year yields for long-term sovereign bonds, declined by about 70 basis points for the euro area, and roughly 100 basis points for Italy and Spain. The authors also estimated a positive impact on the Euro Stoxx index of 3% in the case of the TLTROs (June 2014) and 1% in the case of the APP (January 2015).[26] [27] Interestingly, Altavilla et al. (2015) also considered high-frequency intraday movements of sovereign yields for the largest euro area economies on two Governing Council event dates (i.e. January 22 and March 5, 2015) in which the launch and the timing of the purchase programmes were announced. Figure 3 indicates the Governing Council press conference by the vertical dashed lines. Significant step decline in sovereign yields was found for both event dates.

[26] The impact on other important financial conditions such as exchange rates and inflation expectations are outside the scope of the present paper. For example, the APP announcements in January 2015 are estimated to have led to a depreciation of the euro by 12% against the dollar and the increase in long-term inflation expectations was estimated around 30 basis points for the one-year maturity inflation swap rates and around 20 basis points for the five-year maturity.

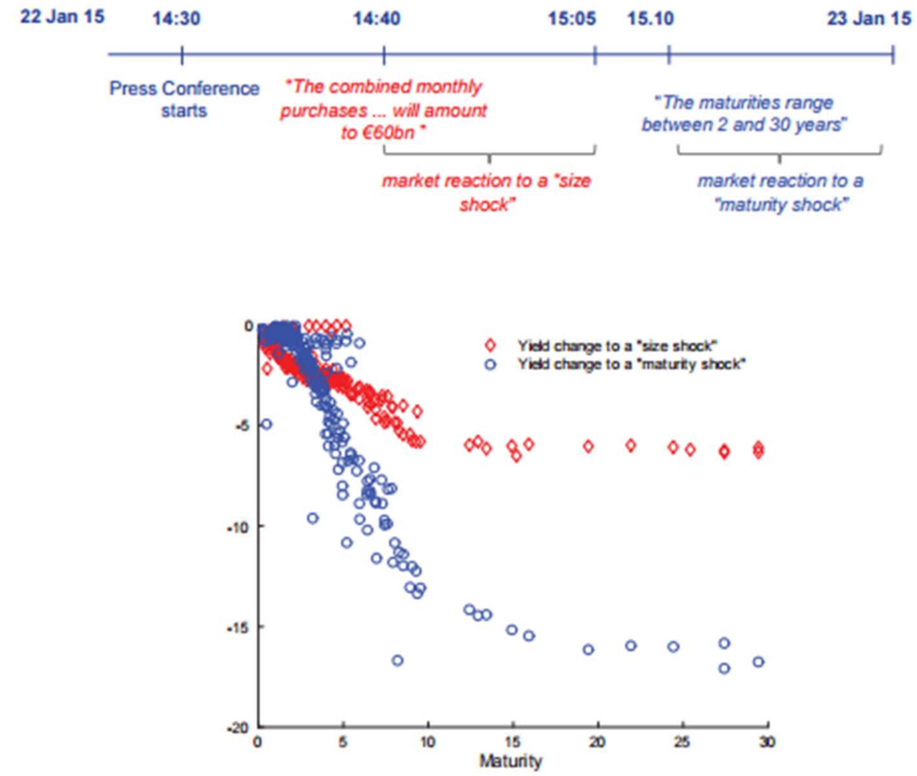
[27] Similar findings were reported for the US economy. For example, Gagnon et al. (2011) argue that the Large-Scale Asset Purchase (LSAP) program decreased longer-term interest rates on a variety of securities (including securities not purchased). Rosa (2012) show that the LSAP program had significant effects on US asset prices.



Source: Thomson Reuters. Note: The solid (blue) line represents movements on 22 January 2015 (LHS axis) and dashed (red) line represents movements on 6 March 2015 (RHS axis).

Figure 3: Intraday movements in 10-year sovereign yields of selected euro area sovereign bonds at the APP announcement dates around the ECB Press Conference (vertical lines)

Figure 4 depicts the high frequency reaction of Bund yields around the announcements of (i) the size of the APP and (ii) the maturities' range of the purchases during the 22 January Press Conference. Overall, the ECB (2015b) states that non-standard measures have helped to reach final borrowers (i.e. household and firms) through the the monetary transmission mechanism (Figure 1). This contributes to reach its inflation target below, but close to, 2% over the medium term.



Note: Each diamond/circle represents the change in an individual bond at the ISIN level.

Figure 4: High frequency reaction of Bund yields around the announcements of (i) the size of the APP and (ii) the maturities' range of the purchases during the 22 January Press Conference

In sharp contrast to the abundance of opinion pieces on the impact of monetary policy to wealth and income inequality, are the very view scientific studies on this topic. Summarising this research evidence, we cannot exclude an impact of monetary policy on inequality, but effects are likely to be modest quantitatively. There are a number of reasons why existing research has not produced clear-cut conclusions (Haldane, 2018). Studies have focussed on different (i) measures of monetary policy shocks (e.g. interest rates versus QE), (ii) methodologies (e.g. macro versus micro), and (iii) monetary policy transmission channels. These inconsistencies in research approaches can generate quite different perspectives on the impact of monetary policy on overall inequality.

The majority of these studies focuses only on the first-round effects of the drop in interest rates and increases in asset prices, given the portfolio compositions of different wealth groups. In the euro area, Adam and Tzamourani (2016) found that an unexpected decrease in the policy rate leads to disproportionately large capital gains at the top end of the wealth distributions. The richest five of households gain on average about five times as much as the rest of the population, mainly through capital gains in equity holdings. They also found that the 2012 OMT announcement had an impact similar to an unexpected 175-basis-point decrease in the policy rate. Using data from the United States Consumer Expenditures Survey, Coibion et al. (2017) found economically significant effects of surprise monetary policy changes on consumption and income inequality since 1980. The authors estimate that a one percentage point surprise increase in the fed funds rate would increase pre-tax income inequality by roughly 0.007 (measured by the Gini coefficient[28]), but only after three to five years. Effects were smaller for earnings inequality and larger for consumption and total expenditures inequality. However, it is essential to assess how large the effect of monetary policy is relative to the historical evolution in income inequality. In this case, the Gini coefficient on pre-tax income has increased 0.05 percentage points, from 0.44 to 0.49 since 1980, and is decreasing again in the recent years. Using

[28] The Gini coefficient is a measure of income inequality, which ranges from zero (perfect equality in society) to one (all income is earned by a single household).

the ECB Household Finance and Consumption Survey (HFCS) Domanski, Scatigna, and Zabai (2016) find that the main drivers of the changes in wealth inequality since the start of the Great Recession have been changes in equity valuations and changes in house prices. Because the main share of total assets in lowest quintiles of the wealth distribution is real estate, increases in house prices will tend to decrease inequality. Rising asset prices will tend to be inequality increasing since financial assets are mainly hold by the very top of the distribution. On the liability side, poorer households tend to be more leveraged, mostly in the form of housing loans. Overall, Domanski et al. (2016) find these changes in returns on assets and cost of debt have increased wealth inequality in the United Sates. In contrast, a study by O'Farrell, Rawdanowicz, and Inaba (2016), using a similar methodology, found insignificant effects. Bivens (2015) used a different approach comparing the effects of the LSAPs on inequality to the counterfactual alternative of no stimulus. The study argues that the LSAP program has reduced inequality significantly, mainly through its effects on output stabilization. Anyhow, the movements in inequality look like the product of long-term, low-frequency forces whereas monetary policy changes more frequently in response to the business cycle.

The next section presents our econometric study. First, we examine the impact of monetary policy shocks on the evolution of return on assets and cost of debt in the Eurozone. Second, we infer wealth implications for households using the ECB Household Finance and Consumption Survey (HFCS).

2 Methodology

The first part of our econometric study entails a simulation of household balance sheets over time. Following the approach of Domanski et al. (2016), the implications of changes in interest rates and asset prices on wealth inequality are simulated. The second part discusses a Vector autoregression (VAR) model to measure monetary policy shocks. An 'identification-through-heteroskedasticity' approach as proposed by Rigobon and Sack (2003,2004) and Wright (2012) was used. Finally, the impact of monetary policy shocks on household portfolio return and wealth inequality is assesed using time series analysis.

2.1 Household portfolio return and wealth inequality simulation

We start from a single point-in-time observation of the composition EU balance sheets in order to obtain country specific household wealth distributions. By doing so, we implicitly assume that portfolio composition is time-invariant while the returns on different portfolio components vary with the business cycle. This assumption can be justified by thinking of our simulation as a partial equilibrium exercise.

We proceed in three steps. First, we use data from the ECB Household Finance and Consumption Survey (HFCS) to construct *household balance sheets* for the second (q2) and the fifth quintiles (q5) of the wealth distribution in each country.[29] Five core countries (Austria, Belgium, France, Germany, the Netherlands) and five periphery countries (Greece, Ireland, Italy, Portugal, Spain) are considered. Portfolio weights are calculated in the following way:

Let $\boldsymbol{A}$ be a vector of asset classes (deposits, bonds, equities and real estate) and $\boldsymbol{L}$ a vector of liability classes (mortgage and consumer credit). Defining $a(q,t)$ and $l(q,t)$ quantities of assets and liabilities of quitile q of the wealth distribution at time t, we have that $a(q,t) = \sum_{i=1}^{A} a(q,i,t)$ and that $l(q,t) = \sum_{j=1}^{L} l(q,j,t)$. The relative weights of different asset classes and liabilities on households' balance sheets are given by $\delta(q,i,t)$ and $\delta(q,j,t)$, respectively. Let

$$\delta(q,i,t) = a(q,i,t)/a(q,t) \tag{2}$$

denote the relative weight of asset i in the asset portfolio of quitile q at time t, with $\sum_{i=1}^{A} \delta(q,i,t) = 1$. Similarly, let

$$\delta(q,j,t) = l(q,j,t)/l(q,t) \tag{3}$$

denote the relative weight of liability j in the liability portfolio of quitile q at time t, with $\sum_{j=1}^{L} \delta(q,j,t) = 1$.[30] A breakdown of balance sheets for the selected quintiles is shown in Figure 5 and Figure 6.

[29] See further. We use the q5/q2 ratio as a measure of inequality instead of the q5/q1 ratio because there are quarters in which q1 has negative wealth for some quarters in our sample. In that case, the ratio is negative and no longer a meaningful measure of inequality.

[30] Note that we make the assumption of time-invariant composition of household balance sheets, which corresponds to fixed relative weights of assets and liabilities at different quintiles of the wealth distribution. Therefore, $\delta(q,i,t)_{i=1}^{A} \equiv \delta(q,i)_{i=1}^{A}$ and $\delta(q,j,t)_{j=1}^{L} \equiv \delta(q,j)_{j=1}^{L}$.

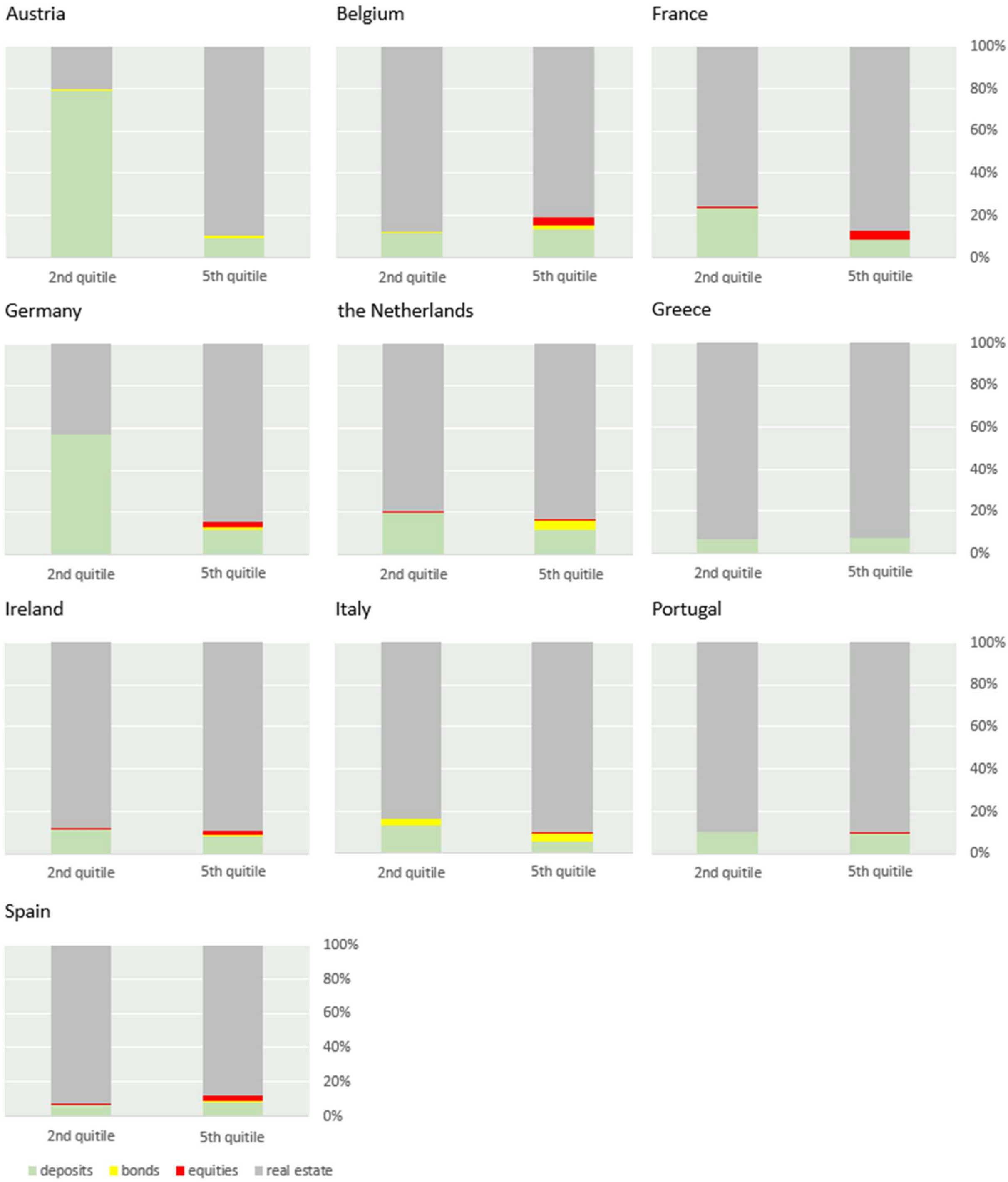


Figure 5: Household balance sheet asset composition

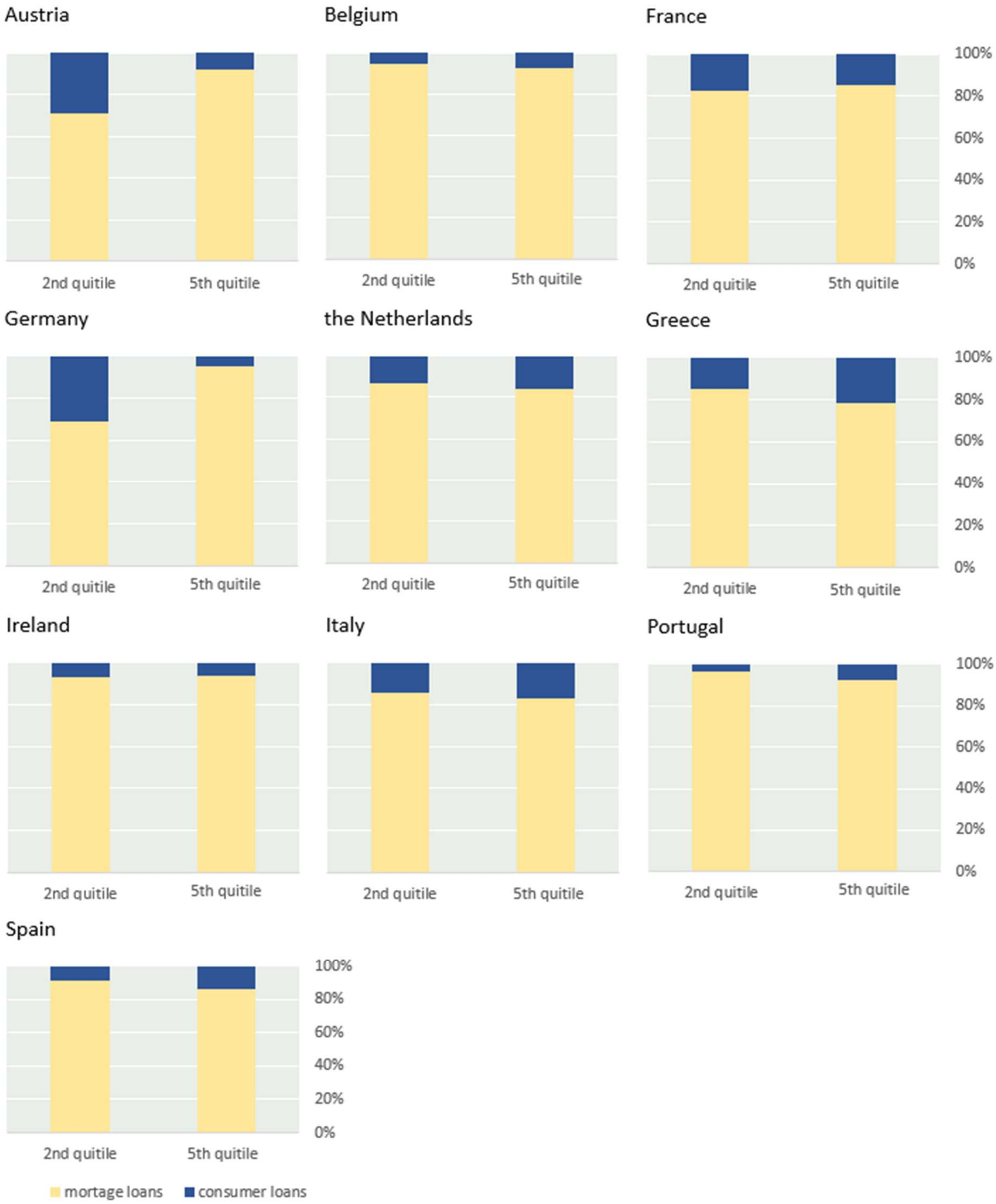


Figure 6: Household balance sheet liability composition

As a second step, we compute the growth rate of household's portfolio. We assume that the growth rate of assets is equal to the *return on assets*, and that the growth rate of liabilities is simply the *cost of debt*.[31] Thereby we assume a strong degree of home bias in the portfolio composition such that all cash flows are reinvested in the same asset. We use European market data from October 2008 to December 2017 (Table 1) to construct quarterly time series of asset returns, $\left[\left(\frac{da(i,t)}{dt}\right)_{i=1}^{A}\right]_{t=1}^{T}$, and lending rates $\left[\left(\frac{dl(j,t)}{dt}\right)_{j=1}^{L}\right]_{t=1}^{T}$. The net growth rate of assets $\frac{da(q,t)}{dt}$ is simply a linear combination of the returns on assets,

$$\frac{da(q,t)}{dt} = \sum_{i=1}^{A} \delta(q,i) \, . \frac{da(i,t)}{dt} \tag{4}$$

, whereas the net growth rate of liabilities is a linear combination of the underlying cost of debt,

$$\frac{dl(q,t)}{dt} = \sum_{j=1}^{L} \delta(q,i) \, . \frac{dl(j,t)}{dt} \tag{5}$$

Finally, the quarterly time series of average household portfolio return (r) for both the second quintile of the wealth distribution (q2) and the fifth quintile (q5) is calculated by applying the formula

$$r(q,t) = \frac{da(q,t)}{dt} - \frac{dl(q,t)}{dt} \tag{6}$$

Figure 7 displays these quarterly household portfolio return time series for the different countries.

[31] This simplification entails that households do not pay down debt, but issue only one-period debt and roll over both principal amount and interest payments in every period. It was not possible to calculate compounded changes in the market value of liabilities as detailed information on the maturity and type of loans is not available in the HFCS survey.

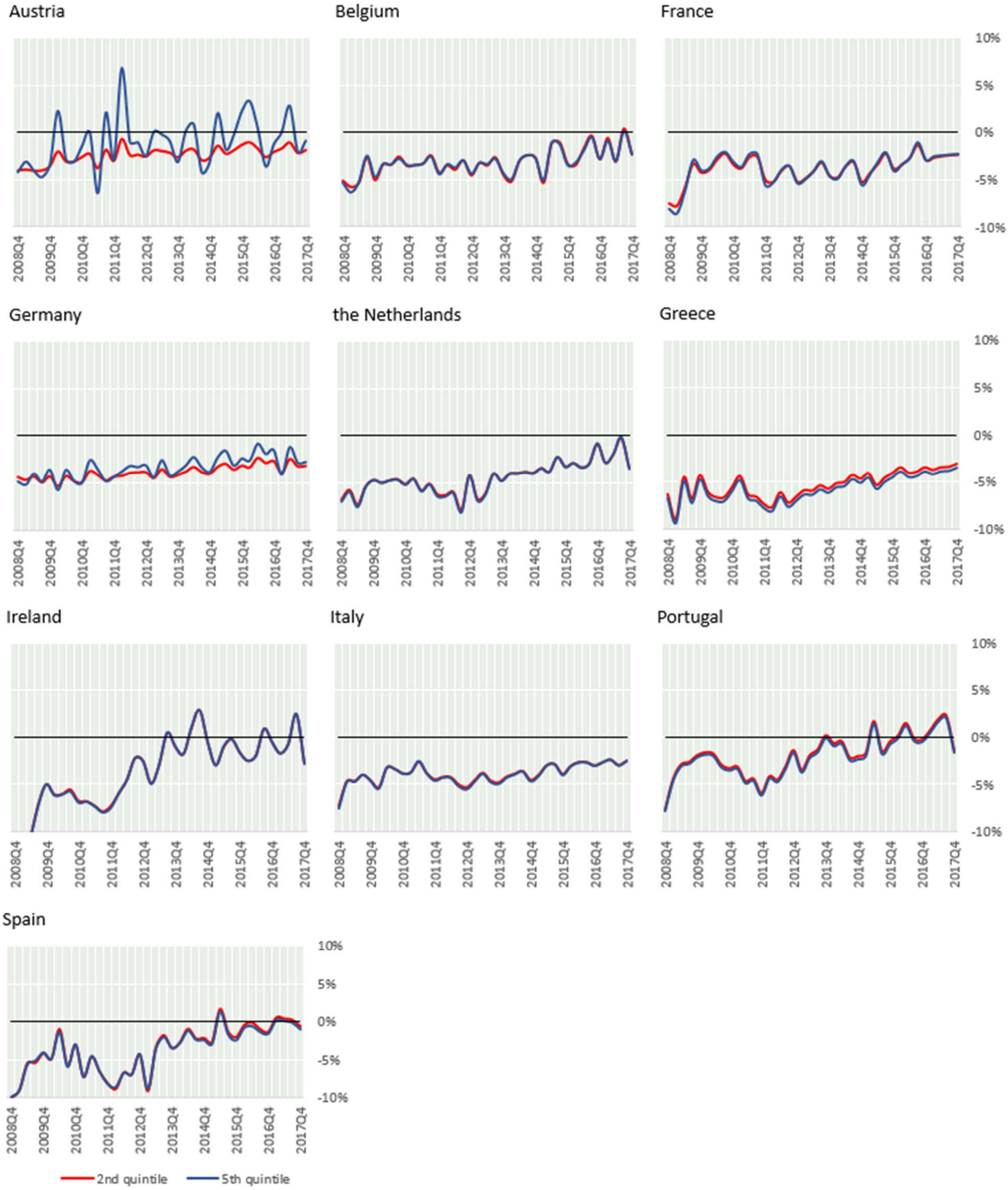


Figure 7: Quarterly household portfolio return

Balance sheet item	Variable	Source
Assets		
Deposits	Average quarterly deposit rate (overnight)	Statistical Data Warehouse[1]
Bonds	5 year domestic government bond yield	Thomson Reuters Datastream
Equities	MSCI country index	Thomson Reuters Datastream
Real estate	Residential property price index	Bank for International Settlements (BIS)[2]
Liabilities		
Mortgage loans	Average quarterly loan rate-house purchase (outstading amounts)	Statistical Data Warehouse[3]
Consumer loans	Average quarterly loan rate- consumer loans (outstanding amounts)	Statistical Data Warehouse[3]

[1]https://sdw.ecb.europa.eu/browse.do?node=9691394
[2]https://www.bis.org/statistics/pp_detailed.htm?m=6%7C288%7C593
[3]https://sdw.ecb.europa.eu/browse.do?node=9691393

Table 1: Return on assets and cost of debt used in the simulation

The third step is to calculate our measure of wealth inequality. Let $w(q,t)$ denote the wealth of quitile q of the wealth distribution at time t, so that $w(q,t) = a(q,t) - l(q,t)$.[32] The ratio

$$w(5,t)/w(2,t) \tag{7}$$

[32] Note that household assets grow following quarterly capitalization expressed by $a(q,i,t+1) = a(q,i,t)\ .(1+\ \Delta a(q,i,t+1)$ while we assume that households issue only one-period debt and re-finance in the next period (see footnote 31).

is used as a measure of wealth inequality. By this metric, inequality increases when q5 accumulates wealth faster than q2. The quarterly time series of wealth inequality is shown in Figure 8.

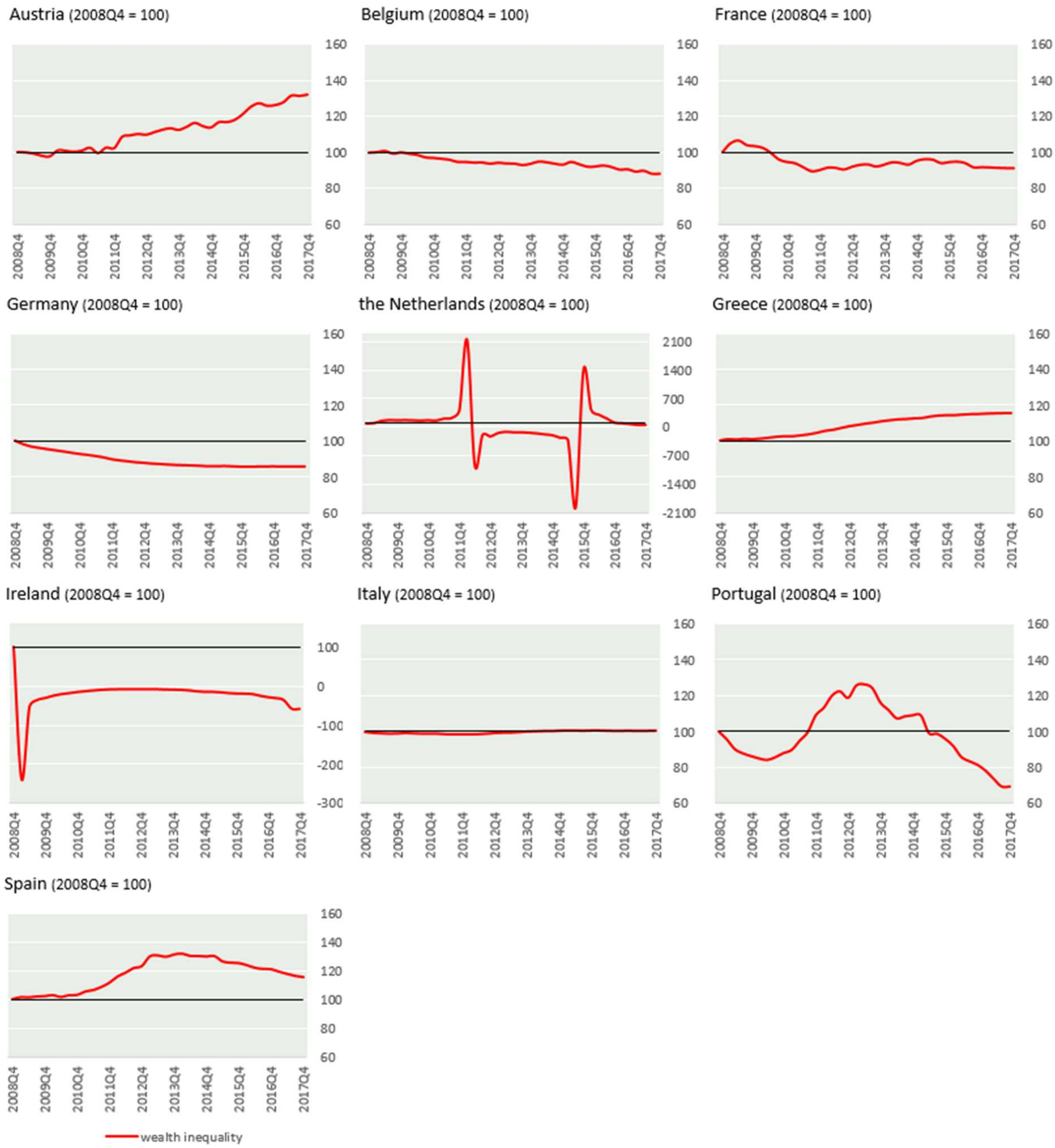


Figure 8: Wealth inequality quarterly time series

2.2 Monetary policy shocks: a vector autoregression (VAR) model

2.2.1 Identification-through-heteroskedasticity

We use an 'identification-through-heteroskedasticity' approach as proposed by Rigobon and Sack (2003, 2004) to quantify monetary policy shocks. The idea is that these shocks will be more volatile on days on which there are monetary policy announcements. At the same time, the volatility of any other structural shocks is assumed to be time-invariant. So we do not assume the absence of other shocks on announcement days, but only that they become reltively less important compared to the monetary policy shock. An advantage of this approach is that it does not require to define the appropriate length of the event window, as is necessary in event studies. For example, an interest rate hike could have been largely anticipated by the market. Consequently, the market reaction on the day of the event would be rather modest because the monetary tightening was already priced in. The same applies to the ECB's non-standard measures. The announcements of both the TLTROs (June 2014) and the expanded APP (January 2015) were largely expected by financial markets, following a number of official ECB communications which indicated the possibility of further non-standard measures being introduced. According to theory, efficient markets should price in the impact of a policy measure in anticipation of its actual implementation. This reasoning implies that asset prices should react to TLTRO and APP-related news in anticipation of the official announcement itself, as market participants revise the likelihood of the programmes being introduced and their expected size. Moreover, in a zero lower bound enivironment the short-term interest rate becomes an invalid instrument to evaluate changes in the monetary policy stance. Alternative measures have therefore been proposed, including the size of the bank balancee sheet (Gambacorta, Hofmann, & Peersman, 2014), the interbank interest rate (Gambacorta & Shin, 2016), long-term interst rates (Gilchrist, Lopez-Salido, & Zakrajsek, 2015), or the term spread (Baumeister & Benati, 2013). Wright (2012) further developed the 'identification-through-heteroskedasticity' approach so that it does not require the definition of a specific policy instrument.

Lamers et al. (2016) construct such a monetary policy shock time series for both the Euro Area and the United States by modelling a set of relevant financial variables in a structural vector autoregression model (VAR) at daily frequency. The VAR models the stochastic process that generates the time series of a vector of endogenous variables. Table 2 presents the financial market variables used to estimate their VAR model for the Eurozone. Following Rogers et al. (2014), those 6 variables that are expected to respond most to a monetary policy shock were selected.

Euro Area financial market variables
10Y German bund yield
2Y German bund yield
5Y, 5Y inflation expectation rate
MSCI Europe
VSTOXX
Spanish 5Y CDS spread

Table 2: Financial market variables used in the VAR model (source: Datastream)

The identification of the monetary policy shock also requires a set of announcement dates. The authors include all ECB announcements pertaining to interest rates, asset purchase programs, long-term refinancing operations, central bank funding conditions, forward guidance and new swap arrangements with other central banks. A detailed overview of specific dates and announcements until the end of 2015 is provided by Lamers et al. (2016) (see Appendix 3).

2.2.2 VAR model

We mimic the Lamers et al. (2016) specification to estimate the following structural VAR model[33] at quartely frequency from October 2008 to December 2017:

[33] VAR model estimation was conducted by E. Meuleman. Simulations and time series analysis were conducted by B. De Clercq.

$$\boldsymbol{Y}_t = \boldsymbol{A}_1 \boldsymbol{Y}_{t-1} + \cdots + \boldsymbol{A}_p \boldsymbol{Y}_{t-p} + \boldsymbol{R}\boldsymbol{\nu}_t \tag{8}$$

where $\boldsymbol{Y}_t =$ 6-dimensional column vector of endogenous financial market variables

$p =$ the number of lags (i.e. 36 quarters from October 2008 to December 2017)

$\boldsymbol{A_1}, \boldsymbol{A_p}$ *and* $\boldsymbol{R} = 6 \times 6$ time-invariant parameter matrices

$\boldsymbol{\nu}_t =$ 6-dimensional column vector of orthogonal structural innovations with mean zero

$\boldsymbol{R}\boldsymbol{\nu}_t = \boldsymbol{\varepsilon}_t$ the reduced-form residuals corresponding to this structural model

For example, ε_{1t} could be an oil price shock on 5Y, 5Y inflation expectations and ε_{2t} could be a shock on the 2Y German bund yield independent from the oil price shock, while the relation between the 2Y German bund yield and 5Y, 5Y inflation expectations is captured by the time-invariant parameter matrices.

In this model we asume that the first[34] structural shock (i.e. the monetary policy shock) changes on announcement days, while the other structural innovations are time-invariant (homoskedastic), so that:

$$Var(\nu_t) = \boldsymbol{\Omega_t} = \begin{cases} \Omega^{(0)} = diag\ (\omega_1, \ldots, \omega_6) & \text{if } \textit{no announcement} \\ \Omega^{(1)} = diag\ (\omega_1^*, \ldots, \omega_6) & \text{if } \textit{announcement} \end{cases} \tag{9}$$

[34] Ordening the monetary policy shock first is purely for conveniene and does not affect estimation results.

As long as the covariance matrix of the reduced form errors V_t changes on announcement days, these assumptions suffice to uniquely identify the first column of $\boldsymbol{R}$ and the structural monetary policy shock. We normalize the monetary policy shock by fixing the response on impact of one of the included variables, so that a one-unit monetary policy shock corresponds to a decrease in the Spanish CDS spread with 5% upon impact. The model defined by equations (8) and (9) is estimated following the iterative estimation procedure of Lanne and Lütkepohl (2008) as described in the study by Lamers et al. (2016) (see Appendix 4).

2.2.3 VAR results

The analysis supports the 'identification-through-heteroskedasticity' approach as the standard deviation of the structural monetary shock is found to more than double on announcement days. Lamers et al. (2016) provide further insight into the shock by presenting impulse response functions to a unit monetary policy shock (Figure 9).

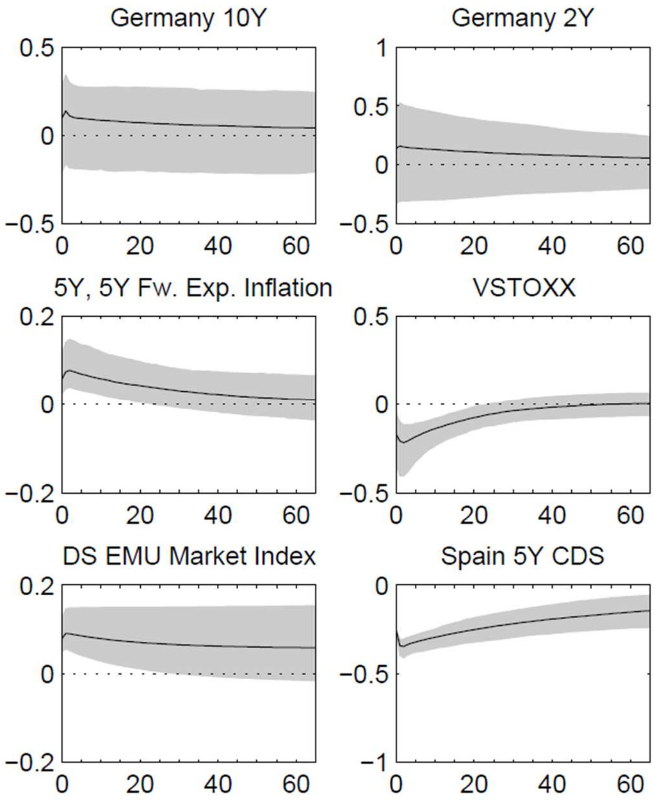


Figure 9: Impulse response function of the variables to a unit monetary policy shock. Gray areas represent 68% confidence intervals that are obtained through a stationary bootstrap with expected block length 10 for non-announcement days. Announcement day residuals are bootstrapped separately. The horizontal axis represents the horizon of the impulse response function in working days, i.e. the IRF's are plotted for a horizon of one quarter (Lamers et al., 2016).

The authors find that an accomodative monetary policy shock increases long-term inflations expectations (5Y, 5Y inflation expectation rate) and the value of the stock market index (MSCI Europe), while decreasing market-wide implied volatility (VSTOXX). A monetary policy shock also has a negative effect on sovereign stress (Spanish 5Y CDS spread) across the whole horizon.[35] There was no significant impact on the yields of medium- (2Y) and long-term (10Y) German bunds. The latter is possibly due to a flight-

[35] Note that the negative contemporaneous impact on sovereign stress (Spanish 5Y CDS spread) is a consequence of our identification strategy.

to-safety scenario in wich monetary easing lowers the demand for safe assets such as German bunds (Altavilla, Giannone, & Lenza, 2014; Rogers et al., 2014).

Figure 10 plots the time series for the cumulative monetary policy shock for the the Eurozone. A rise in the cummulative series corresponds to an accomodative monetary policy shock relative to the prevailing financial market conditions. The series in itself reflects the stance of monetary policy.

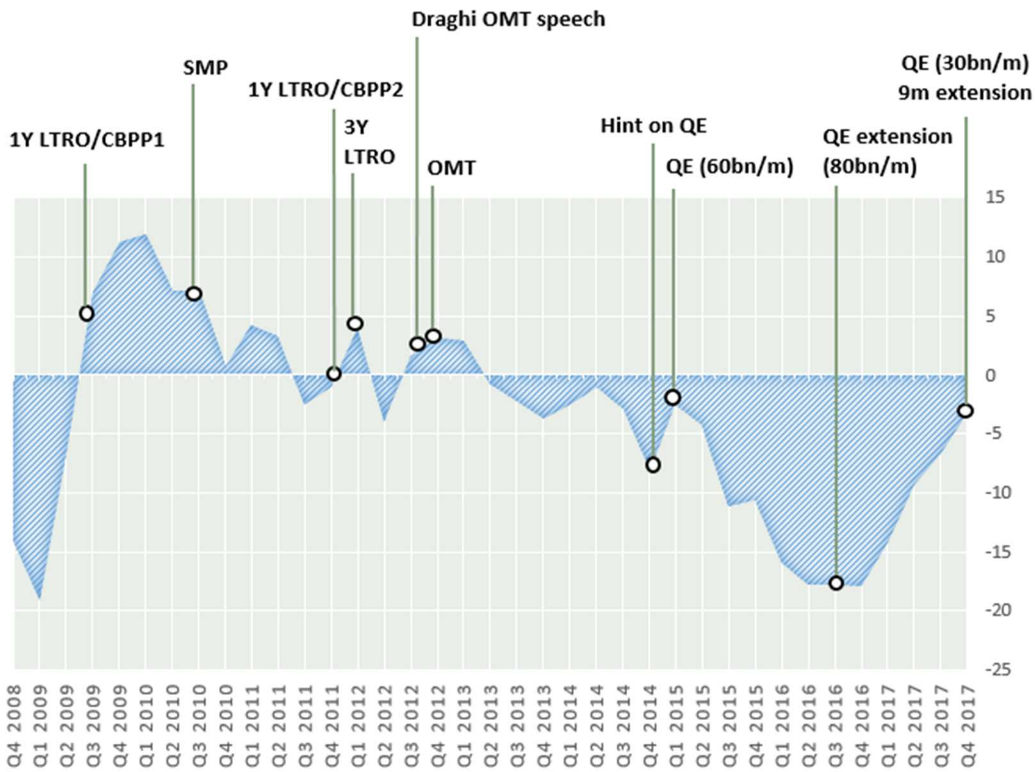


Figure 10: Quarterly cummulative monetary policy shock for the Eurozone

In general, Figure 10 shows that the shocks are able to capture important monetary policy measures, as well as the anticipation of some of these measures. The announcement of the one-year longer-term refinancing operations (LTRO) and covered bonds purchase programme (CBPP1) in May 2009 is among the largest accomodative shock and can therefore be considered a suprise to financial markets. On the other hand, the OMT announcement of Septemeber 2012 was largely anticipated following ECB president Mario Dragi's speech[36] in London on July 26, 2012 in which he made the momentous remark: *"Within our mandate, the ECB is ready to do whathever it takes to preserve the euro. And believe me, it will be enough."* Although the ECB never ended up using this program, the promise was enough to calm investors and to restore bond yields across the Eurozone. Also, the QE announcement of January 2015 appears to have been largely anticipated following preceding speeches by the ECB president, in which he alluded on the implementation of additional unconventional monetary policy measures. An overview of these monthly purchases is presented in Figure 11.

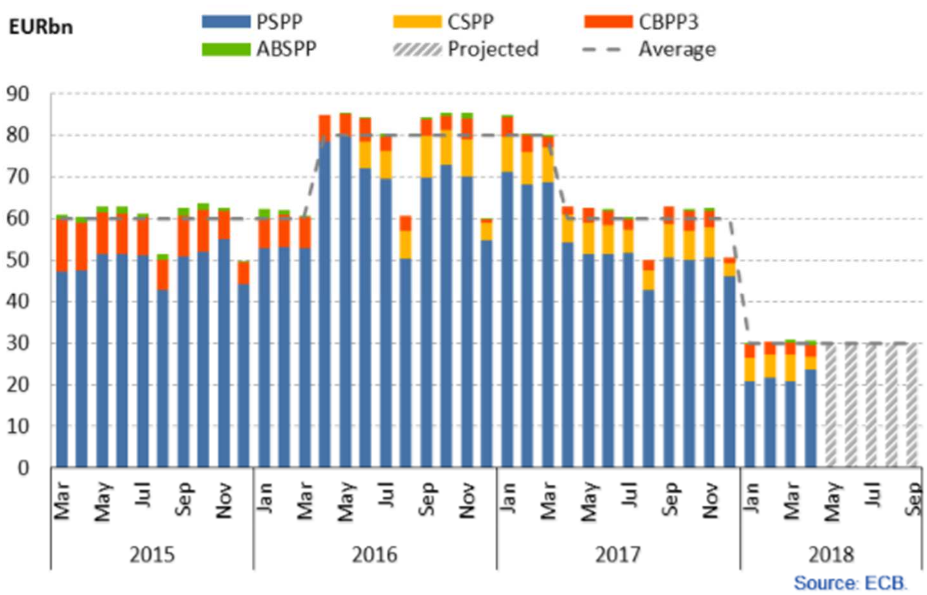


Figure 11: ECB APP monthly net purchases (EURbn), by programme

[36] https://www.youtube.com/watch?v=hMBI50FXDps&feature=youtu.be&t=7m3s

On 26 October 2017 the ECB's Governing Council decided that net purchases would be reduced from the monthly pace of €60 billion to the new monthly pace of €30 billion from January 2018 until the end of September 2018. Importantly, the 9 month extension is open ended because inflation remains too low.[37] In line with our quarterly monetary policy shock series, market analists perceived the ECB decision to be accomodative (De Vijlder, 2017). Financial markets reacted positively with a slight decline in bond yields and the euro, and a limited rise in the Euro Stoxx 50 index (Figure 12). So, what could have been interpreted as a hawkish reduction in the pace of purchases, ended up being considered dovish.

Figure 12: Intraday market evolution at 26 October 2017

In sum, the inspection of the monetary policy shock series further supports the appropriateness of our VAR identification strategy.

[37] Or as the ECB states it*: "From January 2018 the net asset purchases are intended to continue at a monthly pace of €30 billion until the end of September 2018, or beyond, if necessary, and in any case until the Governing Council sees a sustained adjustment in the path of inflation consistent with its inflation aim."* (source: https://www.ecb.europa.eu/press/pr/date/2017/html/ecb.mp171026.en.html)

2.3 Time series analysis

2.3.1 A basic static model

The impact of monetary policy shocks on household portfolio return and wealth inequality is assesed in each country using a set of three similar time series models (one for each dependent variable, i.e. q2 household portfolio return, q5 household portfolio return, and wealth inequality):

$$\boldsymbol{y} = \boldsymbol{X}\hat{\boldsymbol{\beta}} + \hat{\boldsymbol{\varepsilon}} \tag{10}$$

where $\boldsymbol{y} = 37 \times 1$ column vector of 37 quarterly observations on the dependent variable Y from October 2008 to December 2017

$\boldsymbol{X} = 37 \times 2$ data matrix giving 37 observations on the monetary policy shock variable X_2 and a column of 37 1's

$\hat{\boldsymbol{\beta}} = 2 \times 1$ column vector of the OLS estimates[38] of the regression coefficients

$\hat{\boldsymbol{\varepsilon}} = 37 \times 1$ column vector of 37 error terms

So that the system of equations can be written as follows:

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_{37} \end{bmatrix} = \begin{bmatrix} 1 & X_{21} \\ 1 & X_{22} \\ \vdots & \vdots \\ 1 & X_{237} \end{bmatrix} \begin{bmatrix} \hat{\beta}_1 \\ \hat{\beta}_2 \end{bmatrix} + \begin{bmatrix} \hat{\boldsymbol{\varepsilon}}_1 \\ \hat{\boldsymbol{\varepsilon}}_2 \\ \vdots \\ \hat{\boldsymbol{\varepsilon}}_{37} \end{bmatrix} \tag{11}$$

[38] An estimator is a method (formula) to estimate a population parameter using the available information in the sample. Ordinary Least Squares (OLS) is an estimation method that can be used for observed data. The estimates are stochastic (i.e. vary over repeated samples) but approximate the true population parameter well under certain assumptions. If all statistical properties of the OLS estimator hold (Gauss-Markov assumptions), then the OLS estimator is BLUE (best linear unbiased estimator).

where $\hat{\beta}_1$ = the OLS estimate of the intercept

$\hat{\beta}_2$ = the OLS estimate of the partial slope coefficient for the monetary policy shock variable X_2

The OLS estimator is biased[39] and consistent[40] as the observations on the monetary policy shock variable X_2 and the error terms $\hat{\varepsilon}$ are contemporaneously uncorrelated (error terms $\hat{\varepsilon}$ are white noise[41]) but not completely independent. Inference is possible within the static time series model described under equation (10) on the condition that Y and X_2 are stationary series.[42] Stationarity diagnostics for the monetary policy shocks series X_2 are reported in Appendix 5. We interpret the unit root tests in line with the startionarity diagnostics and consider the monetary policy shock series X_2 to be non-stationary. Therefore, the series was transformed to stationary data by taking first differences.[43] Other time series included in model (10) were evaluated analogously (see Table 3 for an overview).

[39] An estimator is unbiased when the expected value over repeated samples equals the true population parameter, $\left(\hat{\beta}\right) = \beta$.

[40] An estimator is consistent when the standard error of the estimate se$\left(\hat{\beta}\right)$ (i.e. the standard deviation σ of the sampling distribution of the estimate) equals zero when the sample size of the repeated samples goes to infinity (∞). Remember the estimates are stochastic (see footnote 34). However, in practice you only have one sample so it is not possible to calculate se$\left(\hat{\beta}\right)$ directly so it will have to be estimated by the OLS algorithm, $\widehat{se}\left(\hat{\beta}\right)$.

[41] A white noise process is a data generating process that is serially uncorrelated, $cov(\varepsilon_t, \varepsilon_{t-k}) = 0$, with a constant mean μ and variance σ^2.

[42] A series is stationary when it has a time-invariant mean $\mu = E(Y_t)$, variance $\sigma^2 = E(Y_t - \mu)^2$, and covariance $E(Y_t - \mu)(Y_{t-k} - \mu)$.

[43] If a series needs to be differenced one time before it becomes stationary, it is said to be integrated of order 1.

Country	2nd quintile return	5th quintile return	wealth inequality
Austria	stationary	stationary	non-stationary
Belgium	stationary	stationary	stationary
France	non-stationary	non-stationary	stationary
Germany	stationary	stationary	non-stationary
the Netherlands	stationary	stationary	stationary
Greece	non-stationary	non-stationary	non-stationary
Ireland	stationary	stationary	non-stationary
Italy	non-stationary	non-stationary	non-stationary
Portugal	stationary	stationary	non-stationary
Spain	stationary	stationary	stationary

Table 3: Stationarity diagnostics for the dependent variables

2.3.2 Dynamic modelling: autoregressive distributed lag (ADL) models

Exploratory analysis indicate that the basic static model described under equation (10) is not an adequate model specification to measure the impact of monetary policy shocks:

$$\boldsymbol{y} = \boldsymbol{X}\hat{\boldsymbol{\beta}} + \hat{\boldsymbol{\varepsilon}}$$

Figure 13 illustrates the case using the data on q2 portfolio return in Belgium. With an R^2 of 1.3%, the actual time series for q2 portfolio return in Belgium is almost fully captured by the residual error term $\hat{\boldsymbol{\varepsilon}}$ instead of the variables $\boldsymbol{X}$ in the model. The correlogram also shows a clear structure in the error terms indicating that the basic static model (10) is not rich enough to caputure all of the dynamics in the Belgian q2 portfolio return series (see Appendix 6).

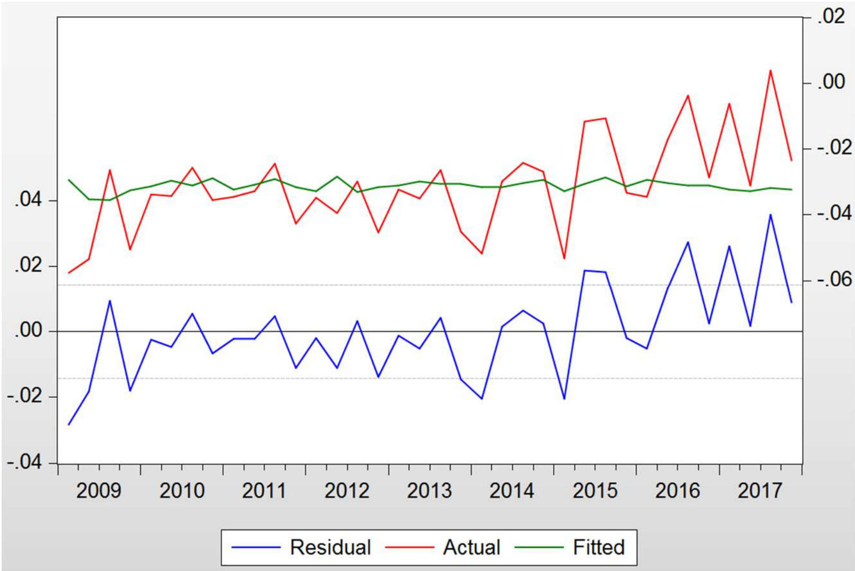


Figure 13: Static time series model for Belgian q2 portfolio return

This shouldn't come as a suprise. In reality, the full-scale market reaction to changing monetary policy is rarely instantaneous. Figure 1 already illustrated the complexity of monetary transmission channels. Moreover, monetary transmission to markets and households might be slow for a whole range of psychological, technological and institutional reasons.[44] Adjustment to new monetary conditions follows a dynamic process so that $\boldsymbol{y}$ responds to $\boldsymbol{X}$ with a lapse of time. Therefore, we extend the basic static model (10) with lagged values from the dependent variable Y, and both current and lagged values of the monetary policy shock variable X_2. First, the basic static model (10) is rewritten into scalar algebra notation (12) wich is less compact admittedly, but more convenient to distinguish between parameters

[44] See for example, Keith M. Carlson, "The Lag from Money to Prices", Federal Reserve Bank of St. Louis, October 1980.

linked to the dependent (α-parameters) and the independent variables (β-parameters):

$$\boldsymbol{y} = \boldsymbol{X}\hat{\boldsymbol{\beta}} + \hat{\boldsymbol{\varepsilon}}$$

$$y_t = \hat{\alpha}_0 + \hat{\beta}_0 x_t + \hat{\varepsilon}_t \tag{12}$$

A simple extension to an autoregressive distributed lag (ADL) model is

$$y_t = \hat{\alpha}_0 + \hat{\alpha}_1 y_{t-1} + \hat{\beta}_0 x_t + \hat{\beta}_1 x_{t-1} + \hat{\varepsilon}_t \tag{13}$$

where $\hat{\alpha}_0$ = the OLS estimate of the intercept

$\hat{\alpha}_1$ = the OLS estimate of the partial slope coefficient for the ***short-run dynamic*** impact of 1 lag of the dependent variable (i.e. the dependent value from the previous quarter)

$\hat{\beta}_0$ = the OLS estimate of the partial slope coefficient for the ***short-run contemporaneous*** impact of monetary policy shock x_t

$\hat{\beta}_1$ = the OLS estimate of the partial slope coefficient for the ***short-run dynamic*** impact of monetary policy shock x_t (i.e. the monetary policy shock from the previous quarter)

$\frac{\hat{\beta}_1+\hat{\beta}_0}{1-\hat{\alpha}_1}$ = the OLS estimate for the ***long-run*** impact[45] of the monetary policy shock x_t

$\hat{\varepsilon}_t$ = the OLS estimate of the error term

The OLS estimator is biased and consistent as the observations on the monetary policy shock variable x_t and the error terms $\hat{\varepsilon}_t$ are contemporaneously uncorrelated (error terms $\hat{\varepsilon}_t$ are white noise) but not completely independent. Inference is possible within the ADL(1,1) model described under equation (13) on the condition that y_t and x_t are stationay series. Stationarity diagnostics are reported in Appendix 5. In case of non-stationarity, series are transformed into stationary data by taking first differences.[46]

Let us return to our illustration using the Belgian data on q2 portfolio return. If we re-estimate the model by employing an ADL approach, the ADL(4,3) specification seems more adequate to measure the impact of monetary policy shocks (full model estimates not shown). Now, the actual time series for q2 portfolio return in Belgium is explained by the variables in the model (i.e. lagged values of q2 return and both current and lagged values for the monetary policy shock) instead of by the residual error term $\hat{\varepsilon}_t$ (Figure 14).

[45] The more persistence ($\widehat{\alpha_1}$) there is in the series, the stronger the long-run impact will be compared to the short-run impact.

[46] Note that inference is only possible within the ADL_{diff} model when there is no coitegration between the time series. Coitegration means that there is a common trends between the series, indicating a long-term relation between the non-stationay time series (Johansen, 1991). Therefore, you would make a specification error by omitting the error correction term in case there is cointegration. We found no evidence for cointegration (see Appendix 7).

Consequently, the R^2 amounts 64.4% compared to only 1.3% in the basic static model. The correlogram shows no patterns in the error terms indicating that the ADL(4,3) model is rich enough to caputure all of the dynamics in the Belgian q2 portfolio return series (see Appendix 6).

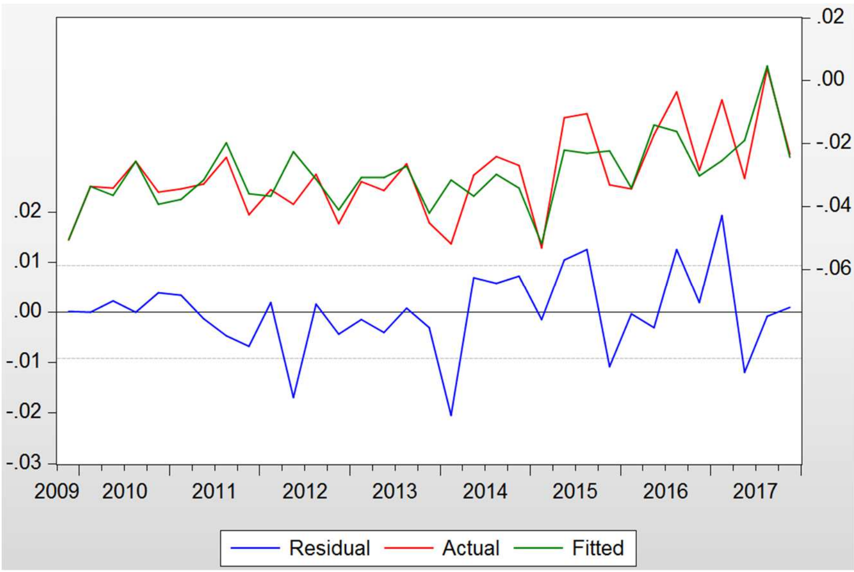


Figure 14: ADL(4,3) time series model for Belgian q2 portfolio return

In order to ensure comparability between country-specific parameter estimates, we use fixed lag ADL models. First, a set of three ADL(0,1) models was estimated in each country (one for each dependent variable, i.e. q2 household portfolio return, q5 household portfolio return, and wealth inequality):

$$y_t = \hat{\alpha}_0 + \hat{\beta}_1 x_{t-1} + \hat{\varepsilon}_t \tag{14}$$

The choice for the ADL(0,1) model is based on the following assumptions:

Modelling assumption 1: households react to the monetary policy stance from the previous quarter (one-quarter lagged impact)

The first assumption is captured by the β_1 parameter.

Second, a set of three ADL(1,4) models was estimated in each country:

$$y_t = \hat{\alpha}_0 + \hat{\alpha}_1 y_{t-1} + \hat{\beta}_0 x_t + \hat{\beta}_1 x_{t-1} + \hat{\beta}_2 x_{t-2} + \hat{\beta}_3 x_{t-3} + \hat{\beta}_4 x_{t-4} + \hat{\varepsilon}_t \tag{15}$$

The choice for the ADL(1,4) model is based on the following assumptions:

Modelling assumption 2: the transmission of monetary policy shocks to households is a slow process with a possible one-year lagged impact (4 quarters)

Modelling assumption 3: household portfolio return and wealth inequality from the previous quarter is highly predictive for current household portfolio return and wealth inequality

The β_0, β_1, β_2, β_3 and β_4 parameters represent the second assumption, and the third assumption is represented by autogregressive parameter α_1. Model estimates are shown in the Results section.

2.3.3 Panel model

Finally, we estimate a panel model for each dependent variable as the data both has a cross-sectional (i.e. 10 countries) as well as a time dimension (i.e. 37 quarters). The main advantage of this approach is that it increases the efficiency of our parameter estimates due to the increased sample size (10 $\times$ 37 = 370 observations). In general terms, the panel model can be specified as:

$$y_{it} = \hat{\alpha}_{0,it} + \hat{\beta}_{1,it} x_{it-1} + \hat{\varepsilon}_{it} \tag{16}$$

with i = the cross-section unit (i.e. 10 Eurozone countries)

t = time (i.e. 37 quarters from October 2008 to December 2017)

$\hat{\alpha}_{0,it}$ = the estimate of the intercept for unit i in period t

$\hat{\beta}_{1,it}$ = the estimate of the partial slope coefficient for the impact of a monetary policy shock x_{it-1} for unit i in period t (i.e. the monetary policy shock from the previous quarter)

$\hat{\varepsilon}_{it}$ = the estimate of the error term for unit i in period t

However, it is not feasible to estimate this model as it allows the estimates to be different for each country at every point in time. This would require too much coefficients to be estimated in one model. Therefore, it is important to put more structure on the coefficients which implies deciding which estimator is most appropriate: the fixed effects estimator or the random effects estimator. From an economic point of view, it makes sense to use the random effects estimator if the cross-sectional units can be viewed as random draws from some distribution. Since we use a selection of Eurozone core and periphery countries, this might not be the case. From an econometric point of view, the distinction depends on the consistency of the estimator. More specifically, the choice of the estimator depends on whether the cross-section effects are correlated with the regressors or not. In case of non-zero correlation the random effects estimator is inconsistent while the fixed effects estimator will still be consistent. Noteworthy, in this study we can a priori assume zero correlation between the cross-section effects and the regressors as the value of the monetary policy shock variable is identical for each Eurozone country. After all, the currency zone has only one monetary policy so the monetary policy stance x_{it-1} is not correlated with fixed country differences $\hat{\alpha}_{0,i}$. Therefore, the random effects estimator is preferable (from an efficiency point of view) as it uses both the between and the within variation (i.e. a weighted average of the between and within estimator).[47] Equation (16) can be re-written as a random effects model:

[47] The within estimator $\hat{\beta}_{1,within}$ or fixed effects estimator is estimated from the variance within cross-sections. The between estimator $\hat{\beta}_{1,between}$ is estimated from the variance between cross-sections (i.e. OLS estimator in the model for country means). Consequently, in this case the random effects estimator (i.e. a weighted average of $\hat{\beta}_{1,between}$ and $\hat{\beta}_{1,within}$) equals the fixed effects estimator as the between estimator equals zero (remeber that monetary policy does not vary between Eurozone countries). This can be verified using the Hauseman test which compares the fixed effects and random effects estimators. A significant difference between the two estimators indicates that the null hypothesis of zero correlation between x_{it-1} and $\hat{\alpha}_{0,i}$ is unlikely to hold. In our case, the Hauseman test statistic equals zero indicating that we would reject a correct null hypothesis in 100 % of the cases.

Pooled OLS (i.e. ignoring the panel structure of the data) is also a weighted average of the between and the within estimator but it uses weights that, in general, lead to an inefficient estimator.

$$y_{it} = \hat{\mu} \ + \hat{\beta}_1 x_{it-1} + \hat{\mu}_{it} \tag{17}$$

where $\hat{\mu}$ = the estimate of the intercept (constant over countries and time)

$\hat{\beta}_1$ = the estimate of the partial slope coefficient for the impact of a monetary policy shock x_{it-1} (constant over countries and time)

$\hat{\mu}_{it} = \hat{\alpha}_{0,i} + \hat{\varepsilon}_{it}$

= the estimate of the error term for unit i in period t

The intercept still varies over countries in the random effects model (17) but the crucial difference is that it is now treated as a part of the error term $\hat{\mu}_{it}$. The latter consists of two components: a country-specific component $\hat{\alpha}_{0,i}$ that does not vary over time, and an erratic component $\hat{\varepsilon}_{it}$ that is uncorrelated over time. As $\hat{\alpha}_{0,i}$ is now part of the error term $\hat{\mu}_{it}$, it should be be uncorrelated with the independent variables. Although we already explained that we can a priori assume zero correlation between the cross-section effects $\hat{\alpha}_{0,i}$ and the regressors x_{it-1}, there will still be some degree of autocorrelation in the error term $\hat{\mu}_{it}$ as $\hat{\alpha}_{0,i}$ is affecting $\hat{\mu}_{it}$ for each country. Therefore, the standard errors for the OLS estimator are incorrent and thus the more efficient Generalized Least Squares (GLS) estimator is used.

3 Results

3.1 Household portfolio return and wealth inequality simulation

The composition of household balance sheets varies considerably both within and between Eurozone countries. Figure 5 shows a breakdown of assets for the second and fifth quintiles of the net wealth distribution according to national HFCS survey data. Within countries, portfolios at the top of the wealth distribution (q5) are more diversified including in particular higher shares of bonds and equities. Household portfolios at the bottom (q2) are rather concentrated consisting mainly of deposits and real estate. Between countries, especially Austria and Germany stand out because of their relatively large share of deposit holdings at the bottom of the wealth distribution. Instead, q2 households in other countries rather substitute deposits into house ownership. The latter typically represents at least 80% of their asset portfolio. Also, differences between core (Austria, Belgium, France, Germany, the Netherlands) and periphery countries (Greece, Ireland, Italy, Portugal, Spain) can be noticed. In comparison with core countries, periphery countries have a lower share of deposits and display a more similar portfolio composition across the selected quitiles of the net wealth distribution. Overall, mortage debt represents the major share of household liabilities (Figure 6). Within countries, q5 households typically hold a larger share of consumer debt in compariso with q2 households. However, for Austria, France and Germany it is the oposite.

Figure 7 shows quarterly household portfolio return time series for the different countries. These returns are driven by (i) national differences in household portfolio composition (Figure 5 & Figure 6), and (ii) national differences in the growth rate of assets and liabilities on the other hand (Table 1).[48] Our simulation excercise shows that the average portfolio return is trending upwards sice the 2008 financial crisis, although quarterly returns are negative for a substantial period of time in almost all of the countries. The latter is probably due to the general increase in household debt ratios since the 2008 financial crisis. Nevertheless, considerable differences between countries are present. The deviating portfolio composition between q2 and q5 households in Austria and Germany (see Figure 5) is translated into a very different return evolution. Two observations stand out. First, households at the top of the wealth distribution generate a higer average portfolio return. Second, the other side of the coin is that these q5 housholds face higher return volatility. However, both observations cannot be generalized to the other Eurozone countries in which the portfolio return evolution is quite similar for q2 and q5 households. Hereby also note that two out of the five periphery countries (Greece and Portugal) are characterized by higher portfolio returns for q2 households across the entire time series.

Figure 8 shows the simulated wealth inequality quarterly time series. Since the onset of the 2008 financial crisis, wealth inequality - measured as the ratio of the net wealth of q5 to q2 households - evolved very differently across the Eurozone. Half of the countries display a fairly linear evolution

[48] See section 2.1 for the calculation of our simulated household portfolio return time series.

over the considered time period. Wealth inequality increased in Austria and Greece, decreased in Belgium and Germany, and remained stable in Italy. The other half of the countries show a more complex picture. Wealth inequality rose sharply in Portugal and Spain during the 2012 Eurocisis but returned to it's initial levels by the end of 2017. In the Netherlands, wealth inequality peaked in both the first quarter of 2012 and the last quarter of 2015. In Ireland, wealth inequality first dropped in the first quarter of 2009 and went back to it's current level from the third quarter of 2009 on. A more in depth interpretation of these divergent results is provided in the conclusion part of the paper.

3.2 Time series analysis

Table 4 shows the estimates of our baseline ADL(0,1) model for all Eurozone countries. None of the β_1-coefficient estimates were significant at the 5% level indicating that the monetary policy stance from the previous quarter has no impact on the dependent variables (i.e. q2 household portfolio return, q5 household portfolio return, and wealth inequality).[49]

[49] The same applies to the contemporaneous β_0-coefficient estimates from the basic static model displayed under equation (10).

Country	Dependent variable	MP shock lag 1 (β_1)	t-statistic	probability
Austria	2nd quintile return	-0.000390	-1.458379	0.1542
	5th quintile return	-0.001019	-1.101901	0.2785
	wealth inequality	-0.064157	-0.960251	0.3439
Belgium	2nd quintile return	0.000124	0.258145	0.7979
	5th quintile return	0.000256	0.579188	0.5664
	wealth inequality	0.109630	0.964191	0.3420
France	2nd quintile return	0.000357	0.887171	0.3814
	5th quintile return	0.000557	1.171907	0.2496
	wealth inequality	0.249137	1.836171	0.0754
Germany	2nd quintile return	-0.000236	-0.927836	0.3602
	5th quintile return	-0.000274	-0.684399	0.4985
	wealth inequality	0.001744	0.142675	0.8874
the Netherlands	2nd quintile return	0.000340	0.573651	0.5701
	5th quintile return	0.000392	0.642727	0.5248
	wealth inequality	-9.393205	-0.443278	0.6605
Greece	2nd quintile return	-0.000292	-0.679210	0.5017
	5th quintile return	-0.000289	-0.678479	0.5022
	wealth inequality	-0.007394	-0.601637	0.5515
Ireland	2nd quintile return	-0.000139	-0.123197	0.9027
	5th quintile return	-0.000107	-0.093204	0.9263
	wealth inequality	-0.959801	-0.866348	0.3926
Italy	2nd quintile return	0.000294	1.204504	0.2370
	5th quintile return	0.000334	1.261290	0.2160
	wealth inequality	-0.002556	-0.407896	0.6860
Portugal	2nd quintile return	0.000429	0.618671	0.5404
	5th quintile return	0.000463	0.671542	0.5065
	wealth inequality	-0.106186	-0.710342	0.4825
Spain	2nd quintile return	0.000545	0.542965	0.5908
	5th quintile return	0.000694	0.730121	0.4705
	wealth inequality	-0.519883	-1.411707	0.1674

MP shock: monetary policy shock
* : 5 % level of significance
** : 1 % level of significance
☐ non-significant impact
☐ positive impact
☐ negative impact

Table 4: Parameter estimates baseline ADL(0,1) model for all Eurozone countries

Table 5 presents both the contemporaneous and lagged impact of a monetary policy shock in five Eurozone core countries (Austria, Belgium, France, Germany, the Netherlands). In general, household portfolio returns and wealth inequality evolutions are mainly predicted by their own past (α - parameters), rather than by monetary policy shocks (β - parameters).[50] No evidence for a significant impact of monetary policy shocks on household portfolio return was found. Also concerning wealth inequality, little evidence was found for a significant impact of monetary policy shocks. Our ADL(1,4) models indicate that an accommodative monetary policy shock has a positive short-run lagged impact in Germany (β_1 = 0.018178, p = 0.0274) and a negative short-run lagged impact in the Netherlands (β_2 = -64.18617, p = 0.0336). Note that effect size is very small in Germany: a one-unit monetary policy shock (1 unit = a decrease in the Spanish CDS spread with 5% upon impact) corresponds with a change in wealth inequality of β_1 units (1 unit = 1 percentage point). The strong reaction to an accomodative monetary policy shock in the Netherlands coincides with the extreme swings in wealth inequality during that period (Figure 15). For example, a large drop in wealth inequaity was found in both the second quarter of 2012 (t+2) and the third quarter of 2015 (t+2). These drops can be linked to important monetary events from two quarters ago, namely the announcement of the new CBPP2 programme (t) and the QE announcement of January 2015 (t), respectively.

[50] Note that we did not calculate impulse response functions but simply interpreted the signal of our coefficients.

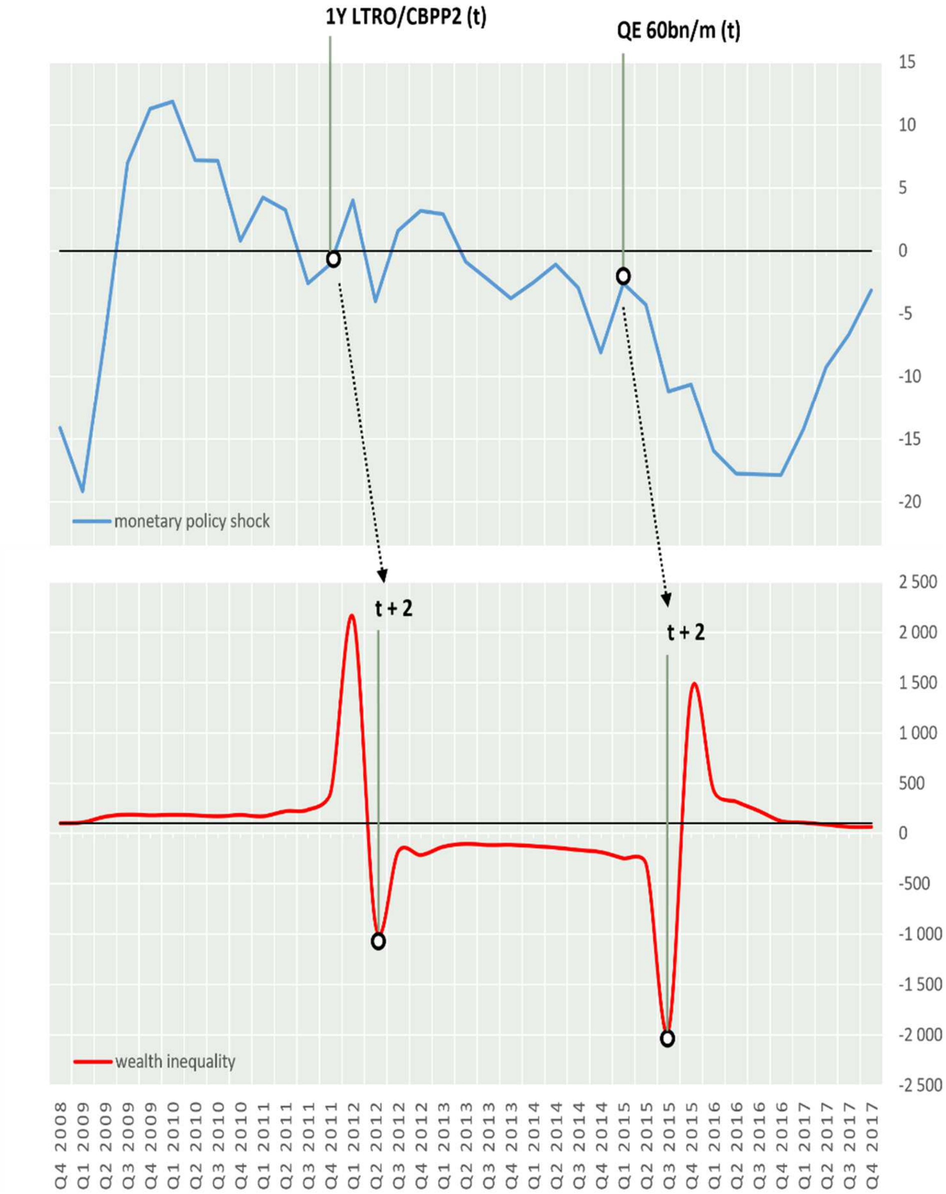


Figure 15: Monetary policy shocks and wealth inequality in the Netherlands (2008Q4=100)

In turn, Tabel 6 presents both the contemporaneous and lagged impact of a monetary policy shock in five Eurozone periphery countries (Greece, Ireland, Italy, Portugal, Spain). In contrast to the core countries, some evidence for a significant impact of monetary policy shocks on household portfolio return was found. In the short run, an accommodative monetary policy shock has a negative contemporaneous impact on Spanish q2 household portfolio returns (β_0 = -0.001751, p = 0.0444), and a positive lagged impact for both q2 (β_3 = 0.002030, p = 0.0395) and q5 households (β_3 = 0.001842, p = 0.0498). In the long run, the impact of accommodative monetary policy shocks turns out positive for Spanish q2 household portfolio returns:

$$\frac{\beta_4 + \beta_3 + \beta_2 + \beta_1 + \beta_0}{1 - \ \alpha_1} = 0.005514$$

Cyclical peaks in Spanish portfolio returns can be linked to the announcement of monetary policy measures three quarters ago (Figure 16). The announcement of the one-year LTRO and CBPP1 programme in the third quarter of 2009 (t) is among the largest accomodative shocks and corresponds to a strong hike in q2 portfolio returns in the second quarter of 2010 (t+3). Another cyclical peak in the second quarter of 2013 (t+3) was preceded by ECB president Mario Dragi's speech[51] in London on July 26, 2012 (t) in which he made the momentous remark: *"Within our mandate, the ECB is ready to do whathever it takes to preserve the euro. And believe me, it will be enough."* Also, note the timely correspondance between the introduction of the 3Y LTRO programme (t) and 2012Q4 peak (t+3).

[51] https://www.youtube.com/watch?v=hMBI50FXDps&feature=youtu.be&t=7m3s

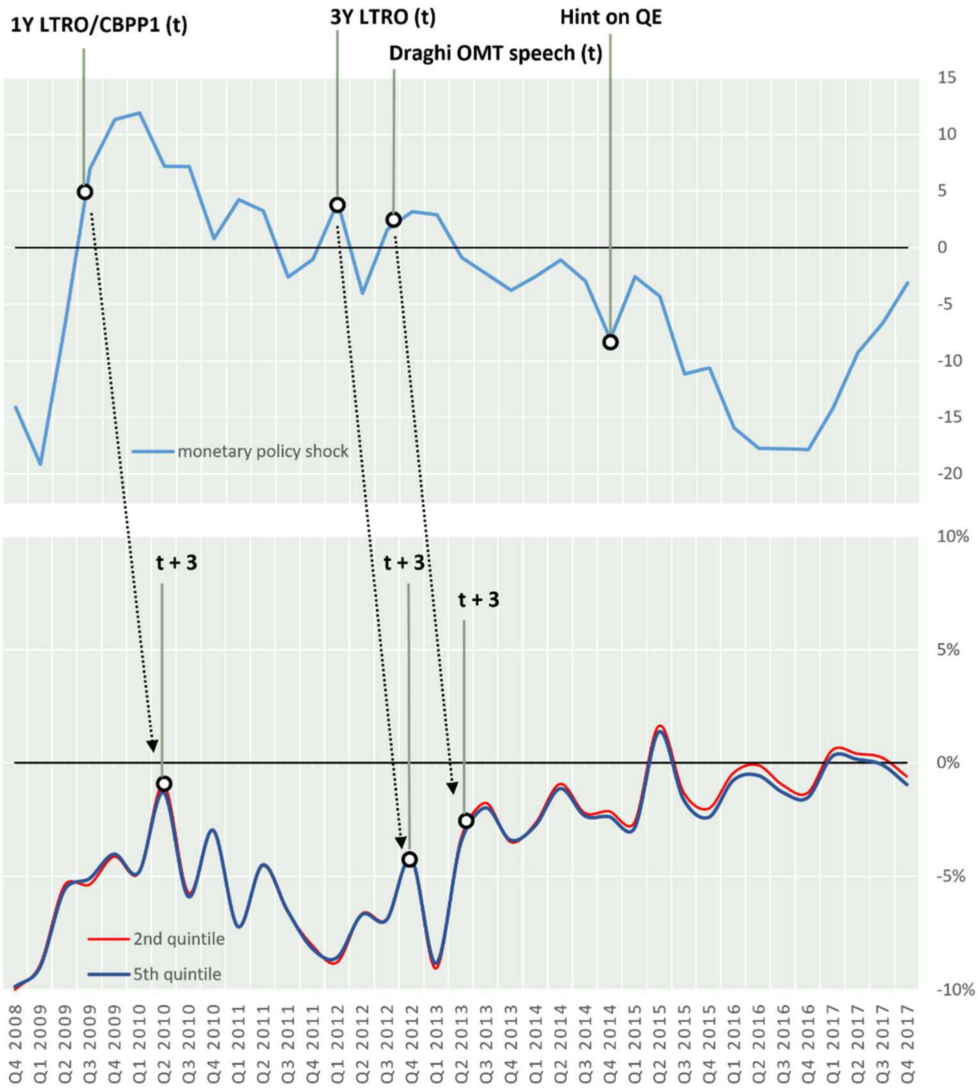


Figure 16: Monetary policy shocks and q2 household portfolio return in Spain

Concerning the evolution of wealth inequality in Eurozone periphery countries, only little evidence was found for a significant impact of monetary policy shocks. Morevore, we believe that the negative short-run dynamic impact of monetary policy in Ireland (β_1 = -0.471880, p = 0.0356) is mainly attributable to a negative correlation between the low monetary policy stance in the first quarter of 2009 (t) and the rise in wealth inequality in the second quarter of the same year (t+1) (Figure 17). The announcement of the extension of the ECB's asset purchases with a pace of 80 billion/month (t) marks the start of an upwards trending monetary policy stance. The latter can also be linked to the downward trend in Irish wealth inequality since the third quarter of 2016 (t+1).

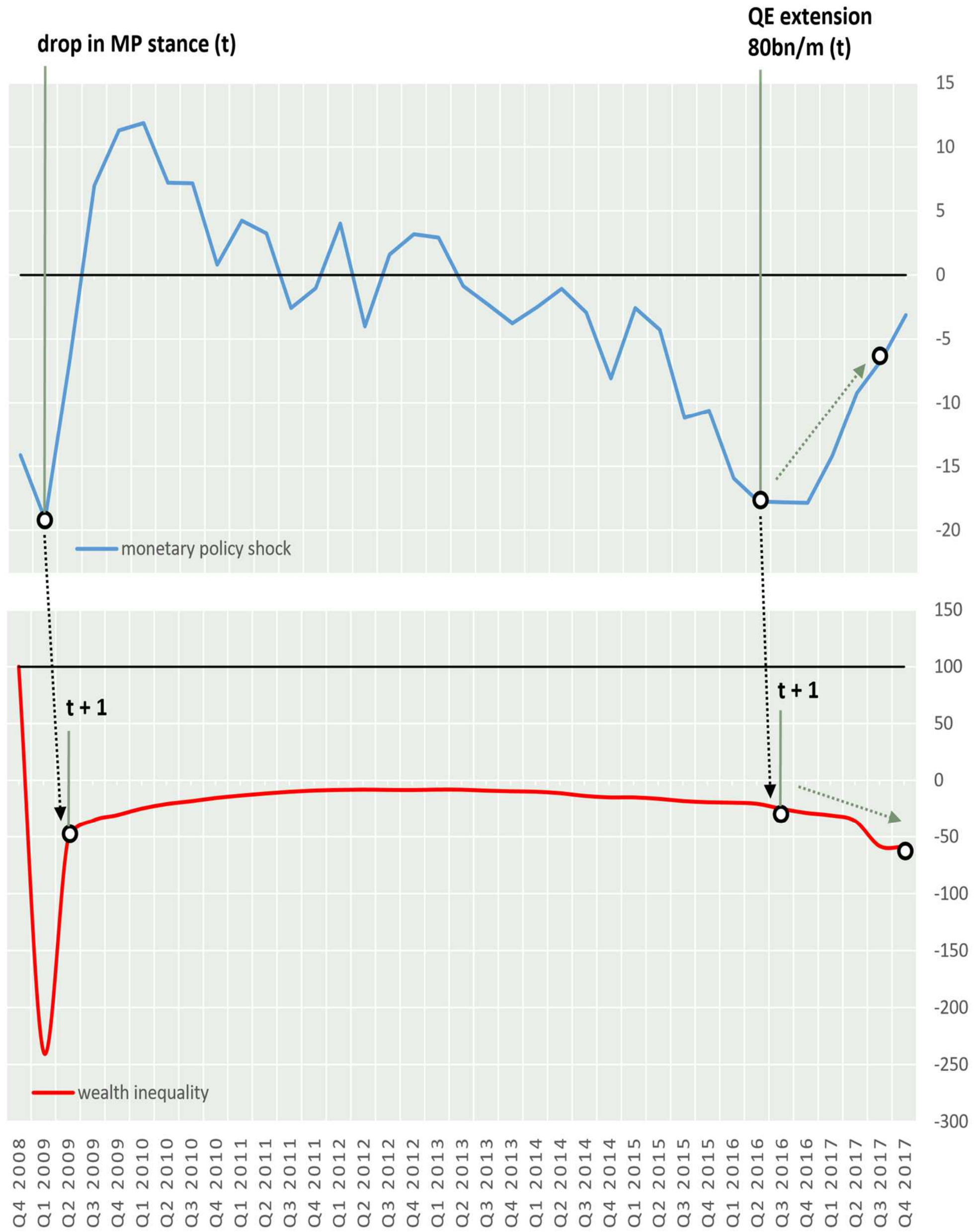


Figure 17: Monetary policy shocks and wealth inequality in Ireland (2008Q4=100)

Country	Dependent variable	Variable	Parameter	Estimate	t-statistic	probability
Austria	2nd quintile return	Dependent lag 1	α_1	0.120926	0.602114	0.5527
		MP shock	β_0	0.000582	1.796558	0.0850
		MP shock lag 1	β_1	9.91E-07	0.002924	0.9977
		MP shock lag 2	β_2	-9.21E-06	-0.027851	0.9780
		MP shock lag 3	β_3	-0.000504	-1.787979	0.0864
		MP shock lag 4	β_4	9.86E-05	0.401689	0.6915
	5th quintile return	Dependent lag 1	α_1	-0.026591	-0.135326	0.8935
		MP shock	β_0	0.001848	1.393487	0.1762
		MP shock lag 1	β_1	-0.000651	-0.491336	0.6277
		MP shock lag 2	β_2	-0.000251	-0.194713	0.8473
		MP shock lag 3	β_3	-0.001731	-1.526233	0.1400
		MP shock lag 4	β_4	0.000804	0.792793	0.4357
	wealth inequality	Dependent lag 1	α_1	-0.014751	-0.075258	0.9406
		MP shock	β_0	0.131641	1.332615	0.1952
		MP shock lag 1	β_1	-0.062171	-0.627937	0.5360
		MP shock lag 2	β_2	-0.020664	-0.214408	0.8320
		MP shock lag 3	β_3	-0.121689	-1.433127	0.1647
		MP shock lag 4	β_4	0.068190	0.901071	0.3765
Belgium	2nd quintile return	Dependent lag 1	α_1	0.096499	0.485804	0.6315
		MP shock	β_0	-3.22E-05	-0.048475	0.9617
		MP shock lag 1	β_1	0.000812	1.173070	0.2523
		MP shock lag 2	β_2	0.001066	1.576113	0.1281
		MP shock lag 3	β_3	-0.000264	-0.455159	0.6531
		MP shock lag 4	β_4	-0.000419	-0.822033	0.4192
	5th quintile return	Dependent lag 1	α_1	0.107749	0.542877	0.5922
		MP shock	β_0	-4.09E-05	-0.066990	0.9471
		MP shock lag 1	β_1	0.000907	1.420025	0.1685
		MP shock lag 2	β_2	0.000944	1.511320	0.1438
		MP shock lag 3	β_3	-0.000257	-0.480239	0.6354
		MP shock lag 4	β_4	-0.000384	-0.820261	0.4201
	wealth inequality	Dependent lag 1	α_1	0.911503**	11.98023	0.0000
		MP shock	β_0	0.023975	0.602545	0.5525
		MP shock lag 1	β_1	0.003468	0.063143	0.9502
		MP shock lag 2	β_2	-0.062008	-1.033338	0.3117
		MP shock lag 3	β_3	-0.036757	-0.770683	0.4484
		MP shock lag 4	β_4	-0.007054	-0.236271	0.8152
France	2nd quintile return	Dependent lag 1	α_1	-0.193567	-0.878594	0.3883
		MP shock	β_0	-0.000238	-0.384166	0.7042
		MP shock lag 1	β_1	0.000596	1.068738	0.2958
		MP shock lag 2	β_2	0.000627	1.162460	0.2565
		MP shock lag 3	β_3	-0.000222	-0.470834	0.6420
		MP shock lag 4	β_4	0.000144	0.324592	0.7483

	5th quintile return	Dependent lag 1	α_1	-0.211457	-0.954951	0.3491
		MP shock	β_0	-0.000267	-0.367327	0.7166
		MP shock lag 1	β_1	0.000851	1.304295	0.2045
		MP shock lag 2	β_2	0.000506	0.804600	0.4289
		MP shock lag 3	β_3	-0.000293	-0.529963	0.6010
		MP shock lag 4	β_4	0.000236	0.455616	0.6528
	wealth inequality	Dependent lag 1	α_1	0.663007**	6.537627	0.0000
		MP shock	β_0	0.008817	0.140813	0.8892
		MP shock lag 1	β_1	-0.005598	-0.068194	0.9462
		MP shock lag 2	β_2	-0.060260	-0.743697	0.4643
		MP shock lag 3	β_3	-0.025781	-0.418625	0.6792
		MP shock lag 4	β_4	0.012553	0.284519	0.7785
Germany	2nd quintile return	Dependent lag 1	α_1	0.455358*	2.735440	0.0115
		MP shock	β_0	0.000368	1.250326	0.2232
		MP shock lag 1	β_1	0.000267	0.773557	0.4467
		MP shock lag 2	β_2	8.03E-05	0.229002	0.8208
		MP shock lag 3	β_3	0.000118	0.386542	0.7025
		MP shock lag 4	β_4	-0.000171	-0.723521	0.4764
	5th quintile return	Dependent lag 1	α_1	0.141036	0.723774	0.4762
		MP shock	β_0	0.000602	1.145883	0.2631
		MP shock lag 1	β_1	0.000374	0.672894	0.5074
		MP shock lag 2	β_2	-0.000265	-0.484663	0.6323
		MP shock lag 3	β_3	-0.000157	-0.330209	0.7441
		MP shock lag 4	β_4	-0.000511	-1.253618	0.2221
	wealth inequality	Dependent lag 1	α_1	0.874232**	9.406840	0.0000
		MP shock	β_0	0.010309	1.649336	0.1121
		MP shock lag 1	β_1	0.018178*	2.349493	0.0274
		MP shock lag 2	β_2	-0.001058	-0.130255	0.8975
		MP shock lag 3	β_3	-0.003139	-0.444302	0.6608
		MP shock lag 4	β_4	0.002825	0.564478	0.5777
the Netherlands	2nd quintile return	Dependent lag 1	α_1	0.722607**	4.753303	0.0001
		MP shock	β_0	-0.000164	-0.258686	0.7981
		MP shock lag 1	β_1	0.000500	0.626770	0.5367
		MP shock lag 2	β_2	2.67E-05	0.031931	0.9748
		MP shock lag 3	β_3	6.68E-05	0.094921	0.9252
		MP shock lag 4	β_4	0.000664	1.372601	0.1826
	5th quintile return	Dependent lag 1	α_1	0.714472**	4.654321	0.0001
		MP shock	β_0	-0.000164	-0.248108	0.8062
		MP shock lag 1	β_1	0.000546	0.657283	0.5173
		MP shock lag 2	β_2	1.29E-05	0.014838	0.9883
		MP shock lag 3	β_3	5.02E-05	0.068475	0.9460
		MP shock lag 4	β_4	0.000693	1.372730	0.1825

wealth inequality	Dependent lag 1	α_1	0.042412	0.207087	0.8377
	MP shock	β_0	57.41229	1.947545	0.0633
	MP shock lag 1	β_1	-28.35101	-0.966616	0.3434
	MP shock lag 2	β_2	-64.18617*	-2.254165	0.0336
	MP shock lag 3	β_3	17.92467	0.724346	0.4759
	MP shock lag 4	β_4	16.81881	0.768054	0.4499

MP shock: monetary policy shock
α -parameters: autoregressive impact
β -parameters: monetary policy shock
* : 5 % level of significance
** : 1 % level of significance
non-significant impact
positive impact
negative impact

Table 5: Short-run static and dynamic impact of a monetary policy shock in Eurozone core countries

Country	Dependent variable	Variable	Parameter	Estimate	t-statistic	probability
Greece	2nd quintile return	Dependent lag 1	α_1	-0.190450	-0.930654	0.3613
		MP shock	β_0	-9.07E-05	-0.226005	0.8231
		MP shock lag 1	β_1	-3.66E-05	-0.094703	0.9253
		MP shock lag 2	β_2	0.000116	0.311473	0.7581
		MP shock lag 3	β_3	-0.000511	-1.535856	0.1377
		MP shock lag 4	β_4	0.000329	1.084321	0.2890
	5th quintile return	Dependent lag 1	α_1	-0.190168	-0.929018	0.3621
		MP shock	β_0	-8.25E-05	-0.207757	0.8372
		MP shock lag 1	β_1	-3.57E-05	-0.093476	0.9263
		MP shock lag 2	β_2	0.000118	0.322236	0.7501
		MP shock lag 3	β_3	-0.000500	-1.518373	0.1420
		MP shock lag 4	β_4	0.000329	1.098125	0.2830
	wealth inequality	Dependent lag 1	α_1	0.647635**	3.853384	0.0008
		MP shock	β_0	0.004539	0.337930	0.7384
		MP shock lag 1	β_1	0.002957	0.179659	0.8589
		MP shock lag 2	β_2	-0.006617	-0.381570	0.7061
		MP shock lag 3	β_3	0.007624	0.513110	0.6126
		MP shock lag 4	β_4	-0.003207	-0.309215	0.7598
Ireland	2nd quintile return	Dependent lag 1	α_1	0.741302**	6.050960	0.0000
		MP shock	β_0	0.000283	0.298463	0.7679
		MP shock lag 1	β_1	0.001080	0.896463	0.3789
		MP shock lag 2	β_2	0.001190	0.937192	0.3580
		MP shock lag 3	β_3	0.001163	1.089889	0.2866
		MP shock lag 4	β_4	0.000235	0.319331	0.7522
	5th quintile return	Dependent lag 1	α_1	0.745252**	6.148964	0.0000
		MP shock	β_0	0.000313	0.329232	0.7448
		MP shock lag 1	β_1	0.001160	0.960349	0.3465
		MP shock lag 2	β_2	0.001207	0.947104	0.3530
		MP shock lag 3	β_3	0.001175	1.096995	0.2835
		MP shock lag 4	β_4	0.000252	0.342498	0.7350
	wealth inequality	Dependent lag 1	α_1	0.053733	0.276072	0.7849
		MP shock	β_0	-0.311782	-1.447896	0.1606
		MP shock lag 1	β_1	-0.471880*	-2.226785	0.0356
		MP shock lag 2	β_2	-0.284526	-1.381357	0.1799
		MP shock lag 3	β_3	0.057129	0.311147	0.7584
		MP shock lag 4	β_4	0.168249	1.056563	0.3012
Italy	2nd quintile return	Dependent lag 1	α_1	-0.232618	-1.168381	0.2541
		MP shock	β_0	2.72E-05	0.074978	0.9409
		MP shock lag 1	β_1	0.000671	1.937879	0.0645
		MP shock lag 2	β_2	-2.07E-05	-0.061382	0.9516
		MP shock lag 3	β_3	0.000138	0.464498	0.6465
		MP shock lag 4	β_4	0.000295	1.071373	0.2947

	5th quintile return	Dependent lag 1	α_1	-0.230384	-1.154526	0.2597
		MP shock	β_0	3.91E-05	0.100135	0.9211
		MP shock lag 1	β_1	0.000744	1.995716	0.0574
		MP shock lag 2	β_2	-5.66E-05	-0.155692	0.8776
		MP shock lag 3	β_3	0.000148	0.462871	0.6476
		MP shock lag 4	β_4	0.000328	1.105066	0.2801
	wealth inequality	Dependent lag 1	α_1	0.422090*	2.311833	0.0297
		MP shock	β_0	0.004660	0.570587	0.5736
		MP shock lag 1	β_1	-0.005828	-0.612456	0.5460
		MP shock lag 2	β_2	-0.003503	-0.358232	0.7233
		MP shock lag 3	β_3	-0.003049	-0.366046	0.7175
		MP shock lag 4	β_4	-0.002531	-0.400461	0.6924
Portugal	2nd quintile return	Dependent lag 1	α_1	0.754582**	5.568937	0.0000
		MP shock	β_0	0.000741	1.104157	0.2805
		MP shock lag 1	β_1	0.000947	1.140948	0.2651
		MP shock lag 2	β_2	-0.000304	-0.345406	0.7328
		MP shock lag 3	β_3	-2.97E-05	-0.038949	0.9693
		MP shock lag 4	β_4	7.17E-05	0.134056	0.8945
	5th quintile return	Dependent lag 1	α_1	0.751158**	5.512677	0.0000
		MP shock	β_0	0.000748	1.112241	0.2771
		MP shock lag 1	β_1	0.000977	1.174311	0.2518
		MP shock lag 2	β_2	-0.000312	-0.353976	0.7264
		MP shock lag 3	β_3	-4.57E-05	-0.059745	0.9529
		MP shock lag 4	β_4	6.75E-05	0.125977	0.9008
	wealth inequality	Dependent lag 1	α_1	0.579500**	3.546940	0.0016
		MP shock	β_0	-0.141276	-0.777234	0.4446
		MP shock lag 1	β_1	-0.142910	-0.645355	0.5248
		MP shock lag 2	β_2	0.299560	1.288836	0.2097
		MP shock lag 3	β_3	0.018606	0.093785	0.9261
		MP shock lag 4	β_4	0.002380	0.016950	0.9866
Spain	2nd quintile return	Dependent lag 1	α_1	0.819723**	6.904082	0.0000
		MP shock	β_0	-0.001751*	-2.121681	0.0444
		MP shock lag 1	β_1	0.001011	0.974465	0.3395
		MP shock lag 2	β_2	-0.000469	-0.429761	0.6712
		MP shock lag 3	β_3	0.002030*	2.177929	0.0395
		MP shock lag 4	β_4	0.000173	0.266206	0.7924
	5th quintile return	Dependent lag 1	α_1	0.817317**	6.819593	0.0000
		MP shock	β_0	-0.001612	-2.041792	0.0523
		MP shock lag 1	β_1	0.001130	1.139753	0.2656
		MP shock lag 2	β_2	-0.000527	-0.504726	0.6184
		MP shock lag 3	β_3	0.001842*	2.066261	0.0498
		MP shock lag 4	β_4	0.000137	0.220997	0.8270

wealth inequality	Dependent lag 1	α_1	0.927121**	22.65709	0.0000
	MP shock	β_0	0.099414	1.094527	0.2846
	MP shock lag 1	β_1	0.036226	0.324168	0.7486
	MP shock lag 2	β_2	0.101863	0.868363	0.3938
	MP shock lag 3	β_3	-0.032822	-0.318676	0.7527
	MP shock lag 4	β_4	-0.008880	-0.121060	0.9047

MP shock: monetary policy shock
α -parameters: autoregressive impact
β -parameters: monetary policy shock
* : 5 % level of significance
** : 1 % level of significance
non-significant impact
positive impact
negative impact

Tabel 6: Short-run static and dynamic impact of a monetary policy shock in Eurozone periphery countries

Finally, Table 7 presents the results from the panel analysis. None of the β_1-parameter estimates were significant indicating that the monetary policy stance from the previous quarter was not related to household portfolio return and wealth inequality in the Eurozone.

Dependent variable	MP shock lag 1 (β_1)	t-statistic	probability
2nd quintile return	7.38E-05	0.376382	0.7069
5th quintile return	7.07E-05	0.326170	0.7445
wealth inequality	-1.127808	-0.537499	0.5913

MP shock: monetary policy shock
* : 5 % level of significance
** : 1 % level of significance
non-significant impact
positive impact
negative impact

Table 7: Panel model estimates for all Eurozone countries

4 Conclusion

This study analyzed the impact of monetary policy shocks on household portfolio return and wealth inequality in the Eurozone. We thereby considered five core countries (Austria, Belgium, France, Germany, and the Netherlands) and five periphery countries (Greece, Ireland, Italy, Portugal, and Spain) in a timeframe from October 2008 to December 2017. Monetary policy shocks were estimated using a VAR model. Household portfolio return and wealth inequality were simulated using ECB HFCS survey data and financial market data. Main findings, limitations of the study, and implications for monetary policy are discussed below.

4.1 Main findings

Our first objective was to investigate the impact of monetary policy shocks on average portfolio returns for households at the bottom (second quintile) and the top (fifth quintile) of the wealth distribution. With the exception of Spain, no evidence for a significant impact of monetary policy shocks on household portfolio return was found. The finding is quite surprising given the abundance of studies demonstrating the impact of monetary policy shocks on yields and asset prices in the Eurozone (Altavilla et al., 2015; ECB, 2015b; Rigobon & Sack, 2003, 2004). However, note that we considered *average* portfolio returns measured as a linear combination of the return on assets and the cost of debt weighted by information on the asset and liability distribution provided by the ECB HFCS survey. A number of reservations are in order here. First, strong effects on particular asset or liability components may be flattened out in the total household portfolio. For example, asset prices typically react strongly to changing monetary policy conditions but only represent a small share of the household balance sheet (Figure 5). Second, the simulation of our household portfolio returns is subject to a number of assumptions of which time-invariant portfolio compostions is probably the most restrictive one. In reality, investors are likely to benefit from rebalancing to weights that take into account the time variation in risk premia (NBIM, 2012), i.e. increasing exposure to risky assets when premia are perceived to be high and reducing them when premia are perceived to be low. Changing monetary policy is thus an important decision parameter for financial markets because equity risk premia and expected equity returns vary over time (Campbell & Diebold, 2009; Cochrane, 2005). Only in Spain we found that accommodative monetary policy shocks had a positive impact q2 household portfolio returns. Cyclical peaks in Spanish portfolio returns can be linked to the announcement of monetary policy measures such as the one-year LTRO and CBPP1 programme, the 2012 Dragi speech, and the 3Y LTRO programme (Figure 16).

The second study objective was to investigate the impact of monetary policy shocks on the evolution of wealth inequality in the Eurozone. We found only little evidence for a significant impact of monetary policy shocks in both core and periphery countries. Results show that an accommodative monetary policy shock had a positive short-run lagged impact in Germany and a negative short-run lagged impact in the Netherlands and Ireland. Interestingly, wealth inequality in Germany and the Netherlands is high by international standards, with only the OECD countries Austria and the United States as well as Sweden and Denmark showing similar or higher levels of wealth concentration (OECD, 2015). The strong reaction to monetary policy shocks in the Netherlands coincides with the extreme swings in wealth inequality during that period (Figure 15). Large drops in wealth inequaity can be linked to the CBPP2 programme and the QE announcement of January 2015. Additional simulation analysis showed that these fluctuations in wealth inequality are driven entirely by the evolution of real estate prices. If we subsitute the Dutch real estate prices by those from neighboring countries, the trend in wealth inequality turns almost flat. The same applies to the Irish wealth inequality time series. Moreover, we believe that the negative short-run dynamic impact of monetary policy in Ireland is mainly driven by the low monetary policy stance in the first quarter of 2009 and the announcement of the extension of the ECB's asset purchases with a pace of 80 billion/month (Figure 17). In sum, monetary policy may possibly exhibit distributional effects over the economic cycle, albeit comparatively weak ones.

These findings are in line with the the small number of studies on this topic. For the Eurozone, a report from the Deutsche Bundesbank (2016) concludes that the much-touted view that non-standard monetary policy measures demonstrably increased inequality cannot be confirmed. It appears very doubtful that the accomodative monetary policy measures in the recent years have caused inequality to increase overall. This particularly holds true for the distribution of income. However, the authors acknowledge that the way in which these policies have affected wealth distribution is less evident.

In this context, Monnin (2017) states that accomodative monetary policy appears to decrease income inequality, mainly through their impact on the labor market,[52] and to increase wealth inequality. Domanski et al. (2016) also find that changes in asset prices and interest rates have increased wealth inequality in the United Sates. In contrast, a study by O'Farrell, Rawdanowicz, and Inaba (2016), using a similar methodology, found insignificant effects. Bivens (2015) argues that the LSAP program has reduced inequality. In the UK, the chief economist of the Bank of England states that there is nothing to suggest monetary policy has had significant effects on either income or wealth inequality over recent years (Haldane, 2018). The accomodative monetary policy after the crisis appears to have delivered significant financial and welfare benefits to almost all cohorts of the UK economy. Anyhow, the movements in inequality look like the product of long-term low-frequency forces, rather than more frequent monetary policy changes in response to the business cycle.

Finally, we developed three additional hypothesis while conducting our econometric study. Our first hypothesis assumes that households react to the monetary policy stance from the previous quarter (one-quarter lagged impact). However, no evidence supporting this hypothesis was found.
Second, we assumed that the transmission of monetary policy shocks to households is a slow process with a possible one-year lagged impact (4 quarters). Indeed, results show that monetary policy shocks dynamically impact

[52] Low-income households benefit more from the increase in labor income following an accomodative monetary shock than high-income households.

on household portfolio return and wealth inequality with a maximum number of 3 lags (i.e. 3 quarters). These findings are in line with a whole range of economic theories that incorporate the aspect of time lags. In this context, the money supply mechanism illustrates the case well (F. S. Mishkin & Serletis, 2011). Suppose the central bank increases the monetary base by buying government securities. The relation between the amount of central bank money (i.e. the monetary base) and the actual supply of money is determined by the monetary base multiplicator, which in turn, consists of the currency preference of the public and the fractional reserve coefficient. The system of fractional reserve banking makes multiple deposit creation possible. Of course, a multiple increase in the money supply will not be created overnight. The process takes times as it is subject to debtor and creditor behavior. Figure 1 further substantiates the complexity of monetary transmission illustrating the dynamic relation between monetary policy and households. Also, the link between inflation and changes in money supply is not instantaneous. For example, Friedman's k-percent rule (M. Friedman & A. Schwartz, 1963) is a fixed monetary policy rule proposing the money supply (M) should be increased by the central bank by a constant growth rate every year in order to achieve it's price (P) stability target.[53] Studies have shown that the lag between the two is anywhere from 3 to about 20 quarters (Carlson, 1980). The long-run impact of a 1 percent change in the money supply on inflation is about 1, which is statistically significant, whereas the short-run impact is about 0.04, which is not significant.

[53] The reasoning is based on a monetarist interpretation (Quantity theory of money) of the Fisher equation M . V = P . T assuming the velocity of money (V) and the number of transactions per unit of time (T) constant.

Our third hypothesis assumes that household portfolio return and wealth inequality from the previous quarter is highly predictive for current household portfolio return and wealth inequality. Indeed, results indicate that household portfolio returns were mainly predicted by their own past (i.e. the autoregressive part of the model), rather than by monetary policy shocks. Note that this finding should be interpreted within a 4-quarter period (cfr. modelling assumption 2).

4.2 Limitations

How realistic is our simulation exercise? Besides the assumption on time-invariant portfolio compositions discussed above, we also assume that the quality of housing held by the poor and the rich is the same. The return on housing is measured at the percentage change of a national index of real estate prices. As a result, it does not take into account potential systematic biases in the changes in the value of property held by the rich and the poor. Also, when we would consider the tails of the wealth distribution, one can generally expect a reinforced picture. For example, the share of equity holdings tends to be even higher at the top 5% or 1% of the distribution. Conversely, net wealth is negative at the bottom of the wealth distribution because liabilities exceed assets. Du Caju (2016) points out that financial wealth is highly concentrated in a small part of the population that is very difficult to contact for participation in survey research such as the HFCS. In this way, we could have underestimated the degree of inequality. Furthermore, we should also take into account that inference was based on 37 observations (i.e. 37 quarters from October 2008 to December 2017) for each of the participating countries. This may hamper the generalizability of our study findings. The latter also explains our choice to put a lot of emphasis on the statistical properties of our models (e.g. autocorrelation). Bearing in mind these limitations, the numerical results should be interpreted as a broad indication of trends, rather than precise orders of magnitude.

4.3 Implications for monetary policy

Issues of inequality have become a prominent topic in many public debates over the past decade. Recent books on the rising tide of inequality even became best-sellers.[54] In the aftermath of the 2008 financial cricis, monetary policy became more expansionary than at any time in recent history (Praet, 2017). Given the increased interest in distributional issues, in combination with an activist central bank, it is perhaps no surprise that there has been increasing public interest in the fusion of the two. In this context, central banks have been critisized sharply. QE is held by some to have increased inequalities between rich and poor (Lysenko, Glass, & Six, 2016). Others have gone further, suggesting that QE may have caused central banks to cross the thin line between economic policy and political economy (Buiter, 2014).

Based on our study findings, we cannot formulate tangible recommendations for monetary policy, as we did not found strong evidence for distributional consequences of monetary policy in the Eurozone. Some evidence was found in countries with extreme swings in wealth inequality (i.e. the Netherlands

[54] Piketty (2014), Atkinson (2015), Stiglitz (2013) and Milanovic (2016)

and Ireland), but these trends were mainly driven by the evolution in housing prices in these countries. After all, the housing crisis in the Netherlands and Ireland can hardly be attributed to the central bank's actions. To name just one figure, a research report form the OTB institute of the University of Delft showed that the transactions for new construction homes in the Netherlands and Ireland decreased with 62,0% and 71,6% respectively, while transactions remained practically unchanged in Belgium and Germany (Dol, van der Heijden, & Oxley, 2010).

When screening a series of opinion pieces and working papers, it becomes clear that all major central banks share the view that addressing inequality is not a direct objective of monetary policy. A research economist from the Federal Reserve Bank of Cleveland formulates it pithy: *"I do not mean to argue that monetary policy has no effect on inequality, but whatever that is, it is likely to be small, at least relative to the effect of more fundamental forces, like education, globalization, demographics, technological change, or corporate trends in compensation"* (Amaral, 2017). In a 2015 opinion piece, former Fed president Ben Bernanke already argued that evolutions in inequality result from deep structural changes in our economy that have taken place over many years, including globalization, technological progress, demographic trends, and institutional change in the labor market and elsewhere (Bernanke, 2015). In comparison with the influence of these long-term factors, the effects of monetary policy on inequality are likely to be modest. Actually, monetary policy aims to promote economic stability and prosperity for the economy as a whole. Bernanke takes it another step further by claiming that distributional consequences from effective monetary policy (suppose they exist) are no reason to forego such policies. Rather, *“the right response is to rely on other types of policies to address distributional concerns directly, such as fiscal policy (taxes and government spending programs) and policies aimed at improving workers’ skills.”*

Based on the current evidence base, we believe that implications for monetary policy are limited up to now. Distributional consequences are at most a matter of attention for central banks, but other types of policies are better suited to addressing legitimate concerns about inequality. Widening inequality and lack of social mobility are issues of first-order significance for economic, social and fiscal policy.

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Appendix 1

A. Schematic representation of monetary transmission (adapted from Mishkin, 1995)

Interest rate channel

M ↑ ⇒ r ↓ ⇒ I ↑ ⇒ Y ↑

Exchange rate channel

M ↑ ⇒ r ↓ ⇒ E ↓ ⇒ NX ↑ ⇒ Y ↑

Asset price channel

Tobin's Q effect:

M ↑ ⇒ r ↓ ⇒ P ↑ ⇒ Q ↑ ⇒ I ↑ ⇒ Y ↑

real wealth effect:

M ↑ ⇒ r ↓ ⇒ P ↑ ⇒ wealth ↑ ⇒ C ↑ ⇒ Y ↑

Credit channel

balance-sheet channel:

M ↑ ⇒ r ↓ ⇒ P ↑ ⇒ cash flow ↑ ⇒ adverse selection ↓ & moral hazard ↓ ⇒ lending ↑ ⇒ I ↑ ⇒ Y ↑

bank-lending channel:

M ↑ ⇒ bank reserves & deposits ↑ ⇒ lending ↑ ⇒ I ↑ ⇒ Y ↑

B. Schematic representation of monetary transmission to financial markets

Policy signaling channel

M ↑ ⇒ r ↓ ⇒ future policy path ⇒ expected policy rates ↓

Portfolio rebalancing channel

M ↑ ⇒ r ↓ ⇒ P ↑ ⇒ sellers excess money ⇒ portfolio rebalancing

⇒ P ↑ until equilibrium ⇒ term premium ↓ & equity risk premium ↓

Liquidity premia channel

M ↑ ⇒ r ↓ ⇒ trade ↑ ⇒ liquidity ↑ ⇒ liquidity premium ↓ ⇒ P ↑

Confidence channel

M ↑ ⇒ r ↓ ⇒ economic outlook ↑ ⇒ consumer confidence ↑

⇒ spending ↑

⇒ uncertainty ↓ ⇒ equity risk premium ↓

C. Schematic representation of channels through which monetary policy affects the distribution of wealth

Inflation tax channel

M ↑ ⇒ $inflation^e$ ↑ ⇒ purchasing power low-income households ↓ ⇒ inequality ↑

Savings redistribution channel

M ↑ ⇒ inflation ↑ ⇒ debt ↓ ⇒ inequality ↓

Channel depending on <u>the household position in the earnings distribution</u>:

Earnings heterogeneity channel

M ↑ ⇒ unemployment ↓ ⇒ bottom income distribution earnings ↑ ⇒ inequality ↓

M ↑ ⇒ wages ↑ ⇒ top income distribution earnings ↑ ⇒ inequality ↑

Channel depending on <u>the population distribution of assets and liabilities</u>:

Interest rate exposure channel

M ↑ ⇒ r ↓ ⇒ value short-duration assets ↑ & value long-duration liabilities ↓ ⇒ inequality ?

Channel depending on <u>the sources of income as a share of household income</u>:

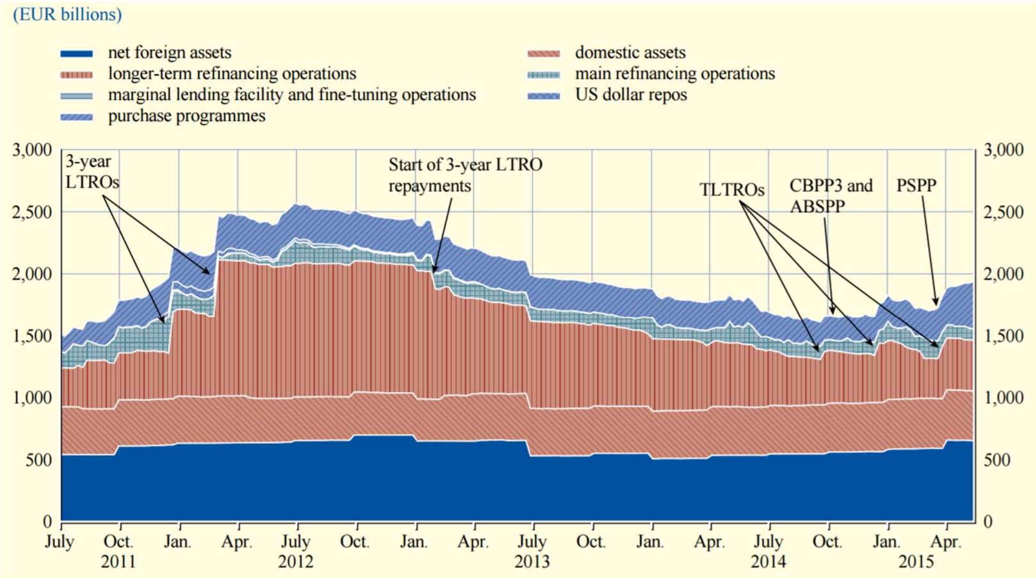
Income composition channel

M ↑ ⇒ unemployment ↓ & wages ↑ ⇒ bottom income inequality ↑

⇒ interest income ↓ ⇒ top income inequality ↓

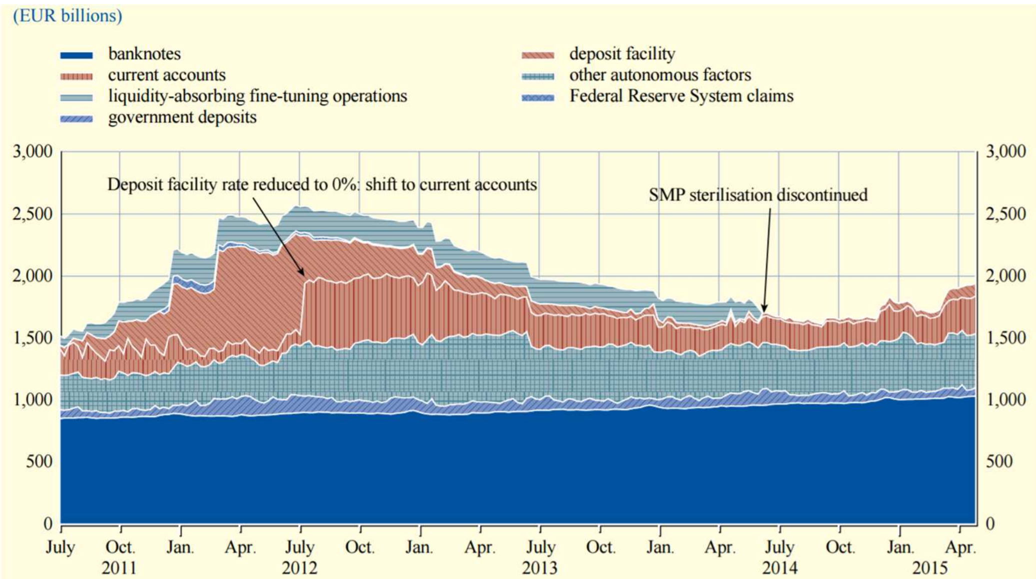
Appendix 2

A. Breakdown of the simplified Eurosystem balance sheet: assets



Source: ECB.

B. Breakdown of the simplified Eurosystem balance sheet: liabilities



Source: ECB.

Appendix 3

ECB announcement dates and content

Date	Details of announcement
08/10/2008	MRO rate decreased to 3.75% + The GovC decided to adopt a fixed rate tender procedure with full allotment
13/10/2008	The GovC decided to conduct U.S. dollar liquidity-providing operations at FRFA
15/10/2008	The GovC decided to expand the list of assets eligible as collateral, enhance the provision of longer-term refinancing operations, and provide U.S. dollar liquidity through foreign exchange swaps
06/11/2008	MRO rate decreased to 3.25%
04/12/2008	MRO rate decreased to 2.50%
18/12/2008	The GovC decided that the main refinancing operations will continue to be carried out through a fixed rate tender procedure with full allotment for as long as needed
19/12/2008	The GovC decided to continue conducting U.S. dollar liquidity-providing operations
15/01/2009	MRO rate decreased to 2.00%
05/02/2009	Interest rates remain unchanged
05/03/2009	The GovC decided to continue the fixed rate tender procedure with full allotment for all main refinancing operations, special-term refinancing operations and supplementary and regular longer-term refinancing operations for as long as needed + MRO rate decreased to 1.50%
02/04/2009	MRO rate decreased to 1.25%
06/04/2009	The GovC decided to establish a temporary reciprocal currency arrangement (swap line) with the Fed
07/05/2009	The GovC decided to proceed with the ECS. In particular, the GovC decided to purchase euro-denominated covered bonds issued in the Euro Area, and to conduct liquidity-providing longer-term refinancing operations with a maturity of one year, MRO rate decreased to 1%
04/06/2009	The GovC decided upon the technical modalities of the CBPP1
02/07/2009	Interest rates remain unchanged
06/08/2009	Interest rates remain unchanged
03/09/2009	Interest rates remain unchanged
08/10/2009	Interest rates remain unchanged
05/11/2009	Interest rates remain unchanged
03/12/2009	The GovC decided to continue conducting its main refinancing operations as fixed rate tender procedures with full allotment for as long as is needed, and to enhance the provision of longer-term refinancing operations (no interest changes)
14/01/2010	Interest rates remain unchanged
04/02/2010	Interest rates remain unchanged
04/03/2010	The GovC decided to continue conducting its main refinancing operations as fixed rate tender procedures with full allotment for as long as is needed, and to return to variable rate tender procedures in the regular 3-month longer-term refinancing operations
08/04/2010	Interest rates remain unchanged
06/05/2010	Interest rates remain unchanged
10/05/2010	The GovC decided to proceed with the SMP, to reactivate the temporary liquidity swap lines with the Fed, to adopt a fixed-rate tender procedure with full allotment in the regular 3-month longer-term refinancing operations, and to conduct new special longer-term refinancing operations
10/06/2010	The GovC decided to adopt a fixed rate tender procedure with full allotment in the regular 3-month longer-term refinancing operations
08/07/2010	Interest rates remain unchanged
28/07/2010	Collateral rules tightened, revised haircuts
05/08/2010	Interest rates remain unchanged
02/09/2010	The GovC decided to continue to conduct its main refinancing operations as fixed rate tender procedures with full allotment for as long as necessary, and to conduct 3-month longer-term refinancing operations as fixed rate tender procedures with full allotment (no interest changes)
07/10/2010	Interest rates remain unchanged
04/11/2010	Interest rates remain unchanged
02/12/2010	The GovC decided to continue to conduct its main refinancing operations as fixed rate tender procedures with full allotment for as long as necessary, and to conduct 3-month longer-term refinancing operations as fixed rate tender procedures with full allotment (no interest changes)
17/12/2010	The ECB announced a temporary swap facility with the Bank of England

Date	Details of announcement
13/01/2011	Interest rates remain unchanged
03/02/2011	Interest rates remain unchanged
03/03/2011	The GovC decided to continue to conduct its main refinancing operations as fixed rate tender procedures with full allotment for as long as necessary, and to conduct 3-month longer-term refinancing operations as fixed rate tender procedures with full allotment (no interest changes)
07/04/2011	MRO rate increased to 1.25%
05/05/2011	Interest rates remain unchanged
09/06/2011	The GovC decided to continue to conduct its main refinancing operations as fixed rate tender procedures with full allotment for as long as necessary, and to conduct 3-month longer-term refinancing operations as fixed rate tender procedures with full allotment (no interest changes)
07/07/2011	MRO rate increased to 1.50%
04/08/2011	The GovC decided to continue conducting its main refinancing operations as fixed rate tender procedures with full allotment for as long as necessary, to conduct 3-month longer-term refinancing operations as fixed rate tender procedures with full allotment, and to conduct a liquidity-providing supplementary longer-term refinancing operation with a maturity of six months as a fixed rate tender procedure with full allotment,SMP covers Spain and Italy (no interest changes)
08/08/2011	The GovC decided to actively implement its Securities Markets Programme for Italy and Spain
08/09/2011	Interest rates remain unchanged
15/09/2011	The GovC decided to conduct three U.S. dollar liquidity-providing operations in coordination with other central banks
06/10/2011	The GovC decided to continue conducting its main refinancing operations as fixed rate tender procedures with full allotment for as long as necessary, to conduct 3-month longer-term refinancing operations as fixed rate tender procedures with full allotment, to conduct two liquidity-providing supplementary longer-term refinancing operation with a maturity of twelve and thirteen months as a fixed rate tender procedure with full allotment, and to launch a new covered bond purchase program (CBPP2)
03/11/2011	The GovC decided upon the technical modalities of CBPP2, MRO rate decreased 1.25% (marginal lending facility:2%, deposit facility: 0.5%)
30/11/2011	The GovC decided in cooperation with other central banks the establishment of a temporary network of reciprocal swap lines
08/12/2011	The GovC decided to conduct two longer-term refinancing operations with a maturity of three years and to increase collateral availability,reserve ratio to 1%, MRO rate to 1%
12/01/2012	Interest rates remain unchanged
09/02/2012	The GovC approved specific national eligibility criteria and risk control measures for the temporary acceptance in a number of countries of additional credit claims as collateral in Eurosystem credit operations (no interest changes)
28/02/2012	The Governing Council of the European Central Bank (ECB) has decided to temporarily suspend the eligibility of marketable debt instruments issued or fully guaranteed by the Hellenic Republic for use as collateral in Eurosystem monetary policy operations.
08/03/2012	Interest rates remain unchanged
04/04/2012	Interest rates remain unchanged
03/05/2012	Interest rates remain unchanged
06/06/2012	The GovC decided to continue to conduct its main refinancing operations as fixed rate tender procedures with full allotment for as long as necessary, and to conduct 3-month longer-term refinancing operations as fixed rate tender procedures with full allotment
22/06/2012	The GovC took further measures to increase collateral availability for counterparties
05/07/2012	MRO rate decreased to 0.75%, deposit facility rate to 0
26/07/2012	Draghi's London speech ("...the ECB is ready to do whatever it takes to preserve the euro.")
02/08/2012	Interest rates remain unchanged
06/09/2012	The GovC announced the technical details of OMT (no ex-ante size limit) and decided on additional measures to preserve collateral availability (no interest changes)
04/10/2012	Interest rates remain unchanged
08/11/2012	Interest rates remain unchanged
06/12/2012	The GovC decided to continue conducting its main refinancing operations as fixed rate tender procedures with full allotment for as long as necessary, and to conduct 3-month longer-term refinancing operations as fixed rate tender procedures with full allotment
10/01/2013	Interest rates remain unchanged

Date	Details of announcement
07/02/2013	Interest rates remain unchanged
07/03/2013	Interest rates remain unchanged
22/03/2013	ECB announces changes to the use as collateral of certain uncovered government-guaranteed bank bonds
04/04/2013	Interest rates remain unchanged
02/05/2013	ECB announces change in eligibility of marketable debt instruments issued or guaranteed by the Cypriot government ,MRO rate to 0.5%, FRFA extended to July 2014
06/06/2013	Interest rates remain unchanged
28/06/2013	Eligibility of marketable debt instruments issued or guaranteed by the Republic of Cyprus
04/07/2013	The Governing Council expects the key ECB interest rates to remain at present or lower levels for an extended period of time .
01/08/2013	Interest rates remain unchanged
05/09/2013	Interest rates remain unchanged
02/10/2013	Interest rates remain unchanged
10/10/2013	ECB and the People's Bank of China establish a bilateral currency swap agreement
31/10/2013	ECB establishes standing swap arrangements with other central banks
07/11/2013	MRO rate decreases to 0,25%
22/11/2013	ECB suspends early repayments of the three-year LTRO's during the year-end period
05/12/2013	Interest rates remain unchanged
09/01/2014	Interest rates remain unchanged, the ECB emphasized the importance of the forward guidance through the sentence 'we firmly reiterate our forward guidance '
06/02/2014	Interest rates remain unchanged
06/03/2014	Interest rates remain unchanged
03/04/2014	Interest rates remain unchanged
08/05/2014	Interest rates remain unchanged
05/06/2014	ECB decides to conduct a series of targeted longer-term refinancing operations (TLTRO's) aimed at improving bank lending and to intensify preparatory work related to outright purchases of asset-backed securities (ABS). , ECB introduces a negative deposit facility interest rate , MRO rate decreases to 0,15%
03/07/2014	ECB announces further details of the targeted longer-term refinancing operations
07/08/2014	Interest rates remain unchanged
22/08/2014	Draghi hints on QE (Jackson Hole speech)
04/09/2014	ECB modifies loan-level reporting requirements for some asset-backed securities/MRO rate decreases to 0,05%
02/10/2014	ECB announces operational details of asset-backed securities and covered bond purchase programs (no interest changes)
06/11/2014	Interest rates remain unchanged
07/11/2014	ECB suspends early repayments of the three-year LTRO's during the year-end period
04/12/2014	Interest rates remain unchanged
22/01/2015	ECB announces a modification to the interest rate applicable to future targeted longer-term refinancing operations, ECB announces expanded asset purchase program
04/02/2015	Eligibility of Greek bonds used as collateral in Eurosystem monetary policy operations
05/03/2015	Interest rates remain unchanged
15/04/2015	Interest rates remain unchanged
03/06/2015	Interest rates remain unchanged
16/07/2015	Interest rates remain unchanged
03/09/2015	Interest rates remain unchanged
22/10/2015	Interest rates remain unchanged
03/12/2015	Deposit facility rate decreases to -0,3% + extension of QE 'until end March 2017'

Appendix 4

VAR model identification

The model defined by equations (8) and (9) is estimated following the iterative estimation procedure of Lanne and Lütkepohl (2008):

1. First, the reduced form VAR model in (8) is estimated using OLS (i.e. under the statistical assumption of homoscedasticity). The estimated residuals are used to construct estimates of the covariance matrices V_t. Defining D_t as a dummy variable that takes value 1 on announcement days and 0 on other days, we can write:

$$\widetilde{V}_t = \begin{cases} \dfrac{\sum_{t=1}^{T}(1-D_t)\,\hat{\varepsilon}_t\hat{\varepsilon}_t'}{T-\sum_{t=1}^{T}D_t} & \text{if } D_t = 0 \\ \dfrac{\sum_{t=1}^{T}D_t\,\hat{\varepsilon}_t\hat{\varepsilon}_t'}{\sum_{t=1}^{T}D_t} & \text{if } D_t = 1 \end{cases}$$

2. In a second step, we minimize the following loss function using our estimates for V_t in order to obtain the estimates for $\boldsymbol{R}$ and $\boldsymbol{\Omega_t}$:

$$\left(\widehat{\boldsymbol{R}}, \widehat{\boldsymbol{\Omega}}_t\right) = \min\left[-\left(\sum_{t=1}^{T}\log|\boldsymbol{R}\boldsymbol{\Omega_t}\boldsymbol{R}'| + \mathrm{tr}\left[\widetilde{V}_t(\boldsymbol{R}\boldsymbol{\Omega_t}\boldsymbol{R}')^{-1}\right]\right)\right]$$

Where min = optimization to optimal minimum

log = logarithmic function

tr = trace of the 6×6 square matrix, defined as the sum of the elements on the main diagonal of this matrix

3. In the third step, estimates $\widehat{\boldsymbol{R}}$ and $\widehat{\boldsymbol{\Omega}}_t$ can then be used to re-estimate the VAR model in (8) using the Feasible Generalized Least Squares (FGLS) estimator.[55] This step again results in estimates for the reduced form residuals, which are used to construct new estimates of the covariance matrix of the reduced form errors V_t.

Steps 2 and 3 are iterated until convergence, resulting in Gaussian maximum likelihood (GML) estimators if we do not impose that the residuals are normally distributed (and quasi-maximum likelihood estimators otherwise). Using $\widehat{\boldsymbol{R}}$ and the FGLS estimates of the reduced form errors, we can then trace out the structural monetary policy shock. Figure 10 plots the time series for the cumulative monetary policy shock for the the Eurozone (see section 2.2.3).

[55] The GLS estimator is used instead of the OLS estimator to estimate the classical lineair regression model when there is autocorrelation in the residuals.

Appendix 5

Stationarity diagnostics

Visual inspection of the monetary policy shocks series suggest an underlying non-stationary stochastic process as both the mean μ and variance σ^2 are time varying (Figure 18). A large accomodative shock is present in the second and third quarter of 2009 followed by alternating accomodative and restrictive shocks around a downward linear trend until the last quarter of 2016.

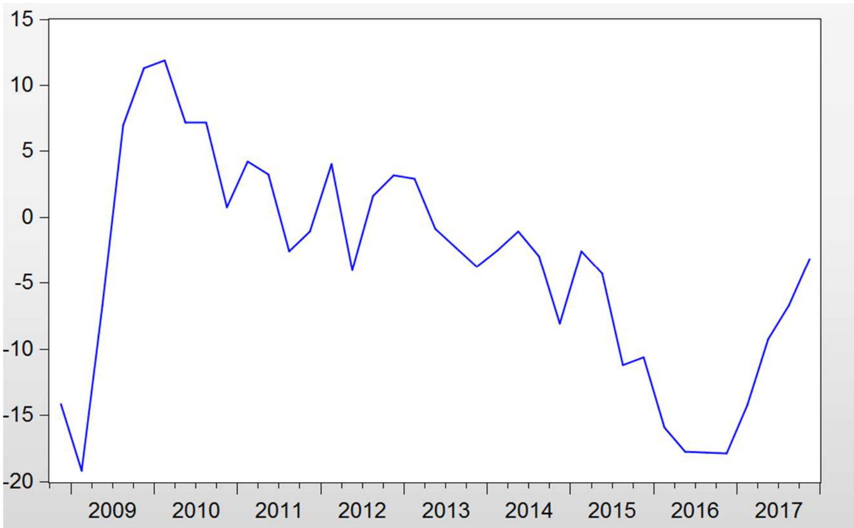


Figure 18: Monetary policy shocks time series

The correlogram in Figure 19 also indicates a clear pattern in the series: the probability of obtaining a Box-Pierce Q-statistic[56] of 145.44 under the null hypothesis that the sum of 36 squared estimated auto-correlations[57] is zero,

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[56] The joint significance of a group of m autocorrelations coefficients ρ_k can be tested by $Q = T\sum_{k=1}^{m}\rho_k^2$ with T being the sample size.

[57] The autocorrelation ρ_k is the correlation between y_t and all of its lags y_{t-k} with $\rho_k = \frac{cov\ (y_t, y_{t-k})}{var\ (y_t)}$.

is very small (0,0%). The partial autocorrelation function[58] cuts off after 1 lag wich is indicative for an AR(1) process, i.e. an autoregressive process of order 1.[59] However, the autocorrelation function does not die out slowly but flips sign and turns significant again at lag 25. On the other hand, it is also not a pure moving average (MA) process either.[60]

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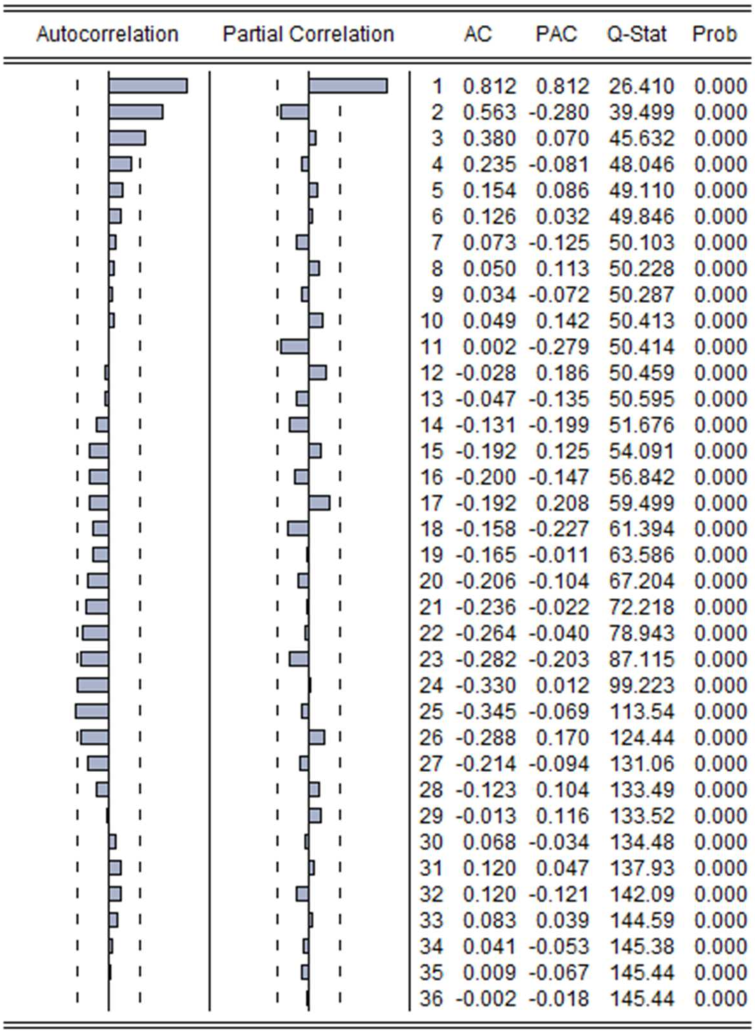
[58] The partial autocorrelation is the correlation between y_t and all of its lags y_{t-k} conditional on $y_{t-1}, \cdots, y_{t-k+1}$

[59] Let ε_t be a white noise process, then $y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i y_{t-i} + \varepsilon_t$ is an autoregressive process of order p, denoted AR(p).

[60] Let ε_t be a white noise process, then $y_t = \alpha_0 + \sum_{i=1}^{q} \beta_i \varepsilon_{t-i} + \varepsilon_t$ is a moving average process of order q, denoted MA(q).



Lag	AC	PAC	Q-Stat	Prob
1	0.812	0.812	26.410	0.000
2	0.563	-0.280	39.499	0.000
3	0.380	0.070	45.632	0.000
4	0.235	-0.081	48.046	0.000
5	0.154	0.086	49.110	0.000
6	0.126	0.032	49.846	0.000
7	0.073	-0.125	50.103	0.000
8	0.050	0.113	50.228	0.000
9	0.034	-0.072	50.287	0.000
10	0.049	0.142	50.413	0.000
11	0.002	-0.279	50.414	0.000
12	-0.028	0.186	50.459	0.000
13	-0.047	-0.135	50.595	0.000
14	-0.131	-0.199	51.676	0.000
15	-0.192	0.125	54.091	0.000
16	-0.200	-0.147	56.842	0.000
17	-0.192	0.208	59.499	0.000
18	-0.158	-0.227	61.394	0.000
19	-0.165	-0.011	63.586	0.000
20	-0.206	-0.104	67.204	0.000
21	-0.236	-0.022	72.218	0.000
22	-0.264	-0.040	78.943	0.000
23	-0.282	-0.203	87.115	0.000
24	-0.330	0.012	99.223	0.000
25	-0.345	-0.069	113.54	0.000
26	-0.288	0.170	124.44	0.000
27	-0.214	-0.094	131.06	0.000
28	-0.123	0.104	133.49	0.000
29	-0.013	0.116	133.52	0.000
30	0.068	-0.034	134.48	0.000
31	0.120	0.047	137.93	0.000
32	0.120	-0.121	142.09	0.000
33	0.083	0.039	144.59	0.000
34	0.041	-0.053	145.38	0.000
35	0.009	-0.067	145.44	0.000
36	-0.002	-0.018	145.44	0.000

Figure 19: Monetary policy shocks series correlogram

A number of Autoregressive Integrated Moving Average (ARIMA) models were evaluated to describe the monetary policy shocks series.[61] Two models display similar model fit but entail different interpretations concerning stationarity of the monetary policy shocks series: the AR(1,2,11) model is a

[61] The order of integration (I) refers to whether a series is stationary or non-stationary. A stationary series is said to be integrated of order 0 (ARMA model). A non-stationary series is said to be integrated of some order > 0.

stationary process whereas the ARMA((1,2,11),1) is a non-stationary process. The AR(1,2,11) model can be written as

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_{11} y_{t-11} + \varepsilon_t \tag{18}$$

The parameters can be estimated using the OLS estimator as y_{t-1}, y_{t-2}, and y_{t-11} are observed in the data,

so that α_1 = 0.78 (t-statistic = 3.55)

α_2 = 0.04 (t-statistic = 0.21)

α_{11} = -0.04 (t-statistic = -0.30)

Residual sum of squares = 335.8360

Akaike information criterion = 5.7040

Schwarz bayesian information criterion = 5.8976

The AR(1,2,11) process has a stable infinite MA representation whereby the characteristic roots of the invertable AR polynomial are > 1 (not shown). Because the latter is stationary by construction, the AR(1,2,11) process is stationary. Also both the necessary ($\alpha_1 + \alpha_2 + \alpha_{11} < 1$) and sufficient condition ($|\alpha_1| + |\alpha_2| + |\alpha_{11}| < 1$) for stationarity hold. The error terms are white noise indicating that the AR(1,2,11) model is rich enough to capture all of the dynamics in the monetary policy shocks series (Figure 20).

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.011	0.011	0.0033	
		2	0.016	0.016	0.0109	
		3	0.254	0.254	2.0582	
		4	-0.116	-0.128	2.4997	0.114
		5	-0.135	-0.149	3.1334	0.209
		6	-0.079	-0.147	3.3600	0.339
		7	-0.202	-0.148	4.9178	0.296
		8	-0.074	-0.010	5.1373	0.399
		9	0.013	0.058	5.1450	0.525
		10	0.055	0.128	5.2834	0.625
		11	-0.221	-0.305	7.6557	0.468
		12	-0.056	-0.195	7.8176	0.553
		13	0.119	0.045	8.6152	0.569
		14	-0.302	-0.218	14.144	0.225
		15	-0.027	-0.009	14.193	0.289
		16	-0.041	-0.172	14.312	0.352
		17	-0.063	0.021	14.637	0.403
		18	0.128	-0.017	16.123	0.374
		19	0.089	0.011	16.943	0.389
		20	0.068	0.032	17.511	0.420
		21	0.133	-0.030	20.073	0.329
		22	-0.031	-0.207	20.246	0.380
		23	0.022	-0.123	20.365	0.435
		24	-0.014	0.082	20.432	0.494
		25	-0.049	-0.029	22.196	0.448

Figure 20: AR(1,2,11) model error terms

The ARMA((1,2,11),1) model can be written as

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_{11} y_{t-11} + \beta_1 \varepsilon_{t-1} + \varepsilon_t \qquad (19)$$

The parameters cannot be estimated using the OLS estimator as ε_{t-1} is not observed in the data. One possible solution is to estimate the parameters from the AR representation of the MA model. The latter is non-linear in the unknown parameter β_1 thus the Non-linear Least Squares (NLS) estimator is used,[62]

[62] The NLS estimator is biased but consistent.

so that α_1 = 1.79 (t-statistic = 9.54)

α_2 = -0.82 (t-statistic = -4.38)

α_{11} = -0.08 (t-statistic = -0.73)

β_1 = -0.99 (t-statistic = -1817.24)

Residual sum of squares = 293.4290

Akaike information criterion = 5.6460

Schwarz bayesian information criterion = 5.8879

The necessary ($\alpha_1 + \alpha_2 \ + \alpha_{11} < 1$) condition for stationarity holds in the ARMA((1,2,11),1) model, but the sufficient condition is violated ($|\alpha_1| + |\alpha_2| + |\alpha_{11}| > 1$). In contrast to the stationary AR(1,2,11) process, the ARMA((1,2,11),1) process is thus non-stationay. Figure 21 shows that the error terms are white noise indicating that the more complex ARMA((1,2,11),1) model also captures the monetary policy shocks series well. We tend to prefer the ARMA((1,2,11),1) model as both the Akaike and Schwarz bayesian information criterion display the best model fit.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.114	-0.114	0.3815	
		2	-0.029	-0.042	0.4066	
		3	0.318	0.314	3.6065	
		4	-0.039	0.034	3.6566	
		5	-0.041	-0.035	3.7149	0.054
		6	0.013	-0.108	3.7211	0.156
		7	-0.192	-0.228	5.1275	0.163
		8	-0.117	-0.170	5.6796	0.224
		9	-0.013	-0.026	5.6864	0.338
		10	-0.024	0.128	5.7129	0.456
		11	-0.329	-0.265	10.961	0.140
		12	-0.044	-0.168	11.062	0.198
		13	0.144	0.081	12.228	0.201
		14	-0.316	-0.200	18.272	0.051
		15	0.056	0.002	18.478	0.071
		16	0.035	-0.080	18.569	0.099
		17	-0.024	0.100	18.614	0.136
		18	0.148	0.030	20.612	0.112
		19	0.027	-0.057	20.688	0.147
		20	-0.016	-0.054	20.719	0.190
		21	0.091	-0.079	21.935	0.187
		22	-0.021	-0.184	22.018	0.231
		23	-0.023	-0.135	22.144	0.277
		24	0.013	0.107	22.202	0.330
		25	-0.005	-0.030	22.219	0.387

Figure 21: ARMA((1,2,11),1) model error terms

In order to take into account the unceraintty around the different ARMA model parameters (i.e. the standard error of the estimate), unit root tests are conducted (see below). We interpret the unit root tests in line with the previous startionarity diagnostics and consider the monetary policy shock series X_2 to be non-stationary. Therefore, the series was transformed to stationary data by taking first differences.[63]

All other time series included in model (10) (i.e both q2 and q5 portfolio return and wealth inequality for each of the participating countries) were evaluated analogously (see Table 3 for an overview).

[63] If a series needs to be differenced one time before it becomes stationary, it is said to be integrated of order 1.

Unit root tests

In order to take into account the uncerainty around the different ARMA model parameters (i.e. the standard error of the estimate), unit root tests are conducted. We use two different models to test for both stochastic and deterministic non-stationarity.

The first model is a random walk model without any deterministic components:

$$y_t = \alpha_1 y_{t-1} + \varepsilon_t \tag{20}$$

Depending on the value of α_1 different cases can be distinguished:

$|\alpha_1| < 1$: stationary case (shocks gradually die out)

$|\alpha_1| = 1$: unit root case (shocks persist in the system)

$|\alpha_1| > 1$: explosive case (shocks have increasingly large influence)

So that the unit root hypothesis corresponds to

$$H_0 : \alpha_1 = 1$$

$$H_1 : \alpha_1 < 1$$

The Dicky-Fuller unit root test uses a more conventient regression, i.e. equation (20) rewritten as

$$\begin{aligned} y_t - y_{t-1} &= (\alpha_1 - 1)\ y_{t-1} + \varepsilon_t \\ \Delta y_t &= \gamma y_{t-1} + \varepsilon_t \end{aligned} \tag{21}$$

with $\gamma = \alpha_1 - 1$ and ε_t a whithe noise error term.

The unit root hypothesis now corresponds to

$$H_0 : \gamma = 0$$

$$H_1 : \gamma < 0$$

which can be tested by calculating the t-statistic.

However, under $H_0 : \gamma = 0$ the standard t-statistic does not have a t-distribution so we can't use the standard critical values from the normal distribution to compare with. Dicky and Fuller (1979) derive the appropriate distribution using Monte Carlo simulation.[64] Table 8 presents the estimates and simulated Dicky-Fuller critical values for the random walk model described under equation (21). We use the MacKinnon (1996) version[65] of the Dicky and Fuller critical values for the estimated parameters in the random walk model, i.e. α_1.

[64] The simulated distribution is skewed to the right so that critcal values are smaller than those from the normal distribution.

[65] These are the simulated critical values as implemented in EViews: http://www.eviews.com/help/helpintro.html#page/content%2Fadvtimeser-Unit_Root_Testing.html%23

	random walk model			drift + trend model		
	estimate	t-stat	simulated critical value	estimate	t-stat	simulated critical value
α_1	-0.17	-2.02	-1.94	-0.31	-2.96	-3.54
α_0	-	-	-	2.59	1.62	3.20
ϕ	-	-	-	-0.19	-2.17	-2.85
AIC	5.9385			5.9100		
SBC	5.9825			6.0419		

AIC: Akaike information criterion
SBC: Schwarz bayesian information criterion

Table 8: Dicky-Fuller unit root test

The second model is the stochastic random walk model (21) in which two deterministic terms are added:

$$\Delta y_t = \alpha_0 + \phi t + \gamma y_{t-1} + \varepsilon_t \qquad (22)$$

with $\gamma = \alpha_1 - 1$ and ε_t a whithe noise error term.

The intercept α_0 adds a detreministic trend, i.e. random walk with drift, to the stochastic trend whereas the ϕ parameter comprises a linear trend. For the parameters in the model with both a drift and trend term, i.e. α_0, α_1, and ϕ, we use the critical values tables provided by the Dicky and Fuller (1981) paper (see Figure 22).

TABLE II

EMPIRICAL DISTRIBUTION OF $\hat{\tau}_{\alpha\tau}$ FOR $(\alpha, \beta, \rho) = (0, 0, 1)$ IN $Y_t = \alpha + \beta t + \rho Y_{t-1} + e_t$.

(Symmetric Distribution)

Sample size n	Probability of a smaller value			
	0.90	0.95	0.975	0.99
25	2.77	3.20	3.59	4.05
50	2.75	3.14	3.47	3.87
100	2.73	3.11	3.42	3.78
250	2.73	3.09	3.39	3.74
500	2.72	3.08	3.38	3.72
∞	2.72	3.08	3.38	3.71
s.e.	0.004	0.005	0.007	0.008

TABLE III

EMPIRICAL DISTRIBUTION OF $\hat{\tau}_{\beta\tau}$ FOR $(\alpha, \beta, \rho) = (0, 0, 1)$ IN $Y_t = \alpha + \beta t + \rho Y_{t-1} + e_t$

(Symmetric Distribution)

Sample size n	Probability of a smaller value			
	0.90	0.95	0.975	0.99
25	2.39	2.85	3.25	3.74
50	2.38	2.81	3.18	3.60
100	2.38	2.79	3.14	3.53
250	2.38	2.79	3.12	3.49
500	2.38	2.78	3.11	3.48
∞	2.38	2.78	3.11	3.46
s.e.	0.004	0.005	0.006	0.009

Figure 22: Simulated critical values from the Dicky and Fuller (1981) paper

Both the Akaike (AIC) and Schwarz bayesian information criterion (SBC) are used to evaluate the specification of our Dicky-Fuller unit root test. The more conservative[66] SBC indicates that the random walk process described

[66] AIC $= T.\,ln(residual\ sum\ of\ squares) + 2k$, and SBC $= T.\,ln(residual\ sum\ of\ squares) + k.\ln(T)$ with T the sample size and k the number of estimated parameters. SBC is a more severe criterion as $\ln(T) > 2$.

under equation (21) fits the data best. The H_0 that the monetary policy shock series has a unit root ($\alpha_1 = 1$ or $\gamma = 0$) can be rejected as the t-stat (-2.02) is to the left of the simulated 5% critical value (-1.94). This would imply that the monetary policy shock series X_2 is stationary. However, the AIC indicates that the random walk with drift and linear trend process described under equation (22) fits the data better. In this case, the H_0 that the monetary policy shock series has a unit root ($\alpha_1 = 1$ or $\gamma = 0$) can't be rejected as the t-stat (-2.96) is to the right of the simulated 5% critical value (-3.54). We interpret the unit root tests in line with the previous startionarity diagnostics and consider the monetary policy shock series X_2 to be non-stationary. Therefore, the series was transformed to stationary data by taking first differences.[67]

[67] If a series needs to be differenced one time before it becomes stationary, it is said to be integrated of order 1.

Appendix 6

A. Basic static model error terms for Belgian q2 household portfolio return series

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.153	0.153	0.9162	0.338
		2	0.183	0.164	2.2655	0.322
		3	0.181	0.140	3.6305	0.304
		4	0.462	0.424	12.760	0.013
		5	0.138	0.026	13.606	0.018
		6	-0.091	-0.303	13.983	0.030
		7	0.096	-0.038	14.419	0.044
		8	0.171	0.018	15.848	0.045
		9	0.119	0.122	16.570	0.056
		10	-0.186	-0.093	18.397	0.049
		11	-0.028	-0.102	18.439	0.072
		12	0.054	-0.045	18.605	0.099
		13	-0.030	-0.071	18.658	0.134
		14	-0.149	0.038	20.035	0.129
		15	-0.114	0.016	20.877	0.141
		16	0.072	0.062	21.228	0.170
		17	-0.065	-0.038	21.530	0.203
		18	-0.093	-0.029	22.192	0.224
		19	-0.038	0.073	22.307	0.269
		20	0.092	0.074	23.034	0.287
		21	-0.089	-0.130	23.753	0.305
		22	-0.149	-0.158	25.918	0.255
		23	-0.057	-0.084	26.258	0.289
		24	0.075	0.117	26.901	0.309
		25	-0.165	-0.082	30.299	0.213
		26	-0.118	0.038	32.211	0.186
		27	-0.086	-0.086	33.334	0.186
		28	0.025	-0.084	33.441	0.220
		29	-0.209	-0.122	41.955	0.057
		30	-0.106	0.123	44.523	0.043
		31	-0.172	-0.104	52.646	0.009
		32	-0.085	-0.142	55.144	0.007
		33	-0.089	0.075	58.751	0.004
		34	-0.168	0.005	78.141	0.000
		35	-0.036	0.089	79.884	0.000

B. ADL(4,3) model error terms for Belgian q2 household portfolio return series

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.121	-0.121	0.5262	0.468
		2	0.120	0.107	1.0661	0.587
		3	-0.121	-0.098	1.6306	0.652
		4	0.150	0.119	2.5296	0.639
		5	-0.104	-0.059	2.9794	0.703
		6	-0.050	-0.106	3.0860	0.798
		7	0.315	0.368	7.5065	0.378
		8	-0.151	-0.157	8.5635	0.380
		9	0.154	0.105	9.6980	0.375
		10	-0.149	-0.029	10.814	0.372
		11	-0.028	-0.271	10.854	0.456
		12	-0.361	-0.243	18.026	0.115
		13	-0.075	-0.191	18.350	0.145
		14	0.112	0.062	19.117	0.161
		15	-0.150	-0.093	20.554	0.152
		16	0.058	-0.023	20.786	0.187
		17	-0.099	0.021	21.490	0.205
		18	0.102	0.029	22.290	0.219
		19	-0.194	0.103	25.385	0.148
		20	0.072	0.074	25.842	0.171
		21	-0.072	-0.088	26.339	0.194
		22	-0.010	-0.014	26.348	0.237
		23	0.045	-0.121	26.587	0.274
		24	0.037	-0.101	26.760	0.316
		25	0.029	-0.112	26.883	0.362
		26	-0.023	0.032	26.973	0.411
		27	0.022	-0.121	27.066	0.460
		28	-0.011	0.003	27.097	0.513
		29	0.001	0.055	27.097	0.566
		30	-0.000	-0.010	27.097	0.618
		31	-0.000	0.069	27.097	0.667
		32	0.000	-0.015	27.097	0.713

Appendix 7

Cointegration analysis

We estimate the static model outlined in equation (10) and (12) using the wealth inequality data from Austria:

$$\boldsymbol{y} = \boldsymbol{X}\hat{\boldsymbol{\beta}} + \hat{\boldsymbol{\varepsilon}}$$

$$y_t = \hat{\alpha}_0 + \hat{\beta}_0 x_t + \hat{\varepsilon}_t$$

If the residuals ε_t of the regression are integrated of order 0 (stationary), i.e. $\varepsilon_t \sim I(0)$, then y_t and x_t are said to be cointegrated of order CI(1,1) with cointegrating vector $\beta = (1, -\alpha_0, -\beta_0)$. This means that y_t and x_t have individual stochastic trends $I(1)$ and their linear combination is $I(0)$. The concept of cointegration would indicate the existence of a long-run equilibrium relation between monetary policy x_t and wealth inequality y_t, such that deviations from the equilibrium are stationary:

$$\hat{\varepsilon}_t = y_t - (\hat{\alpha}_0 + \hat{\beta}_0 x_t)$$

where $\hat{\varepsilon}_t$ = the equilibrium error, i.e. the distance the economic system is away from equilibrium at time t

The econometric implication of the cointegration case is that the OLS estimator $\hat{\beta}_0$ is a super consistent estimator for β_0 , so that $\hat{\beta}_0$ converges to β_0 at a much faster rate than with conventional asymptotics.[68] More important, the error correction term $\hat{\varepsilon}_t$ should be added to the ADL model in first differences in case of cointegration because otherwise you would make a specification error by omitting the error term (see further equation (23)). The mechanism that drives variables back to their long-run equilibrium relationship is called the error-correction model which is a simple reparameterization of the ADL in levels (Granger representation theorem).

We use the Engle-Granger two-step approach to test for cointegration. The first step is to estimate the static model (12). We consider two alternative tests. The cointegrating regression Durbin-Watson (CRDW) test statistic equals 0.24 and is to the right of 5% critical value for the CRDW test (0.20). Thus, we can reject the null hypothesis of no cointegration ($\varepsilon_t \sim I(1)$). Although, this is indicative for cointegration, the CRDW test is only valid when residuals follow an AR(1) process which is not the case here. In turn, the Augmented Dicky-Fuller (ADF) cointegration test tests for a unit root in the estimated residuals $\hat{\varepsilon}_t$ using the standard ADF specification:

$$\mathrm{H}_0 : \gamma = 0 \quad (\varepsilon_t \sim I(1))$$
$$\mathrm{H}_1 : \gamma < 0 \quad (\varepsilon_t \sim I(0))$$

which can be tested by calculating the t-statistic.

[68] If non-stationary variables are not cointegrated, results from the static regression model are not meaningful, i.e. the spurious regression problem.

Note that standard DF critical values are not valid because the residuals $\hat{\varepsilon}_t$ are estimates from the static model rather than observed data (ε_t).[69] Appropriate critical values are simulated by MacKinnon (1990) and can be calculated from the following function:

$$C(p) = \phi_\infty + \phi_1 T^{-1} + \phi_2 T^{-2}$$

where T = sample size

p = significance

ϕ_∞, ϕ_1 and ϕ_2 = response surfaces for the critical values

The MacKinnon 5% critical value for a test for cointegration on a static model including two variables, a constant and no trend for a sample of 37 observations equals -3.50 (= -3.3377 – (5.769/37) – (8.98/37^2). The test statistic equals -2.95 so we cannot reject the the null hypothesis of no cointegration ($\varepsilon_t \sim I(1)$).

In a second step, we construct the following error-correction model using the estimated residuals $\hat{\varepsilon}_t$ from the long-run static model (12):

$$y_t = \hat{\alpha}_0 + \hat{\alpha}_1 y_{t-1} + \hat{\beta}_0 x_t + \hat{\varphi}_1 \hat{\varepsilon}_t + \hat{\mu}_t \tag{23}$$

[69] The ADF test was originally developed as a unit root test on observed data series, but the residuals from the long-run static model $\hat{\varepsilon}_t$ are estimated within this model. By including these estimated residuals within the error-correction model we can take the uncertainty around these estimates into account by performing a t-test and comparing it with standard critical values (in case of cointegration) or MacKinnon (1990) critical values (in case of spurious regression).

The error-correction model (23) consist of the best fitting ADL (1,0) model in first differences and the error correction term $\hat{\varepsilon}_t$ (i.e. estimated residuals $\hat{\varepsilon}_t$ from the long-run static model). Note that the ADF unit root test on the estimated residuals $\hat{\varepsilon}_t$ of the long-run static model (step 1 Engle-Granger approach) indicated that we could not reject the null hypothesis of no cointegration. Since we can assume that the monetary policy x_t and wealth inequality y_t series are not cointegrated, the estimated residuals from the long-run static model (12) are a non-stationary $I(1)$ process. So, when these are included in the error-correction model (23), we can't compare their t-stat to standard critical values (like this would have been the case for a I(0) variable in case of cointegration between monetary policy x_t and wealth inequality y_t). The t-stat of $\hat{\varphi}_1$-parameter of the estimated residuals $\hat{\varepsilon}_t$ from the long-run static model within the the error-correction model (1.99) is to the right of the MacKinnon 5% critical value (-3.50). Therefore, the error-correction term $\hat{\varepsilon}_t$ is not signifcant at 5% level.[70] This also confirms the interpretation of the ADF test of no cointegration between the monetary policy x_t and wealth inequality y_t in Austria. All other combinations of non-stationary variables (see Table 3) were evaluated analogously.

[70] Interestingly, the residuals from the error-correction model (23) have $I(0)$ behavior because these are almost identical to the ADL (1,0) model as no cointegration was found. The error-correction term $\hat{\varphi}_1$ equals zero, and thus error-correction model = ADL_{diff} = ADL_{levels}