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Heterogeneous macro and financial effects of ECB asset purchase programs

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ABSTRACT

Like other central banks, the ECB resorted to asset purchase programs (APPs) to replace conventional policy measures. We examine their impact on the Euro area with a focus on the heterogeneity among its constituents and across financial markets. Our analysis combines a Bayesian structural VAR with an identification scheme based on market surprises at the announcement time, effectively capturing structural dynamics. At the Euro area level, APPs stimulate the economy, lower government bond yields, elevate stock prices, and reduce corporate and sovereign stress. The impact shows heterogeneity in the stock market with a widened value-growth spread in stocks and varying sector impacts, particularly favoring financial stocks, and across countries with stronger effects on southern Euro area countries. Our results show strong spillover effects between countries, indicating challenges in the precise targeting of APPs.

1. Introduction

The past two decades have witnessed the introduction of new types of central bank policy interventions in Europe. After the financial crisis of 2007–2008, the European Central Bank (ECB) adopted several conventional and unconventional measures to stabilize financial markets and bank lending, and to support monetary policy transmission mechanisms. Starting July 2009, the ECB started several bond purchase programs. Following other central banks in quantitative easing,[1] the ECB announced on January 22, 2015, its first large-scale asset purchase program (APP). The goal of this program is to promote price stability and to reduce deflation risk by easing financial conditions for both households and firms as the interest rate approached the effective lower bound. This APP is as of yet the ECB's largest, concerning trillions of Euros. Fig. 1 illustrates the ECB's balance sheet, highlighting a significant asset increase from 2015, exceeding 50% of Euro-zone GDP by 2020.

In this study, we investigate the heterogeneity of the effects of the ECB's asset purchase programs on the economies and financial markets of the Euro area. As the balance sheet of the ECB continues to grow and given the possible need of additional purchase programs in the future (European Parliament, 2020), it is vital to understand the transmission of such programs. According to the ECB, these APPs ensure price stability, but also help firms to have better access to credit, boost investment, and support economic growth by job creation. Importantly, the ECB emphasizes that it is shaped by fragmentation within the Euro zone and that their

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[1] Examples are the Federal Reserve's large scale asset purchase programs in the US taking place between 2008–2012, Bank of Japan's quantitative easing policy (2001–2018) and the Bank of England's quantitative easing program in 2009–2010. See Rogers et al. (2014) for an overview of these programs.

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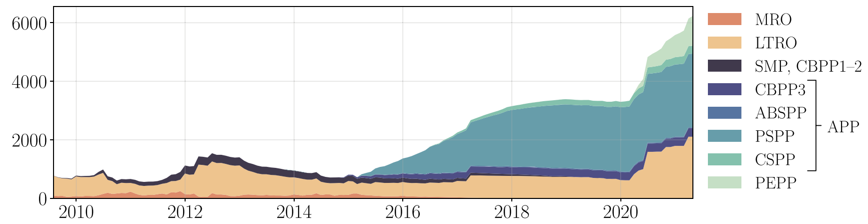


Note: Liquidity purpose programs: long-term refinancing operations (LTRO) and main refinancing operations (MRO). Monetary purpose programs: securities market program and covered bond purchase programs (SMP, CBPP1–2), CBPP3, corporate sector purchase program (CSPP), public sector purchase program (PSPP), asset-backed securities purchase program (ABSPP), and the pandemic emergency purchase program (PEPP).

Fig. 1. Balance sheet European Central Bank in billions of Euros.

effectiveness depends on spillovers between countries, but whether the financial effects are heterogeneous and as targeted is not yet known. We focus on government bond yields, stocks, sovereign debt and corporate debt markets. Specifically, we consider sector-specific indices to shed light on the effect across stocks, and country-specific data to analyze the transmission across countries, while also focusing on the spillover effects.

We study these dynamic effects using a Bayesian structural vector autoregression (SVAR) analysis and examine cross-country heterogeneity through a global vector autoregression (GVAR) analysis (Pesaran et al., 2004). We use a novel identification method based on Jarociński and Karadi (2020) to identify an asset purchase (AP) shock through sign and zero restrictions. This approach isolates AP announcements, excluding supply and demand shocks. We determine AP shocks using market reactions to central bank announcements, assuming direct responses in stock prices and interest rates. Additionally, we define an information shock as the positive co-movement of interest rate and stock price changes, distinguishing it from non-monetary central bank statements. Our Bayesian estimation approach allows us to take into account estimation uncertainty. We analyze the dynamic effect of both structural shocks using impulse response analysis, and measure the long-term effect of the programs introduced until March 2021.

We start by validating our model at the European level to capture the Euro area's fundamental economic dynamics and assess the impact of AP shock. Our findings show that an AP shock leads to a rise in real GDP and CPI. In financial markets, asset purchases immediately reduce 1- and 10-year Euro area government bond yields by 4 basis points and boost the stock market, with the most profound increase of 0.6% after three months. Value stocks, with lower cash-flow duration, gain more from asset purchases compared to growth firms by 0.6%. Financial stocks, especially those in covered bond purchase programs, are significantly positively affected. Lower bank lending rates, indicating improved financial conditions, benefit other sectors as well. Asset purchases stabilize markets by reducing corporate credit spreads and alleviating stress in sovereign bond markets. Central bank information shocks provide a temporary boost to financial markets.

Delving further with our GVAR analysis, which can accommodate spillover effects, we not only shed light on heterogeneity in transmission, but also its origins—revealing that a portion stems more from spillovers than direct effects. Every Euro area economy experiences output and price stimulation, with Southern regions impacted the most, intensified by spillovers. All European stock markets see a 0.3–1.5% increase, more pronounced in higher credit rating economies. Government bond yields generally follow a similar pattern post-AP announcement, with minor variations due to the ECB's flexible APPs. Asset purchases significantly stabilize Southern Euro area sovereign debt markets. Spillovers usually dominate direct effects in both macro and financial variables, emphasizing the need to consider inter-country spillovers. Central bank information shocks are more homogeneous and transient, but can help to reduce heterogeneity across countries.

Next to the evidence for heterogeneity and spillover effects, our VAR-based approach identifies the working mechanisms of the Euro area's APPs. The reduction in government bond yields point towards the signaling channel, as an asset purchase announcement signals that enduring low interest rates, driving down short-term rate expectations and yields. We observe evidence of the portfolio rebalancing channel, where post AP announcement, a surge in asset demand elevates prices and depresses yields, reducing bank risk and lending rates. Notably, APP-targeted assets and countries experience the most pronounced effects. We note a preference for assets with low cash-flow duration as alternatives to long-term bonds and identify a re-anchoring channel, with asset purchases pushing investors to riskier assets in search for yield. Our VAR-approach captures the transmission channels predicted by theory (Andrade et al., 2016) and is in line with empirical evidence (e.g., Fabo et al., 2021).

We further assess the workings of the transmission channels using the New Keynesian model of Gertler and Karadi (2013), calibrated to fit the European context. The model's impulse responses are aligned through matching them to our European baseline results. The structural analysis reveals that interest rates being at the effective lower bound and low household portfolio adjustment costs serve as key components in the functioning of the portfolio rebalancing channel in response to an asset purchase shock. In the absence of these components, the transmission would differ substantially from our baseline findings.

Our paper contributes to the literature on central bank asset purchase programs by studying heterogeneity in transmission on financial markets and across countries in a structural setting. The GVAR allows us to investigate heterogeneity across countries while accounting for spillover effects. Given the diverse nature of Euro area economies and the lack of coordinated fiscal policy, our approach is relevant for studying the impact of quantitative easing in currency areas like the Euro area, complementing other studies on central bank asset purchases in the US, UK, and Japan (e.g., Wright, 2012; Rogers et al., 2014; Weale and Wieladek, 2016). Our findings show that central banks can somewhat target specific countries or industries, but economic spillovers complicate steering effects to particular countries.

Several policy recommendations can be obtained from our analysis. While asset purchase programs target Euro zone inflation expectations, their impact is notably stronger in Southern Euro area countries, stabilizing these regions and reducing Euro area heterogeneity. However, concerns have been raised about the APPs, like the ECB's public sector purchases potentially exceeding its legislative scope (Viterbo, 2021). Our findings also caution the ECB about possible side effects, such as increased investor risk-taking indicated by rising stock prices and narrowing credit spreads. We observe a dampening effect on market volatility and a modest decrease in stress indices. Another side effect could be stemming from low lending rates, which might keep non-viable firms alive at the cost of more productive firms, as we document a decrease in lending rates.

The paper is structured as follows. Section 2 discusses the related literature. In Section 3 we introduce the data, and in Section 4 we discuss the methodology. Section 5 presents the results, and Section 6 concludes.

2. Literature

In this section, we discuss two strands that are particularly relevant for our research, being the identification of an asset purchase shock, and the transmission channels of such a shock.

2.1. Identification of an asset purchase shock

Traditional monetary policy works through adjusting policy rates. Yet, at the effective lower bound, rate-based stimulus becomes ineffective. Consequently, central banks use unconventional tools like LSAPs for economic stimulation. The complexity of these programs demands alternative methods for identifying these types of policy shocks, necessitating the use of additional variables beyond policy rates.[2]

One way to identify an asset purchase shock is through the central bank's balance sheet in an SVAR setting. For the Euro area, Gambacorta et al. (2014), Boeckx et al. (2017) and Lewis and Roth (2019) identify an AP shock using sign restrictions, in combination with contemporaneous zero restrictions on output and prices.[3] They find a positive effect on output and prices, but these macroeconomic effects are heterogeneous among Euro countries. Recent research challenges the premise whether the increase in balance sheet of central banks correctly identifies unconventional monetary policy.[4]

Another way to identify an AP shock is through financial market responses. As financial markets respond directly to announcements, Kuttner (2001) suggests using financial market responses, isolating the unexpected policy announcement components through short-window market movements around central bank announcements (Nakamura and Steinsson, 2018). Various event studies, including those by Bernanke and Kuttner (2005) and Gürkaynak et al. (2005) for the US, analyze price movements surrounding such announcements. Altavilla et al. (2019) study price changes of a broad class of assets and find lasting effects of quantitative easing on stocks and the 10-year maturity yield curve. Meanwhile, studying ECB's APPs impact, Georgiadis and Gräb (2016) find decreasing government bond yields, increased stock prices, and Euro depreciation against other major currencies.

In an SVAR setting, financial market responses are utilized as external instruments or exogenous variables. Gertler and Karadi (2015) use interest rate surprises as instruments to identify monetary shocks via a proxy VAR approach, a strategy similarly employed by Rogers et al. (2018) and Hachula et al. (2020) for unconventional policy shocks. Paul (2020) demonstrates the equivalence of including such surprises as exogenous variables in time-varying SVAR settings. Investigating policy announcements' macroeconomic effects in the US and Euro area, Jarociński and Karadi (2020) incorporate price changes in futures and a stock index into a VAR model, identifying monetary and information shocks–termed *Odyssean* and *Delphic* shocks, respectively, involving central bank commitments and forward guidance announcements (Campbell et al., 2012).

We use shock decomposition to identify an asset purchase shock. Concurrently, we identify a central bank information shock, based on the co-movement of these surprises. By re-ordering variables we naturally impose the initial responses of output and prices to zero, such that AP shocks are isolated from supply or demand induced shocks. Inspired by Weale and Wieladek (2016), we also construct an asset purchase volume variable containing the cumulative value of an announced package at the date of announcement. This variable is restricted to increase in case of an asset purchase shock. We further include financial variables in our baseline VAR, such as government bonds, stock indices, and stress measures to shed more light on the transmission of these shocks. We also use sector-specific stock indices and country-specific financial variables. We leave these responses unrestricted.

2.2. Transmission of an asset purchase shock

In monetary economics, the dynamic impact of (unconventional) monetary policies is often assessed through the concept transmission channels.[5] Asset purchases do not directly affect the economy but operate through these channels. Andrade et al. (2016)

[2] See Rossi (2020) for an overview of research on the identification and estimation of unconventional monetary policy shocks in vector autoregressive settings.

[3] Other papers also identify unconventional monetary policy shocks as an increase in the balance sheet. For example, Weale and Wieladek (2016) focus on the US and UK, Schenkelberg and Watzka (2013) on Japan.

[4] Elbourne and Ji (2019) replace the central bank's balance sheet by random numbers and find similar results as Boeckx et al. (2017). They argue that identification based on balance sheet expansion does not identify unconventional monetary policy shocks. Yet Boeckx et al. (2019) claim that the identification of these shocks by balance sheet data is valid as they show qualitative and statistical differences between the random numbers shock and the original unconventional monetary policy shock. Therefore, the validity of balance sheet identification remains ambiguous.

[5] See Woodford (2011) for an overview of monetary policy transmission mechanisms.

categorize these mechanisms into three groups. The signaling channel, according to Eggertsson et al. (2003), suggests that ECB announcements on unconventional policies strengthen the credibility of sustained low interest rates. This signals lower future short-term rates, leading to a decrease in yields across all maturities, primarily through expected short rates rather than the term premium. This effect is broad, influencing a wide range of yields. Bauer and Rudebusch (2014) provides evidence for this signaling effect in the US.

Unconventional monetary policy can also work through narrower channels, that is, having most impact on the targeted assets of the programs. The portfolio rebalancing channel implies that if investors have preferred habitats (Vayanos and Vila, 2021), asset purchases affect yields sensitive to interest rate risk or yields with a high maturity, through the impact of the purchases on duration and scarcity as a consequence of market segmentation. This leads to decreased long-term yields via reduced term premiums, not changes in short-term rate expectations. Consequently, investors favor private debt and equity over less appealing long-term government bonds. Additionally, higher bond prices from asset purchases enhance bank valuations, enabling riskier loans and lower lending rates. Bechtel et al. (2021) provides empirical support, finding a 6% drop in accessible safe assets following ECB's asset purchases.

The re-anchoring channel suggests that AP announcements direct inflation expectations and confirm the ECB's dedication to economic stimulation, especially when short-term rates are low. These announcements lower uncertainty about future output and inflation, possibly reducing durable consumption uncertainty and spurring investor risk-taking, which boosts consumption and lowers the risk premium. Krishnamurthy and Vissing-Jorgensen (2011) note reduced inflation uncertainty and default risk premia from US quantitative easing.

While short-term impacts of asset purchase programs are widely documented, their long-term effects are less explored. Mamaysky (2018) shows that while government bonds in the US, UK, and EU react quickly to asset purchase announcements, equity and its volatility respond slower, within 3-4 weeks. The portfolio rebalancing channel suggests non-targeted assets could be affected through lower borrowing costs, leading to varied impacts. This aspect has been examined in event studies (Haitsma et al., 2016; Fratzscher et al., 2016), though not in structural analyses. Our study casts light upon this issue in the broader perspective of SVAR models that capture the propagation of shocks in a system of connected macroeconomic and financial variables.

Finally, financial market fragmentation within the Euro zone makes it challenging to conduct effective and fair monetary policy. Georgiadis (2015) and Burriel and Galesi (2018) show there is macroeconomic heterogeneity in the transmission of conventional and unconventional monetary policy within the Euro zone, respectively. However, the ECB has found ways to accommodate heterogeneity in unconventional monetary policy, ensuring their APPs are flexible to market conditions.[6] We use our identification approach based on market surprises combined with sign and zero restrictions in a GVAR setting to investigate the transmission across eight Euro area countries. This approach enables us to analyze country-specific heterogeneity and spillover effects within a one encompassing model.

3. Data

We use aggregated European data and specific data from Austria, Belgium, France, Germany, Italy, the Netherlands, Portugal, and Spain, the largest Euro zone economies comprising over 80% of its GDP.[7] Our dataset spans from July 2009 to March 2021, starting in 2009 when the ECB began unconventional monetary measures in response to the 2007–2008 financial crisis. Section 3.1 and Section 3.2 detail the variables for identifying structural shocks, Section 3.3 outlines the dependent variables, and Appendix B provides a complete data description.

3.1. Central bank announcements

We obtain Euro area central bank announcement surprises from the EA-MPD of Altavilla et al. (2019), detailing asset price changes due to European policy events. The ECB shifted its monetary policy meetings from a four-week to a six-week cycle in January 2015. A monetary event usually contains a press statement at 13:45 followed by a one-hour press conference with Q&A, starting at 14:30. Price changes are gauged in an 85–100 minute window around these events, reducing the influence of external factors, such as a pre-announcement drift (Lucca and Moench, 2015). Our sample comprises 116 central bank monetary events.[8]

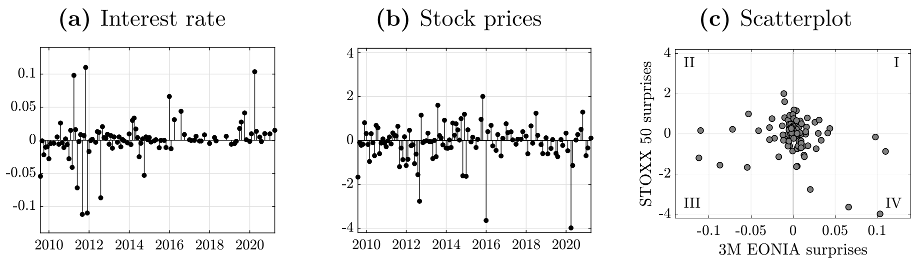
We focus on surprises in the 3-month EONIA rate-based overnight index swap[9] and the EURO STOXX 50, which includes the top fifty liquid Euro area stocks. The 3-month OIS swap price change indicates unexpected shifts in interest rate expectations two meetings ahead, and the STOXX 50 change mirrors stock price fluctuations. Figs. 2a and 2b display these surprises over time. Notably, the most significant 3-month EONIA swap surprises occurred around 2011 and 2012, coinciding with conventional measures and initial asset purchase program announcements. The 10 basis point surprise on March 12, 2020, was due to escalating COVID-19

[6] See, for example, the speech of Cœuré (2019) on *heterogeneity and the ECB's monetary policy* and https://www.ecb.europa.eu/mopo/implement/app/html/index.en.html.

[7] Greece is excluded due to temporary suspension of its bond documentation, though Greek stocks and bonds closely align with Portugal's.

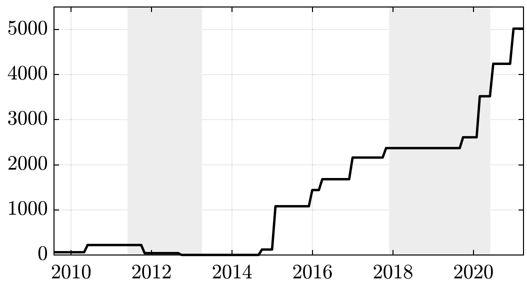
[8] Appendix A contains a detailed description of the ECB asset purchase programs. The timing of these meetings within a month is challenging. Until 2015, ECB meetings were in the beginning of the month and therefore the time between monthly data and the policy announcement is similar. After the change to a six-week cycle, meetings took place at different days within the month. We only have a small number of meetings at the end of the month in our sample—not enough to analyze this separately. We leave this for further research.

[9] Similar results are obtained using the 1-year overnight index swap.



Note: Figs. 2a and 2b show the change in the 3-month overnight index swap based on the EONIA rate and the change in the EURO STOXX 50 index around a monetary event, respectively. Fig. 2c shows both these changes, where each dot is an ECB announcement. Source: EA-MPD (Altavilla et al., 2019).

Fig. 2. Market surprises in percentage points.



Note: Shaded areas correspond to the OECD based recession indicators for the Euro area from the period following the peak through the trough.

Fig. 3. ECB's Asset purchase announcement series, volume in billions of Euro.

concerns in Europe, followed by the PEPP announcement. Stock price surprises are more evenly spread over time, with negative surprises tending to be larger.

Fig. 2c shows that the financial market responses are quite evenly spread across the quadrants. The surprises in the second quadrant are associated with AP shocks, as for example the asset purchase announcement on September 4, 2014 and January 22, 2015.

3.2. Announced volume of asset purchases

We construct a variable for the announced volume of asset purchase programs following Weale and Wieladek (2016). The cumulative value is calculated in the announcement month, regardless of when the program starts. This method overcomes timing issues. For example, the package announced on January 22, 2015, started in March 2015. Our approach addresses these timing discrepancies. For re-calibration announcements, we compute the cumulative corrected value. These announcements, depicted in Fig. 3 in billions of Euros, show significant increases in January 2015, with an 18-month program of 60 billion Euros monthly purchases, and in March 2020, with the announcement of additional asset purchase packages and the PEPP.

3.3. Variables of interest

We are interested in the effect of the asset purchase programs on a broad array of macroeconomic and financial variables. We consider output and CPI as macroeconomic indicators, and use Chow-Lin interpolation to construct a monthly proxy for economic output. Specifically, we interpolate quarterly real GDP based on 19 Euro countries using the monthly industrial production index, both seasonally adjusted. Prices are for the Euro area modeled by the seasonally adjusted Harmonized Index of Consumer Prices.

For financial variables, we use data on stocks and bonds. Specifically, we utilize the Euro area government bond yield for 1- and 10-year maturities, based on AAA-rated issuers. The MSCI Europe index represents stock prices.[10] To analyze asset purchase shock impacts on different stock types, we include the MSCI EU value and growth indices spread ratio. We also consider the BBB bond spread, reflecting Euro zone corporate debt market conditions, and a Euro zone sovereign stress index. This index is the GDP-weighted Sovereign Composite Indicator of Systemic Stress (CISS) (Hollo et al., 2012), indicating current stress in sovereign debt markets.

In our baseline model, we incorporate eleven variables: two surprises from Section 3.1, the asset purchase (AP) volume announcement series from Section 3.2, and six macroeconomic and financial variables. We log-transform output, prices, announcement series,

[10] Other indices like EURO STOXX 50 and EURO STOXX 600 provide similar results.

and stock price indices and ratios.[11] To further explore shock transmission, we add the nominal effective exchange rate, lending rates for corporations and households, and the 5-year forward inflation expectation rate to our model. We also include various sector-specific MSCI indices to examine stock market heterogeneity. For the country-specific analysis we consider each country's real GDP, CPI, 1 and 10-year government bond yields, MSCI index, MSCI value-growth ratio and sovereign stress index.

4. Methodology

First, in Section 4.1, we introduce the structural VAR model we use to analyze the effect of asset purchase shocks and central bank information shocks. We then describe the identifying restrictions we impose and our Bayesian estimation method. Last, we introduce the GVAR framework we use to investigate country-specific effects—which is a multi-country model consisting of multiple domestic VAR models and one common VAR model. We use the same identification and estimation approach for the GVAR as for the aggregate baseline setting.

4.1. Euro area baseline setting

Let Y_t denote the vector containing all N variables. In the spirit of Jarociński and Karadi (2020), we partition Y_t in three groups, where h_t are the surprises, and z_t and x_t are the combined macroeconomic and financial variables, in which z_t are the N_z variables on which the contemporaneous impact of the exogenous shocks are restricted to be zero and x_t are the variables responding to the exogenous shocks. We can thus write $Y_t = (z_t', h_t', x_t')'$. In the baseline setting we study a vector autoregression (VAR) of order p

$$\begin{pmatrix} z_t \\ h_t \\ x_t \end{pmatrix} = \begin{pmatrix} \mu_z \\ 0 \\ \mu_x \end{pmatrix} + \sum_{\ell=1}^{p} \begin{pmatrix} B_\ell^{zz} & B_\ell^{zh} & B_\ell^{zx} \\ 0 & 0 & 0 \\ B_\ell^{xz} & B_\ell^{xh} & B_\ell^{xx} \end{pmatrix} \begin{pmatrix} z_{t-\ell} \\ h_{t-\ell} \\ x_{t-\ell} \end{pmatrix} + \begin{pmatrix} u_t^z \\ u_t^h \\ u_t^x \end{pmatrix}, \qquad \begin{pmatrix} u_t^z \\ u_t^h \\ u_t^x \end{pmatrix} \sim \mathcal{N}(0, \Sigma), \tag{1}$$

where we use μ to denote the intercept, thus $\mu = (\mu_z', 0', \mu_x')'$, and B_ℓ similarly denotes the coefficient matrices corresponding to lag ℓ. The surprises are modeled to have zero mean and no dependency on other variables, imposed by the zeros in B_ℓ. We set $p = 2$. Details on model fit and lag selection are reported in Appendix E.

In order to conduct structural analysis, we consider the following SVAR representation of Equation (1), such that

$$A_0 Y_t = a + \sum_{\ell=1}^{p} A_\ell Y_{t-\ell} + \varepsilon_t, \qquad \varepsilon_t \sim \mathcal{N}(0, I_N), \tag{2}$$

where a is the intercept vector, A_0 denotes an invertible coefficient matrix capturing the contemporaneous effects, and A_ℓ denotes the coefficient matrices corresponding to lag ℓ. We can link the disturbances $u_t = (u_t^{z\prime}, u_t^{h\prime}, u_t^{x\prime})'$ and structural shocks ε_t through $u_t = A_0^{-1}\varepsilon_t$. The variance-covariance matrix Σ of u_t contains $N(N-1)/2$ unknown parameters. Because A_0 contains N^2 parameters, the system of Equation (2) is not identified and additional identifying restrictions need to be imposed.

To identify the shocks of interest, we follow Uhlig (2005) and Rubio-Ramirez et al. (2010) and define an orthogonal rotation matrix Q, which we use to transform the structural parameters from Equation (2) into the reduced-form parameters from Equation (1). That is, $u_t = PQ\varepsilon_t$, with P being the lower triangular Cholesky factor of Σ with non-negative diagonal elements. It follows that $A_0^{-1} = PQ$. Given a candidate solution for A_0^{-1}, we can calculate the impulse response functions (IRF). We impose restrictions on these IRFs to identify S structural shocks of interest. These restrictions are discussed in the next section.

The VAR approach in Equation (1) with restricted coefficient matrix can be interpreted as a VARX model with h_t as exogenous variables. Paul (2020) shows that the VARX approach yields consistent estimates of the true relative IRFs, even if the surprises are contaminated by independent measurement errors. Our approach is akin to the internal instrument approach of ordering instruments first in a VAR (Plagborg-Møller and Wolf, 2021), when the instruments are uncorrelated to z_t and x_t. Appendix C elaborates on this.

Alternative methods include using a proxy VAR with external variables (Stock and Watson, 2012; Mertens and Ravn, 2013) or the local projection instrumental variable approach (Stock and Watson, 2018). Plagborg-Møller and Wolf (2021) demonstrate that this approach and the internal instrument SVAR approach yield identical impulse response functions. The internal instrument approach remains valid for noninvertible shocks, unlike the proxy VAR, which requires invertibility. To avoid potential noninvertibility issues with including ECB announcement surprises, we integrate these surprises into our VAR model instead of using them as external instruments, enabling one-step parameter estimation.

4.2. Identification

We identify structural shocks using an economic theory-based scheme with sign and zero restrictions on impulse responses, following Canova and De Nicolo (2002) and Uhlig (2005). Variables are ordered as in (1), imposing zero restrictions on z_t responses to S shocks. Our baseline VAR includes real GDP, CPI, interest rate and stock price surprises, asset purchase volume, government bond yields, MSCI index, value-growth ratio, BBB spread, and a sovereign stress index. We identify two structural shocks: an asset

[11] We analyze data in levels to maintain long-term variable relationships. Stock and bond variables are measured monthly, while macroeconomic variables are flow variables. This does not affect our results. See Appendi B for data transformation details and variable types.

Table 1
Identifying restrictions on the shocks.

		Asset purchase shock	Central bank information shock
z_t	Output	0	0
	Prices	0	0
h_t	EONIA 3-months surprise	−	+
	STOXX 50 surprise	+	+
x_t	Announced asset purchase volume	+	
	1-year government bond yield		
	10-year government bond yield		
	MSCI index		
	MSCI value-growth ratio		
	BBB spread (corporate debt)		
	Sovereign CISS (sovereign debt)		

Note: + denotes that the impulse response is restricted to be increasing (non-negative) and − decreasing (non-positive). 0 corresponds to the impulse response set at zero. No specification corresponds to impulse response being unrestricted. All restrictions are imposed upon impact.

purchase shock and a central bank information shock, corresponding to the third and fourth column of A_0^{-1}. Table 1 details these shocks' identifying restrictions.

The first column outlines the identifying restrictions for an AP shock. We define monetary policy shocks as financial market movements during the ECB's announcements and press conferences. Measured in a narrow window around these events, they reflect the immediate market reaction. Both conventional and unconventional monetary policy shocks, like APPs, manifest as negative co-movements between interest rate changes and stock prices. Expansionary policy, which includes both conventional and unconventional measures (Kerssenfischer, 2019), lowers interest rates (3-month OIS) and boosts stock prices due to increased expected future dividends and reduced discount rates. To link this negative co-movement specifically to an AP shock, the announced asset purchase volume must rise (Weale and Wieladek, 2016), signaling an ECB balance sheet expansion. This variable, along with other unrestricted ones, is included in x_t.

We align with monetary policy literature in assuming no immediate effect of policy measures on output and prices. Consequently, the initial responses of output and CPI are constrained to zero. This approach helps filter out aggregated supply and demand shocks. Prices and output are permitted to respond starting one month post-shock, as per the imposed zero restrictions.

The second column of Table 1 shows the identifying restrictions for a central bank information shock. To differentiate AP shocks as *Odyssean*, where central banks commitment to future actions, we introduce a *Delphic* shock, relating to central bank news or potential monetary actions. Distinguishing these shocks, as suggested by Jarociński and Karadi (2020) and Andrade and Ferroni (2021), is crucial due to their distinct economic impacts. Both are marked by positive interest rate and stock price co-movement. We also assume output and prices do not immediately respond to these shocks. Results to alternative identification schemes are reported in Appendix E.

4.3. *Estimation*

We estimate the reduced-form parameters $(\mu, B_1, ..., B_p, \Sigma)$ of Equation (1) in a Bayesian fashion. In line with the Bayesian VAR literature, we choose a Minnesota type prior, $p(\mu, B_1, ..., B_p, \Sigma) = p(\mu, B_1, ..., B_p)p(\Sigma)$, where $p(\Sigma)$ follows an Inverse Wishart distribution and $p(\mu, B_1, ..., B_p)$ follows a normal distribution.[12] Gibbs sampling produces posterior distribution draws by sampling from two conditional posteriors of Σ and $(\mu, B_1, ..., B_p)$, which follow the Inverse Wishart and normal distribution. We draw from the Normal-Inverse-Wishart posterior over the orthogonal reduced-form parameterization, and transform the draws to a Normal-Generalized-Normal posterior over the structural parameterization, conditional on the zero and sign restrictions using an importance sampler of Arias et al. (2018).

To obtain estimates for A_0^{-1}, we construct Q in the spirit of Rubio-Ramirez et al. (2010). This algorithm also allows us to construct confidence bounds based on the multiple model draws. Specifically, for each posterior draw containing estimates of the reduced-form parameters, we construct a matrix Q and propose a candidate solution for $A_0^{-1} = PQ$. The orthogonal matrix Q is constructed as

$$Q = \begin{pmatrix} I_{N_z} & 0 & 0 \\ 0 & Q_S & 0 \\ 0 & 0 & I_m \end{pmatrix}, \tag{3}$$

where Q_S is a 2×2 orthogonal matrix obtained from a QR decomposition on matrix-valued Gaussian random variables. Here, I_{N_z} and I_m denote identity matrices, where $m = N - N_z - 2$. As P denotes the lower triangular Cholesky factor of Σ, the effect of the

[12] Appendix C provides a sensitivity analysis on the prior hyperparameters and a discussion on conditional priors (Giannone et al., 2015).

two shocks on z_t upon impact is by construction restricted to be zero. If the candidate orthogonal IRFs match the sign restrictions in Table 1, we save the structural responses.

Constructing Q such that the zero restrictions hold is not sufficient to draw independently from the set of all structural parameters, as the set of all structural parameters satisfying the zero and sign restrictions is substantially small. To obtain these independent draws, we determine importance weights following Arias et al. (2018) and re-sample the considered structural responses with replacements from the draws using these weights. Details on the estimation procedure, including prior and posterior distributions and determining the importance sampler weights are provided in Appendix C.

The reported results are based on a burn-in period of 5,000 draws, and we store every third draw from the following draws until we obtain 1,000 stable models from the posterior distribution. This results in 541 impulse responses after re-sampling.

The restrictions we impose provide set-identification, where the resulting IRFs are not unique. In case of unique IRFs, the SVAR is exactly identified. Rubio-Ramirez et al. (2010) show that this is the case when the total number of restrictions is equal to $N(N-1)/2$ and additional rank conditions are satisfied. Giacomini and Kitagawa (2021) note that for set-identified SVARs, the parameter prior can be split into two parts: one for the reduced-form parameters and another for the rotation matrix Q, which remains unchanged by data. Thus, we also present confidence bounds of Giacomini and Kitagawa (2021), which are robust to different priors on Q, in Appendix E.

4.4. Country-specific GVAR framework

In order to investigate the country-specific heterogeneity of asset purchase programs, we consider the GVAR framework of Burriel and Galesi (2018), introduced in Pesaran et al. (2004) and extended by Dees et al. (2007), for 8 Euro area countries. Each country's economy is modeled by a domestic VAR, and common Euro area factors are modeled in a separate VAR. The framework allows for modeling direct effects of an asset purchase shock, and for cross-country interactions. The domestic VARX(p_i, q_i) for economy i is denoted by

$$Y_{it} = c_i + \sum_{\ell=1}^{p_i} C_{i,\ell} Y_{i,t-\ell} + \sum_{\ell=0}^{q_i} \Lambda_{i,\ell} Y^*_{i,t-\ell} + \sum_{\ell=0}^{q_i} \Gamma_{i,\ell} X_{t-\ell} + u_{it}, \tag{4}$$

where Y_{it} denotes the vector containing endogenous country-specific variables. We consider 7 domestic variables; output, prices, 1- and 10-year government bond yield, MSCI index, value-growth spread and sovereign stress index. Here, p_i denotes the lag length of these variables, q_i denotes the lag length of all exogenous variables and u_{it} are idiosyncratic country-specific shocks, which are assumed to be serially uncorrelated with zero mean and variance-covariance matrix Σ_{ii}. The intercept is c_i, $C_{i,\ell}$ are coefficient matrices of the endogenous variables, and $\Lambda_{i,\ell}$ and $\Gamma_{i,\ell}$ are coefficient matrices of exogenous variables $Y^*_{i,t-\ell}$ and $X_{t-\ell}$, respectively. The foreign-specific variables $Y^*_{i,t-\ell}$ capture relative spillover effects between countries. Specifically,

$$Y^*_{it} = \sum_{j\neq i} w_{ij} Y_{jt}, \text{ where } \sum_{j\neq i} w_{ij} = 1. \tag{5}$$

The weights are trade-based weights and are assumed constant over time. We consider all domestic variables as spillovers. We further model three common Euro area variables X_t, two market surprises and the asset purchase announcement series, as a VARX(p_x, q_x) process

$$X_t = c_x + \sum_{\ell=1}^{p_x} \Psi_\ell X_{t-\ell} + \sum_{\ell=0}^{q_x} \Phi_\ell \widetilde{Y}_{t-\ell} + u_{xt}, \tag{6}$$

where c_x is the intercept, Ψ_ℓ and Φ_ℓ are coefficient matrices. Again, the idiosyncratic shocks u_{xt} are assumed to be serially uncorrelated with zero mean and variance–covariance matrix Σ_{xx}. The vector $\widetilde{Y}_t$ is the GDP-weighted average of all countries' domestic variables.

In short, the GVAR allows for cross-country interactions through cross-country linkages by foreign-specific variables in Equation (4), non-zero contemporaneous dependence of shocks, e.g., $\Sigma_{ij} \neq 0$ for country i and j, and common Euro area factors. Exploiting that $Y^*_{i,t}$ and $\widetilde{Y}_t$ are linear combinations of country-specific variables, we can combine Equation (4) and Equation (6) into one SVAR model as shown in Burriel and Galesi (2018), such that

$$H_0 \mathcal{Y}_t = h_0 + \sum_{\ell=1}^{\max_i (p_i)} H_\ell \mathcal{Y}_{t-\ell} + e_t, \tag{7}$$

where $\mathcal{Y}_t$ contains the stacked country-specific and common variables. In our setting, $\mathcal{Y}_t$ has 59 variables, as we consider 8 countries with 7 domestic variables for each, and 3 common variables. Here, e_t are residuals with variance-covariance matrix Σ_e. Provided that H_0 is invertible, we obtain the reduced-form VAR given by

$$\mathcal{Y}_t = k_0 + \sum_{\ell=1}^{\max_i (p_i)} K_\ell \mathcal{Y}_{t-\ell} + \eta_t, \tag{8}$$

Table 2
Impulse responses of identifying variables upon impact.

	Asset purchase shock		Central bank information shock	
	Median	16–84 perc.	Median	16–84 perc
Interest rate surprise (3 month EONIA)	−2.4	(−2.6, −1.6)	0.7	(0.1, 2.0)
Stock prices (STOXX 50)	30	(15, 60)	60	(34, 68)
Asset purchase announcement volume	3.6	(0.8, 12)		

Note: Median and 16–84th percentiles of the posterior distribution to one-standard deviation shocks. Surprises are reported in basis points, asset purchase announcement volume increase in percentage.

where $\eta_t = H_0^{-1} e_t$ with $\mathbb{E}[\eta_t \eta_t'] = H_0^{-1} \Sigma_e \left(H_0^{-1}\right)' = \Omega$. We use the same partition as in Equation (1). That is, we stack the zero restricted variables for each country, followed by the common variables and the other responding country-specific variables. We also restrict the market surprises by imposing zero restrictions on coefficient matrix K_ℓ.

We estimate the model in a country-per-country fashion as in Pesaran et al. (2004), as the model in Equation (8) contains too many parameters to estimate as a whole.[13] For each economy and the common factors, we estimate the reduced-form parameters in a Bayesian fashion described in Section 4.3 and impose the identifying restrictions of Table 1. This Bayesian set up differs from aforementioned research, as they use a bootstrap procedure to construct new samples. We choose a parsimonious lag structure; we set $p_i = 2$ and $q_i = 0$ for every country, such that we only consider contemporaneous relation to the exogenous variables, and we set both lags to 2 for the common model. We use the same Gibbs settings as described in Section 4.3, which results in 700 impulse responses.

5. Results

We now turn to the results. In Section 5.1, we explore the impact of asset purchase shocks across the Euro area, providing a clear picture of the model's functionality while also laying the groundwork for further analysis. In Section 5.2 we shift our focus to explore variations in how these shocks impact different industries and individual countries within the Euro area, with a particular focus on spillovers.

5.1. Euro area results

Table 2 shows the initial responses of key variables in our baseline VAR to a one standard deviation shock. These variables are 3-month EONIA rate shifts, stock price fluctuations around the policy event, and variations in announced asset purchase volumes. The market surprises are exogenous, and therefore have zero post-impact IRFs. An asset purchase shock entails a 2 basis point interest rate drop, a 30 basis point stock price rise, and a 4% announced volume increase. A central bank information shock leads to a 1 basis point interest rate rise and a 61 basis point stock price increase.

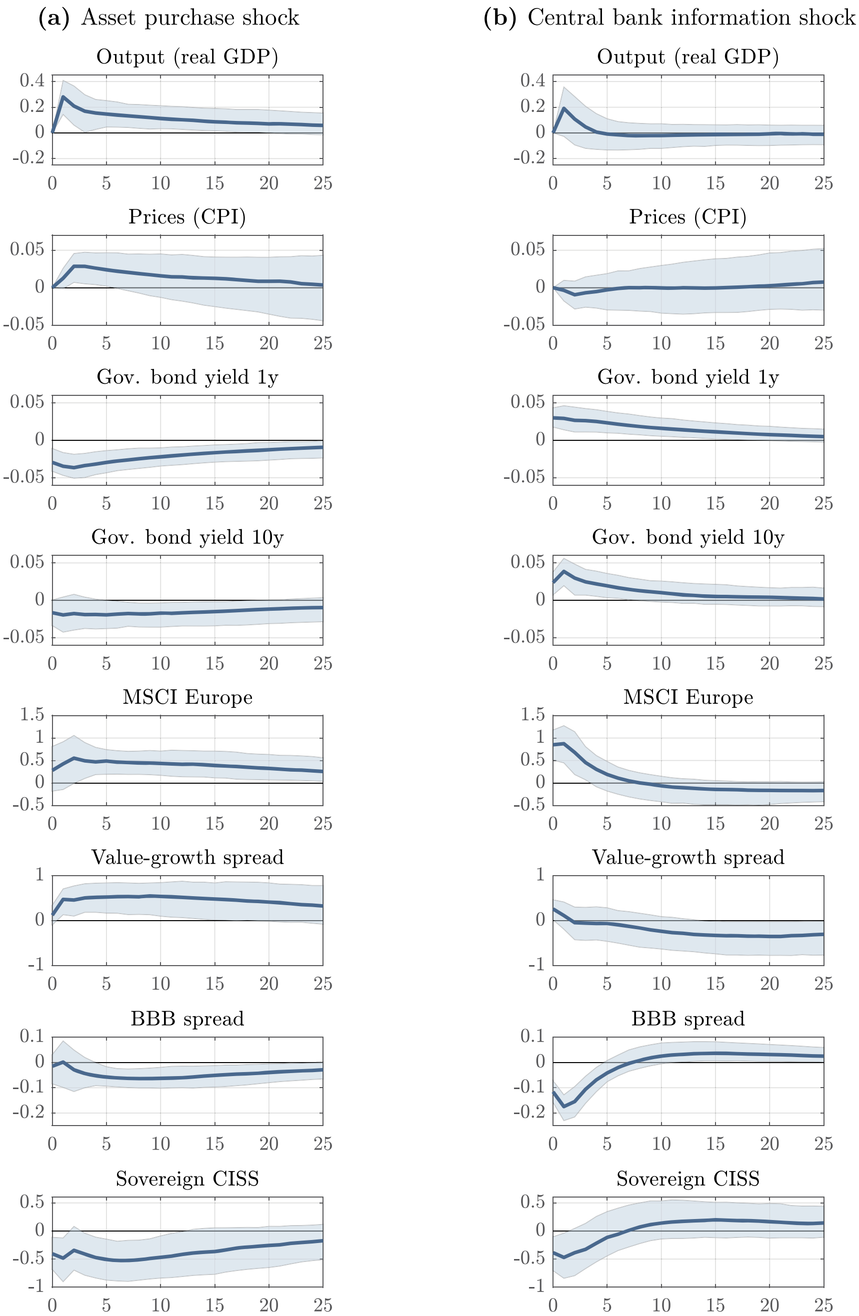
Fig. 4 shows macroeconomic and financial variable responses to asset purchase and central bank information shocks over 25 months. Median responses are shown with blue solid lines, and 16th and 84th percentiles of the posterior distribution with shaded areas. Asset purchases positively impact macroeconomics, notably with a 28 basis point real GDP increase in the first month, significantly positive for over six months. Price increases peak at 3–4 basis points after two months, remaining significant for about six months. Despite introducing a central bank information shock, the impulse responses of macro variables to asset purchase shocks in our study are consistent with aggregated results from prior European studies, see Appendix E Table E.3. Compared to conventional monetary policy shocks, asset purchase shocks more significantly affect output than prices. Central bank information shocks have minimal impact on both.

Regarding financial variables, we find that the 1-year AAA Euro area government bond yield drops 4 basis points after the announcement and goes slowly back to zero. The 10-year yield drops about 2–3 basis points, but with more estimation uncertainty. It seems that the dynamic effect on short-term yields is somewhat more profound than on 10-year yields.[14]

We identify a portfolio rebalancing channel marked by falling government bond yields, where an AP shock increases asset demand and lowers yields. Also, a signaling channel is noted, with short-term rates dropping when an AP announcement signals prolonged low interest rates. Our analysis does not support the expected significant decrease in long-term bond yields predicted by the portfolio rebalancing channel. While our observations align with Jarociński and Karadi (2020) in documenting similar yield responses to monetary policy shocks in the US, they contrast with findings by Eser et al. (2019) and Swanson (2021). These studies report a marked decline in long-term yields in both the Euro zone and the US, using an arbitrage-free term structure model. Notably, our subsequent structural analysis reveals that the anticipated reduction in long-term yields is not necessarily directly observable in empirical data. Further, central bank information shocks raise government bond yields, reflecting an anticipated monetary tightening due to a positive economic outlook.

[13] An alternative would be apply Bayesian shrinkage to the full model, as in Bańbura et al. (2010).

[14] Fig. E.5 in Appendix E reports the results for AA Euro area government bonds. This drop in yield is bigger in magnitude—a 13 and 7 basis point drop in yields for 1- and 10-year maturity, respectively. These results imply a heterogeneous effect of an AP shock on the yields for Euro area countries.

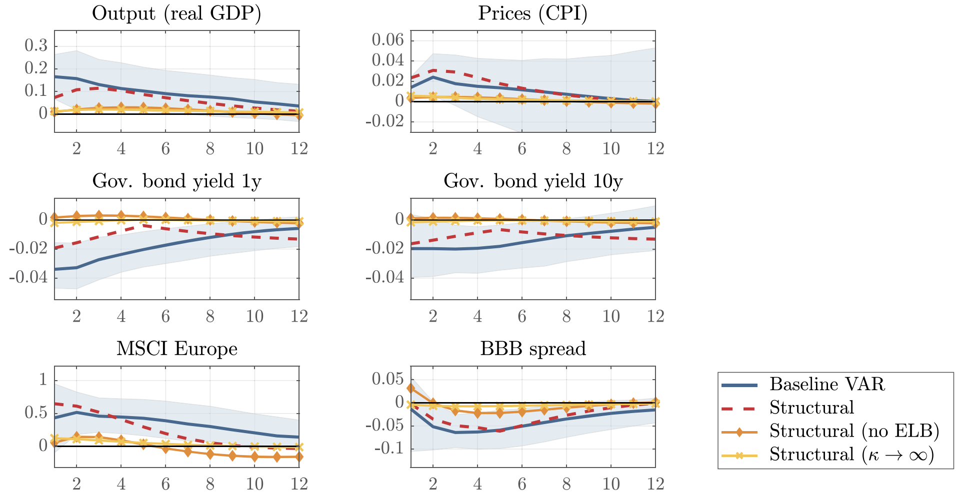


Note: Responses to one-standard deviation shocks over a 25 month horizon. Median (solid line), 16–84th percentiles (shaded area).

Fig. 4. Impulse response functions of macroeconomic and financial variables.

The European MSCI index shows a maximum 0.6% rise three months after an asset purchase shock, outlasting the immediate 1% increase from a central bank information shock, which returns to zero within six months. The MSCI value-growth spread increases by 0.6%, indicating value stocks benefit more from asset purchase shocks than growth stocks. However, the value-growth spread shows no significant change after a central bank information shock. These findings, highlighting firm-specific variations in response to unconventional monetary policies,[15] show more uniform reactions to central bank information shocks.

[15] This finding complements Durante et al. (2022), who find that younger and durable goods-producing firms are more sensitive to interest rate shocks using micro firm-level data.



Note: Impulse response functions over a 12 quarter horizon. Blue solid line corresponds to median averaged responses to one-standard deviation shocks over a 12 quarter horizon. Median (solid line), 16–84th percentiles (shaded area). The dashed red line corresponds to the matched impulse responses of the structural model. The orange diamond-marked line to the structural responses without restrictions to the effective lower bound (ELB), and the yellow cross-marked line to the structural responses where the portfolio adjustment costs κ become large.

Fig. 5. Structural impulse response functions to an asset purchase shock.

Stock price increases support both portfolio rebalancing and signaling channels. The rise in the value-growth spread might be due to bond investors moving to the stock market in search for yield, favoring stocks with low cash-flow duration. Additionally, declining short-term interest rates benefit value stocks with low cash-flow duration, while lower long-term rates could advantage growth firms as their dividends are further out in the future. It seems that the former effect dominates.

The BBB spread initially remains unaffected, then falls 7 basis points after four months, lasting over a year. Conversely, a central bank information shock quickly lowers the BBB spread by 20 basis points, but this effect reverses faster than an asset purchase shock. Both shocks reduce sovereign stress. These outcomes indicate that AP and central bank information announcements reassure both corporate and sovereign debt markets, with the former demonstrating a longer-lasting effect. These findings support the re-anchoring channel, wherein AP announcements guide inflation expectations and assure price stability. This channel posits that risk premia diminish as investors divert to riskier assets.

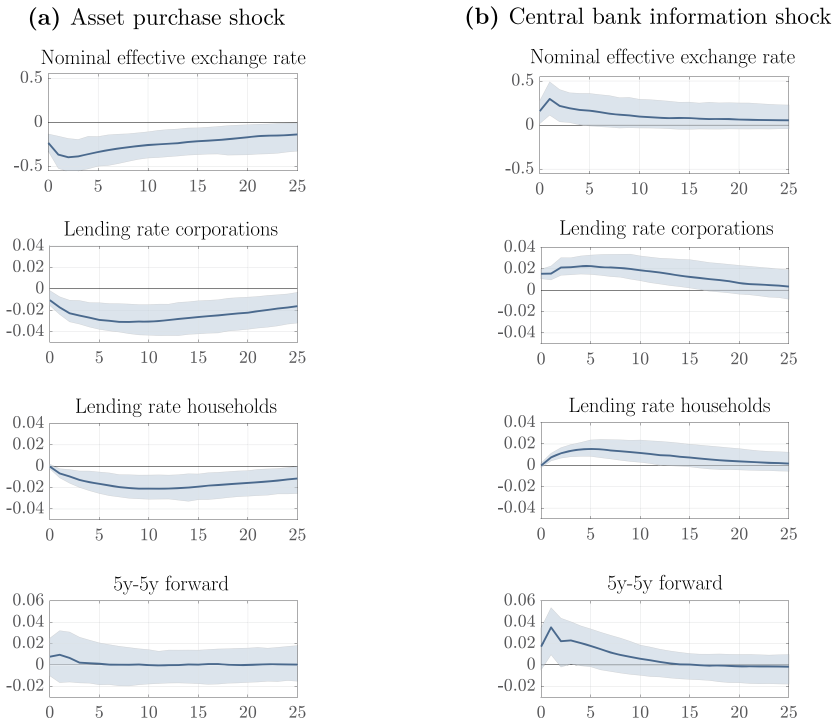
5.1.1. Link to structural model

We anchor our Euro area analysis to the New Keynesian model of Gertler and Karadi (2013), an extension of Gertler and Karadi (2011), to provide a theoretical foundation to our empirical baseline VAR. Specifically, we study the workings of the transmission channels. In this model, interest rates are lowered by asset purchases through a mechanism that involves reducing excess returns in financial markets. By purchasing assets, the central bank bids up their prices, thereby lowering their yields. This reduces the excess returns on these assets, effectively leading to lower overall interest rates in the economy. The model highlights how the central bank's unique ability to obtain funds, unaffected by the constraints faced by private financial intermediaries, allows it to affect asset prices and interest rates. These purchases are especially effective in scenarios where private arbitrage is limited, like during financial crises, as they directly impact the effectiveness of monetary policy interventions in the markets. An asset purchase shock here is characterized as an unexpected surge in long-term government bond holdings of the central bank.

This model incorporates the signaling channel, assuming stable interest rates in the first year after an AP shock, reflecting that expectations of stable interest rates are accurate and indeed remain unaltered for the foreseeable future. Additionally, it integrates the portfolio rebalancing channel, influenced by investor preferences and market frictions, where changes in private sector asset availability due to asset purchases affect asset prices and yields.

To align with the structural model's quarterly timescale, we convert our monthly baseline VAR responses to quarterly by averaging over three months. Responses are matched and simulated using calibrated parameters, setting the asset purchase shock at a 3.6% rise in the steady-state balance sheet volume to match the asset purchase shock in our baseline VAR. Appendix D reports details on the transmission mechanisms in the structural model, as well as on the calibrated parameters and calibration procedure.

Fig. 5 shows the matched impulse responses of the structural model (dashed red line), and compares them to those of the baseline VAR (blue solid line) over a quarterly horizon. In this structural model, an asset purchase shock occurs at the effective lower bound. The responses to an AP shock when interest rates are not constrained by the effective lower bound, are illustrated by the diamond-marked orange line. These more dimmed responses highlight the role of the effective lower bound in the transmission of an AP shock, as opposed to having the ability to lower interest rates. These particular responses can be interpreted in the context of the absence of the signaling channel, since interest rates are allowed to respond following an AP shock. Moreover, portfolio adjustment costs significantly influence the efficacy of transmission via the portfolio rebalancing channel. Higher costs diminish the effectiveness of asset purchases, while their reduction enhances transmission strength. This finding contrasts with traditional monetary policy



Note: Responses to one-standard deviation shocks over a 25 month horizon. Median (solid line), 16–84th percentiles (shaded area).

Fig. 6. Impulse response functions other variables.

as in Jarociński and Karadi (2020), where lower adjustment costs tend to weaken transmission of conventional monetary policy. Conversely, with increased financial frictions faced by households, the effectiveness of asset purchase transmission diminishes, as they are unable to capitalize on the excess returns generated by banks' arbitrage limitations. The structural model shows that our baseline results can be linked to the portfolio rebalancing channel in scenarios where interest rates are at the effective lower bound.

5.1.2. *Impact on other variables*

As we find empirical evidence for all three transmission channels, we delve deeper into their economic implications. We augment the baseline model with separate variables: the exchange rate to gauge the Euro area's relative economic strength, lending rates to assess the risk mitigation effect of asset purchases on banks, and a forward rate to study the term premium. These IRFs are presented in Fig. 6.

First, we assess the Euro's strength via the nominal effective exchange rate. It depreciates following an asset purchase shock, a long-lasting effect that corroborates the exchange rate effect described by Rogers et al. (2014), possibly due to a shift in demand for higher-yield, non-domestic assets. Conversely, a positive central bank announcement briefly boosts the value of the Euro. Similar results arise using the real effective exchange rate.

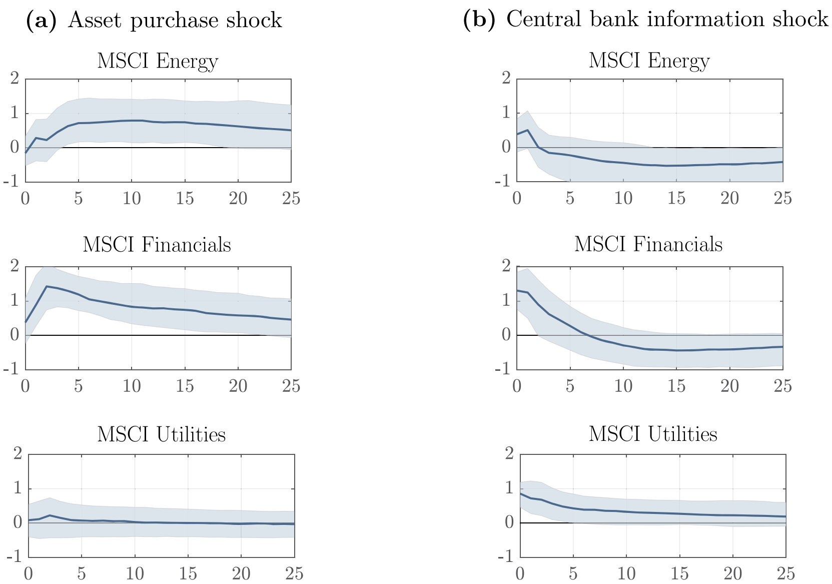
Lending rates for corporations and households decline, with a sharper drop for corporations. This aligns with two channels. The portfolio balancing channel indicates increased demand relative to supply for assets, reducing yields and raising prices—as seen in Fig. 4. This mitigates risk for banks, allowing them to lower lending rates. The signaling channel suggests that signaling lower interest rates promotes reduced rates on long-term loans. The slight increase in issued long-term loans further supports this, see Appendix E.

Fig. 4 shows a similar response of the 1- and 10-year government bond yields to an AP shock. However, long spot rates may be contaminated with expectations about short-term movements in the interest rate. Analyzing the impact on the term premium through the 5 year forward rate 5 years ahead (5y–5y), a recognized measure for long-term market-based inflation expectations, reveals no apparent response to an AP shock. However, a central bank information shock appears to temporarily elevate the term premium, aligning with Cieslak and Schrimpf (2019), who affirm that announcements of non-monetary news can influence the term premium.

Appendix E Fig. E.6 shows the responses of different subcategories of the stress index. All indicators generally decrease within the initial three months after an AP shock, suggesting a universal market reassurance. Positive central bank information announcements seem to reassure financial and non-financial equity markets the most.

5.1.3. *Robustness*

We perform several robustness checks to analyze the baseline setting. We first analyze the baseline model by examining the model residuals and varying the lag order. Second, we use alternative hyperparameters on the Minnesota prior. Third, we analyze the influence of the implied prior on rotation matrix Q using the multiple prior robust approach of Giacomini and Kitagawa (2021).



Note: Responses to one-standard deviation shocks over a 25 month horizon. Median (solid line), 16–84th percentiles (shaded area).

Fig. 7. Impulse response functions stock market sectors.

Next to that, we use alternative identification strategies to identify an asset purchase shock. We find that our results are to a large extent robust to model specification, hyperparameter selection, prior specification and alternative identification schemes. Results of these robustness checks are reported in Appendix E.

5.2. Heterogeneous transmission

To examine the varied transmission of asset purchase and central bank information shocks, we study differences in stock market responses and across countries.

5.2.1. Heterogeneous effects on the stock market

In our baseline, value firms are impacted more positively by an asset purchase shock than growth firms. Analyzing heterogeneity in transmission across eleven industry sectors using sector-specific MSCI indices based on the GICS, we separately add these into the baseline model. Fig. 7 displays impulse responses for the distinctively different energy, financial, and utilities sectors, given their respective vulnerabilities to business cycle fluctuations and impact from AP shocks. The remaining sectors are reported in Appendix E Fig. E.7.

We find that energy stocks increase by a maximum of 0.9% after half a year in response to an asset purchase shock. The peak effect on financial stock prices is roughly 1.4%, three months after an AP shock. On the other hand, utility stocks are not affected. This is expected, as utility companies provide basic necessities such as gas, electricity and water. These companies are generally not affected by the state of the economy.

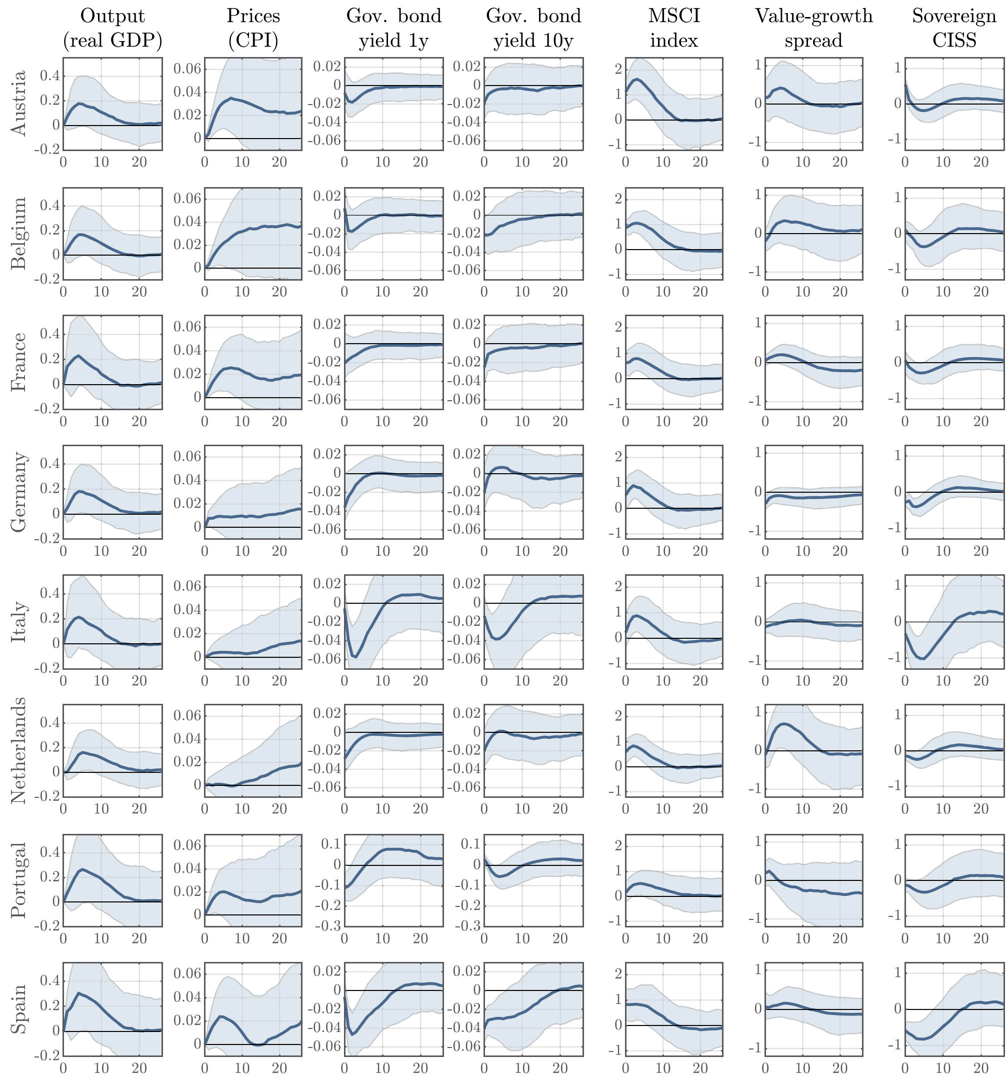
The impact of an AP shock positively affects the industrials, consumer discretionary, information technology, and real estate sectors, resulting in a 0.5–0.8% increase. Sectors such as materials, consumer staples, health care and communication services are not significantly affected by an asset purchase shock. As noted before, stocks positively impacted are typically business cycle-sensitive, benefiting from enhanced economic conditions, while unaffected stocks show less susceptibility to these cycles.

Central bank information shocks prompt an initial 0.5–1.5% increase across all sector indices, regardless of business nature, fading after three months. The transmission of these shocks seems to be more homogeneous. This could be due to the positive announcement, which encourages investors to invest.

To identify the most impacted industries within the energy and financial sectors by an AP shock, we examine more detailed industry classifications (see Fig. E.8 in Appendix E). The strongest effect is present among financial stocks, in particular banking. This is in line with the potential narrow transmission of an AP shock, as the ECB bought covered bonds issued by European banks under the covered bond purchase programs. Further, the ECB launched the corporate sector purchase program as part of their APP in June 2016, where the ECB committed to buying corporate bonds by issued European non-bank corporations from all kinds of sectors. Hence, the positive effect on various sectors might not solely stem from bond purchases, but also from enhanced financial conditions.

5.2.2. Heterogeneous effects across countries

In our baseline VAR model, asset purchase announcements positively impact the economy and stock market while reducing government bond yields. Given the diversity within the Euro area, we study variations in shock transmission across countries and their spillover effects, as shown in Fig. 8. Each row represents a country.



Note: Responses to a one-standard deviation shock over a 25 month horizon. Median (solid line), 16–84th percentiles (shaded area).

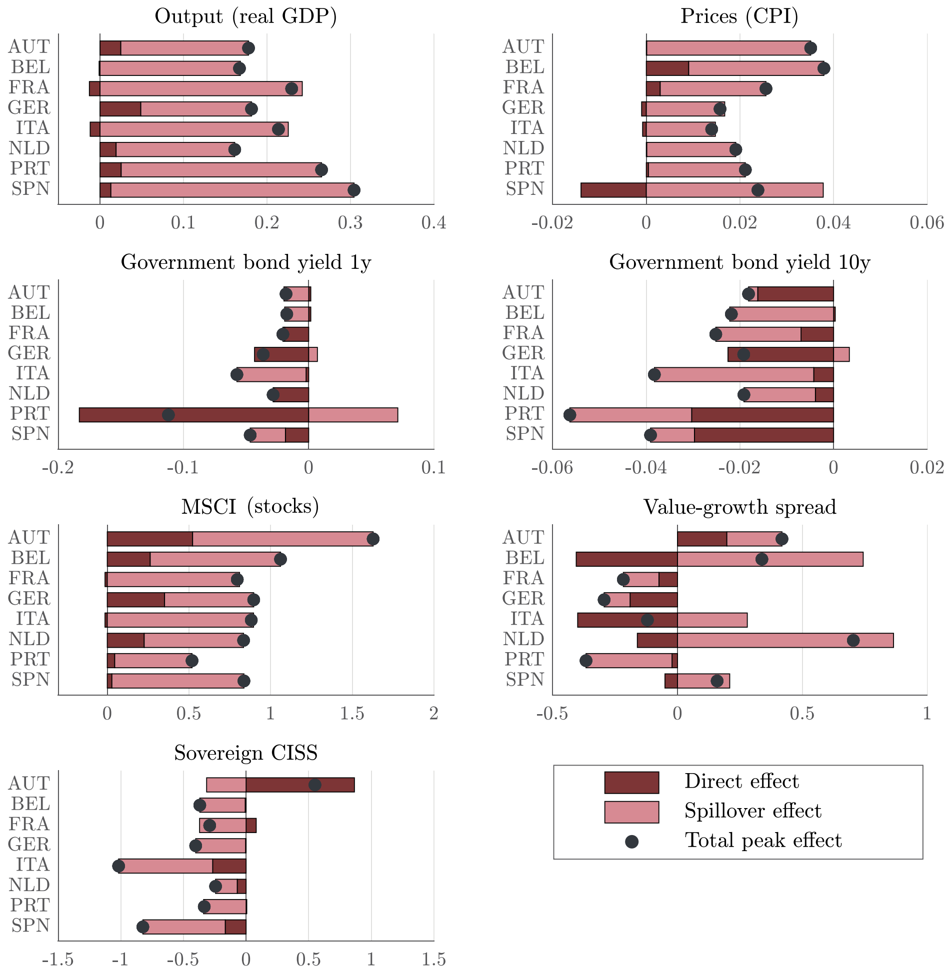
Fig. 8. Impulse responses to an asset purchase shock.

As on the European level, asset purchase shocks stimulate the economy of all countries. The effect of an asset purchase shock on output is between 25 and 30 basis points for Southern Euro area countries, whereas for other Euro area countries this effect is below 20 basis points. The effect on prices is between 2 and 4 basis points similar across countries.

In our baseline model, government bond yields decrease after an AP shock. The yields generally decrease similarly on the short and long end of the yield curve. The yields of Southern European countries decrease more compared to other countries. The yields of the countries with higher credit ratings are in our sample close to zero—bounded by the effective lower bound. These yields do not have a lot of room to decrease. Nonetheless, an AP shock does seem to bring the yields closer to each other, unifying the Euro area more.

This result broadens the scope of Corradin et al. (2021), who ascribe the substantial reduction in Italian and Spanish yields observed on the day of the PEPP announcement to a decrease in the default risk component of the yields, and Demir et al. (2022), who document a widespread impact of the ECB's unconventional monetary policy on government bond yields across all maturities, with the market component of these yields dropping. The risk component yields of Southern Euro area decrease more, offset by a minor rise in core countries' yields.

All country-specific MSCI indices increase by 0.5–1.5% in response to an asset purchase shock, and remain positive for about half a year. The core economies are most positively affected. There does not seem to be a significant difference across value and growth stocks across countries. An asset purchase announcement seems to alleviate stress in sovereign debt markets for Southern Euro area countries, as sovereign stress drops by 0.5–1%. For the core countries this effect is also slightly negative. This reduction in Southern Euro area sovereign stress extends the insights of Eser and Schwaab (2016) regarding the Securities Market Program's effect on reducing default risk premia in the Southern Euro area.



Note: Median peak responses to a one-standard deviation asset purchase shock, i.e., the maximal absolute effect over 25 months. Direct effects, calculated by nullifying cross-country linkages in domestic models ($\Lambda_{i,\ell}$ in Equation (4)), contrast with spillover effects, determined as the difference between the baseline GVAR model effects and those in a model with cross-country linkages set to zero. The peak effect matches the largest absolute median effect in Fig. 8.

Fig. 9. Direct and spillover effects of an asset purchase shock.

As we document some heterogeneity in transmission of an AP shock across countries, we examine whether this heterogeneity originates from direct or spillover effects across countries. For each economy i, we estimate the direct effect by only considering the effect of the common factors and its own factors, i.e., by setting $\Lambda_{i,\ell}$ to zero in Equation (4). The spillover effects are then calculated as the difference between the estimated IRFs and the direct effects. Fig. 9 shows the direct and spillover median peak effects of an asset purchase shock. The median peak response is the maximum absolute effect for each variable over the horizon. Generally, spillovers amplify positive output and price effects, contributing to a total output effect of 15–30 basis points, of which under 5 basis points are direct for each country. For government bond yields, direct effects are more prominent in magnitude, especially for the 10 year government bond yield of Portugal and Spain. The effect on stock prices is amplified by spillover effects. For the higher credit rating countries we find a larger direct effect compared to Southern European countries. The direct and spillover effect on the value-growth spread and stress index offset each other in some cases, which becomes more clear considering the effects over time (see Fig. E.10 in Appendix E). Thus, ignoring spillover effects would result in underestimating the impact of an asset purchase shock, underscoring their role in heterogeneous transmission.

A central bank information shock, reported in Fig. E.11 in Appendix E, leads to brief, positive effects on output and prices. Further, 1- and 10-year government bond yields rise by 2–4 basis points across countries, and stock indices increase by 0.5–1%. The shock generally reduces sovereign debt market stress. These shocks tend to be more uniform and short-lived, yet they can play a role in minimizing disparities between countries.

6. Conclusion

This study examines the transmission of the European Central Bank's asset programs from July 2009 to March 2021 on the macroeconomy and financial markets. Using Bayesian structural VAR analysis, we identify asset purchase shocks through market movements around monetary events and employ theory-driven sign and zero restrictions. Differentiating between policy and economic outlook announcements, our identification approach uncovers heterogeneous transmission of asset purchase shocks across stocks and EMU nations.

In the Euro area, asset purchase shocks temporarily boost output more than prices. Both short- and long-term bond yields decrease, while stock prices, especially in value firms with shorter cash-flow duration, rise gradually. Financial stocks benefit most, partly due to targeted covered bond purchases, and lower bank lending rates positively impact other sectors. Corporate bond spreads and the sovereign stress index slowly decrease, suggesting stabilizing effects on debt markets. The nominal effective exchange rate depreciates with a nearly two-year impact. Central bank information shocks briefly stimulate financial markets. These findings provide empirical evidence for the signaling channel, portfolio rebalancing channel, and the re-anchoring channel. We show that interest rates being restricted at the effective lower bound and low portfolio adjustment costs are key factors for these transmission channels of an asset purchase shock.

Zooming in on the stock market, our sector-specific stock analysis confirms the heterogeneous transmission as we document heterogeneous responses across sectors in response to an asset purchase shock. Financial stocks are the most affected and this effect lasts over one year. Other sectors like energy, industrial, consumer discretionary, information technology, and real estate also benefit. Using GVAR analysis that accounts for spillover effects, we reveal that these spillovers often overshadow the direct impact of an asset purchase shock. Asset purchase shocks temporarily increase output more than prices, with a stronger impact in Southern countries, amplified by spillovers. Government bond yields generally decrease, with slight variations attributed to the ECB's flexible purchasing approach. Stock prices rise but more slowly, especially in higher credit rating countries. Asset purchase shocks stabilize Southern Euro area countries most, significantly reducing sovereign stress. Meanwhile, central bank announcements do seem to reduce heterogeneity across countries.

CRediT authorship contribution statement

Terri van der Zwan: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Erik Kole:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing. **Michel van der Wel:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

Nothing to declare.

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Appendix. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jimonfin.2024.103073.

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