The Financial Market Effects of the ECB's Asset Purchase Programs*

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Abstract

The European Central Bank's asset purchase programs, while intended to stabilize the economy, may have unintended side effects on financial stability. This paper aims at gauging the effects on financial markets, the banking sector, and lending to non-financial firms. Using a structural vector autoregression analysis, we find both in the euro area and in Germany a positive effect on output, while prices do not respond significantly. Asset purchases reduce financial stress, but this beneficial effect is overturned in the medium run. In Germany, implicit firm default rates rise, while loan write-offs by banks decrease. This could point to an avoidance of balance sheet repair in the financial sector.

Keywords: asset purchase programs, balance sheet, monetary policy, central bank, shock identification, VAR

JEL classification: C32, E44, E52, E58.

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1 Introduction

The effectiveness of unconventional policy in terms of balance sheet expansions is subject to ongoing debate. We employ a vector autoregression (VAR) model to estimate the dynamic effects of asset purchase programs on the macroeconomy and financial markets. The identification strategy we propose is novel in the literature and well-suited to consider possible side effects on financial markets. Compared to existing empirical studies, our approach is explicitly agnostic about the effects of policy measures on financial markets because we refrain from restricting the respective responses ex ante.

Recent economic developments within the euro area macroeconomy have led the European Central Bank (ECB) and the Eurosystem[1] to develop new tools in order to fulfill their mandate and keep inflation stable. Following the collapse of Lehman Brothers in September 2008, financial markets in many countries experienced turbulent times, impairing bank lending and monetary policy transmission. Due to increased uncertainty, the interbank market was disrupted, which induced liquidity stress for the banking system.[2] Bank lending to non-financial firms declined, which had severe consequences for the real economy. Output dropped sharply and inflation rates fell below the ECB's definition of price stability. In a situation with policy rates approaching the zero lower bound, the ECB had to consider new measures, among which it implemented several asset purchase programs and other lending schemes in the following years aiming to provide banks with liquidity and to improve bank lending. The euro area sovereign debt crisis emerged in late 2009, which again induced pressure on financial markets and made new policy actions necessary.

While the transmission channel of *conventional* interest rate policy is well understood and many – empirical as well as theoretical – studies exist on that topic, the effects of the diverse set of *unconventional* measures, of which balance sheet policy is one particular example, are still being explored. There is, as yet, no consensus to what extent those measures are effective in bringing inflation and output back to their target levels, or whether any unintended side effects unfold particularly within financial markets.

There is a small but growing literature on the effects of non-standard policies on the macroeconomy.[3] Some studies approach the question with event studies like Eser and Schwaab (2016), who show that the Securities Market Programme (SMP) had a significant impact on sovereign bond yields. They consider common factors to control for aggregate developments. Krishnamurthy and Vissing-Jorgensen (2011) show that in the US, the quantitative easing programs QE1 and QE2 were both effective in lowering nominal interest rates, but the magnitude of the effect differs across asset classes. Lambert and Ueda (2014) consider US banks and their reaction to policy news. They do not find a positive effect on bank returns, while bank credit risk increases over the medium term. Szczerbowicz (2015) shows the effectiveness of different unconventional measures in the euro area. In particular, the interconnectedness between banks

[1] For convenience, in the following we will not explicitly mention the Eurosystem but use 'ECB' as an abbreviation for the institutions responsible for monetary policy decisions in the euro area.

[2] See for instance Rixtel and Gasperini (2013), Abbassi et al. (2015) or Arciero et al. (2016).

[3] An assessment of the ECB's asset purchase programs, for example, can be found in Andrade et al. (2016).

and sovereigns amplifies the effect of policy announcements.

While those studies distinguish specific purchase programs and focus an impact effects, they cannot estimate a *dynamic* effect on the aggregate economy. In this respect, Casiraghi et al. (2013) use a combination of two strategies. They investigate the effects of the SMP, Outright Monetary Transactions (OMTs) and Longer Term Refinancing Operations (LTROs) within an event study. Subsequently, they feed their results into a macroeconomic model of the Italian economy. They find that the SMP as well as the OMTs were effective in decreasing government bond yields, while LTROs improved lending conditions. Kühl (2016) shows in a DSGE analysis that government bond purchases are beneficial with respect to economic activity especially if financial frictions are more "severe". Lenza et al. (2010) estimate a Bayesian VAR model and compute counterfactual developments of key macroeconomic variables. They show that monetary policy in exceptional times, represented by central bank liquidity management, is effective. Notably, their analysis refers to the fixed rate full allotment policy of the ECB and therefore highlights demand-driven liquidity provisioning of the banking system. Gambacorta et al. (2014) apply a mean group estimator to a cross-country VAR model to show that balance sheet expansions have a positive effect on output and prices. They consider information from eight currency areas, which helps them to overcome the problem of a relatively short sample. Peersman (2011) compares conventional interest rate policy responses to unconventional balance sheet policy. He finds that both measures have a positive effect on output and prices, while the transmission of a balance sheet expansion is more sluggish. However, the analysis cannot distinguish exogenous policy shocks from endogenous demand-driven effects originating in the banking sector. Similarly, Darracq Pariès and De Santis (2013) use information in the Bank Lending Survey in order to compute dynamic effects of a credit supply shock. They show that the ECB's 3-year LTRO program from December 2011 is expansionary with respect to output and inflation. Bluwstein and Canova (2016) find important cross-country spillover effects of unconventional policy measures taken by the ECB.

Our analysis is related to the work of Peersman (2011), Gambacorta et al. (2014), and Boeckx et al. (2017), who investigated the effects of balance sheet shocks at an aggregate level. In particular, Boeckx et al. (2017) set up a VAR model and consider the dynamic effects of the ECB's balance sheet policies. Their analysis focuses on non-financial macroeconomic developments. They show that an increase in the ECB balance sheet has a positive effect on output, prices, and bank lending. In general, they find favorable macroeconomic effects, with heterogeneity among euro area countries. To identify an expansionary balance sheet shock, they impose a negative reaction of euro area financial stress. Weale and Wieladek (2016) identify an 'asset purchase announcement shock' (as opposed to an uncertainty shock) by requiring real stock prices to rise.

Our contribution to the literature is twofold. First, we use a novel identification strategy for the policy shock. It requires an ECB balance sheet expansion through particular balance sheet items but is agnostic with respect to financial market variables. Since we are particularly interested in the response of financial stress, we do not restrict this variable in our identification

scheme. We find favorable effects of balance sheet policies with respect to financial stress and output within the first year. Thereafter, the effect on output vanishes, while financial stress increases above its pre-shock level. The identified effect on prices is subject to a high degree of uncertainty; impulse responses can hardly be distinguished from zero. Output, inflation and financial stress respond much more strongly to a financial stress shock than to an asset purchase shock.

Second, we add to the literature a country-specific impact study, with a focus on the German economy. Krishnamurthy et al. (2014) have shown that the ECB's SMP and OMT were successful in reducing government bond yields in periphery countries. We show that macroeconomic effects in Germany are similar to those in the euro area as a whole: output rises, while prices do not respond. Financial stress, however, falls only initially. Over the medium run, the composite stress indicator actually increases, together with stock market volatility and risk aversion. While corporate lending does not increase significantly, implicit default rates rise and write-offs go down, which may reflect an increase in risky lending as banks avoid writing off questionable loans.[4]

We note that our approach, which focuses on macroeconomic time series data, applies to lower frequencies and therefore generally does not pick up announcement effects that might be visible at higher frequencies. However, as pointed out by Bluwstein and Canova (2016), event studies which employ high-frequency data cannot capture dynamic macroeconomic effects, which take time to unfold. Furthermore, such data may be more noisy, leading to less reliable results. Importantly, we study the effects of the ECB's asset purchase programs at the time of their implementation. Any anticipation effects of policy announcements are therefore not picked up by our identification scheme.

The remainder of this paper is organized as follows. Section 2 discusses our data set and gives a brief outline of the recent policy measures in the euro area. Section 3 describes the econometric framework, as well as our identifying assumptions. The estimation results are discussed in Section 4. Section 5 concludes.

2 Data and the ECB balance sheet

We use time series data from July 2009 until March 2016. The short time period makes it necessary to consider monthly observations in order to have sufficient information available to estimate the VAR model. While there exist monthly data before July 2009, it is important for our analysis to focus on the particular episode where the ECB injected liquidity through asset purchase programs. The following paragraph gives a short overview of the recent actions undertaken in response to the financial crisis and the European sovereign debt crisis.[5] Figure 1 shows the evolution of the ECB's balance sheet item "securities held for monetary policy

[4] We use a confidential series on implicit firm defaults. Further information on this series can be found in Bundesbank (2015, p. 17–27).

[5] For a more detailed exposition, see Szczerbowicz (2015) who provides a timeline of the ECB's decisions, announcements and the design of policy measures.

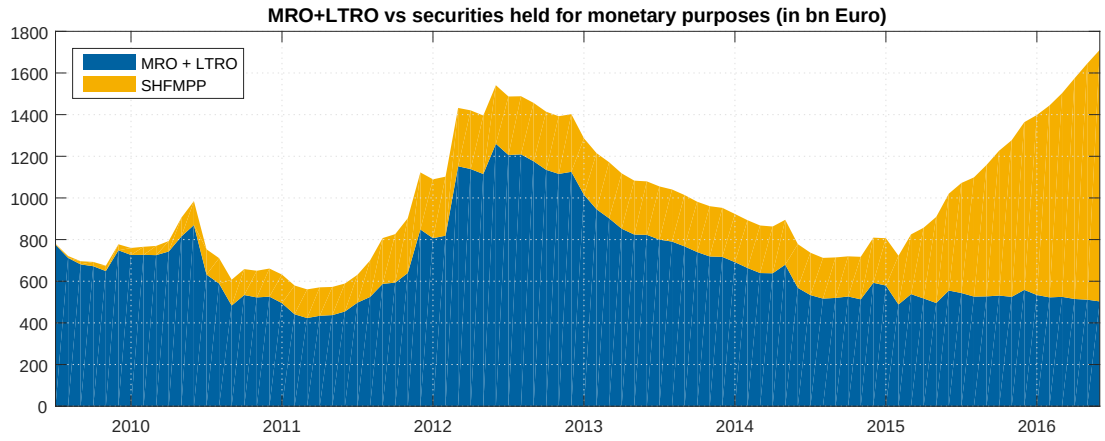

Figure 1: Evolution of the sum of the ECB balance sheet items "main refinancing operations" and "longer term refinancing operations", and "securities held for monetary policy purposes". Source: ECB Statistical Data Warehouse and http://www.ecb.europa.eu/stats/monetary/res/html/index.en.html.

purposes" (SHMPP), which comprises assets affected by the purchase programs, as well as the sum of main refinancing operations (MROs) and longer term refinancing operations (LTROs). This distinction of balance sheet items is central for our structural shock identification as it helps us to distinguish exogenous policy measures from endogenous balance sheet expansions.

During the sample period, the ECB conducted several asset purchase programs in order to stabilize bank lending and to maintain a functioning monetary transmission mechanism. The ECB argues that purchase programs aim to bring inflation back to levels comformable with the definition of price stability.[6] Consequently, the effect on prices and output should appropriately reflect the effectiveness of the new measure. At the same time, they may have desired or undesired effects on financial stress, which are of interest.

In July 2009, the Eurosystem central banks started to buy covered bonds, which, as argued by the ECB, are an important source for banks' refinancing. The total aggregate value of the purchase program was 60 billion euros. Even though the first Covered Bond Purchase Programme (CBPP1) ended in June 2010, there is still a significant fraction of those assets on the ECB balance sheet.

In May 2010, the Eurosystem started the SMP where it bought securities for 230 billion euros. The second Covered Bond Purchase Programme (CBPP2) was conducted between November 2011 and October 2012. Bonds worth a total of 16 billion euros were purchased. In November 2014, national central banks started the Asset-Backed Securities Purchase Programme (ABSPP). One month later, the third Covered Bonds Purchase Programme (CBPP3) was introduced and proposed to be conducted until June 2016. Finally, in March 2015 the Public Sector Purchase Programme was launched. The Eurosystem planned to buy a monthly aggregate volume of 60 billion euros under the ABSPP, the CBPP3 and the PSPP. The PSPP represents the most important component of the Asset Purchase Programme (APP), which was raised by 20 billion euros in April 2016. Since June 2016, the Corporate Sector Purchase

[6] See e.g. https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html.

Programme has been appended to the APP. In December 2016, the Eurosystem decided to switch back to a monthly volume of 60 billion euros in April 2017.

Prior to these measures, the ECB announced a fixed rate full allotment policy in October 2008. At a predetermined interest rate, it allows banks to obtain as much liquidity as needed, given adequate collateral. The full allotment policy aims at improving the liquidity position of banks and it works through MROs and LTROs. One may argue that during the time frame considered, MROs and LTROs can, to some extent, be regarded as unconventional policy measures as well, especially because of the full allotment policy. Our analysis distinguishes asset purchase programs from other unconventional policy measures.

With respect to the aforementioned measures, we separate two types of instruments that affect the balance sheet of the ECB through different positions. We label the first one direct asset purchases. This shock induces an expansion of the ECB balance sheet item "Securities Held for Monetary Policy Purposes", while it does not positively affect main- and longer term refinancing operations. The second represents endogenous liquidity provisioning and induces expansions of the balance sheet items "Main Refinancing Operations" and "Longer Term Refinancing Operations". While the first instrument is used by the central bank in a discretionary fashion, the second adjusts to the liquidity demand of the financial sector and is therefore endogenous. The distinction is crucial for our identification scheme, which we explain in Section 3.2. In general, the aim of the asset purchase programs was to encourage bank lending in order to repair the transmission channel of monetary policy and ultimately to bring inflation back to a value of below (but close to) 2%.[7]

Before June 2014, the securities held for monetary policy purposes (SHMPP), mainly includes the purchases made under the ECB's Securities Markets Programme (SMP). Under the SMP, the ECB has purchased securities worth around 200 billion euros. Purchases were concentrated in five euro area countries (Italy, Spain, Portugal, Ireland and Greece). It is particularly interesting, therefore, to analyse the SMPs effects on the euro area as a whole. Any visible effects on the degree of monetary accommodation and risk taking in a core euro area country like Germany could provide insights into the possible transmission channels of these unconventional policy actions.[8]

For the baseline specification of the VAR model we consider the MRO rate to represent the conventional monetary policy instrument. The monthly data frequency does not allow us to directly use GDP as a measure of output or economic activity. We instead interpolate the quarterly series using the Chow and Lin (1971) method on the basis of the monthly industrial production index.[9] Euro area prices are measured by the harmonized index of consumer prices (HICP); for Germany, we use the consumer price index (CPI).

In order to measure financial stress in the euro area, we use the Composite Indicator of Systemic Stress (CISS) proposed by Holló et al. (2012), while for the German case we use the

[7] See e.g. https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html.

[8] Bekaert et al. (2013) and Buch et al. (2014) study the effect of monetary policy on risk taking.

[9] We want to keep our estimation results comparable to the literature and therefore follow Boeckx et al. (2017) and Gambacorta et al. (2014) in this respect. Figure C.4 in the appendix shows results obtained with an alternative specification using industrial production as a proxy for output.

comparable Bundesbank Stress Indicator for the German Financial System. A particularly important component of our exercise is the Composite Indicator of Systemic Stress. The CISS is meant to condense the state of financial instability into a single statistic. It aggregates five market-specific subindices created from a total of 15 individual financial stress measures. The weights used in the aggregation reflect time-varying cross-correlations between subindices. This puts relatively more weight on situations in which stress prevails in several market segments at the same time. The CISS provides an ex-post measure of systemic risk, i.e. risk which has materialized already. The construction of the CISS considers comprises data from money markets, equity markets, bond markets, foreign exchange markets, and financial intermediaries. It uses standard securities market indicators, e.g. volatilities, risk spreads, cumulative valuation losses.

Most of the data are publicly available, where the main data sources are the ECB Statistical Data Warehouse (SDW) and the Bundesbank.[10] More detailed information on the data is provided in Table A.1 of the Appendix.

3 VAR Model

We analyze the effects of monetary policy with a vector autoregression model, where we employ a novel set of identifying assumptions on the asset purchase shock. The VAR allows us to model the effects of shocks dynamically, while imposing a minimum set of assumptions about the structure of the economy.

3.1 Specification

Let us first consider the following reduced form VAR system,

$$\boldsymbol{y}_t = \boldsymbol{c}_1 + \boldsymbol{c}_2 t + \sum_{j=1}^{p} \boldsymbol{B}_j \boldsymbol{y}_{t-j} + \boldsymbol{u}_t, \quad \text{with } t = 1, \ldots, T, \tag{1}$$

where $\boldsymbol{y}_t$ is an $N \times 1$ vector of endogenous variables, $\boldsymbol{u}_t \sim \mathcal{N}(\boldsymbol{0}, \boldsymbol{\Sigma})$ is an $N \times 1$ vector of reduced form residuals, $\boldsymbol{c}_1$ is an $N \times 1$ intercept vector, $\boldsymbol{c}_2$ is an $N \times 1$ coefficient vector on the linear time trend, and $\boldsymbol{B}_j$ are $N \times N$ matrices containing the VAR coefficients. In order to generate results comparable to the literature, we opted for a lag length of $p = 4$.[11] We propose the following selection of endogenous variables:

$$\boldsymbol{y}_t = \begin{bmatrix} r_t & y_t & p_t & s_t & x_t & l_t \end{bmatrix}', \tag{2}$$

[10] Data on the Stress Indicator for the German Financial System, presented in Bundesbank (2013, p. 7–20), is not publicly available.

[11] Throughout the analysis and across different specifications, we keep the specification comparable by using the same lag length. Robustness checks with different lag lengths showed similar results, see section B.2 in the Appendix.

where r_t denotes the policy rate, y_t denotes output, p_t denotes the price index, s_t denotes the central bank assets held for monetary policy purposes, x_t is an indicator of financial stress or another financial market variable, and l_t is the sum of MRO and LTRO volumes. All variables, except for the policy rate and financial stress, are in logarithms.

To conduct a structural analysis, we identify the following model,

$$\boldsymbol{A}_0\boldsymbol{y}_t = \boldsymbol{a}_1 + \boldsymbol{a}_2 t + \sum_{j=1}^{p} \boldsymbol{A}_j \boldsymbol{y}_{t-j} + \boldsymbol{e}_t, \quad \text{with } t = 1, \ldots, T, \tag{3}$$

where $\boldsymbol{A}_0$ is an $N \times N$ matrix such that $\boldsymbol{A}_j = \boldsymbol{A}_0\boldsymbol{B}_j$, $\boldsymbol{a}_1 = \boldsymbol{A}_0\boldsymbol{c}_1$, $\boldsymbol{a}_2 = \boldsymbol{A}_0\boldsymbol{c}_2$ and $\boldsymbol{e}_t = \boldsymbol{A}_0\boldsymbol{u}_t$ with $\boldsymbol{e}_t \sim \mathcal{N}(\boldsymbol{0}, \boldsymbol{I}_N)$, $\boldsymbol{I}_N$ is the $N \times N$ identity matrix and $\mathbb{E}(\boldsymbol{u}_t\boldsymbol{u}_t') = (\boldsymbol{A}_0'\boldsymbol{A}_0)^{-1} = \boldsymbol{\Sigma}$ is the covariance matrix of the VAR residuals. Since the estimated model (1) does not allow us to identify the structural form (3) without additional assumptions, we impose identifying restrictions on the impulse response functions (IRFs) of shocks. The literature has developed several methods to determine $\boldsymbol{A}_0$ based on economic considerations. We identify the shocks using a combined sign and zero restrictions approach and rely on the method of Arias et al. (2014), who propose an algorithm which is robust to erroneous credible intervals and unintended additional sign restrictions.[12]

3.2 Identification

The literature has developed different identifying assumptions on the asset purchase shock. Given the ECB's switch to fixed rate full allotment provisioning during the considered time frame, banks can in principle obtain as much liquidity as they need at a given interest rate. Both exogenous balance sheet policy decisions and higher liquidity demand by banks lead to an expansion of the central bank balance sheet. Similarly, Szczerbowicz (2015) discriminates between "asset purchases" and "other exceptional liquidity provisions". In contrast, Peersman (2011) does not distinguish demand-driven expansions from asset purchase programs. He argues that even though a balance sheet expansion is demand-driven, the policy decision to provide the banking sector with as much liquidity as needed when financial stress occurs, is still taken by the ECB and as such represents a policy decision. Boeckx et al. (2017) and Gambacorta et al. (2014) use variables which indicate financial stress periods or periods with high risk aversion in order to ensure exogeneity of their policy shock. They require those measures to be non-increasing if an expansionary unconventional shock hits the economy. This assumption excludes demand-induced balance s heet expansions which occur in stress periods but it precludes the authors from interpreting the responses to stress itself.

In order to investigate the effects of a discretionary asset purchase shock, it has to be defined and identified unambiguously. In particular, the shock should be orthogonal to other possible shocks in the system. We impose a mixture of sign and zero restrictions on the impulse responses of certain variables in our VAR model. Our identifying restrictions are summarized

[12] Arias et al. (2014) show that other algorithms may lead to additional sign restrictions on variables which are seemingly unrestricted. Consequently, point estimates and confidence bands are estimated with error.

Variable		Asset purchase shock	Financial shock
Policy rate	r_t	0 (3)	0 (3)
Output	y_t	0 (1)	0 (1)
Prices	p_t	0 (1)	0 (1)
SHFMPP	s_t	≥ 0 (3)	≥ 0 (3)
Financial stress	x_t		≥ 0 (3)
MRO + LTRO volumes	l_t	≤ 0 (3)	> 0 (3)

Table 1: Identifying restrictions. Number in brackets is horizon (in months) over which restriction is imposed.

in Table 1.

For our analysis, we consider asset purchases associated with expansions of the ECB balance sheet.[13] In particular, we require securities held for monetary policy purposes (s_t) to increase if an expansionary *asset purchase shock* hits the economy. The literature on monetary policy transmission traditionally assumes that output (y_t) and prices (p_t) are not contemporaneously affected by the policy measure. In the same vein, it can be argued that a discretionary expansion of the central bank's balance sheet should not change output and prices on impact. As discussed above, the ECB's fixed rate full allotment policy requires us to distinguish the asset purchase shock from a demand-driven balance sheet expansion. Generally, a policy-induced increase in the balance sheet can be attributed either to the endogenous response of liquidity demand l_t or to an exogenous asset purchase shock s_t.[14] In order to make sure that our asset purchase shock is truly exogenous and does not reflect an endogenous response through a sort of "balance sheet rule", we impose an additional restriction. Since demand-driven balance sheet expansions operate through either MROs or LTROs, we require the sum of the two, l_t, not to increase. The restriction on the MRO and LTRO volumes is a convenient way to identify the shock without restricting the responses of financial stress. The policy rate r_t does not react when an asset purchase shock hits the system.[15]

For comparison, we also identify a *financial shock* that increases stress on financial markets x_t. Differently from the asset purchase shock, banks are assumed to increase the ECB's balance sheet through either MROs and LTROs or SHFMPP, while the policy instrument remains unrestricted. Output and prices are sluggish and do not react contemporaneously to the shock. We interpret the dynamic responses to this shock as picking up endogenous reactions to financial stress periods, which includes effects of the ECB's fixed rate full allotment policy. As we impose banks to demand liquidity through MROs and LTROs in response to the shock, the dynamics allow us to evaluate the effectiveness of those measures. Gambacorta et al. (2014) and Boeckx et al. (2017) identify their version of a balance sheet shock by excluding endogenous

[13] We abstract from other unconventional measures, such as loosening of collateral requirements, lower reserve requirements, maturity transformations of refinancing operations, or forward guidance.

[14] Other balance sheet items are less relevant for our analysis.

[15] The chosen sample period is well-suited to analyze asset purchase shocks while it seems not sensible to identify conventional policy rate shocks. However, for illustrative purposes we simulated responses to a policy rate shock within our sample. Results can be found in section B.3 in the Appendix.

reactions to stress which we capture in the financial shock. In this spirit, Lenza et al. (2010), focus on effects of those endogenous and demand-driven measures which should not be confused with the asset purchase shock in the second column of Table 1.

Restrictions with respect to variables that relate to the ECB balance sheet or monetary policy are generally applied up to the 3-month horizon, while output and prices are allowed to react in the month after the shock.

3.3 Estimation

The model is estimated with Bayesian methods using a flat prior distribution. In particular, we employ the specification in Uhlig (2005) and set the respective prior matrices to zero, which yields the posterior distribution with respect to the reduced form model (1). Regarding the structural model (3), we employ the algorithm in Arias et al. (2014) to draw the contemporaneous impact matrix $\boldsymbol{A}_0$. As suggested by the authors, we obtain the reduced form estimates $\boldsymbol{B} = [\boldsymbol{c}_1, \boldsymbol{c}_2, \boldsymbol{B}_1, \ldots, \boldsymbol{B}_p]$ and $\boldsymbol{\Sigma}$ first, then a candidate random matrix $\boldsymbol{A}_0$ is proposed. If the sign restrictions are satisfied, we keep the matrices $\{\boldsymbol{B}, \boldsymbol{\Sigma}, \boldsymbol{A}_0\}$. Otherwise, we discard the triple. This procedure is repeated until we have generated a sample of 15,000 draws from the posterior distribution, where the first 5,000 draws are discarded in order to minimize the impact of the starting point.

4 Results

The analysis is performed in two steps. First, we consider impulse response functions with respect to aggregate euro area data. Estimates for the euro area aggregate are useful because they allow us to compare our estimated effects of asset purchase shocks to the existing literature, which – as mentioned earlier – has focused on balance sheet shocks more broadly. Beyond that, we discuss the validity of the identified asset purchase shock and identify a financial stress shock. Then, we estimate the model on German data in order to assume a country-specific perspective. In particular, we focus on variables that contain information on firm and financial market responses.

4.1 Euro area

Let us start with our baseline specification, where the euro area composite stress index captures effects on financial markets. The CISS has been proposed by Holló et al. (2012); it consists of five sub-indices and lies on the unit interval. Since we employ a novel identification scheme, the baseline specification also helps us to compare our results to the existing literature on central bank balance sheet expansions.

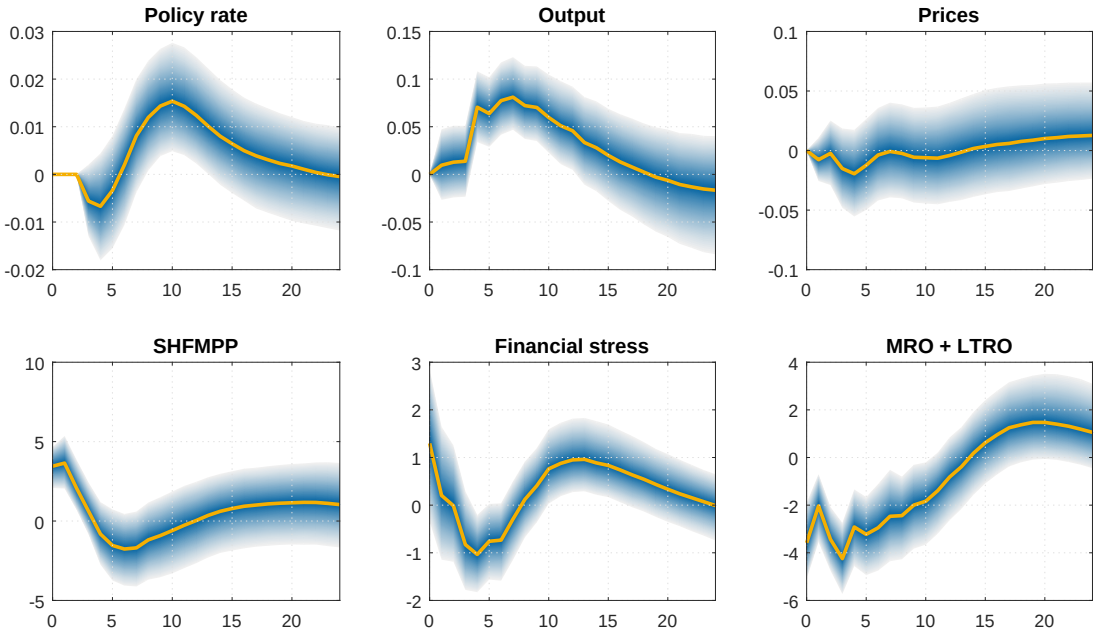

Figure 2: Euro area. Monthly impulse responses to a one standard deviation asset purchase shock, all multiplied by 100.

4.1.1 Asset purchase shock

We assume that an asset purchase shock hits the economy in period 0. As shown in the respective column of Table 1, the ECB balance sheet item SHFMPP (securities held for monetary policy purposes) is restricted to increase, monetary policy is not allowed to use its conventional interest rate instrument, while at the same time the sum of the balance sheet positions related to the ECB's MROs and LTROs are required not to increase. Inflation and output are allowed to react with a one-period lag to policy decisions. The key innovation of our identification scheme is that we explicitly leave the reaction of the stress index unrestricted, because we want to let the data speak on the response of financial stress.

The results of this first exercise are depicted in Figure 2. Throughout the paper, solid lines depict the median and the blue-shaded area includes the 16-84% quantiles of the posterior distribution.

The median initial effect on financial stress is positive, while surrounded by uncertainty bands that include zero. In the following periods, financial stress declines and falls below its pre-shock level. At the same time, the shock has a temporary expansionary effect on the real economy; we observe a statistically significant[16] increase in output over the medium term.[17] Prices do not change significantly. The tendency for the policy rate to rise in the medium term might reflect the central bank's reaction to the increase in output. This contractionary monetary policy response may explain why, a few months after the shock, stress starts to increase and eventually overshoots its pre-shock level. To some degree, then, conventional monetary policy offsets the initial stress-reducing effect of the asset purchase policy impulse.

[16]Even though we use Bayesian estimation techniques we will in the following use the word 'significant' to mean that the respective quantiles of the posterior distribution do not include zero.

[17]Using industrial production instead produces similar results, see Figure C.4 in the appendix.

Following a peak after around one year, financial stress falls back to its initial level, while MRO and LTRO volumes expand as banks exploit the fixed rate full allotment scheme. Note that we observe a stress-reducing impact of increasing MROs and LTROs in response to a financial shock (see below).

Comparing our impulse response functions to those in Boeckx et al. (2017), reveals quantitative and qualitative differences. The size of the output reaction is smaller in our case and the response of prices is insignificant. Most notably, as opposed to the identifying assumptions imposed by Boeckx et al. (2017), who propose that financial stress does not increase initially, for our sample, stress falls with a lag of some months. In fact, after about 10 months, we observe positive reactions of stress which draws a somewhat ambiguous picture of the overall impact on stress. One could worry that our approach may mix up heterogeneous and potentially opposing effects of the asset purchase programs undertaken by the ECB. However, as Szczerbowicz (2015) has shown, the interconnectedness between banks and governments rather leads to an amplification of policy measures.

4.1.2 Financial shock

As our discussion about the identifying assumptions of the asset purchase shock has shown, it is important to disentangle such a shock from a financial stress shock which comprises endogenous reactions of private banks or the central bank in response to stress periods. In order to show the differences in the transmission, we identify a financial shock, which induces banks to obtain liquidity from MRO or LTRO operations and the central bank to react through asset purchases. This shock captures the endogenous responses we excluded for the structural and exogenous asset purchase shock. The identifying assumptions are summarized more formally in the respective column of Table 1. We keep the duration of the restrictions comparable to the asset purchase shock.

The dynamic responses to this shock are shown in Figure 3. Liquidity demand rises for several months and financial stress shows some persistence as well. The combination of asset purchases and liquidity provision through MROs and LTROs is quite effective in containing adverse effects on macroeconomic variables: output and prices do not change significantly over the response horizon. Financial stress peaks on impact and falls rapidly as the central bank provides liquidity. The median stress response eventually falls below its pre-shock level.

4.2 Germany

The responsibility for financial stability is not exclusively assigned to euro area institutions, but lies to a large degree at the national level. Since one might argue that the euro area is not a group of homogeneous countries, it is insightful to investigate the effects of the asset purchase programs for specific cases. Access to internal firm- and bank-related data allows us to evaluate the financial effects of unconventional policy measures for the German case.

We conduct similar experiments as for the euro area case. First, we estimate impulse response functions for the baseline specification. Then we replace the financial stress index with

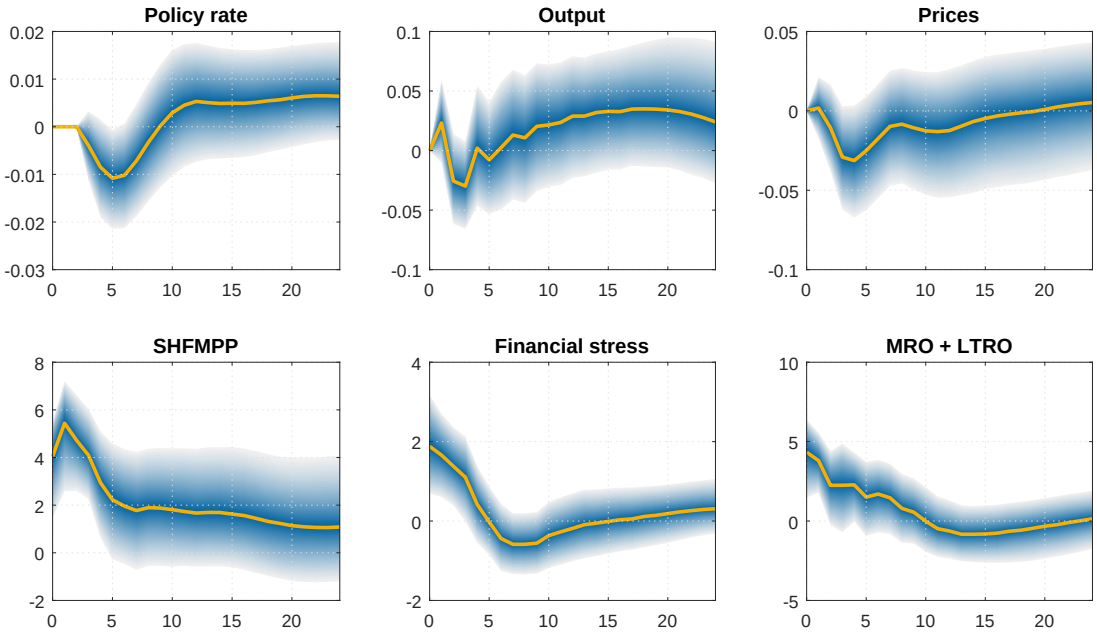

Figure 3: Euro area. Monthly impulse responses to a one standard deviation shock to financial stress, all multiplied by 100.

other variables of interest. We consider the same time horizon, lag length, and identification scheme as for the euro area.[18]

Results for the baseline model are depicted in Figure 4. Compared to the euro area exercise, qualitatively responses of macroeconomic variables show a similar pattern. Output rises over the medium term, while prices do not change significantly. The composite stress index for Germany displays a short-run drop. However, we also find that the purchase programs significantly *raise* market financial stress over the medium run. This points to possible undesirable second-round effects of the purchase programs.

One reason for these unfavorable effects might be that banks grant riskier loans in response to the shock, which has adverse effects on credit risk. Implicit default rates of German non-financial firms rise on impact, consistent with this conjecture. Eser and Schwaab (2016) find a strong but temporary reduction of liquidity risk premia due to the SMP in Greece, Ireland, Portugal, Italy, and Spain, while bid-ask spreads widened again afterwards. Lambert and Ueda (2014) find for US data that credit risk increases over the medium term in response to unconventional policy news.

In order to get a more detailed picture on how the asset purchase programs affect the corporate and financial sectors, we consider alternative specifications to our baseline choice of variables (2). In particular, we successively replace the financial stress index x_t with a series from a set of variables that contain information on the policy transmission channel or capture potential unintended side effects. Figure 6 contains the responses of those variables to an asset purchase shock.[19]

[18] The only exception is the series on implicit firm defaults for which we have observations until March 2015 only.

[19] We omit plots of the other 5 variables included in the VAR.

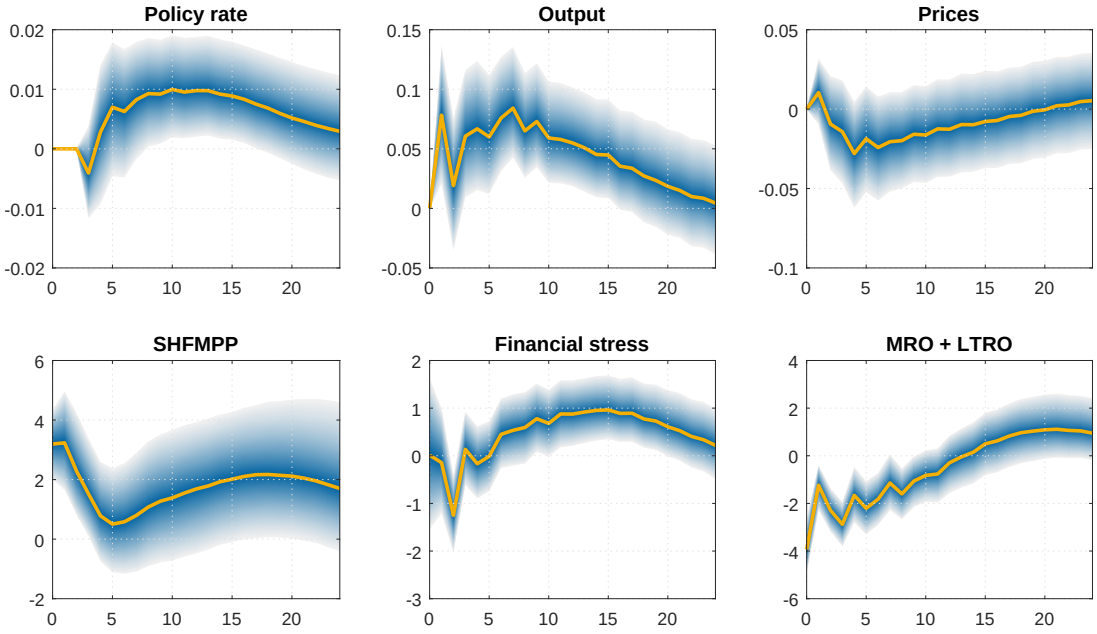

Figure 4: Germany. Monthly impulse response functions to a one standard deviation asset purchase shock, all multiplied by 100.

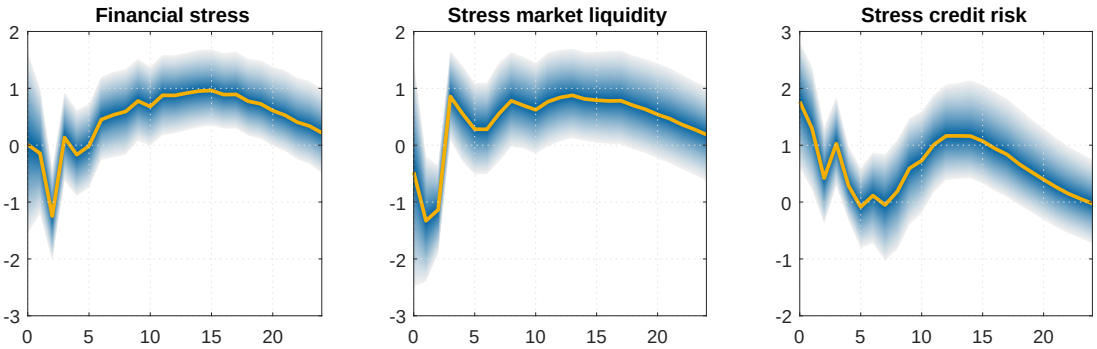

Figure 5: Germany. Monthly impulse responses of financial market variables to an asset purchase shock, all multiplied by 100.

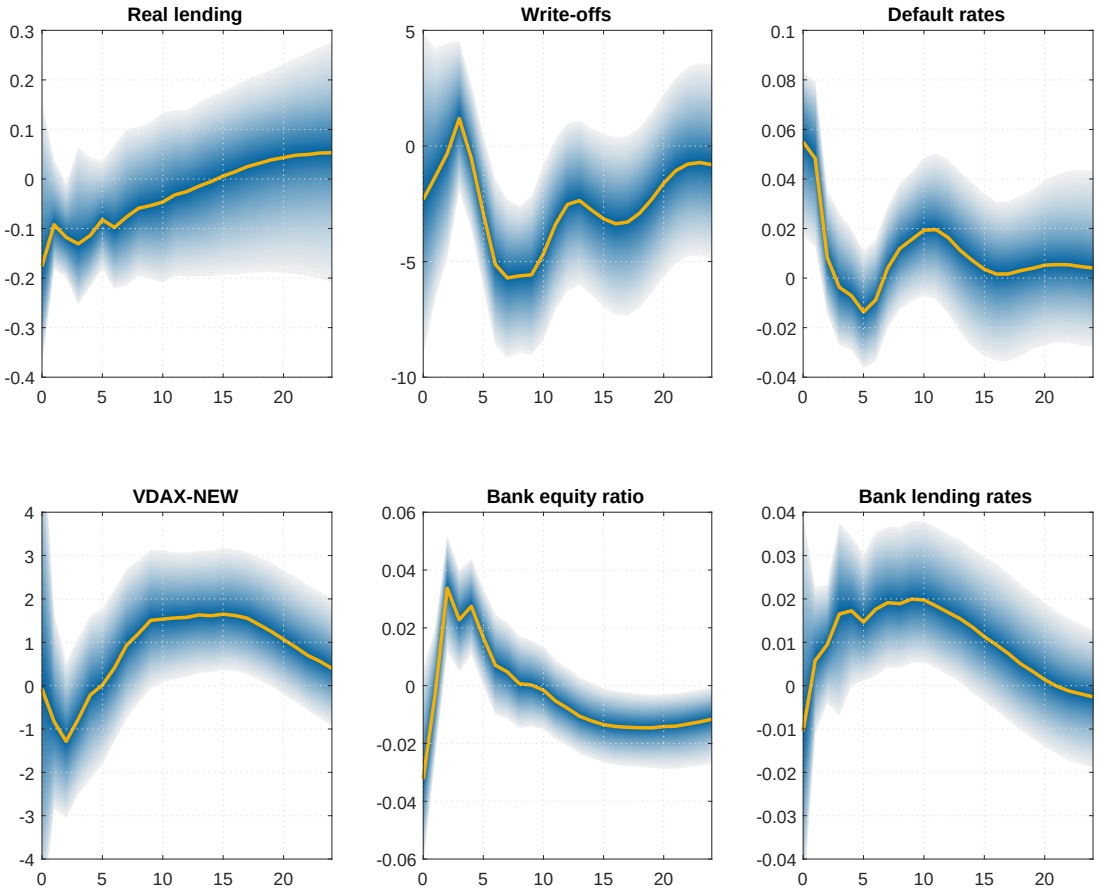

Figure 6: Germany. Monthly impulse responses of financial market variables to an asset purchase shock, all multiplied by 100. Loan write-offs are measured as a moving average of write-offs recorded by banks in the 12 months ahead. Banks are not required to report write-offs contemporaneously and often do so with several months' delay. An alternative (contemporaneous) measure of write-offs is shown in Figure C.5 of the appendix.

The ECB argues that its unconventional measures help to restore the monetary transmission channel. They involve supporting banks' credit provision to non-financial firms in order to finance new investment projects. Figure 6 however indicates that, in Germany, asset purchases did not generate more lending to non-financial firms.

We proxy credit risk by loan write-offs of corporate loans by German banks. Ceteris paribus, i.e. for a given default risk in the corporate sector, a reduction in write-offs indicates that banks are less cautious with respect to potential losses. Consequently, ex-ante credit risk rises. Our use of data on write-offs differs from Angbazo (1997) or Dick (2006), who view them as a direct measure of credit default, such that increased write-offs reflect higher ex-post credit risk. One concern related to liquidity injections is that banks might roll over existing loans or extend new loans to nonviable firms, which would be reflected in increased net loan write-offs.[20] The median response shows that, at least in the short run, liquidity provisioning induces banks to reduce their loan write-offs. While this result is associated with much estimation uncertainty, it may suggest that banks do not fully take into account credit risk. In connection with the increase in implicit firm defaults, this result may point to higher financial stability risks.

[20] Lambert and Ueda (2014) find US banks to avoid repairing their balance sheet and call this "evergreening".

The VDAX-NEW index reflects risk aversion and volatility in the stock market.[21] Results show that market participants become less optimistic about future stock market developments as volatility significantly rises over the medium run. The initial response to the shock is insignificant.

The positive response of the equity ratio in figure 6 may suggest that the banks to some extent use the liquidity provided by the central bank in order to recapitalize their balance sheets by obtaining more equity financing. However, Figure C.5 in the appendix reveals that equity falls on impact, before gradually returning to its pre-shock level. This implies that the rise in the equity ratio is driven by a fall in the denominator: banks cut back on their asset holdings. It is perhaps not surprising that, as the central bank buys assets, commercial banks shrink their balance sheets by offloading some of their assets. However, we do not observe that banks raise more equity or lend more to firms, as policy makers might hope.

Given that lending to firms does not expand, why does output react positively to central bank asset purchases? One possible explanation is an expectation of higher future demand, creating confidence and optimism among firms. In Figure C.4 in the appendix, we show the impulse responses of the German stock market (DAX) and Eurostat's Economic Sentiment Indicator for businesses. Both variables exhibit a positive reaction to the ECB's balance sheet expansions. This evidence, taken together, suggests that the APPs are effective in stimulating the economy, but the transmission works through an expectations or signalling channel, rather than an easing of financing conditions and an expansion of credit to firms.

The portfolio balancing channel has often been mentioned in connection with central bank asset purchase programs.[22] Among other things, it predicts a decline in interest rates. If the central bank undertakes large-scale asset purchases, the prices of those assets should rise and yields should decline accordingly. Since interest rates on assets fell and investors are equipped with liquidity from the central bank, they have an incentive to rebalance their portfolios and to buy comparable but more profitable assets. The increased demand will in turn induce asset prices to increase and interest rates to fall further. We introduce bank lending rates in the VAR in order to test the pass-through to lending rates to non-financial corporations. From the impulse response functions we find that lending rates show a tendency to fall initially. However, the width of the error bands shows that this result is quite imprecise. Lending rates actually rise over the medium term in response to the ECB's asset purchase programs. Thus, we do not observe the intended effect on bank lending rates. Looking at this result more closely, we note that lending rates are tightly connected to the policy rate and follow its pattern. As the policy rate rises some months after the shock, lending rates mimic this response.[23]

To conclude, while macroeconomic effects of asset purchase programs in Germany are fa-

[21] Similar to the VDAX, the VDAX-NEW is a volatility index. The construction of the VDAX-NEW is more closely related to the VSTOXX. Instead of of relying on fictitious option price data it is compiled with traded options.

[22] See e.g. Draghi (2014).

[23] We carried out a robustness exercise, where we require the policy rate to stay unchanged only on impact instead of three months. In that case, the policy rate is lowered in response to the shock, which allows bank lending rates to decline. The respective impulse response functions are available upon request.

vorable, with output increasing significantly and no effect on prices, financial market variables paint a less optimistic picture. Lending to firms does not expand or become cheaper, implicit firm default rates rise and financial stress also increases eventually. Our results imply some uncertainty with respect to initial reactions to the shock while medium-term effects are exposed more clearly. Different from event studies which focus on short-term impact of measures, our model emphasizes the medium-term implications.

5 Conclusion

This paper estimates the effects of ECB's asset purchase programs, focusing on financial market variables. We disentangle asset purchase shocks from changes in the balance sheet that reflect endogenous liquidity provisioning through the fixed rate full allotment policy. We find that ECB balance sheet policies, in the form of direct asset purchases, bring down financial stress for some periods after the shock. This positive effect is reversed thereafter as stress increases above its pre-shock level. At the same time, asset purchase shocks have an expansionary effect on economic activity, while the effect on prices remains insignificant. Our approach differs from the existing literature in that we do not impose restrictions on financial stress in order to identify discretionary asset purchase shocks. We also find that liquidity provisioning through a fixed rate full allotment policy in response to a financial shock appears to be successful in containing adverse effects on output and prices.

Macroeconomic implications of the asset purchase programs for the German economy are generally similar. Initially, financial stress declines. However, after several months financial stress rises, which suggests that a more detailed analysis of financial market responses is warranted. Stock market volatility and risk aversion increase in response to the policy measure. We find that asset purchases are not successful in restoring credit creation in Germany. Bank lending rates do not decrease as suggested by the portfolio balancing channel. Loan write-offs decline while implicit firm default rates rise significantly, indicating that bank lending might be becoming more risky. To sum up, our analysis shows that, while output effects in the euro area and Germany are positive, there are indications of increasing risks to financial stability. While event studies usually document short-term implications of policy measures, our analysis gives insights into the dynamic responses of the macroeconomy and financial variables.

The question remains to which extent asset purchase programs influence individual financial institutions and how effects feed back to the macroeconomy. It would be particularly interesting to consider data at an institutional level in order to overcome the small sample size problem. Examining more disaggregated data using appropriate empirical models is left for future research.

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Series	Source	Identifier
Euro area		
Securities held for monetary policy purposes	ECB SDW	ILM.W.U2.C.A070100.U2.EUR
Real GDP	Eurostat	namq_10_gdp
Industrial production	ECB SDW	STS.M.I8.Y.PROD.NS0010.4.000
HICP	ECB SDW	ICP.M.U2.S.000000.3.INX
CISS	ECB SDW	CISS.D.U2.Z0Z.4F.EC.SS_CI.IDX
MRO rate	ECB SDW	FM.B.U2.EUR.4F.KR.MRR_FR.LEV
EONIA rate	ECB SDW	FM.M.U2.EUR.4F.MM.EONIA.HSTA
MRO volumes	ECB SDW	ILM.W.U2.C.A050100.U2.EUR
LTRO volumes	ECB SDW	ILM.W.U2.C.A050200.U2.EUR
Germany		
CPI	Bundesbank	BBDP1.M.DE.Y.VPI.C.A00000.I10.A
Real GDP	Eurostat	namq_10_gdp
Industrial production	Bundesbank	BBDE1.M.DE.Y.BAA1.A2P300000.G.C.I10.A
Composite stress index	Bundesbank	Internal data
Market liquidity index	Bundesbank	Internal data
Credit risk index	Bundesbank	Internal data
Implicit default rates	Bundesbank	Internal data
VDAX-NEW	Datastream	VDAXNEW
Write-offs	Bundesbank	Internal data
Equity ratio	Bundesbank	Internal data
Lending growth	ECB SDW	BSI.M.DE.N.A.A20T.A.I.U2.2240.Z01.A
Lending rates	ECB SDW	MIR.M.DE.B.A2I.AM.R.A.2240.EUR.N

Table A.1: Data and corresponding sources.

Appendix

A Data

Table A.1 gives a detailed overview of the data series used in our analysis. Some of the series were transformed before estimation. Data on real GDP is not available on a monthly frequency. For this reason we imputed the missing values using the Chow and Lin (1971) method as it is done in Boeckx et al. (2017) and Gambacorta et al. (2014). In general, we used seasonally and working day adjusted data where available. In the case of German loan write-offs and the equity ratio we used unadjusted data. The data on loan write-offs and the equity ratio are taken from the monthly balance sheet statistics ("monatliche Bilanzstatistik") which consists of confidential data on German MFIs balance sheets. The former are net write-offs, depreciation less revaluation of credit to the corporate sector as an aggregate over the German banking sector, while the latter is aggregate equity divided by total assets of German banks (MFIs). Bank lending comprises lending to non-financial corporations.

B Other exercises

B.1 Alternative identification

We have performed a robustness exercise regarding the horizon over which the sign restrictions are binding. In our baseline identification of the asset purchase shock, except for output and

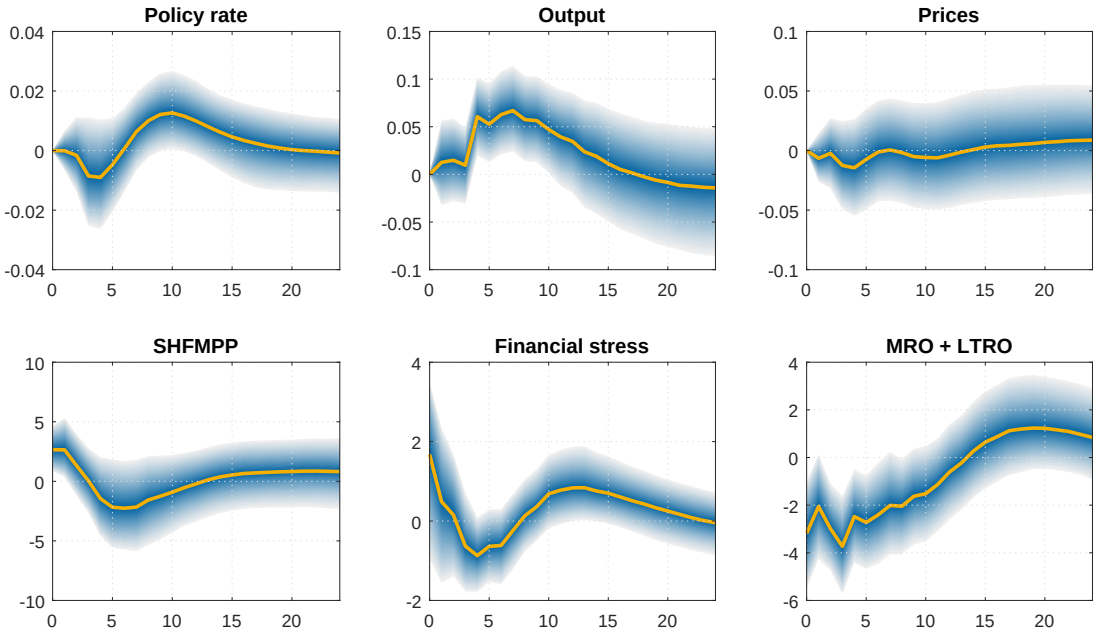

Figure B.1: Euro area. Monthly impulse responses to a one standard deviation asset purchase shock with alternative identifying assumptions, all multiplied by 100.

prices, we choose a three-month horizon to take into account that the ECB's purchase programs are generally quite persistent. In particular, we imposed prolonged zero restrictions on the policy rate r_t for two reasons. First, we do not want to mix up conventional policy shocks with balance sheet policy which leads us to keep this restriction at least as long as the sign restriction on the balance sheet prevails. Second, our results should contain some information about constrained conventional monetary policy environments, i.e. the zero lower bound restriction. In Figure B.1 we provide results of an alternative identification scheme, where the restriction on the policy rate is imposed only on impact.

B.2 Alternative lag length

We performed an additional robustness exercise with respect to the lag length of the model. In Figure B.2 we provide results for the asset purchase shock in a model with only two lags. Impulse responses have a similar pattern compared to the baseline case. Stress falls after some months but then rises again and rises above its pre-shock level. The response of output is positive over the medium term. Quantitatively, we find a longer lasting positive response of output and a very short-lived negative response of prices. However, we would still argue that we can hardly verify a noticeable effect on prices since error bands include zero from period 4 onwards.

B.3 Policy rate shock

We also computed impulse responses to a "conventional" policy rate shock. The policy rate is assumed to decrease on impact and in the following two months, while output, prices and the balance sheet items do not react on impact. Results are depicted in Figure B.3. We find that

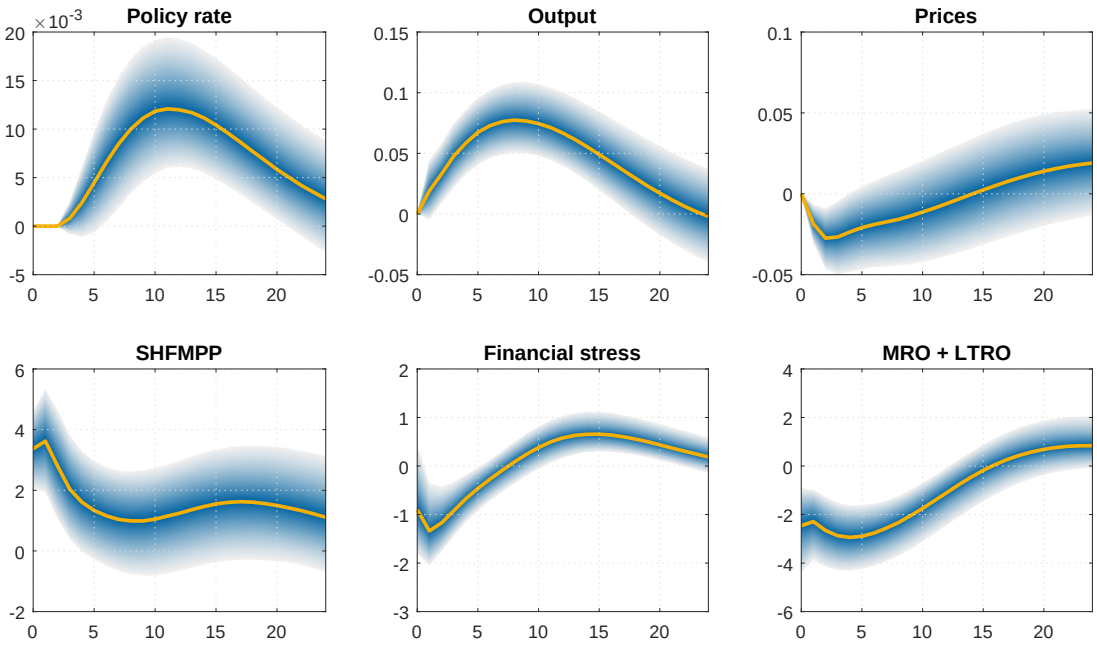

Figure B.2: Euro area. Monthly impulse responses to a one standard deviation asset purchase shock with alternative lag length specification, all multiplied by 100.

the policy instrument is ineffective with respect to output and we observe a positive response of prices which lasts for a few months. The effectiveness of conventional policy instruments appears to be limited within our sample.[24]

C Other experiments

[24]Results are consistent with the findings of Abbassi and Linzert (2012), who observe a loss in conventional policy effectiveness. In fact, the impact of conventional policies on financial stress is insignificant in our sample. If at all, it seems to reduce stress after about 4 to 5 months.

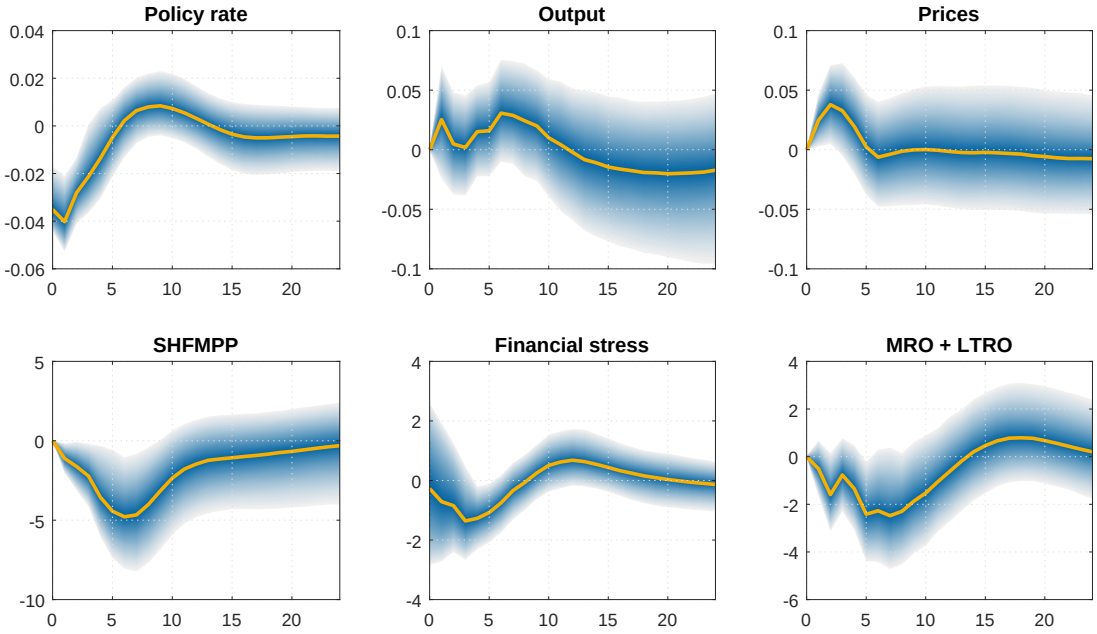

Figure B.3: Euro area. Monthly impulse responses to a one standard deviation policy rate shock, all multiplied by 100.

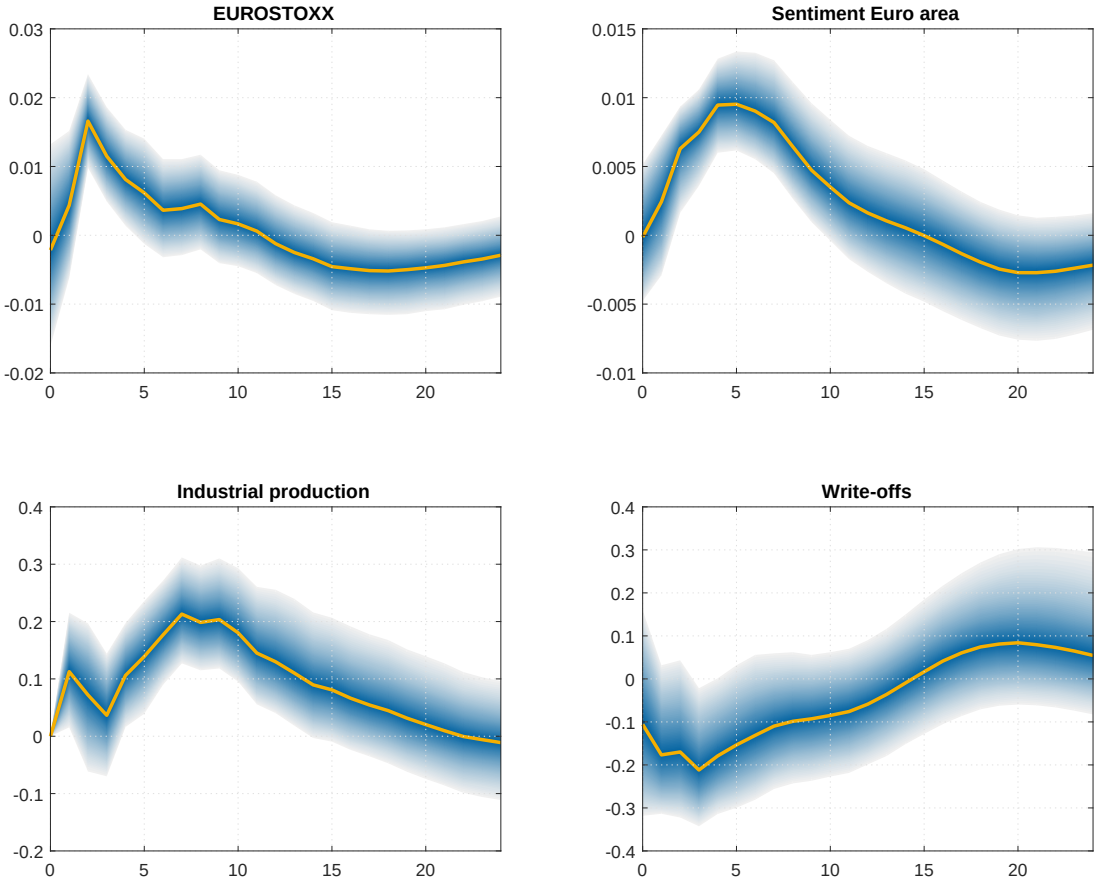

Figure C.4: Euro area. Additional monthly impulse responses to an asset purchase shock, all multiplied by 100. Alternative measure of write-offs using values reported by banks in the corresponding month.

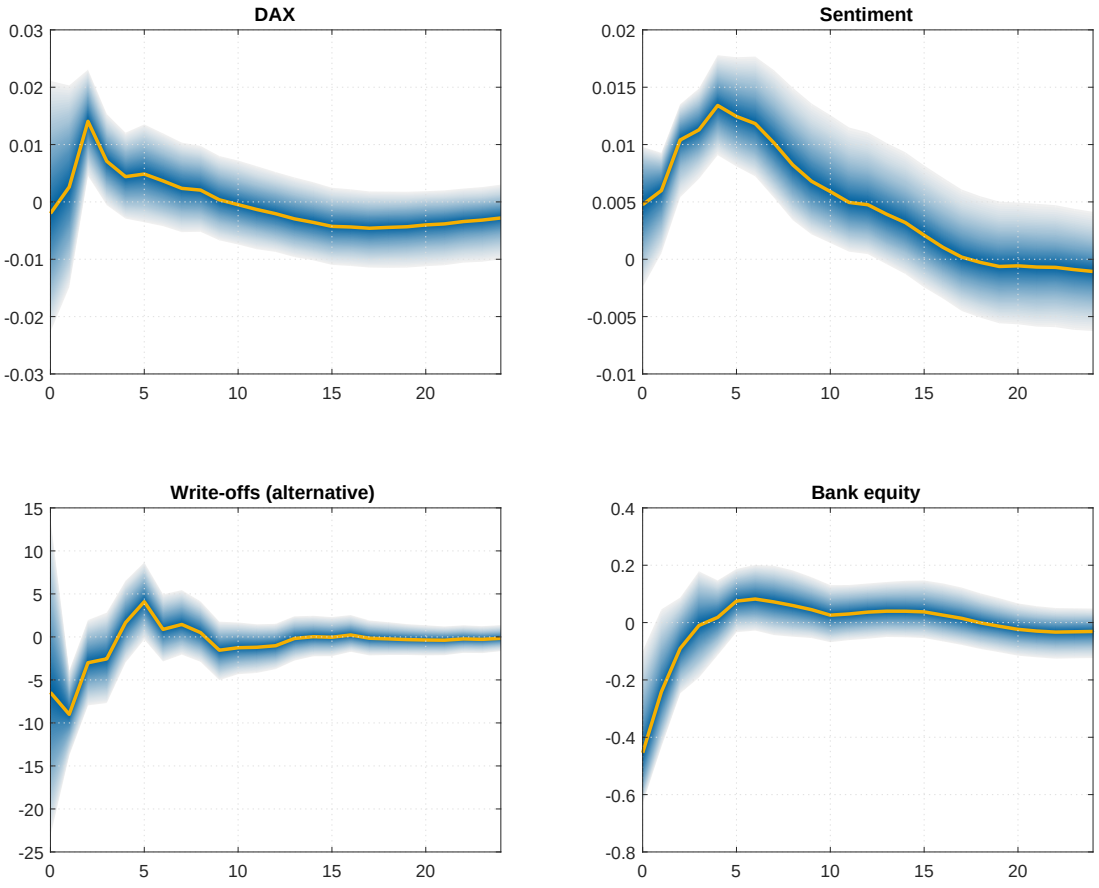

Figure C.5: Germany. Additional monthly impulse responses to an asset purchase shock, all multiplied by 100.