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Unconventional Monetary Policy, Fiscal Side Effects and Euro Area (Im)balances*

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Abstract

We study the macroeconomic effects of unconventional monetary policy in the euro area using structural vector autoregressions, identified with external instruments. The instruments are based on the common unexpected variation in euro area sovereign yields for different maturities on policy announcement days. We first show that expansionary monetary surprises are effective at lowering public and private interest rates and increasing economic activity, consumer prices, and inflation expectations. We then document that the shocks lead to a rise in primary public expenditures and a widening of internal trade balances.

JEL classification: E52, E58, E63

Keywords: Central banks, structural VAR with external instruments, fiscal policy, monetary union.

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1 Introduction

Following the outbreak of the global financial crisis in 2007 nearly all major central banks engaged in unconventional monetary policy, in the form of credit easing, forward guidance, or asset purchases. While more and more rounds of easing have been implemented, the academic literature has reached no consensus on the macroeconomic effectiveness of these policies and on how they pass-through to the real economy. Empirical evidence about their potential side effects is also scarce, in particular about their fiscal and distributional consequences in a currency union.

In this paper, we use vector autoregressions to study the economy-wide effects of unconventional monetary policy in the euro area. Starting from August 2007, the European Central Bank (ECB) engaged in a variety of non-standard policies. These policies can be broadly separated into two phases, which we analyse separately. The first phase was the period between August 2007 and May 2014. Monetary policy was directed towards reducing sovereign spreads of crisis-hit countries relative to non-crisis countries. The measures included large scale liquidity provision to banks, interventions in stressed sovereign debt markets through outright purchases, and the institutional arrangements for Outright Monetary Transactions. The second phase started in June 2014, after which the ECB first set negative deposit rates, prepared markets for the subsequent large scale asset purchase programs, and increasingly relied on forward guidance. These policies were aimed at stimulating the economy by lowering the risk-free yield curve.

The identification of causal effects associated with unconventional monetary policy raises new challenges, because identification cannot fully rely on the strategies developed for conventional interest rate policies (Wright, 2012). In this paper, we achieve identification by exploiting daily data on government bond yields of various euro area countries at different maturities. We first extract the common

component of changes in yields around the announcements of unconventional monetary policy measures by the ECB. Building on the 'event study' literature (Kuttner, 2001, or Gürkaynak et al., 2005), we view the estimated common yield variations in a narrow window around the announcements as a noisy measure of the exogenous components of policy decisions. We then use the constructed measures as instruments for unobserved unconventional monetary policy shocks in several proxy vector autoregressions (VARs). In doing so, we follow the methodology developed by Stock and Watson (2012) and Mertens and Ravn (2013), and used by Gertler and Karadi (2015) and Rogers et al. (forthcoming).

For our application we derive two separate proxies, one for 'phase 1' and one for 'phase 2' unconventional monetary shocks. Since phase 1 was largely directed at mitigating the credit risk of periphery countries relative to core countries, we construct a proxy for phase 1 using yields of periphery countries around the policy announcements during this early period. By contrast, since policies during phase 2 were targeted at the risk-free yield curve, we construct a proxy for phase 2 shocks using yields of core countries around the policy announcements in this latter period. As in Stock and Watson (2012), we identify one structural shock at the time using the corresponding instrument.

Our results are as follows. Exogenous monetary expansions that lower the average two-year rate on euro area government bonds lead to a significant rise in consumer prices and output, and a decline in the unemployment rate in the euro area as a whole. Several measures of inflation expectations at different horizons also increase. The monetary policy shocks seem to be transmitted through private and public interest rates, asset prices, as well as credit spreads and volume. Theses dynamics are qualitatively similar for the two phases of ECB unconventional monetary policy, although the effects are weaker and tend to be less precisely esti-

mated for phase 2. Consistent with the aim of each phase, we find that monetary innovations during the first phase significantly reduce credit risks and lower yields and spreads of periphery countries, while surprise expansions during the second phase reduce yields in all countries and lower in particular long term rates. In addition, phase 1 exogenous expansions lead to an appreciation of the euro, potentially reflecting a reduction in break-up risk for the euro area. By contrast, phase 2 monetary expansions generate a more conventional depreciation of the euro, and have a stronger positive effect on euro area equity prices. We also show that the effects of unconventional policy shocks are similar to those of conventional monetary innovations, which we identify for the period 1999-2006. Relative to models for unconventional monetary policy that identify shocks from changes in central banks' balance sheets, the responses of industrial production and prices in our models are slower and stronger, with economic activity leading prices.

Our estimates also document several side effects of the monetary interventions. The fall in sovereign yields after unanticipated expansions in phase 1 leads to a rise in primary public expenditures. When looking at individual expenditure categories, the rise in primary spending seems to be mainly driven by increases in public consumption. This holds on average for the euro area as a whole as well as for most member states. It holds also in response to conventional monetary shocks, but less so after phase 2 unconventional shocks. As the economies of the member countries are affected differently by the common monetary surprises and as national fiscal authorities respond differently, intra-euro area trade balances widen. Trade deficits of countries which are on average net importers or more severely hit by the crisis rise as the increase in domestic demand and prices is more pronounced in these countries. In contrast, trade surpluses of the main net exporters within the union (Germany, Belgium, and the Netherlands) increase vis-à-vis the rest of the

euro area. While statistically significant, the trade adjustments are quantitatively small, however, and primarily hold after phase 1 shocks.

The literature on the effects of unconventional monetary policy has evolved around two approaches. The first approach uses high frequency identification and mainly assesses the contemporaneous effects of these policies on variables available at high frequency, typically financial variables. Among others, Krishnamurthy and Vissing-Jorgensen (2011), Gagnon et al. (2011), Wright (2012), Rogers et al. (2014), and Fratzscher et al. (2016) find that unconventional policies lower interest rates and term premia, and increase asset prices.[1] The second approach uses structural VARs and quantifies the dynamic effects on macroeconomic variables, either on a monthly or on a quarterly frequency, using zero or sign restrictions. Kapetanios et al. (2012), Baumeister and Benati (2013) and Ciccarelli et al. (2013) identify monetary policy shocks as exogenous variations in interest rates or spreads. On the other hand, Peersman (2011), Gambacorta et al. (2014), Boeckx et al. (2017), and Weale and Wieladek (2016) isolate unexpected changes in central banks' balance sheets.

In this paper, we use high frequency data for the identification of VAR models for unconventional monetary policy in the euro area. In doing so, we combine the two approaches discussed above, and complement the analysis of existing VAR studies, which mainly focus on the US and the UK. We build on Gertler and Karadi (2015), who show how the identification through external instruments allows embedding high frequency financial market data on monetary policy surprises into a structural VAR model for the US economy.[2] We follow the modification of this

[1] Christensen and Rudebusch (2012), Hamilton and Wu (2012) and Wu and Xia (2016) use term structure models to evaluate the impact of unconventional monetary policy on yields and the macro-economy.

[2] Their approach is also used by Cesa-Bianchi et al. (2016) to study unconventional

approach by Rogers et al. (forthcoming), who use high frequency data by combining estimates of the relative response of variables based on data at different frequencies. The authors mainly analyze the effects of US unconventional monetary policy on exchange rates, dedicating less attention to the euro area. We focus on the euro area in detail and investigate fiscal effects and country heterogeneity.

Our work also builds on Altavilla et al. (2016), who analyze the effects of selected ECB policies by studying the reaction of sovereign yields on days of policy announcements. We follow their approach of measuring the surprise component of monetary policy, but extend their framework by proposing a panel setup that extracts the unexpected common variation in yields of different countries and maturities. We view this extension as important, given the partially segmented nature of financial markets in the euro area after the financial crisis, and the temporary inversion of yield curves. In addition, we use the high frequency estimates for the identification of the VAR models rather than using a recursive structure, as in their paper. Compared to contributions that employ central banks' balance sheets, the identification of the model through information contained in yields has the advantage of capturing the effects of monetary interventions without restricting them to their implementation. This is important because the *announcement* of monetary interventions is a main source of the effectiveness of monetary policy in general (Blinder et al., 2008) and, in particular, in recent years, when central bank communication in the form of forward guidance has become a main policy tool (den Haan, 2013, Ed.). Finally, the paper connects to the ongoing discussion on the causes and consequences of euro area imbalances (Blanchard and Giavazzi, 2002, Chen et al., 2013, Wyplosz, 2013 or Kang and Shambaugh, 2016).

The paper is structured as follows. In Section 2 we discuss the VAR model and

monetary policy for the UK.

the identification strategy. Section 3 contains the main results for the euro area as a whole, and then for individual countries. Section 4 provides a comparison with conventional monetary policy. The last section concludes.

2 The VAR model

In this section we first discuss the specification of the reduced form model, which is the same for the two structural unconventional monetary policy shocks that we identify. We then outline how we construct two instruments that capture the unconventional ECB monetary policy shocks in phase 1 and phase 2, respectively. Last, we show how the instruments are used to identify the model.

2.1 Reduced form model

The VAR model used can be written as

$$y_t = c + \Pi(L)y_{t-1} + u_t, \tag{1}$$

and refers to variables at a monthly frequency. The $k \times 1$ vector c includes constant terms, the matrix $\Pi(L)$ in lag polynomials captures the autoregressive part of the model, and the vector u_t contains k serially uncorrelated innovations, or reduced form shocks, with $V(u_t) = \Sigma$ and $u_t \sim N(0, \Sigma)$.

We employ different specifications for the endogenous variables in y_t. In the baseline VAR y_t includes the six variables discussed below, which refer to euro area aggregates. In the other specifications y_t includes the baseline variables plus one additional variable, which changes across specifications, ranging from measures of inflation expectations to financial variables, fiscal variables and others, both at a euro area level and for single countries. In adding one additional variable at a time

we follow Beaudry and Portier (2014) and Gertler and Karadi (2015), who modify the marginal variable in a baseline VAR. This approach is particularly flexible and does not require a Bayesian perspective, a panel VAR, or factor structure to deal with the curse of dimensionality.

The variables included in the baseline VAR are

$$y_t = \begin{pmatrix} \text{Average two-year rate on euro area government bonds} \\ \text{BBB-AAA corporate bond credit spread} \\ \log(\text{Credit to non-financial corporations}) \\ \log(\text{Harmonized index of consumer prices}) \\ \log(\text{Industrial production}) \\ \text{Unemployment rate} \end{pmatrix}.$$

These variables capture financial and interest rate conditions, prices, as well as real economic activity. As a variable reflecting the stance of monetary policy for the euro area as a whole, a 'policy indicator', we use a weighted average of the two-year rates on government bonds of 13 euro area countries.[3] We follow Gertler and Karadi (2015), who employ the one-year US treasury rate, and use a (medium-term) government bond rate as policy indicator. Compared to the short-term interest

[3]The 13 countries are Austria, Belgium, Finland, France, Germany, Ireland, Italy, Latvia, the Netherlands, Portugal, Slovakia, Slovenia, and Spain. We exclude Greece due to the effect of its debt restructuring on the two-year yield in the period considered. We exclude the remaining 5 countries from the EA19, namely Cyprus, Lithuania, Luxembourg, Estonia and Malta, due to data availability. The weights used to compute the average euro area yield are constructed on the average GDP of each country in the period 1999-2016. To improve the ability of the policy indicator to capture the monetary policy stance by the ECB, we construct the indicator using data starting from the day in which each country adopted the euro.

rates typically used in VAR studies on conventional monetary policy, the variable used has the advantage of taking into account non-standard policy innovations that are aimed at influencing expectations and yields at longer horizons. Moreover, short-term interest rates like the Eonia or the Euribor are less suitable because in our sample they are constrained by the effective lower bound.

In addition to the consumer price index (CPI) and the real activity variables commonly included in monetary VAR models we add a measure of credit spreads, as several non-standard ECB measures were triggered by financial market developments. Moreover, Caldara and Herbst (forthcoming) show that adding corporate bond spreads is important for the identification of conventional monetary policy shocks in structural VARs. Specifically, we include the spread between BBB and AAA rated corporate bond two-year yields. Further, we add credit to non-financial firms to the model because several ECB unconventional measures had the purpose of stimulating bank lending, for instance long-term refinancing operations. Lastly, we include the unemployment rate as a measure of labor market slack and inflation pressure, since the ECB's large-scale asset purchase programs were specifically targeted at lifting prices and inflation expectations. Appendix A contains details on all variables used. We include five lags of the endogenous variables.[4]

The reduced form model is estimated on monthly data from 2002M5 to 2016M11. While we aim for the estimation of model for the full period after the adoption of the euro, data availability for credit spreads makes the analysis feasible starting

[4]Schwarz's Bayesian and the Hannan and Quinn information criteria both suggest the use of one lag, while Akaike's information criterion indicates three lags. Since we view either as a relatively low lag number, we use five lags. The Ljung-Box test for autocorrelation never rejects the null hypothesis of no autocorrelation of the residuals at conventional significance levels for lags 1 to 1-10. In the sensitivity analysis we show that the results hold when using eight lags.

from 2002M5. The sample period features both conventional and unconventional types of monetary policy. In Appendix B we test for structural breaks between both episodes using the baseline VAR. We first carry out tests on each individual equation of the model. We then jointly test for structural breaks in the entire multivariate reduced form model. Last, we estimate impulse responses adding interaction terms that allow for a structural break either in the constants, autoregressive components, covariance matrix, or all three parts simultaneously. Overall, we find that only some of the single equations might have been subject to a structural break around the beginning of the unconventional monetary policy period. The effect of such parameter instability on the multivariate model and on the impulse responses is insignificant and small, however. These results suggest that the linear model offers a good approximation of the dynamics of the system. Further robustness checks show that the main findings also hold when estimating the model using data only for the unconventional period (see Appendix D).

The VAR innovations are assumed to be linearly driven by a non-standard monetary policy shock ϵ_t^m, which we aim to identify, and other structural shocks ϵ_t^*, which are of no interest for the purpose of this paper. For the moment, we generically refer to ϵ_t^m as an unconventional monetary shock, without explicit reference to whether it captures phase 1 or phase 2 of the ECB's unconventional monetary policy. The VAR innovations u_t are related to the structural shocks ϵ_t^m and ϵ_t^* through equation

$$u_t = b^m \epsilon_t^m + B^* \epsilon_t^*. \tag{2}$$

The $k \times 1$ vector b^m captures the impulse vector to a monetary shock of size 1 and is required to generate impulse responses to a one standard deviation shock.

Our identification strategy follows the variant of Rogers et al. (forthcoming) of the identification approach with external instruments developed by Stock and

Watson (2012) and Mertens and Ravn (2013). As shown in the latter two papers, when a variable m_t is available such that

$$E(m_t \epsilon_t^m) \neq 0, \tag{3a}$$

$$E(m_t \epsilon_t^*) = 0, \tag{3b}$$

it can be used to consistently estimate the impulse vector b^m. We now discuss how we compute m_t in order to ensure that conditions (3) are satisfied, and then outline how we use m_t to estimate b_t^m and identify ϵ_t^m.

2.2 Proxies for monetary policy shocks

Define m_t as a measure correlated with unconventional monetary policy shocks for the euro area, for now without explicit reference to whether it captures phase 1 or phase 2 of unconventional monetary policy. To construct a proxy (or instrument) m_t for unconventional monetary shocks, we build on Kuttner (2001) and the subsequent literature that uses high frequency data in an event study manner. This approach focuses on one or more financial indicators related to the policy rate. It postulates that the price of the indicator closely before a monetary announcement incorporates the (expected) endogenous response of monetary policy to the state of the economy. Accordingly, any variation in this price from before to after the announcement reflects an unexpected component of monetary policy revealed by the announcement, and is interpreted as exogenous with respect to the economy (see Gürkaynak et al., 2005, for a discussion).

The proxy m_t is not required to be a correct measure of monetary shocks, in that several forms of measurement error can be accounted for (Mertens and Ravn, 2013). What is required is that m_t correlates with ϵ_t^m. To construct a measure

correlated with monetary policy shocks we build on Altavilla et al. (2016) and use daily data on euro area government bond yields. We extract the common variation in sovereign yields for different maturities of several euro area countries around monetary policy announcements by the ECB. Thereby, we extend the analysis of Altavilla et al. (2016) to a panel across countries and maturities.

Specifically, we employ the regression

$$x_{cmt} = \alpha_c + \beta x_{cmt-1} + \sum_{a=1}^{N_a} \gamma_a D_{at} + \sum_{n=1}^{N_z} \delta_n z_{nt} + \eta_{cmt}, \tag{4}$$

on a daily frequency. In equation (4), x_{cmt} represents the sovereign bond yield of country c on maturity m at time t, α_c are country-specific constants, and D_{at} represents a dummy variable taking value 1 if the monetary policy announcement a took place at day t and zero otherwise, with $a = 1, ..., N_a$ and N_a the number of events. z_{nt} controls for the release of macroeconomic news on variable $n = 1, .., N_z$. We include $N_z = 139$ macroeconomic news variables, computed as the surprise component in economic data releases for the euro area, the UK, and the US, to attenuate the risk that the one day window covers realizations of structural shocks that differ from the shock of interest.[5]

The key parameters in equation (4) are the coefficients γ_a. Each of these coefficients captures the common variation in yields in response to ECB event a, and aims to detect the exogenous component of the announcement. After estimating (4), we transform the estimated vector $(\hat{\gamma}_1, .., \hat{\gamma}_A)'$ into one daily series m_t^D, taking value zero on non-announcement days and value $\hat{\gamma}_a$ on the day of announcement a. We then aggregate the vector m_t^D into a monthly series m_t^M by summing within

[5]For each variable, we construct a daily time series as the difference between the first-released data and the expected values, the latter corresponding to the median estimate of a panel of experts surveyed by Bloomberg.

months.[6]

The selection of the sample period, of the announcement days, and of the countries whose yields are used in equation (4) depends on which type of unconventional monetary policy shock we aim to capture. We divide the period after 2007 into two non-overlapping phases of ECB unconventional monetary policy, which were broadly characterized by distinct aims of ECB policy.

We define phase 1 as the period between 2007M8 and 2014M5. In this period, the ECB interventions mainly aimed at reducing sovereign and bank credit risk in periphery countries, and at lowering spreads vis-à-vis core countries. The objective of these measures was to restore the functioning of impaired interbank markets, lower funding risk, and stimulate credit supply, in particular in stressed countries. Different types of longer-term refinancing operations (LTROs) were introduced between 2007 and 2012, with up to 36 month maturity. Moreover, the ECB intervened in sovereign debt markets through outright purchases of government debt of troubled countries under its Securities Market Programme (SMP) in 2010/11, and by giving an implicit guarantee against a speculative run on euro area sovereign debt with the announcement of Outright Monetary Transactions (OMT) in 2012. For phase 1 we use announcement days in which the ECB made explicit or implicit reference (either during regular meetings or other relevant speeches and communication) to at least one of the above-mentioned non-standard policy measures. This selection delivers 29 announcement days. The choice of events closely

[6]In the sensitivity analysis, we show that our results are similar if we construct m_t^M after winsorizing m_t^D at 80% to control for outliers, and if we use two day rather than one day windows around the policy announcements. The latter approach is implemented by replacing $\sum_{a=1}^{N_a} \gamma_a D_{at}$ with $\sum_{a=1}^{N_a} (\gamma_a^1 D_{at} + \gamma_a^2 D_{a-1t})$ in model (4) and by defining $\gamma_a = \gamma_a^1 + \gamma_a^2$, with D_{a-1t} a dummy variable taking value 1 if the monetary policy announcement a took place at day $t-1$.

follows Wright (2012) and Rogers et al. (2014), updated until 2014M5. The full list of events for both phases is shown in Table A.3 in the online appendix.

We define phase 2 as the period between 2014M6 and 2016M11. The unconventional measures adopted by the ECB were now targeted at lowering the risk-free yield curve in the euro area, instead of credit spreads. The main policy tools were negative interest rates on the deposit facility, the large-scale Asset Purchase Programme (APP), which was announced on January 22, 2015, and forward guidance, either on purchases or on interest rate policy. The measures were intended to affect yields of long-term investment-grade public and private securities, and to shape expectations about future policy behavior, thereby giving the central bank some control over long-term interest rates. Overall, phase 2 includes 22 events at which the ECB made reference to at least one of these non-standard policy measures. We collect the events from Motto et al. (2015), Breckenfelder et al. (2016) and the ECB website. We include decisions to set negative interest rates on the deposit facility into the definition of unconventional monetary policy because they were unprecedented in the euro area at that time, and to increase the number of events in phase 2. Some of these decisions were accompanied with small changes in the key interest rate.

Since phase 1 was mainly targeted at improving funding conditions in troubled countries, we first estimate equation (4) using as dependent variable the sovereign yields of those countries. By contrast, since phase 2 was aimed at lowering the risk-free yield curve, for phase 2 we estimate (4) using the sovereign yields of core countries.[7] While we consider different countries for phase 1 and phase 2, in both

[7]The instrument for phase 1 is constructed using the yields of Belgium, Greece, Ireland, Italy, Latvia, Malta, Portugal, Slovenia, Slovakia and Spain. The instrument for phase 2 uses data on Austria, Finland, France, Germany and the Netherlands. Data on the yields of Cyprus, Estonia, Lithuania and Luxembourg are not available. We use data of

cases we use yields for two, five, and ten year maturity. We do so for several reasons. First, compared to bonds with longer maturity, these segments are typically more liquid, especially for the smaller countries in the panels. Second, compared to bonds with shorter maturity, these segments are less constrained by the zero lower bound and, thus, provide more variation. Third, data on such yields are available throughout most of the sample. Fourth, in phase 1 the yield curve of several crisis countries was inverted at some point during the euro area debt crisis, when several important non-standard measures were announced. The inversion of the curve makes it *a priori* difficult to determine which maturity best reflects the announced interventions. Finally, in phase 2 the policy tools were targeted generally at the long end of the yield curve, making it safer to include more than one specific maturity.[8]

2.3 Identification of the structural VAR

The procedure discussed in Section 2.2 delivers a daily proxy m_t^D and a corresponding monthly proxy m_t^M for each phase of ECB unconventional monetary policy. We now discuss how we use m_t^M for the identification of the structural VAR.

The key step in the identification of the model consists of estimating what we will refer to as the relative impulse vector. Call b_i^m the entry i of the $k \times 1$ impulse vector b^m from equation (2). We normalize the variance of the structural shocks to unity, so that b_i^m captures how variable i responds to a one standard deviation change in ϵ_t^m. The $k \times 1$ relative impulse vector is defined as $\tilde{b}^m = b^m / b_1^m =$

each country for the period when it is available, irrespectively on whether the country had already joined the euro or not. We do so because the ECB is likely to affect also the yields of countries which are about to join the euro but have not done so already.

[8] Data on two, five and ten year maturity was used except when not available (as for the two-year yield for Malta) or when excessively erratic (as for the two- and ten-year rates of Latvia, the two- and five-year rates of Greece and the ten-year rate of Slovakia).

$(1, b_2^m/b_1^m, ..., b_k^m/b_1^m)'$ and captures the response of the last $k-1$ variables relative to the first variable (which in our ordering is the policy indicator). $\tilde{b}^m$ can be estimated as $(1, \hat{\psi}_2^{(1)}/\hat{\psi}_1^{(1)}, ..., \hat{\psi}_k^{(1)}/\hat{\psi}_1^{(1)})'$, with $\hat{\psi}_i^{(1)}$ the estimated coefficients in the regressions

$$\hat{u}_{it} = \phi_i^{(1)} + \psi_i^{(1)} m_t^M + \eta_{it}^{(1)}, \quad i = 1, ..., k, \tag{5}$$

with $\hat{u}_{it}$ the estimated VAR residual corresponding to equation i of model (1).[9] The consistency of the estimate for $\tilde{b}^m$ follows from the fact that $E(u_t m_t^M) = b^m \phi$ with $\phi = E(\epsilon_t^m m_t^M)$, due to (2) and (3). As outlined in Mertens and Ravn (2013), once an estimate of $\tilde{b}^m$ is available, it can be combined with the covariance restrictions $\Sigma = BB'$ with $B = [b^m, B^*]$ to estimate the impulse vector b^m.

To improve upon the estimation of $\tilde{b}^m$ we follow the approach by Rogers et al. (forthcoming). Call w_{it}^D the first difference of variable i around the same policy announcements used to construct m_t^D, and zero otherwise. If w_{it}^D was available for all variables, then the estimation of the relative impulse vector could be achieved by running the regressions

$$w_{it}^D = \phi_i^{(2)} + \psi_i^{(2)} m_t^D + \eta_{it}^{(2)}, \quad i = 1, ..., k, \tag{7}$$

and estimating the relative impulse vector as $(1, \hat{\psi}_2^{(2)}/\hat{\psi}_1^{(2)}, ..., \hat{\psi}_k^{(2)}/\hat{\psi}_1^{(2)})'$.[10] Since

[9] An alternative approach consists of running the regressions

$$\hat{u}_{it} = \phi_i^{(4)} + \psi_i^{(4)} \hat{u}_{1t} + \eta_{it}^{(4)}, \quad i = 2, ..., k, \tag{6}$$

and instrumenting $\hat{u}_{1t}$ with m_t^M (Mertens and Ravn, 2013, Gertler and Karadi, 2015). The two procedures deliver the same estimate for $\tilde{b}^m$ already in a finite sample, as can be verified analytically.

[10] As in the event-study literature, this approach exploits the fact that a consistent estimate for $\psi_i^{(2)}$ can be obtained by isolating and using only periods in which m_t^D is

daily data are only available for a subset of the variables, we follow Rogers et al. (forthcoming) and estimate models

$$w_{it}^{M} = \phi_i^{(3)} + \psi_i^{(3)} m_t^{M} + \eta_{it}^{(3)}, \quad i = 1, ..., k. \tag{8}$$

In equation (8), w_{it}^{M} equals $\hat{u}_{it}$ if variable i is not available at a daily frequency and equals the sum within month of w_{it}^{D} if variable i is available at a daily frequency. After estimating $\tilde{b}^m$ as $(1, \hat{\psi}_2^{(3)}/\hat{\psi}_1^{(3)}, ..., \hat{\psi}_k^{(3)}/\hat{\psi}_1^{(3)})'$, we estimate b^m following the approach by Mertens and Ravn (2013) and compute impulse responses to a one standard deviation shock.[11]

We use equation (8) to assess the strength of the instruments that we constructed in Section 2.2. We do so by computing the F-statistic for the null hypoth-

exogenous. For applications see Gürkaynak et al. (2005) and Ehrmann and Fratzscher (2005).

[11] We also consider the following alternative approach. For variables only available at a monthly frequency we estimate the parameters $\psi_i^{(3)}$ from equation (8) as explained in the text. Instead, for the variables available at a daily frequency we first estimate the model

$$w_{it}^{D} = \phi_i^{(4)} + \psi_i^{(4)} m_t^{D} + \mu_i^{(4)} w_{it-1}^{D} + \eta_{it}^{(4)}, \tag{9}$$

with w_{it}^{D} defined in the text. We use the estimates of $\mu_i^{(4)}$ and $\psi_i^{(4)}$ to recursively simulate an impulse response function for the 22 days (the average number of days per month for which data is available) and set $\psi_i^{(3)}$ equal to the sum of the daily impulse response for the month. Last, we use the estimates of the relative impulse vector $(1, \hat{\psi}_2^{(3)}/\hat{\psi}_1^{(3)}, ..., \hat{\psi}_k^{(3)}/\hat{\psi}_1^{(3)})'$ to estimate b^m. To account for estimation uncertainty in $\mu_i^{(4)}$ and $\psi_i^{(4)}$ we apply a standard bootstrap procedure to equation (9). Figures E.15, E.16 and E.17 in the online appendix show that the results are similar compared to the approach used in the baseline analysis. The estimation in the main analysis is frequentist. To further assess the robustness of the results, Appendix C proposes and uses a Bayesian estimation of the model.

esis $\psi_1^{(3)} = 0$, focusing on the equation of the VAR featuring the policy indicator as dependent variable. For the proxy for phase 1 we find an F-statistic equal to 138. For phase 2 it equals 221. This indicates that the instruments are sufficiently strong.

3 Results

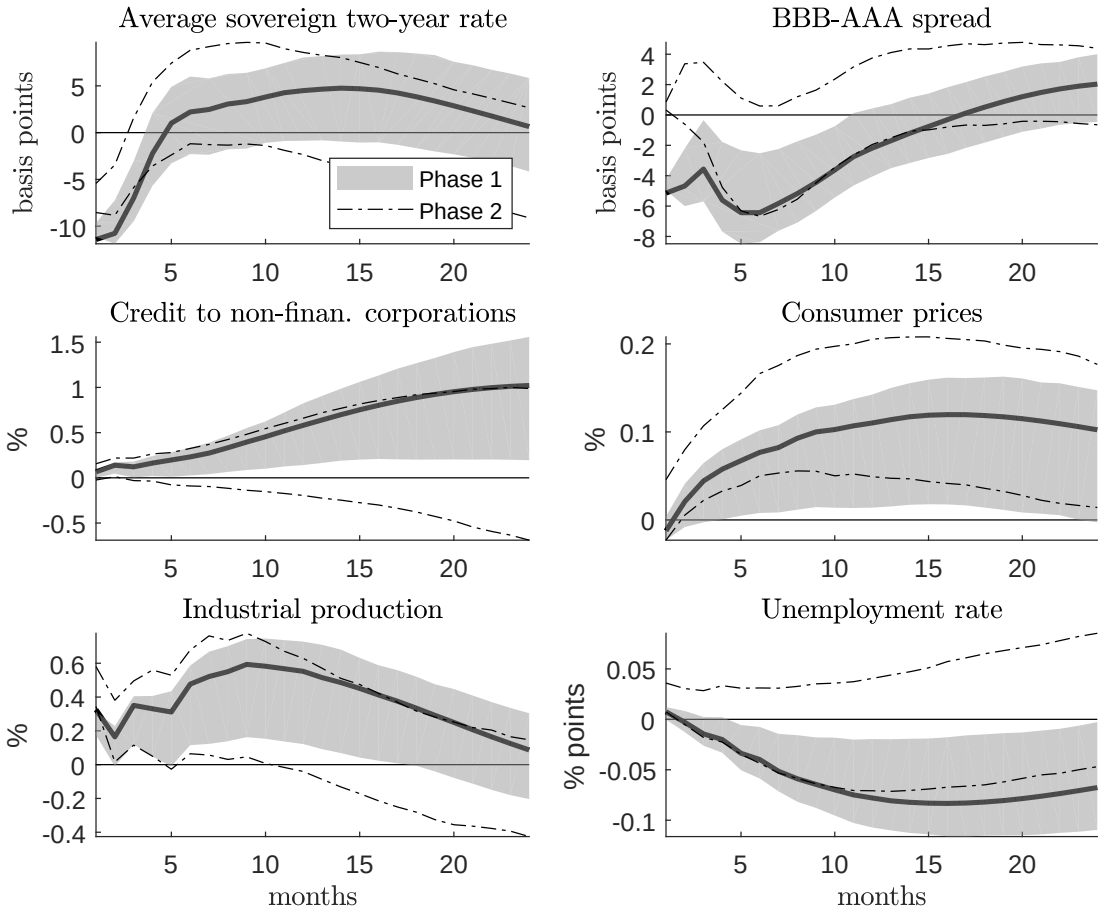
We discuss the effects of unconventional monetary policy mainly using estimated impulse responses to one standard deviation shocks. We first discuss the effectiveness and transmission of the shocks. We then turn to their effects on fiscal variables, both at the euro-area level and at the country level. Last, we evaluate the effects on further country-specific variables and explore how trade balances within the union respond. For each impulse response, we report the 90% confidence bands computed using bootstrap techniques.[12]

3.1 Effectiveness

Figure 1 reports the impulse responses of the variables in the baseline VAR. The solid line and the shaded area refer to a phase 1 monetary shock and show the point estimate and the confidence band, respectively. The dash-dotted lines depict

[12]We apply a fixed-design wild bootstrap, as in Mertens and Ravn (2013) and Gertler and Karadi (2015). For each bootstrap we recursively generate pseudo data after randomly selecting a subset of months and then changing sign of the estimated vectors of VAR innovations in those months. For the identification within each bootstrap, in correspondence to the same months we change sign of m_t^M, as well as of w_{it}^M for the variables available at a daily frequency. Within each bootstrap we then apply the procedure discussed in Section 2.3. To account for possible small sample bias, the autoregressive component of the VARs within the bootstrap is estimated using the procedure by Kilian (1998). Confidence bands are constructed on 500 bootstrap replications.

Figure 1: Baseline model for the euro area



Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase. The sample is 2002M5 through 2016M11.

the confidence region corresponding to the phase 2 monetary shock. To make the figure clearer, we omit the point estimates associated with phase 2.

Consider first a phase 1 shock. The top left panel shows that a one standard deviation surprise expansion induces an impact decline in the average sovereign two-year rate in the euro area of 11 basis points. The policy indicator remains

significantly lowered for several months, before overshooting after half a year. The monetary innovation leads to a significant and long-lasting reduction in private credit risk, as measured by the BBB-AAA corporate bond spread, which drops immediately by 5 basis points and remains low for more than a year. The volume of credit to non-financial corporations increases gradually and reaches a peak of 1% above trend after two years. These responses are associated with significant increases in consumer prices and industrial production, with economic activity peaking after around 10 months, slightly earlier than prices. The price dynamics are consistent with the overshooting in the policy rate. The responses of prices and production are also mirrored in the behavior of the unemployment rate, which bottoms after more than a year, before returning to the level where it would have been without the monetary impulse.

The responses to a phase 2 monetary innovation are qualitatively similar. However, with the exception of prices, the effects tend to be smaller and less statistically significant. A one standard deviation phase 2 shock implies a reduction in the two-year rate of 6 basis points. Consumer prices increase significantly and more strongly than in response to a phase 1 shock, but the response of production is less pronounced and more short-lived. In addition, the increase in credit volume and the drop in the corporate bond spread are barely significant, both on impact and subsequently. The response of the credit spread indicates a difference in the goals and transmission of phase 1 shocks compared to phase 2 shocks, a point to which we return to below. Overall, the results for phase 2 shocks need to be treated with a bit of caution. While the instruments for both phases are strong (Section 2.3), we have fewer observations for the identification of phase 2, which potentially leads to less precise estimates.

While revealing several noteworthy quantitative differences, the results for both

phases are qualitatively in line with existing evidence on the effects of unconventional monetary policy shocks. Gambacorta et al. (2014), Boeckx et al. (2017), and Weale and Wieladek (2016) identify policy surprises as shocks to central banks' balance sheets. They also find significant effects on economic activity and prices, documenting that the effect on the former is larger than on the latter. Relative to their estimates, we find a more sluggish response of both variables. Economic activity and prices peak only after a year and slowly return to trend, whereas their estimates suggest a peak response after approximately six months and a quick decay of the effects. Moreover, the effects of comparably sized balance sheet shocks tend to be smaller.[13]

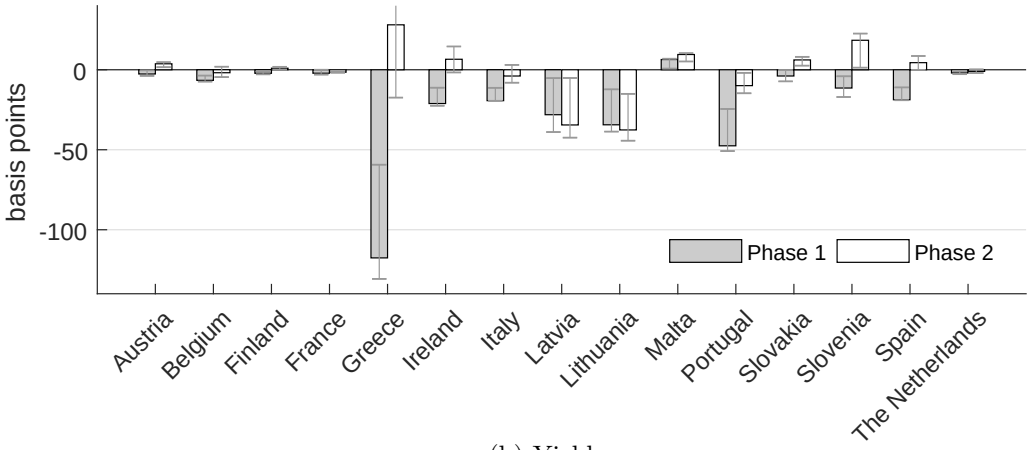
We now analyze the differences between phase 1 and phase 2 shocks in more detail. Figure 2 shows the peak responses of country-specific government spreads versus Germany with ten-year maturity (panel *a*) and of yields on such bonds (panel *b*) to a one standard deviation monetary innovation, together with 90% confidence bands. The full underlying impulse responses are reported in Figures D.1 and D.2 in the online appendix. As outlined above, we augment the baseline six-variable VAR from Figure 1 with one additional variable at a time.[14] Consistent with the objective of monetary policy during phase 1 of mitigating credit risk and

[13] According to the estimates of Gambacorta et al. (2014), for example, a shock to central bank assets that lowers the VIX by one percentage point on impact has a peak effect on production and prices that is less than half of what we find if we substitute the BBB-AAA spread with the VStoxx and rescale our shock to the two-year rate such that it lowers the VStoxx by one percentage point on impact.

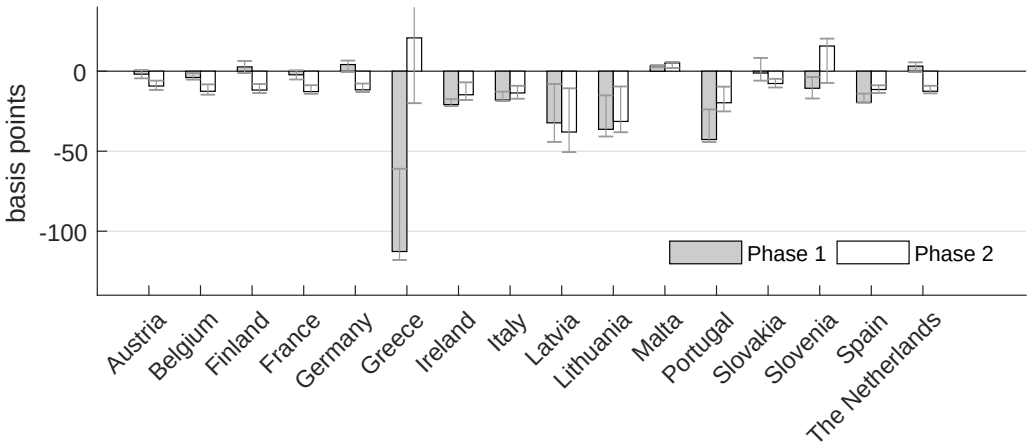
[14] Due to the availability of the data, the sample used for the estimation of the extended VARs may change depending on the marginal variable included. Appendix A reports the sample for which each variable is available. The sample used for the estimation of each extended VAR is the intersection between the sample in the baseline VAR and the sample of the marginal variable added.

Figure 2: Peak responses of country-specific ten-year spreads and yields on government bonds

(a) Spreads versus Germany



(b) Yields



Notes: The figure shows the peak responses of ten-year country-specific sovereign spreads versus Germany (panel a) and of ten-year government bond rates (panel b) after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the point estimate for a shock from the second phase. In panel *a*, the peaks are reached after the following months from the shock (phase 1-2): Aut 4-3; Bel 2-7; Fin 5-3; Fra 7-0; Gre 3-4; Ire 2-7; Ita 2-7; Lat 14-14; Lit 7-7; Mal 23-1; Por 4-2; Svk 2-1; Svn 2-4; Spa 2-3; Nld 5-5. Panel *b*: Aut 10-1; Bel 1-1; Fin 5-1; Fra 10-1; Ger 5-1; Gre 2-4; Ire 0-1; Ita 1-1; Lat 15-15; Lit 7-7; Mal 0-1; Por 3-2; Svk 23-1; Svn 2-5; Spa 1-0; Nld 2-1. Figures D.1 and D.2 in the online appendix report the full underlying impulse responses.

fragmentation within the euro area, we observe significant declines in sovereign spreads of virtually all periphery countries. The effects are particularly pronounced

for Greece, Portugal, and Lithuania, but spreads also fall sharply by between 10 and 20 basis points for Spain, Slovenia, Italy, and Ireland. In contrast, the effects on spreads of core countries are considerably smaller, at about 2 basis points.

The bottom panel shows that the ten-year rates of some core countries (Finland, Germany and the Netherlands) actually rise following a shock in phase 1. This positive–rather than negative–reaction of yields can be explained by at least two factors. First, government bonds of these countries were seen as safe havens in euro-denominated securities markets during the European debt crisis. As the non-standard policy interventions reduced uncertainty and increased risk appetite, the demand for safe-haven assets declined. Second, several of the measures during the first phase of unconventional policy most likely reduced the perceived risk of a break-up of the euro area and thereby lowered currency revaluation risks priced in these bonds.

In phase 2, the response patterns change substantially. While there are smaller effects on spreads, yields now significantly fall in 13 out of the 16 considered member states, and in particular in all core countries including Germany. This suggests that the policies adopted during phase 2 were successful in achieving their main goal of lowering the risk-free yield curve.

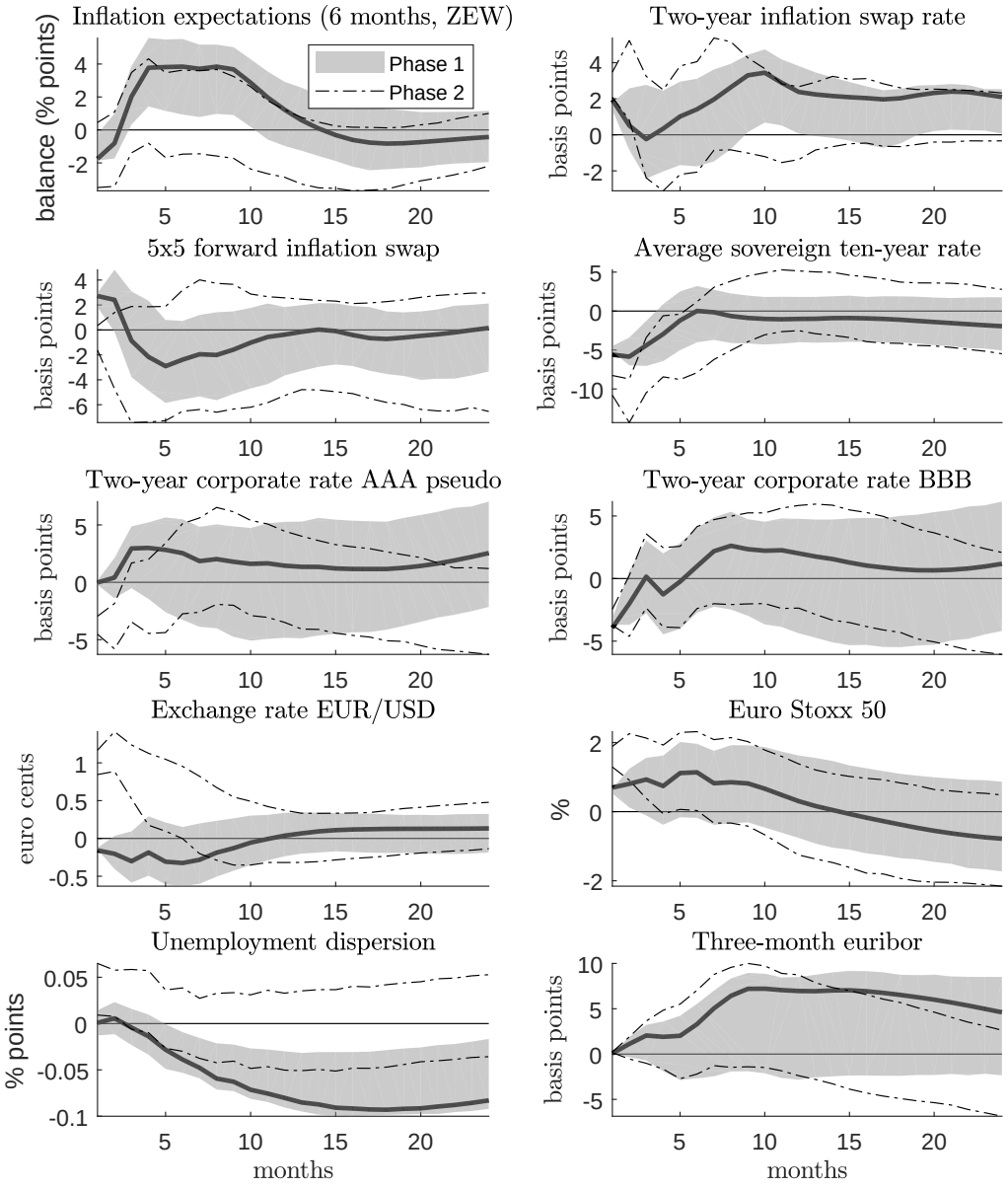
In Figure 3 we next evaluate the effects of the monetary surprises on several measures of inflation expectations, selected interest rates, other asset prices, and a measure of unemployment dispersion. The first panel shows the response of a monthly survey-based measure of inflation expectations, where financial market experts are asked for their inflation expectations for the euro area over the next six months. Focusing on phase 1, the response shows that the differential between the share of analysts who expect a rising inflation rate and those who anticipate a falling inflation rate increases significantly after the shock, by about four percentage

points. The next two panels show the responses of two financial market-based measures of inflation expectations. The two-year swap rate increases significantly upon impact. From unreported impulse responses of the five- and ten-year swap rate, we compute the five-year, five-year forward inflation swap rate, which has been one of the ECB's preferred measures of inflation expectations in recent years. This indicator also increases significantly, by about three basis points.

In the remaining panels we analyze selected variables through which unconventional monetary policy surprises are potentially transmitted to the economy. Considering phase 1, the average ten-year rate on euro area government bonds and the corporate bond BBB rate both decline significantly on impact and remain low for several months. In contrast, there is no reaction of the corporate AAA rate. Equity prices increase, while the exchange rate appreciates, likely because the exogenous expansion decreases the perceived risk of a break-up of the euro area. Unemployment dispersion, measured as the cross-sectional standard deviation of unemployment rates across countries, gradually declines, a finding consistent with the stronger effect of the monetary intervention on periphery yields and spreads. Finally, the insignificant response of the three-month Euribor upon impact supports our identification strategy of unconventional monetary policy shocks, as it indicates that the identified innovations reflect unexpected ECB actions orthogonal to conventional short-term policy rate changes.

Overall, the effects of phase 2 shocks are similar to those of phase 1 shocks, although there are several significant differences. First, long-term inflation expectations do not increase following phase 2 shocks. Second, in phase 2 the ten-year rate drops by more and the corporate bond AAA rate now declines significantly. Third, stock prices increase by more upon impact. Fourth, the euro depreciates, in line with standard economic theory. To sum up, the monetary shocks during

Figure 3: Other variables



Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

phase 2 have stronger effects on the longer end of the yield curve, they depreciate the euro and boost equity prices, while phase 1 shocks mainly lower credit risk and spreads, and lead to an appreciation of the euro. We evaluate the sensitivity of the baseline results. Appendix E shows that they are robust along a large number of dimensions.

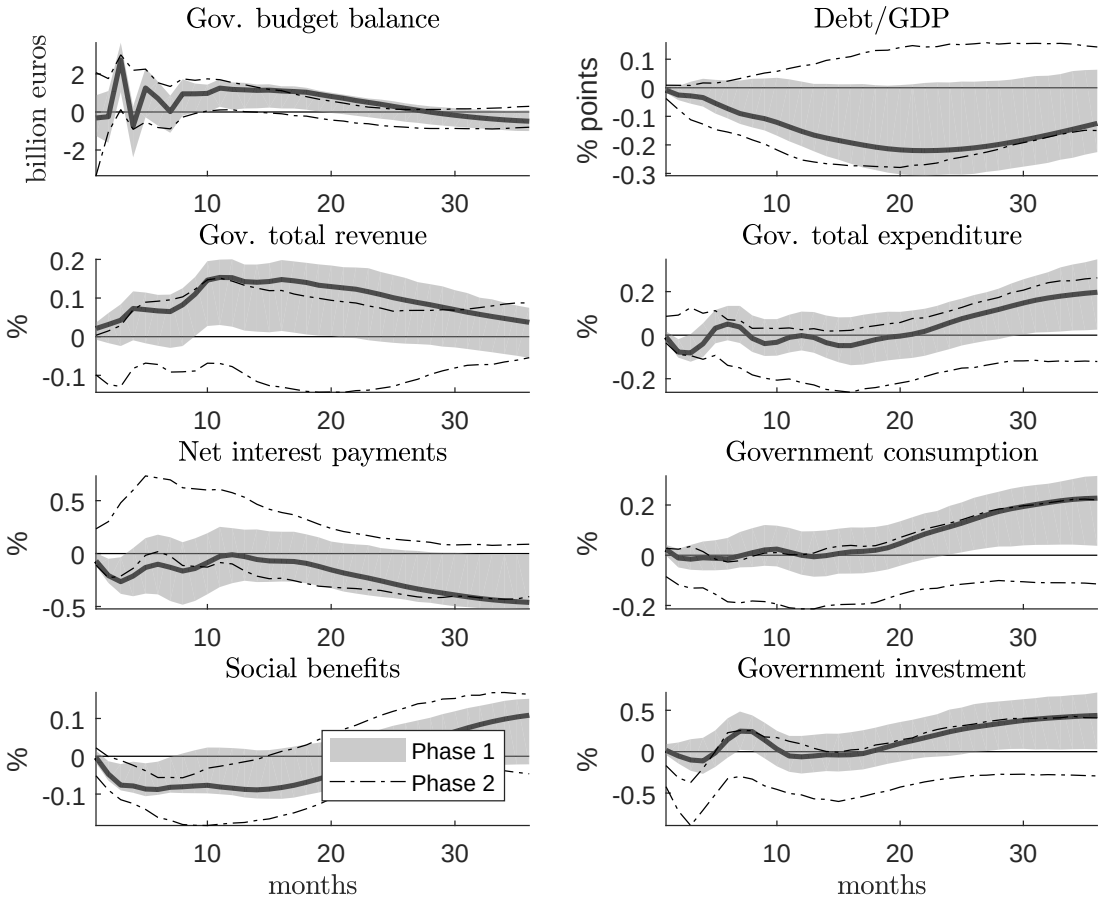
3.2 Effects on fiscal variables

Next, we assess whether the identified monetary surprises have effects on fiscal variables. Such effects have been at the centre of an active discussion in many member countries, the European Commission and the ECB (Schmidt et al., 2015, Weidmann and Knot, 2015, Liikanen, 2015, Commission, 2015, ECB, 2015). In particular, possible windfall gains, that is, savings on lower than expected public interest payments, could be used to increase government spending.

We start with an analysis for the euro area as a whole using GDP-weighted averages. The first four panels in Figure 4 show the behavior of the overall budget, the debt-to-GDP ratio, revenues, and expenditures.[15] Focusing on phase 1, the average government balance in the euro area improves after a monetary expansion. The effect is consistent with standard economic theory, given that the monetary surprise stimulus lowers sovereign yields and raises economic activity and prices. The maximum response equals 2 billion euro. The budget balance remains above its pre-shock level for about a year and then undershoots. Due to the increase in activity, the debt-to-GDP ratio nevertheless falls and declines by 0.2 percentage points around two years after the shock. Decomposing the dynamics of the overall

[15] Since the fiscal variables from this section have quarterly frequency, we first interpolate them before adding them as marginal variables to the VAR. Figures E.21, E.22 and E.23 in the online appendix show that the results are overall robust when using quarterly rather than monthly VARs.

Figure 4: Fiscal responses at the euro area level



Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

budget into changes in revenues and expenditures shows that revenues increase significantly as output increases above trend. Conventional theory suggests that automatic stabilizers contribute to the improvement in the overall budget during the first year and a half after the shock (Van den Noord, 2000).

The response of total expenditures, on the other hand, is difficult to reconcile with the theory of automatic stabilizers. The estimate of the elasticity of expen-

ditures to the output gap in the euro area is –0.1 (Girouard and André, 2006). This value would predict a small decline in expenditures when economic activity increases. Moreover, in the special case of an interest rate shock that raises production, spending is expected to decline somewhat more strongly as public interest payments are likely to fall. Compared to this, the response of expenditures to the shock shows a significant increase towards the end of the impulse horizon. This finding rationalizes the undershooting of the overall balance and suggests that, on average across countries, fiscal policy is responding to non-standard monetary policy innovations in a procyclical manner.

The bottom four panels decompose the dynamics of total expenditures into its main components. As expected, the expansionary monetary shock in phase 1 leads to a significant reduction in net interest payments and social security contributions. The latter response is in line with the notion that automatic stabilizers on the spending side work mostly through unemployment benefits and age- and health-related outlays, as economic activity increases and the unemployment rate falls (Darby and Melitz, 2008). On the other hand, public consumption and investment increase significantly. Together, these responses suggest that windfall profits from unexpectedly lower interest expenditure and reduced social outlays are partly used to increase intermediate good consumption and compensation of public employees, as well as to increase government investment. The latter response is also consistent with the decline in sovereign yields, which makes public investments more profitable.

In phase 2, the budget balance shows a similar response as in phase 1, but the effects on the other fiscal variables are largely insignificant. This finding bears at least two interpretations. One is that the effects on fiscal variables associated with monetary policy are mainly a phenomenon of the spread-reducing interventions and less of the policies targeted at lowering the risk-free curve. The other is that the

Table 1: Percentage contribution of phase 1 and phase 2 monetary policy shock to forecast error variance of public expenditures (monthly horizon)

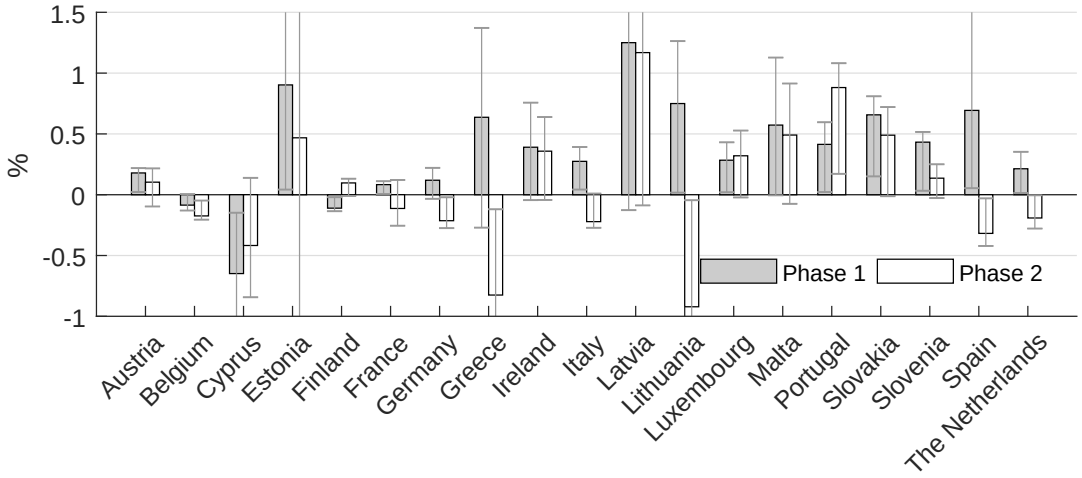
	Net interest payment		Government consumption		Social security expenditures		Government investment	
	phase	*phase*	*phase*	*phase*	*phase*	*phase*	*phase*	*phase*
horizon	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*
3	4	2	0	6	7	10	0	47
12	2	19	0	24	9	23	2	28
24	3	16	2	21	8	27	2	24
36	9	15	15	11	7	18	7	14

lower length of the sample used for the identification of phase 2 shocks makes the inference for these shocks more challenging.

We compute forecast error variance decompositions in order to quantify the average economic relevance of unconventional monetary policy shocks for the evolution of the different expenditure components. Table 1 shows the percentage contribution of phase 1 and phase 2 unconventional monetary shocks to the variance of the four spending categories. As discretionary fiscal spending responds relatively slowly to the monetary shocks, phase 1 monetary innovations explain only a small fraction of the variability of consumption and investment at shorter horizons. For longer horizons, however, the shocks are a non-negligible driver of these two spending categories.

Since revenues and spending in the euro area are largely determined at the member state level, we next study commonalities and differences in the response of fiscal policy to the common monetary surprise across member states. To focus the exposition, Figure 5 concentrates on the peak responses of government consumption. This expenditure category is more directly controlled and quickly adjusted by the national fiscal authorities, compared to net interest payments, social security outlays or public investment. Mirroring the aggregate response at the euro area level, public consumption in almost all member states increases following an expansionary monetary shock in phase 1, and the peak effects are mostly statisti-

Figure 5: Peak responses of government consumption



Notes: The figure shows the peak responses of country-specific government consumption after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the point estimate for a shock from the second phase. The peaks are reached after the following months from the shock (phase 1-2): Aut 34-2; Bel 2-5; Cyp 4-3; Est 21-21; Fin 1-31; Fra 35-2; Ger 35-8; Gre 34-7; Ire 28-2; Ita 4-12; Lat 18-16; Lit 20-3; Lux 9-32; Mal 24-8; Por 35-2; Svk 32-28; Svn 35-2; Spa 35-6; Nld 35-12. Figure D.3 in the online appendix reports the full underlying impulse responses.

cally significant. They are also economically relevant. For seven countries (Estonia, Greece, Latvia, Lithuania, Malta, Slovakia and Spain) the peak effects are relatively large and range between 0.5% and 1%. Government consumption falls only in three countries (Belgium, Cyprus, Finland), and the declines are mostly small. For phase 2 the picture is more mixed, with the peak effects usually being indistinguishable from zero. Overall, the responses of government consumption are mostly in line with the country-specific effects on sovereign yields to the common monetary shock (Figure 2).

As several of the country-specific as well as euro area peak effects occur relatively late within the impulse horizon, we also estimate a Bayesian version of the model. This allows us to increase the lag number of the endogenous variables to 8, adding to the credibility of the responses at longer horizons while still obtaining

precise estimates. Appendix C details the estimation procedure and shows that the conclusions from the frequentist approach using 5 lags hold.

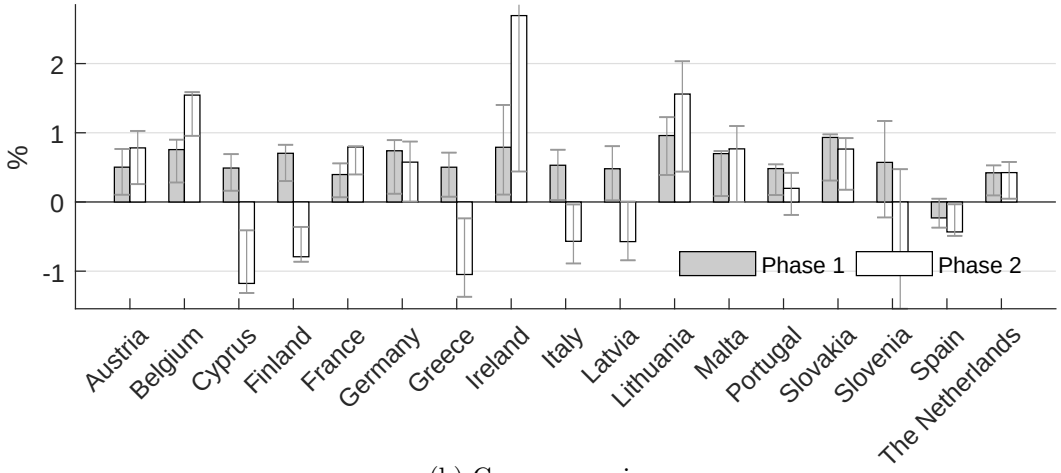
3.3 Further country heterogeneity and internal trade balances

We now investigate whether there is further evidence of heterogeneity in the country-specific responses to the common monetary shocks, and whether the heterogeneous responses translate into movements in intra-union trade balances. Figure 6 shows the estimated peak effects of the monetary shocks on country-specific industrial production (panel *a*) and CPI (panel *b*). Industrial production increases significantly in most countries for both phase 1 and phase 2. The rise tends to be stronger in crisis and periphery countries, in line with the more pronounced drop in their yields. In phase 2 the largest peaks are found for Belgium, Ireland and Lithuania, where the increase exceeds 1%. The boost to production equals roughly 0.5% in most core countries and in both phases. For consumer prices, there is only one negative response, and the picture is similar both across countries and compared to industrial production. Most crisis and periphery countries experience a significant increase in prices in both phase 1 and phase 2. The increases are in the order of 0.1% for phase 1 and about 0.2% for phase 2.

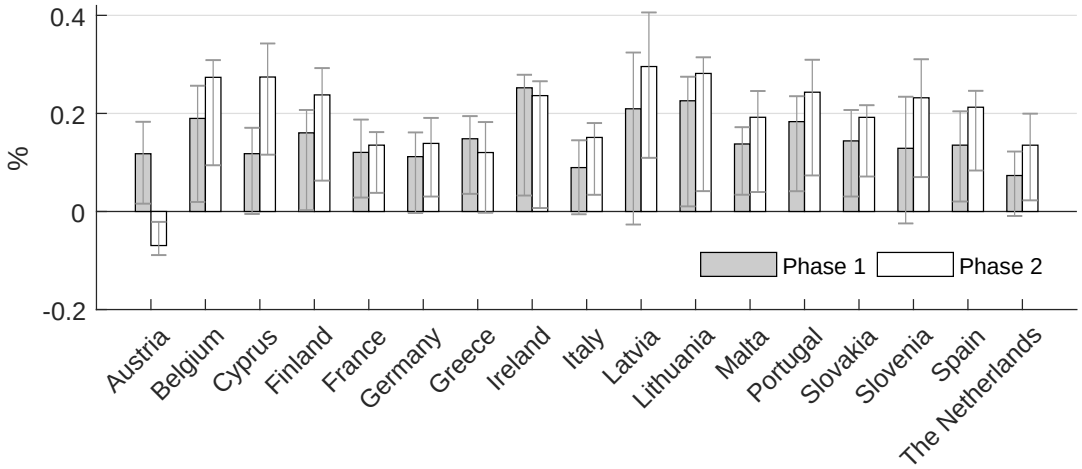
The heterogeneity in the responses of production and partly in prices can generate movements in real exchange rates and intra-euro area trade balances. Some countries could loose competitiveness if demand and prices respond more strongly there than in other countries, implying an appreciation of their real exchange rates. Figure 7 shows the responses of three aggregate variables which summarize trade within the union in terms of GDP. These variables are the average absolute trade balances, the average trade balance of countries which are net exporters on av-

Figure 6: Peak responses of industrial production and consumer prices

(a) Industrial production

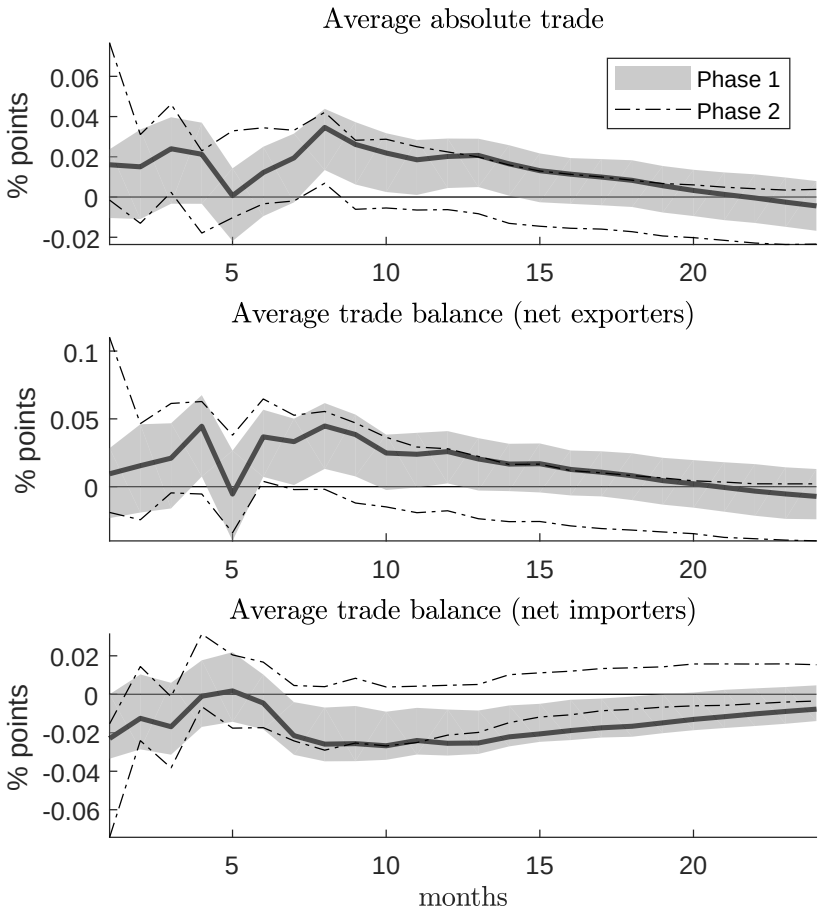


(b) Consumer prices



Notes: The figure shows the peak responses of country-specific industrial production (panel *a*) and consumer prices (panel *b*) after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the point estimate for a shock from the second phase. In panel *a*, the peaks are reached after the following months from the shock (phase 1-2): Aut 10-8; Bel 8-0; Cyp 11-0; Fin 3-0; Fra 8-0; Ger 9-6; Gre 1-0; Ire 12-0; Ita 10-23; Lat 8-0; Lit 7-0; Mal 0-7; Por 0-6; Svk 8-0; Svn 8-0; Spa 23-23; Nld 9-3. In panel *b*, the peaks are reached after the following months from the shock (phase 1-2): Aut 14-0; Bel 14-8; Cyp 5-6; Fin 14-14; Fra 14-8; Ger 18-13; Gre 9-4; Ire 18-10; Ita 17-8; Lat 19-5; Lit 20-18; Mal 6-15; Por 14-11; Svk 16-8; Svn 17-13; Spa 14-7; Nld 16-15. Figures D.4 and D.5 in the online appendix report the full underlying impulse responses.

Figure 7: Trade within the euro area



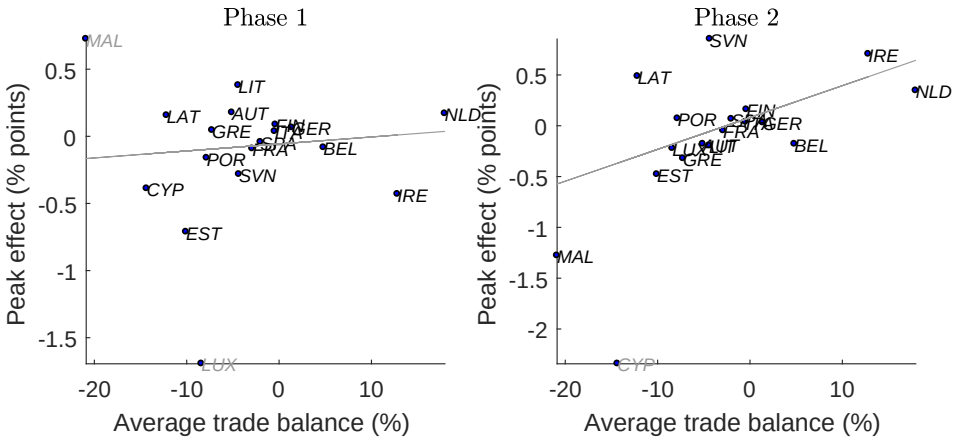
Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

erage over the sample, and the average trade balance of countries which are net importers. Averages are computed using country average GDP as weights. Absolute trade increases significantly after half a year. This effect is driven by net exporters increasing their surpluses and net importers widening their deficits.

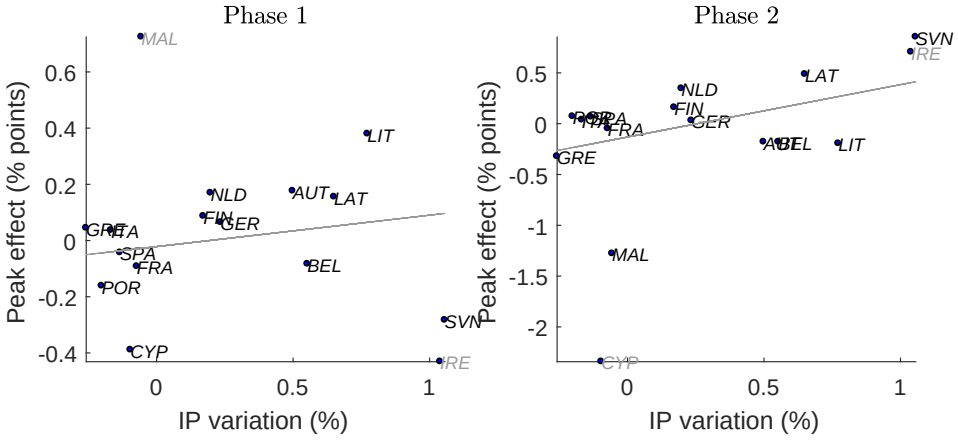
To investigate in more detail how different countries are affected by the monetary shocks, we plot the country-specific peak effects of the trade balance in terms

Figure 8: Peak responses of net exports within the euro area

a) plotted versus the average trade balance on the full sample period



b) plotted versus the variation in IP from the beginning to the end of the sample



Notes: The figure shows the peak responses of country-specific net export towards the euro area against two variables: the average trade balance versus the euro area computed within the sample period and weighted by country average GDP (panel *a*), and the country variation in industrial production from the beginning to the end of the sample (panel *b*). The fitted line is estimated after excluding outliers, which are labeled in grey in the figure. In panel *b*, we exclude Ireland due to their data issues in 2015 in the computation of industrial production. The slope of the line is statistically significant in the top right quadrant. Figure D.6 in the online appendix reports the full underlying impulse responses.

of GDP against the following two measures. First, we use the average trade balance relative to GDP over the sample period, weighted by country GDP. Second, to approximate how well a country weathered the global financial and euro area crisis, we use the overall change of its industrial production from the start to the end of our sample. Figure 8 shows a positive relation of both measures with the peak effects of net exports during both phases. In particular, countries with higher average net exports and countries that grew faster in our sample tend to increase their surpluses, while countries with trade deficits on average and countries with a weak recovery from the crisis widen their deficits.[16] Together with the evidence from the previous figure, these results indicate that there is some heterogeneity in the countries' reaction to the common policy shocks in terms of relative price movements and trade balances, but the effects are rather small.

4 Comparison to conventional monetary policy

We conclude the analysis by identifying a conventional monetary policy shock. This analysis can provide some assurance about the specification of the baseline monetary VAR model. Moreover, it allows for a direct comparison of conventional and unconventional monetary policy shocks. Finally, it documents whether the effects on fiscal variables discussed in Section 3.2 are a specific phenomenon of unconventional monetary policy or whether they are present also in a conventional low interest rate environment.

To identify a conventional monetary policy shock we build on the procedure used in the main analysis. We construct the proxy using as dependent variable in

[16] Before computing the regression line we exclude countries which are outliers. We also exclude Ireland from the computation of the regression line panel *b* due to data revisions in 2015.

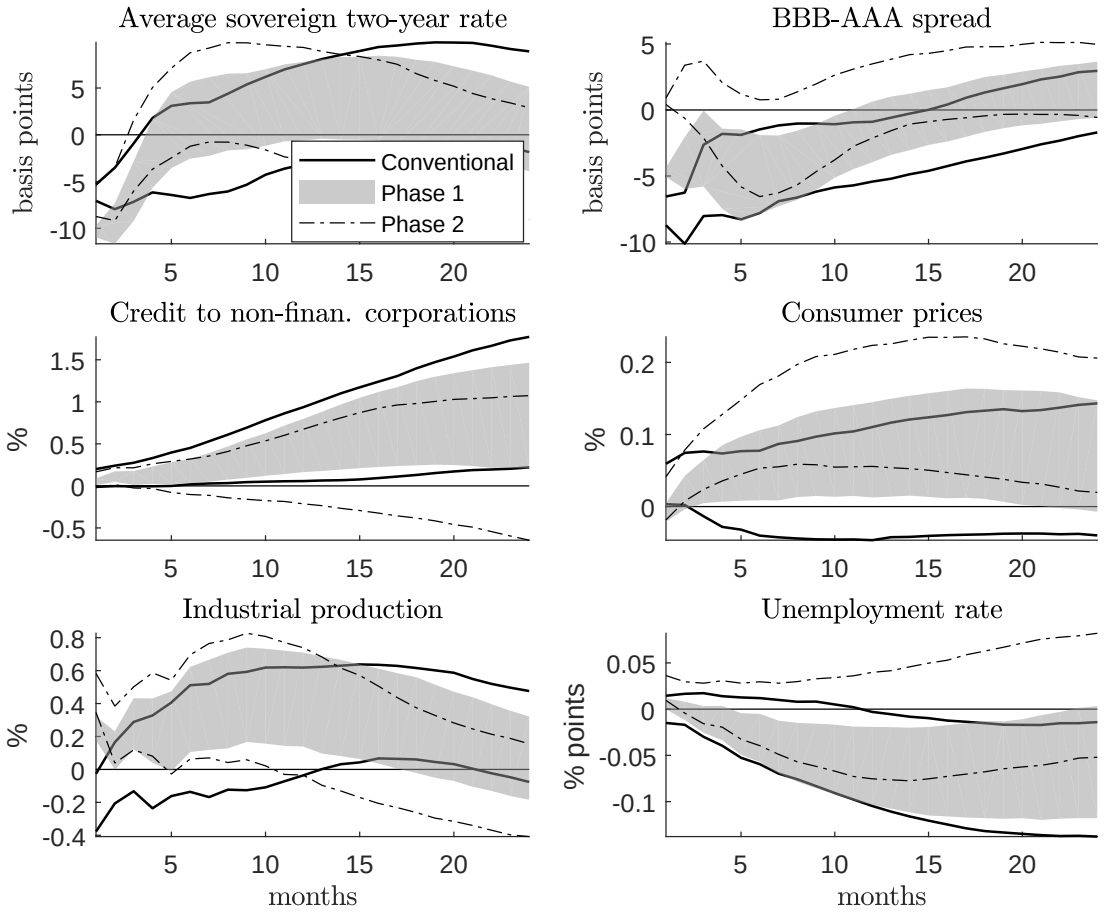
model (4) the next-to-maturity three-month Euribor future rate, and employing all ECB meetings between 1999M1 and 2007M7 as event days. Then, we use the three month OIS (Overnight Index Swap) rate as the policy indicator in the VAR model in order to capture ECB-induced changes in short-term rates. We use the OIS rate because the Eonia displays strong noise at the daily frequency due to technical reasons. We also investigated other combinations of variables to compute the proxy and policy indicators. The chosen combination yields the highest F-statistic on the strength of the instrument.[17]

The continuous lines in Figure 9 show the 90% confidence band of the impulse responses to a one standard deviation conventional monetary policy shock. To make the figure clearer we do not report point estimates. After a conventional monetary surprise expansion the policy indicator drops immediately and stays below the level without the shock for five months. This leads to a significant and long-lasting reduction of credit spreads. The volume of credit to non-financial firms increases slowly and reaches a peak of roughly 1% above trend. After approximately a year, industrial production rises significantly and the unemployment rate falls. Consumer prices, on the other hand, increase only slowly and not significantly. Overall, these estimates are in line with previous findings (Christiano et al., 1999, Ciccarelli et al., 2013, Gertler and Karadi, 2015) and suggest that the baseline model provides a reasonable basis for the identification of monetary policy shocks.

Figure 9 also reports the confidence bands for the responses to the two unconventional monetary policy shocks from Figure 1. The comparison to conventional monetary policy shows several interesting commonalities and differences. For all

[17] As candidate indicators we consider the three-month Euribor, the one-week, one-month, three-month, and one-year OIS rates. As candidate dependent variables in model (4) we consider the nearest, second nearest, and fifth nearest to maturity three-month Euribor future as well as all three futures jointly in a panel model.

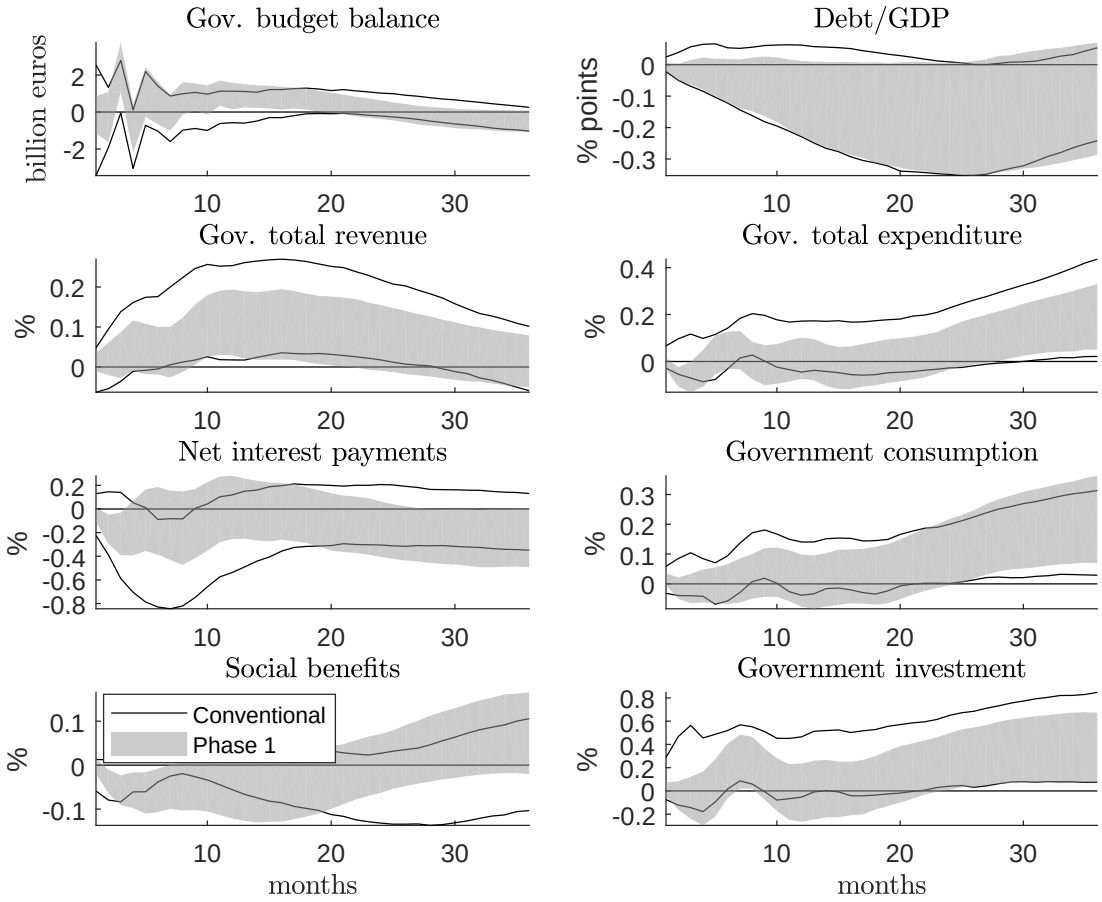
Figure 9: Baseline model – comparison to conventional monetary policy



Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the confidence band for a shock from the first phase of ECB unconventional monetary policy, the dashed lines show the confidence band for a shock from the second phase, the continuous lines show the confidence band for a shock from the period of conventional monetary policy. The policy indicator equals the average sovereign two-year rate when identifying the unconventional monetary policy shocks and the three-month OIS rate when identifying the conventional monetary policy shock.

three types of shocks, the responses of individual variables are qualitatively the same. However, the dynamics following an unconventional shock in phase 1 are overall more similar to a conventional shock than to an unconventional shock in phase 2. With the exception of consumer prices, the former two shocks imply larger

Figure 10: Fiscal responses at the euro area level – comparison to conventional monetary policy

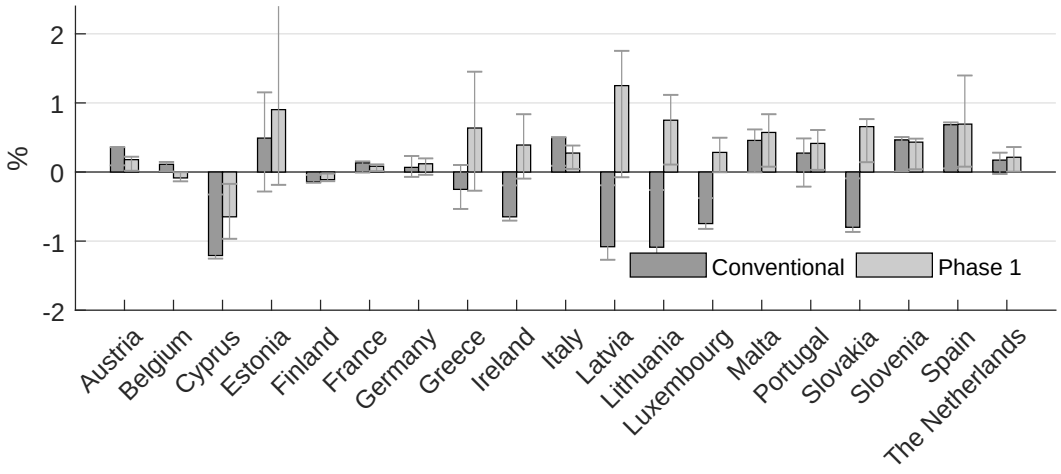


Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the confidence band for a shock from the first phase of ECB unconventional monetary policy, while the continuous lines show the confidence band for a shock from the conventional period.

and more statistically significant effects. By contrast, the latter does not lead to a fall in credit spreads.

We conclude the analysis by studying the response of fiscal variables to a conventional monetary shock. Figures 10 and 11 replicate the analysis for the fiscal variables studied in Section 3.2, focusing on conventional and phase 1 unconven-

Figure 11: Peak responses of government consumption – comparison to conventional monetary policy



Notes: The figure shows the peak responses of country-specific government consumption after a conventional one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The light shaded area shows the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dark shaded area shows the point estimate for a shock from the conventional period. The peaks are reached after the following months from the shock (conventional-phase 1): Aut 7-34; Bel 8-2; Cyp 2-4; Est 33-211; Fin 0-1; Fra 10-35; Ger 35-35; Gre 15-34; Ire 2-28; Ita 2-4; Lat 2-18; Lit 2-20; Lux 2-9; Mal 35-24; Por 6-35; Svk 1-32; Svn 22-35; Spa 35-35; Nld 35-35. Figure D.7 in the online appendix reports the full underlying impulse responses.

tional shocks. Overall, the results discussed in Section 3.2 hold in response to a conventional monetary shock, including the increase in expenditures for the euro area. Country-specific peak responses to a conventional monetary policy shock show that public consumption increases in several countries, and in a statistically significant way. Taken together, we conclude that an increase of fiscal consumption following a surprise monetary expansion is not a feature specific to the first phase of unconventional monetary policy, but is likely to hold also during the phase of conventional monetary interventions.

5 Conclusions

In this paper, we estimate the macroeconomic effects of unconventional monetary policy in the euro area using structural VARs, identified with external instruments. We consider two phases of ECB non-standard policy, an earlier phase where monetary policy was aimed at reducing credit risk and spreads, and a later period during which the central bank's measures were targeted at affecting the risk-free yield curve. We find that in both phases monetary surprise interventions that lower euro area sovereign yields are effective at raising production, prices, and inflation expectations, but that overall shocks in the first phase seem to have had stronger effects on these variables.

Our results are qualitatively similar to existing contributions, which find that unconventional monetary policy is effective and is transmitted to the real economy mainly through interest rates and credit spreads (Wright, 2012, Baumeister and Benati, 2013, Kapetanios et al., 2012). The findings also reveal that the dynamics of economic activity and prices are more similar to the response of these variables to conventional ECB interest rate innovations, or to existing estimates for conventional monetary policy shocks for the US (Christiano et al., 1999, Gertler and Karadi, 2015), than to unconventional monetary policy shocks identified through changes in the central bank balance sheet (Gambacorta et al., 2014, Boeckx et al., 2017, and Weale and Wieladek, 2016).

In addition, our estimates complement existing studies on unconventional monetary policy by revealing several side effects. First, we provide evidence that primary fiscal expenditures rise significantly following a surprise monetary expansion. Second, we document a heterogeneous reaction of fiscal policy across the currency union to the common monetary policy shock and show that sovereign spreads, yields, production, and prices also respond differently. Finally, the results suggest

that trade imbalances widen, although the effects are quantitatively small.

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Unconventional Monetary Policy, Fiscal Side Effects and Euro Area (Im)balances

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APPENDIX

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Appendix A : Data description

The dataset used for the analysis is assembled from different sources. Table A.1 contains a detailed description of the original data that we use, including the source (with respective mnemonics), the available sample period and the underlying frequency. If applicable, we also outline how we transform the original data to obtain the data used in our analysis.

Table A.1: Data construction and sources

Variable	Construction and source
Average euro area sovereign bond yields	*Source:* own computations based on sovereign bond yields from datastream. Synthetic two year and ten year yields for euro area bonds are computed as GDP-weighted averages of all individual member countries for which yields of the respective maturity are available at a certain point in time (see below). Only Greece is excluded as it went through debt restructuring over the sample period. Yields of member states that enter the monetary union over the sample are included once the country is part of the euro area. Results are robust to including all available yields right from the start of the sample. *Available for:* 1999M01 - 2016M11. *Frequency:* Daily.
Sovereign bond yields and sovereign bond spreads	*Source:* Datastream, 2yr and 10yr yield to redemption of sovereign bonds if available, Austria: TROE2YT, TROE10T, Belgium: TRBG2YT, TRBG10T, Finland: TRFN2YT, TRFN10T, France: TRFR2YT, TRFR10T, Germany: TRBD2YT, TRBD10T, Ireland: TRIE2YT, TRIE10T, Italy: TRIT2YT, TRIT10T, Netherlands: TRNL2YT, TRNL10T, Portugal: TRPT2YT, TRPT10T, Spain: TRES2YT, TRES10T, Greece: TRGR2YT, TRGR10T, Latvia: TRLV2YT, TRLV10T, Lithuania: TRLT10T, Malta: TRMT10T, Slovakia: TRSK2YT, TRSK10T, Slovenia: TRSI2YT, TRSI10T, Cyprus: TRCP2YT. Spreads are computed as the difference in yields of bonds of different maturities to German bonds with the same maturity. *Available for:* 1999M01 - 2016M11, with shorter samples for some bonds. TROE2YT starts in 2003M2, TRBG2YT in 2005M01, TRSK2YT and TRSK10T in 2004M01, TRLV2YT and TRLV10T in 2004M10, TRSI2YT and TRSI10T in 2007M04, TRMT10T in 2008M02, TRLT10T in 2003M04, TRGR2YT in 2004M07, TRGR10T in 2000M01. TRCP2YT available from 2012M04 until 2015M07. *Frequency:* Daily.

BBB-AAA spread and corporate bond yields	*Source:* Datastream. Yields to redemption of euro area benchmark corporate bonds with 2year and 10 year maturity. BBB 2 year (TRECLYB), BBB 10 year (TRECLYJ), A 2 year (TRECAYB), A 10 year (TRECAYJ), AA 2 year (TRECBYB), AA 10 year (TRECBYJ), AA 2 year (TRECCYB), AA 10 year (TRECCYJ). The BBB-AAA corporate bond spread is computed as the difference between the 2 year BBB and the 2 year AAA rate. As the 2 year AAA rate is available only until April 2016, we extrapolate it for the rest of the sample using the basis point variation in the 2 year AA rate. *Available for:* 2002M04 - 2016M11. *Frequency:* Daily.
Credit to non-financial corporations	*Source:* ECB data warehouse. Financial transaction data (flows) for euro area (changing composition). Series key: credit to non-financial corporations 117.BSI.M.U2.N.A.A20.A.4.U2.2240.Z01.E. The series contains flows that we sum to obtain credit volumes and then seasonally adjust in EVIEWS with X-ARIMA-12. *Available for:* 1999M01 - 2016M11. *Frequency:* Monthly.
Consumer Prices	*Source:* Datastream, Index of consumer prices, seasonally adjusted if available, else we seasonally adjust in EVIEWS with X-ARIMA-12. Euro area: EKCONPRCF, Austria: OECPALLRF, Belgium: BGCONPRCF, Finland: FNCONPRCF, France: FRCONPRCE, Germany: BDCONPRCE, Ireland: IRCONPRCF, Italy: ITCONPRCF, Netherlands: NLCONPRCF, Portugal: PTCONPRCF, Spain: ESCONPRCF, Greece: GRCONPRCF, Latvia: LVCONPRCF, Lithuania: LNCONPRCF, Malta: MACPHARMF, Slovakia: SJCONPRCF, Slovenia: SXCONPRCF, Cyprus: CPCONPRCF. *Available for:* 1999M01 - 2016M11 and 2000M01 - 2016M11 for Slovakia. *Frequency:* Monthly.
Industrial Production	*Source:* Datastream, Index of industrial production or manufacturing production, respectively, seasonally adjusted if available, else seasonally adjusted in EVIEWS with X-ARIMA-12. Euro area: EKCIND..G, Austria: OEESIMANG, Belgium: BGIPMAN.G, Finland: FNIPTOT.G, France: FRIPTOT.G, Germany: BDIPTOT.G, Ireland: IRIPTOT.G, Italy: ITIPTOT.G, Netherlands: NLESIMANG, Portugal: PTESIMANG, Spain: ESIPTOT.G, Greece: GRIPMAN.G, Latvia: LVIPTOT.G, Lithuania: LNCIND..G, Malta: MAIPTOT.G, Slovakia: SJIPTOT.G, Slovenia: SXI66..BH, Cyprus: CPIPTOT.H. *Available for:* 1999M01 - 2016M11. BGIPMAN.G, PTESIMANG, NLESIMANG, LVIPTOT.G, MAIPTOT.G start in 2000M01 *Frequency:* Monthly.
Unemployment Rate	*Source:* Eurostat dataset [une_rt_m]s, Unemployment as percentage of active population - monthly average, seasonally adjusted, for euro area aggregate and individual countries. Euro area total: EA19. *Available for:* 1999M01 - 2016M11. Data for Estonia, Cyprus and Malta start in 2000M02. *Frequency:* Monthly.

Inflation Expectations	*Source:* Datastream. Survey data from Centre for European Economic Research (ZEW) based on opinions of financial market analysts (EMZEWCP.R). 2 year (EURIS2Y), 5 year (EURIS5Y), and 10 year (EURIS10) inflation swap rates. The response of the five year five year forward rate is computed from responses of the 5 year and the 10 year swap: $5x5 = \frac{(1+10yr)^{10}}{(1+5yr)^{5}}^{\frac{1}{5}} - 1$. *Available for:* 2008M07 - 2016M11. *Frequency:* Daily.
Interest Rates and Futures	*Source:* Datastream. Euro short term repo (eurepo) - middle rate (EURORPS), Euribor 3m delayed (euribor) - offered rate (EIBOR3M), Liffe - 3 MTH euribor continuous 2nd future - sett. price (LEICS00(PS)), Liffe - 3 MTH euribor continuous future - sett. price (LEICS20(PS)), Liffe - 3 MTH euribor continuous 5th future - sett. price (LEICS50(PS)), Overnight Index Swap (OIS) 3 month - middle rate (OIEUR3M), OIS 12 month - middle rate (OIEUR1Y). *Available for:* 1999M01 - 2016M11. *Frequency:* Daily.
Exchange Rate	*Source:* Datastream. US $ to EURO (WMR&DS) - exchange rate (USEURSP). *Available for:* 1999M01 - 2016M11. *Frequency:* Daily.
Stock price index	*Source:* Datastream. Euro Stoxx 50 price index (DJES50I). *Available for:* 1999M01 - 2016M11. *Frequency:* Daily.
Unemployment Dispersion	Standard deviation of monthly changes of unemployment rates between euro area countries. *Available for:* 1999M01 - 2016M11. *Frequency:* Monthly.
Government budget balance	*Source:* Eurostat dataset quarterly non-financial accounts for general government [gov_10q_ggnfa], General government Net lending (+) /net borrowing (-) for euro area aggregate and individual countries. Euro area total: EA19. Quarterly data is seasonally adjusted with X-ARIMA-12 and then linearly interpolated to the monthly frequency in EVIEWS. Resulting monthly series are converted to real terms using euro area and individual country CPIs. *Available for:* 1999M01 - 2016M11, starting in 2001M03 for Austria, and in 2002M03 for euro area, Germany, Estonia, Ireland, Luxembourg. *Frequency:* Monthly.
Government debt-to-GDP	*Source:* Eurostat dataset quarterly government debt [gov_10q_ggdebt], Government consolidated gross debt, Percentage of gross domestic product for euro area aggregate and individual countries. Euro area total: EA19. Quarterly data is seasonally adjusted with X-ARIMA-12 and then linearly interpolated to the monthly frequency in EVIEWS. *Available for:* 2000M03 - 2016M11, starting in 1999M03 for Belgium and Spain, and in 2000M12 for Luxembourg and Malta. *Frequency:* Monthly.

Government total revenue	*Source:* Eurostat dataset quarterly non-financial accounts for general government [gov_10q_ggnfa], Total general government revenue for euro area aggregate and individual countries. Euro area total: EA19. Quarterly data is seasonally adjusted with X-ARIMA-12 and then linearly interpolated to the monthly frequency in EVIEWS. Resulting monthly series are converted to real terms using euro area and individual country CPIs. *Available for:* 1999M01 - 2016M11, starting in 2001M03 for Austria, and in 2002M03 for euro area, Germany, Estonia, Ireland, Luxembourg. *Frequency:* Monthly.
Government total expenditure	*Source:* Eurostat dataset quarterly non-financial accounts for general government [gov_10q_ggnfa], Total general government expenditure for euro area aggregate and individual countries. Euro area total: EA19. Quarterly data is seasonally adjusted with X-ARIMA-12 and then linearly interpolated to the monthly frequency in EVIEWS. Resulting monthly series are converted to real terms using euro area and individual country CPIs. *Available for:* 1999M01 - 2016M11, starting in 2001M03 for Austria, and in 2002M03 for euro area, Germany, Estonia, Ireland, Luxembourg. *Frequency:* Monthly.
Government net interest payments	*Source:* Eurostat dataset quarterly non-financial accounts for general government [gov_10q_ggnfa], Interest, payable (D41PAY) - Interest, receviable (D41REC) for euro area aggregate and individual countries. Euro area total: EA19. Quarterly data is seasonally adjusted with X-ARIMA-12 and then linearly interpolated to the monthly frequency in EVIEWS. Resulting monthly series are converted to real terms using euro area and individual country CPIs, starting in 2001M03 for Austria, in 2002M03 for euro area, Germany, Estonia, Ireland, Luxembourg, and in 2003M03 for Lithuania. *Available for:* 1999M01 - 2016M11. *Frequency:* Monthly.
Government consumption	*Source:* Eurostat dataset quarterly non-financial accounts for general government [gov_10q_ggnfa], Compensation of employees, payable (D1PAY) + Intermediate consumption (P2) for euro area aggregate and individual countries. Euro area total: EA19. Quarterly data is seasonally adjusted with X-ARIMA-12 and then linearly interpolated to the monthly frequency in EVIEWS. Resulting monthly series are converted to real terms using euro area and individual country CPIs. *Available for:* 1999M01 - 2016M11, starting in 2001M03 for Austria, and in 2002M03 for euro area, Germany, Estonia, Ireland, Luxembourg. *Frequency:* Monthly.

Government social benefits	*Source:* Eurostat dataset quarterly non-financial accounts for general government [gov_10q_ggnfa], Social benefits other than social transfers in kind and social transfers in kind purchased market production, payable (D62_D632PAY) for euro area aggregate and individual countries. Euro area total: EA19. Quarterly data is seasonally adjusted with X-ARIMA-12 and then linearly interpolated to the monthly frequency in EVIEWS. Resulting monthly series are converted to real terms using euro area and individual country CPIs. *Available for:* 1999M01 - 2016M11, starting in 2001M03 for Austria, and in 2002M03 for euro area, Germany, Estonia, Ireland, Luxembourg. *Frequency:* Monthly.
Government investment	*Source:* Eurostat dataset quarterly non-financial accounts for general government [gov_10q_ggnfa], Gross fixed capital formation (P51G) for euro area aggregate and individual countries. Euro area total: EA19. Quarterly data is seasonally adjusted with X-ARIMA-12 and then linearly interpolated to the monthly frequency in EVIEWS. Resulting monthly series are converted to real terms using euro area and individual country CPIs. *Available for:* 1999M01 - 2016M11, starting in 2001M03 for Austria, and in 2002M03 for euro area, Germany, Estonia, Ireland, Luxembourg. *Frequency:* Monthly.
Trade balances versus rest of the euro area	*Source:* Eurostat dataset trade by BEC product group since 1999 [ext_st_28msbec], Exports - Imports, Total - All products, Partner Euro area (19 countries), for individual countries. Monthly Data is seasonally adjusted with X-ARIMA-12, multiplied by three and divided by countries' quarterly GDP linearly interpolated to monthly frequency. *Available for:* 1999M01 - 2016M11, starting in 2000M01 for Malte, no GDP is available for Slovakia which is therefore excluded. *Frequency:* Monthly.
Surprise component in economic data releases	*Source:* Bloomberg. Difference between the first-released data and the expected value (median expectation of a panel of experts surveyed by Bloomberg). The difference is divided by its standard deviation. Variables from the following countries are included: Euro Area, Germany, France, Italy, Spain, the UK, and the US. The included variables for each country is given in Table A.2. *Available for:* 1999M01 - 2016M11. *Frequency:* Daily. The list of economic data releases used is reported in Table A.2.

Table A.2: List of economic data releases included in equation (4)

Euro area	**France**	**Germany**
EC Bus. Climate Ind.	CPI YoY	CPI YoY
Current Account Net WDA SA	CPI MoM	CPI MoM
EC Cons. Conf. Ind.	Cons. Conf. Ind.	Manu. Ord. YoY NSA
CPI YoY	Bus. Conf. Ind. (Manu.)	Manu. Ord. MoM SA
CPI MoM	Prod. Outlook Ind.	Trade Bal. Exp. MoM SA
BOP CA Net NSA	Bus. Sent. Ind.	Trade Bal. Imp. MoM SA
New Orders (Manu.) YoY	Cons. Spending MoM	Trade Bal. EUR NSA
GFCF QoQ	CPI ex Tobacco	Retail Sales NSA YoY
EC Serv. Conf. Ind.	real GDP QoQ	Retail Sales SWDA MoM
Markit Comp. PMI SA	real GDP YoY	Prod. Prices MoM
Markit Serv. PMI SA	ML & OS Unemployment Rate	Ind. Prod. YoY NSA WDA
Retail Sales Vol. YoY WDA	Markit Manu. PMI SA	Ind. Prod.n MoM SA
Retail Sales Vol. MoM SA	Markit Serv. PMI SA	Ind. Prod. YoY SA
ZEW Exp. of Econ. Growth	PPI MoM	Unem. Rate SA
Trade Bal. with non EZ	PPI YoY	Unem. Change SA
M3 Money Supply 3 M. MA	Jobseekers Total SA	Ifo Pan Bus. Climate
PPI Industry Ex Constr.YoY	Trade Balance EUR	Ifo Pan Bus. Expectations
PPI Industry Ex Constr. MoM	Manu. Prod. MoM SA	Current Account EUR
Unem. Rate	Own-Comp. Prod. Outlook	Import Price Index MoM
GDP SA QoQ (real SA)		Markit Manu. PMI SA
		GDP Priv.Cons. QoQ
		GDP GFCF QoQ
		GDP Inv. in Const. QoQ
Italy	**UK**	**Spain**
CPI NIC Incl Tbc. YoY NSA	CPI Core YoY	CPI YoY
CPI NIC Incl Tbc. MoM NSA	GDP YoY	CPI Core YoY
Cons. Conf. Ind. SA	GDP MoM	PPI MoM
Bus. Conf. Manu. Sector	Ret. Sales Ex Auto. YoY SA	Trade Balance EUR
Hourly Wages MoM SA	Ret. Sales Ex Auto. MoM SA	Unem. MoM Net Change
Ind. Orders YoY NSA	PPI Manu.Prod. YoY NSA	Avg LC per Worker YoY
Ind. Orders MoM SA	PPI Manu. Prod. MoM NSA	PMI Manu. SA
Ind. Prod. YoY WDA	PPI Input Prices MoM NSA	
Ind. Prod. MoM SA	PPI Input Prices YoY NSA	
Ind. Prod. YoY	Ind. Prod. YoY SA	
Ind. Sales YoY	Unem. Rate SA (Change)	
Ind. Sales MoM SA	Markit/CIPS Const. PMI SA	
Manu. PMI SA	Markit/CIPS Serv PMI SA	
Serv. PMI SA	Govt. Budget Balance	
PPI Manu. MoM	Priv. Cons. QoQ	
PPI Manu. YoY	House Price Ind. MoM SA	
PPI Manu. YoY	Cons. Conf. Ind.	

Priv. Cons. QoQ SA WDA	Gov. Spending QoQ	
Retail Sales MoM SA		
Retail Sales YoY		
Trade Balance Total		
Unem. Rate SA		
Real GDP YoY SA WDA		
Trade Balance Non EU NSA		
US		
CPI YoY NSA	CPI Ex. Fd. & En. YoY NSA	Pers. Cons. Exp. CPI YoY SA
CPI MoM SA	UM Cons. Conf. Ind.	Gov. Budget Balance
Cons. Spend. GR MoM SA	Markit Manu. PMI SA	Ind. Prod. MoM SA
Core PPI	PPI - Fin. Goods	In. Jobless Claims SA
Housing Starts/Permits	Diff. between Exp. and Imp.	GDP QoQ SAAR
PPI Fin. Goods SA MoM%	Cap. Util.n % of Tot. Cap.	Bus. Inventories MoM SA
Avg. H Earnings YoY% SA	Avg. H Earnings MoM% SA	Constr. Spend. MoM SA
Dur. Goods Orders MoM SA	CB Leading Ind. MoM	Production Nonfarm QoQ SA

Source, sample and frequency are discussed at the end of Table A.2

Table A.3: ECB Monetary Policy Announcements used

Date	Policy Announcement / Date of Council Meeting
	Conventional Monetary Policy
Council Meetings:	*2000*: 05.01., 20.01., 03.02., 17.02., 02.03., 16.03., 30.03., 13.04., 27.04., 11.05., 25.05., 08.06., 21.06., 06.07., 20.07., 03.08., 31.08., 14.09., 05.10., 19.10., 02.11., 16.11., 30.11., 14.12. *2001*: 04.01., 18.01., 01.02., 15.02., 01.03., 15.03., 29.03., 11.04., 26.04., 10.05., 23.05., 07.06., 21.06., 05.07., 19.07., 02.08., 30.08., 13.09., 17.09., 27.09., 11.10., 25.10., 08.11., 06.12. *2002*: 03.01., 07.02., 07.03., 04.04., 02.05., 06.06., 04.07., 01.08., 12.09., 10.10., 07.11., 05.12. *2003*: 09.01., 06.02., 06.03., 03.04., 08.05., 05.06., 10.07., 31.07., 04.09., 02.10., 06.11., 04.12. *2004*: 08.01., 05.02., 04.03., 01.04., 06.05., 03.06., 01.07., 05.08., 02.09., 07.10., 04.11., 02.12. *2005*: 13.01., 03.02., 03.03., 07.04., 04.05., 02.06., 07.07., 04.08., 01.09., 06.10., 03.11., 01.12. *2006*: 12.01., 02.02., 02.03., 06.04., 04.05., 08.06., 06.07., 03.08., 31.08., 05.10., 02.11., 07.12. *2007*: 11.01., 08.02., 08.03., 12.04., 10.05., 06.06., 05.07.
	Unconventional Monetary Policy: Phase 1
22.08.2007	Supplementary liquidity-providing longer-term refinancing operation (LTRO) with a maturity of three months
28.03.2008	LTROs with a maturity of six months
29.09.2008	Special term refinancing operation
08.10.2008	Fixed rate tender procedure with full allotment on the main refinancing operation(MROs)
15.10.2008	List of assets eligible as collateral in Eurosystem credit operations extended
07.05.2009	LTROs with a maturity of one year
04.06.2009	Details on Purchase program for covered bonds (CBPP)
03.12.2009	Phasing out of 6-month LTROs, indexation of new one year LTROs
04.03.2010	Phasing out of 3-month LTROs, indexation of six month LTROs
10.05.2010	Securities Markets Program (SMP)
28.07.2010	Risk control measures in collateral framework reviewed
03.03.2011	Further LTROs
09.06.2011	MROs as fixed rate tender procedures with full allotment (FRFA) for as long as necessary, at least until October 2011
04.08.2011	Further LTROs with a maturity of three and six months
08.08.2011	ECB will actively implement its Securities Market Program

06.10.2011	New covered bond purchase program (CBPP2)
08.12.2011	Two additional LTROs with a maturity of three years
21.12.2011	Results of first three year LTRO
09.02.2012	ECB's Governing Council approves eligibility criteria for additional credit claims
28.02.2012	Results of second three year LTRO
06.06.2012	FRFA on MROs as long as necessary, and at least until January 2013
26.07.2012	'Whatever it takes...' speech by ECB President Mario Draghi in London
02.08.2012	Outright Monetary Transactions program (OMT)
06.09.2012	Technical features of OMT
06.12.2012	FRFA on MROs as long as necessary, and at least until July 2013
22.03.2013	Collateral rule changes for some uncovered government guaranteed bank bonds
02.05.2013	FRFA on MROs as long as necessary, and at least until July 2014
04.07.2013	Governing Council expects the key ECB interest rates to remain at present or lower levels for an extended period of time (open-ended forward guidance)
08.11.2013	FRFA on MROs as long as necessary, and at least until July 2015

Unconventional Monetary Policy: Phase 2

05.06.2014	Targeted longer-term refinancing operations (TLTROs)
03.07.2014	Details on TLTROs published, deposit rate –0.1
04.09.2014	Deposit rate –0.2
22.01.2015	Announcement of expanded asset purchase programme (APP)
16.07.2015	Reaffirmation that purchases are intended to run until end of September 2016
31.08.2015	New category of assets added as eligible collateral
03.09.2015	Increase in PSPP issue share limit
23.09.2015	Eurosystem adjust purchase process in ABS programme
22.10.2015	Questions on requirements for APP extension answered
09.11.2015	Increase in PSPP issue share limit enlarges purchasable universe
03.12.2015	APP extended until March 2017,deposit rate –0.3
21.01.2016	Review and possibly reconsider monetary policy stance at next meeting
10.03.2016	New targeted longer-term refinancing operations (TLTRO II), APP expanded, corporate bonds added to APP, deposit rate –0.4
21.04.2016	Details on implementation of APP expansion
03.05.2016	Legal acts relating to TLTRO II is published
02.06.2016	Details on corporate sector purchase programme (CSPP) published
21.07.2016	Confirmation that APP at 80 billion per month to run at least until March 2017
08.09.2016	Council meeting confirming continuation of APP

05.10.2016	Changes to collateral eligibility criteria and risk control measures for unsecured bank bonds
20.10.2016	Council meeting confirming continuation of APP

Appendix B : Tests on structural breaks

We conduct a battery of tests and robustness checks to study whether the baseline VAR model displays structural breaks. We first carry out tests on each individual equation of the model. We then jointly test for structural breaks in the entire multivariate reduced form model rather than equation by equation. Last, we estimate impulse responses adding interaction terms that allow for a structural break. Overall, we find that only some of the single equations might have been subject to structural breaks around the beginning of the unconventional monetary policy period, that the multivariate model seems stable, and that the effect of potential breaks on the impulse responses is small. We take the results as suggesting that the linear model offers a good approximation of the dynamics of the system.

We carry out two separate tests in addressing possible breaks for each equation of the reduced form model. We first run a Chow test for the null hypothesis that no break occurred in 2007M8. This point in time coincides with the beginning of the ECB unconventional monetary policy. Then, for each equation we carry out the cumulative sum (CUMSUM) test originally proposed by Brown et al. (1975), assessing whether the recursively estimated innovations in each equation display behaviour suggesting structural breaks.

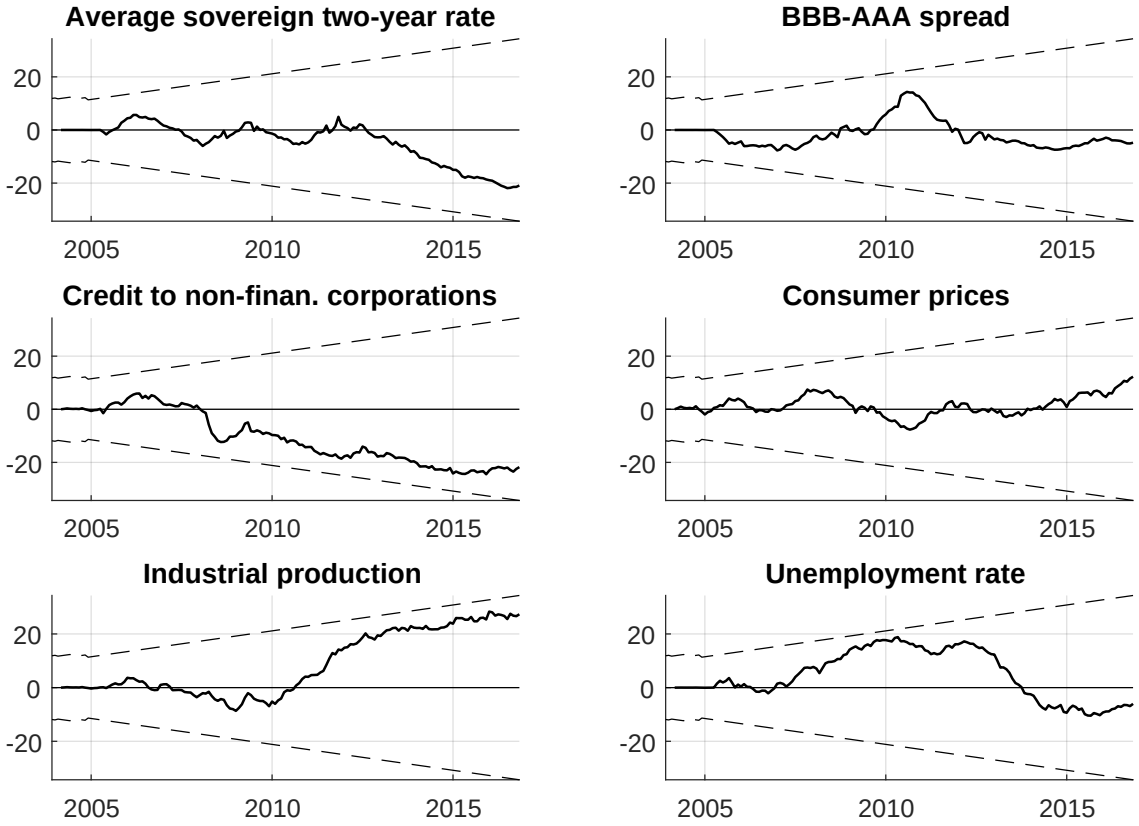
The results for the Chow tests are shown in Table B.1, while the results from the CUMSUM analysis are reported in Figure B.1. Overall, the results are mixed. The Chow tests suggest the presence of structural breaks for four equations of the VAR model, as indicated by the low p-value for the second, third, fifth and sixth equation of the VAR. On the contrary, the CUMSUM test finds that the estimated innovations are always inside the error bands, providing no evidence in favour of breaks.

Table B.1: Chow tests on each equation of the baseline VAR

Break point: 2007M8			
Null Hypothesis: No breaks at specified breakpoint			
VAR equation	*Dependent variable*	*F-statistic*	*p-value*
1	Average sovereign two-year rate	0.96	0.53
2	BBB-AAA corporate bond spread	1.63	0.03
3	Credit to non-financial corporations	4.67	0.00
4	Consumer prices	0.38	0.99
5	Industrial production	1.47	0.07
6	Unemployment rate	1.94	0.01

We then study to what extent the possible presence of structural breaks in some equations maps into breaks for the entire reduced form model, and in which period. To do so we use the Chow test for multivariate dynamic models. As discussed by Candelon and Lütkepohl (2001), in a multivariate framework the asymptotic distributions for the test statistics can be particularly misleading in small samples, whereas the bootstrapped version of the test performs more accurately. We follow their procedure and calculate bootstrapped p-values for the test statistics. We refer to Candelon and Lütkepohl (2001) and Lütkepohl and Krätzig (2004) for a description of the test and of the bootstrap.

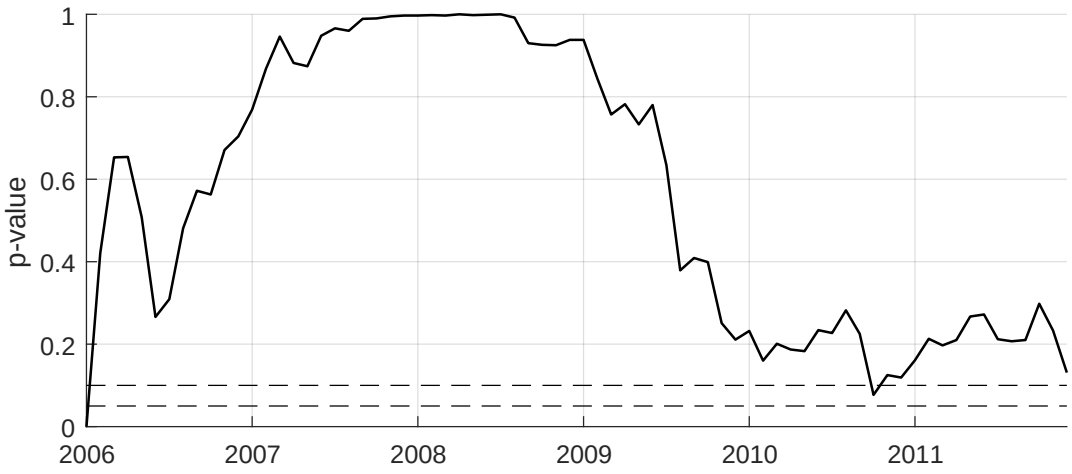
Figure B.1: Cumulative Sum test on each equation of the baseline VAR



We implement the multivariate Chow tests as follows. We first select the subperiod between 2006M1 and 2011M12 as the period within which we assess the presence of a single structural break, and then run the test for each month within this period. For each month, we split the sample period from 2002M5 until 3 months before the candidate break, and from 3 months after the candidate break until 2016M11. We then compute the break-point Chow test statistics and calculate the p-value using 1000 bootstrap repetitions.

The results of the analysis are shown in Figure B.2. The figure reports

Figure B.2: Break-point Chow test on the multivariate model



Notes: p-values are computed using 1000 bootstrapped draws, as in Candelon and Lütkepohl (2001). The test is run for each month within the period 2005M1 through 2011M12.

the p-value computed for each month within the period considered, together with the 0.05 and the 0.10 critical values. The tests find p-values that are largely above the critical values for most of the considered break points, hence failing to reject the null hypothesis of no break. There is some evidence of a break in at the beginning of the break point window and in 2010. However, the former point is most likely due to the small number of observations in the first part of the sample as the p-value quickly increases afterwards, and the latter point is only significant at the 10% level. Moreover, the results should be treated with caution because, as discussed by Kilian and Lütkepohl (2017), in finite sample the break tests of the type discussed by Candelon and Lütkepohl (2001) are prone to rejecting the null hypothesis of no break even when the null hypothesis is true.

To study to what extent a possible break around the beginning of the

unconventional policy affects the impulse responses we modify the baseline version of the model from equation (1) in the paper by adding interaction terms. We use a general framework that allows for a break in the constant, in the autoregressive parameters and in the covariance matrix of the innovations. The model is written as

$$y_t = c + \Pi(L)y_{t-1} + d_t[\tilde{c} + \tilde{\Pi}(L)y_{t-1}] + u_t, \tag{B.1}$$

with $u_t \sim N(0, \Sigma + \tilde{\Sigma}d_t)$ and d_t a dummy variable taking value of one after a pre-selected sample break, an zero otherwise. The model is estimated and identified as in the paper, treating phase 1 and phase 2 of ECB unconventional monetary policy separately (see Section 2.3 of the paper).

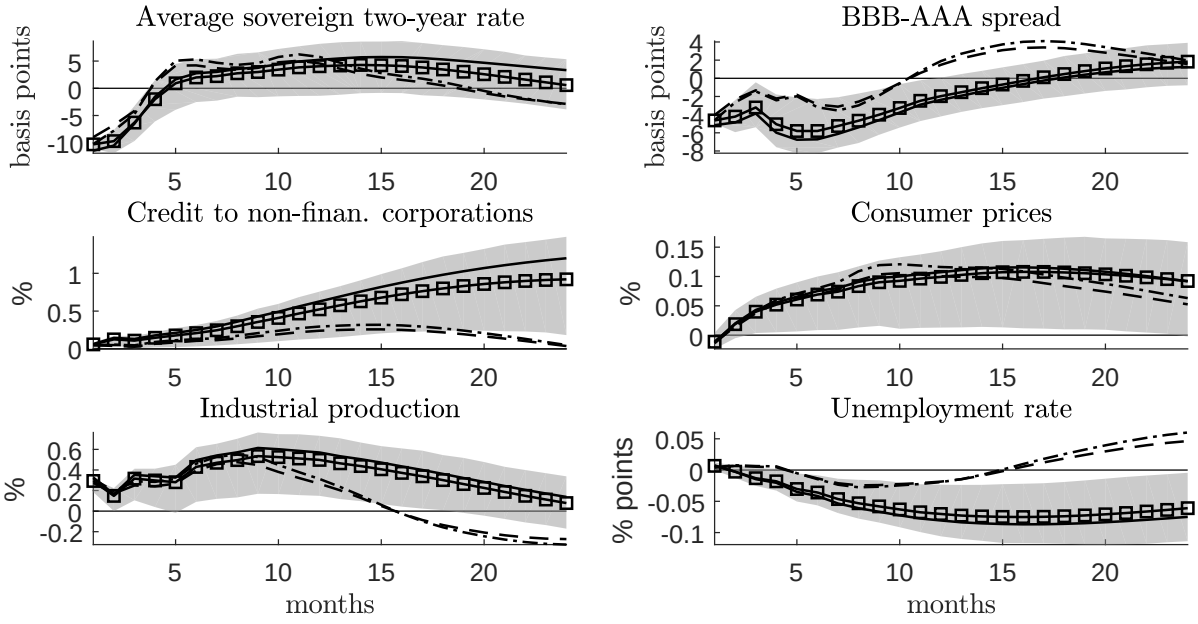
The results are shown in Figure B.3. We report the impulse responses computed when allowing for a change only in the constant terms, only in the autoregressive components, only in the covariance matrix, or in all three sets of parameters. Such approach allows exploring which component of the reduced form model potentially contributes to the presence of breaks in the impulse responses. Figure B.3 shows the results using 2007M8 as a break point, which is the break point considered also in Table B.1. The impulse responses estimated from the interacted model are largely inside the estimated confidence band from the linear model. Some divergence is documented when allowing for the autoregressive components to change, although the differences emerge only at longer horizons. Within the first

year from the shock all impulse responses from the interacted models fall within the confidence bands of the linear VAR.

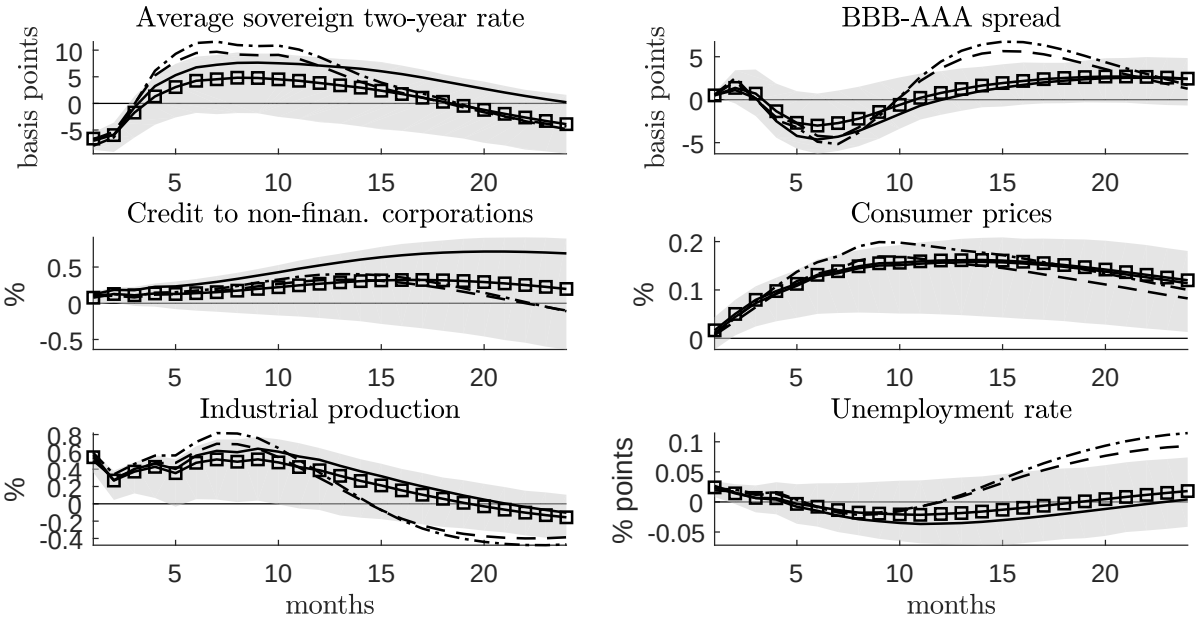
Overall, having found that a potential structural break between the conventional and the unconventional period matters only for specific equations, rather than for full reduced form model or for the impulse response dynamics, we base the analysis of the paper on a linear specification of the VAR model. Robustness checks in Appendix E show that the results of the analysis also hold when estimating the linear reduced form model using data only for the unconventional period.

Figure B.3: Modelling an interaction term (breakpoint 2007M8)

(A) Phase I of unconventional monetary policy



(B) Phase II of unconventional monetary policy



Notes: The shaded area shows the confidence bands from the baseline specification from Figure 1 in the paper. The point estimates refer to impulse responses computed from model (B.1), allowing for a structural break in the constant term (solid line), autoregressive parameters (dashed dotted line), covariance matrix of the VAR innovations (squared line) or all three sets of parameters (dashed line).

Appendix C : A Bayesian analysis

In Section 3.2 of the paper we discuss the effects of the monetary shocks on fiscal variables, and remark that the responses tend to materialize in the medium horizon. In this appendix we assess the robustness of these results by estimating the model with eight lags and adopting a Bayesian approach to the estimation.

As discussed in Section 2 of the paper, the model consists of two key equations, namely equation (1) and equation (8). We replicate them here for convenience:

$$y_t = c + \Pi(L)y_{t-1} + u_t, \tag{C.1}$$

$$w_{it}^M = \phi_i^{(3)} + \psi_i^{(3)} m_t^M + \eta_{it}^{(3)}, \quad i = 1, ..., k, \tag{C.2}$$

with $u_t \sim N(0, \Sigma)$. Equation (C.1) shows the reduced form model, while equation (C.2) shows the equations estimated for the identification of the model. In (C.2), m_t^M is the monthly instrument and w_{it}^M is either the VAR innovation u_{it} or the monthly aggregation w_{it}^D of the daily variable of interest, depending on the original frequency of variable i (see Section 2.3 for a discussion). The frequentist estimation of the model takes 5 steps:

1. estimate model (C.1) and obtain $\hat{c}, \hat{\Pi}(L), \hat{\Sigma}, \{\hat{u}_t\}_{t=1}^T$;

2. for each $i = 1, ..., k$, use the data $\{w_{it}^D\}_{t=1}^T$ and the estimated residuals $\{\hat{u}_t\}_{t=1}^T$ to construct $\{w_{it}^M\}_{t=1}^T$;

3. for each $i = 1, ..., k$, estimate model (C.2) and obtain $\{\hat{\psi}_i^{(3)}\}_{i=1}^k$;

4. combine $\{\hat{\psi}_i^{(3)}\}_{i=1}^k$ into the relative impulse vector $\hat{\tilde{b}}^m = (1, \hat{\psi}_2^{(3)}/\hat{\psi}_1^{(3)}, ..., \hat{\psi}_k^{(3)}/\hat{\psi}_1^{(3)})'$ and convert it into the impulse vector $\hat{b}^m$ using $\hat{\Sigma}$;

5. use $\hat{b}^m$ and $\hat{\Pi}(L)$ to compute impulse responses to a one standard deviation shock.

We estimate the model with Bayesian methods using the popular independent Normal-inverse Wishart prior on the parameters in model (C.1), and using uninformative priors on the parameters in (C.2). The estimation builds on two results, which we take from the literature:

1. after rewriting model (C.1) as $Y = \tilde{\Pi}X + U$ with $\tilde{\Pi} = [c, \Pi_1, ..., \Pi_p]$ and defining $\iota = vec(\tilde{\Pi})$, prior beliefs $\iota \sim N(\mu_\iota, V_\iota)$ and $\Sigma \sim iW(S_\Sigma, v_\Sigma)$ lead to the conditional posterior distributions $\iota|Y, \Sigma \sim N(\mu_\iota^*, V_\iota^*)$ and $\Sigma|Y, \iota \sim iW(S_\Sigma^*, v_\Sigma^*)$ with $V_\iota^* = [V_\iota^{-1} + (XX' \otimes \Sigma^{-1})]^{-1}$, $\mu_\iota^* = V_\iota^*[V_\iota^{-1}\mu_\iota + (X \otimes \Sigma^{-1})vec(Y)]$, $S_\Sigma^* = S_\iota + (Y - \tilde{\Pi}X)(Y - \tilde{\Pi}X)'$ and $v_\Sigma^* = v_\Sigma + T$. Hence, the joint posterior distribution $p(\iota, \Sigma|Y)$ can be explored numerically using the Gibbs sampler (see Koop et al., 2010);

2. in the linear model taking the general form $z = W\gamma + \nu$ with $\nu \sim N(0, h^{-1})$, prior beliefs $\gamma|h \sim N(\mu_\gamma, h^{-1}V_\gamma)$ and $h \sim \Gamma(s_h, v_h)$ jointly considered with the uninformative specification $v_h = 0$ and $V_\gamma = cI$ with $c \to 0$ lead to the marginal posterior $\gamma_i|z \sim t(\hat{\gamma}_i, s^2\hat{V}_{ii}, N)$, with N the number of observations in z minus the number of elements in γ, $\hat{\gamma}_i$ the ith element of the least square estimate of γ and s^2 the consistent

estimator of the variance of ν (see Koop, 2003).

Our Bayesian estimation of the model makes use of the above results, after acknowledging that the observations used in the linear model $z = W\gamma + \nu$ depend on the posterior draws from model (C.1).

More precisely, we estimate the model following eight steps:

1. set the hyperparameters μ_ι, V_ι, S_Σ and υ_Σ;

2. simulate numerically from the joint posterior distribution $p(\iota, \Sigma|Y)$ and store draws $\{\iota_d, \Sigma_d\}_{d=1}^{D}$;

3. for draw d and for each equation i of the VAR, set $\{w_{it}^{M,d}\}_{t=1}^{T}$ of model (C.2) to either $\{w_{it}^{D}\}_{t=1}^{T}$ or to the ith VAR innovations corresponding to ι_d, depending on the frequency of variable i;

4. for each $i = 1, ..., k$, compute the OLS estimates $\hat{\psi}_i^{(3),d}$ and $s_d^2\hat{V}_{ii,d}$;

5. for each $i = 1, ..., k$, generate one draw $\psi_i^{(3),d}$ from the posterior $\psi_i^{(3)} \sim t(\hat{\psi}_i^{(3),d}, s_d^2\hat{V}_{ii,d}, N)$;

6. use $\{\psi_i^{(3),d}\}_{i=1}^{k}$ to compute the relative impulse vector $\hat{b}^{m,d}$ and convert it into the impulse vector $b^{m,d}$ using the estimate of Σ consistent with the VAR innovations implied by ι_d;

7. compute the impulse response associated with ι_d and $b^{m,d}$;

8. replicate steps 3 to 7 for each draw $d = 1, ..., D$.

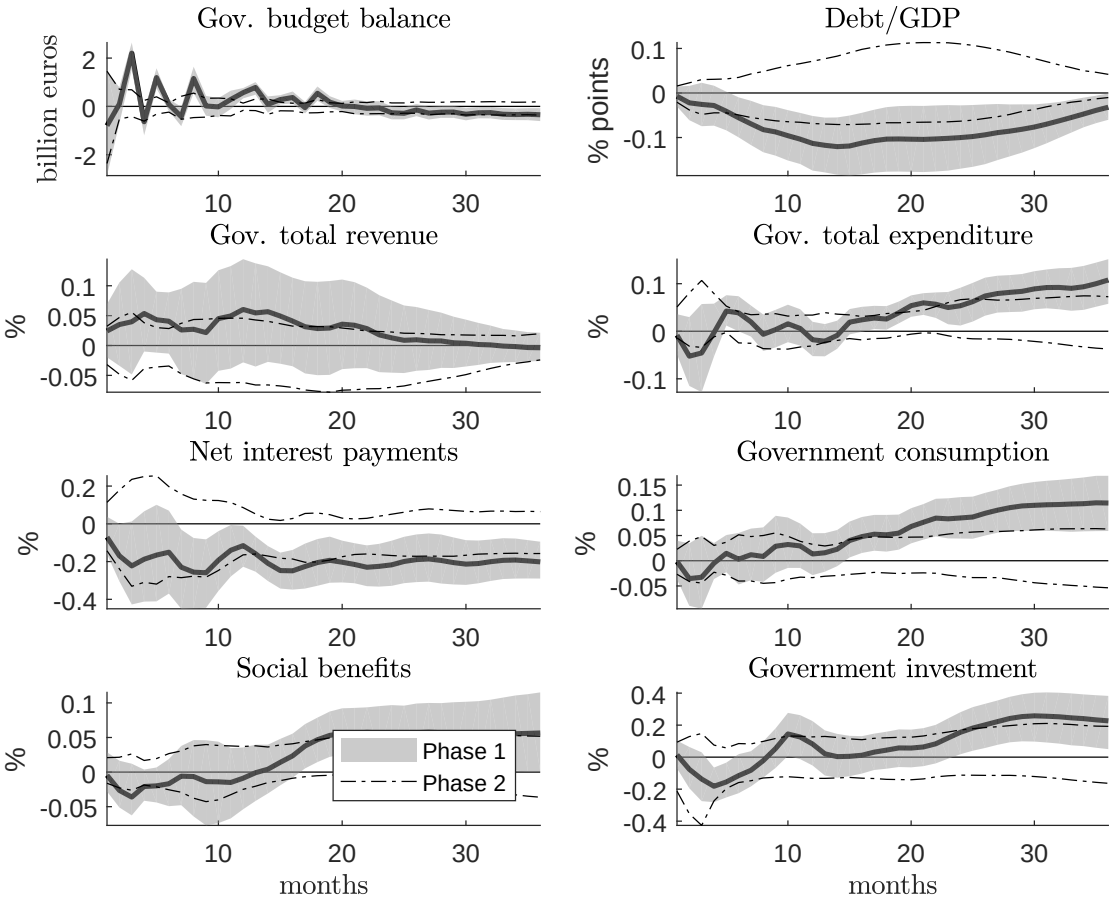
The above approach to the Bayesian estimation of proxy SVAR models builds on Rogers et al. (forthcoming). We depart from their contribution

and use the traditional independent Normal-inverse Wishart prior for the VAR parameters rather than a diffuse prior. In addition, we do not further restrict the draws such that selected sign restrictions are satisfied. Our approach also differs from Caldara and Herbst (forthcoming) in that we do not combine the VAR model and the auxiliary regressions (C.2) together, but keep them separate, as in the original specification of the proxy VAR methodology by Stock and Watson (2012) and Mertens and Ravn (2013).

In our application, we set the hyperparameters μ_ι such that the prior distribution on each equation of the VAR is a white noise process, and set V_ι such that the variance on "own lags" and lags of "other variables" are treated asymmetrically (see Koop et al., 2010, Canova, 2007). We run the Gibbs sampler for 4000 draws and burn in the first 2000.

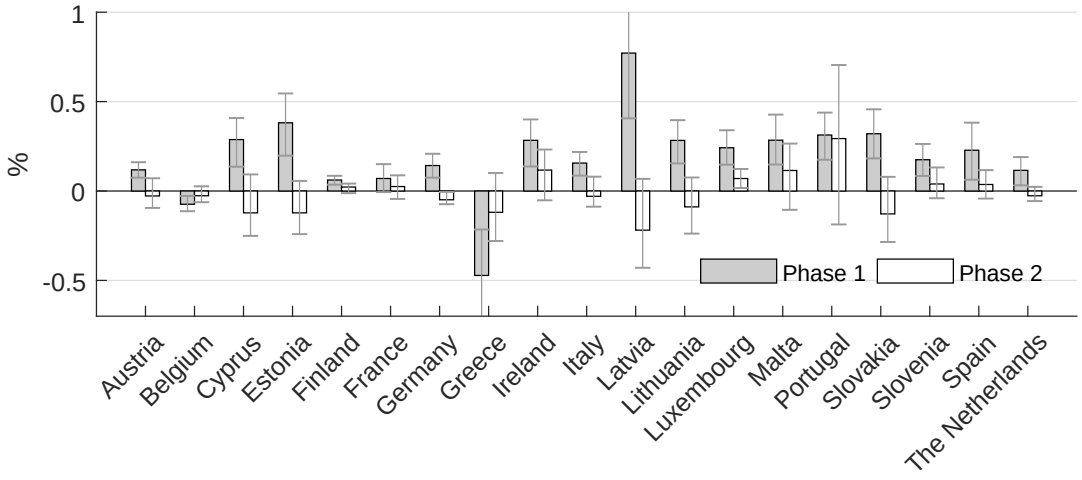
The results of the analysis are documented in Figures C.1 and C.2. As expected, the Bayesian framework allows us to increase the lag length and still estimate the effects of monetary policy with precision. The increases and the peak effects take place earlier, and more responses are statistically significant. This supports our result from Section 3.2.

Figure C.1: Robustness: variables from Figure 4 using Bayesian estimation with eight lags



Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% Bayesian credible sets obtained using 2000 posterior draws. The shaded area and the continuous line show the credible set and the pointwise median response for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the credible set for a shock from the second phase.

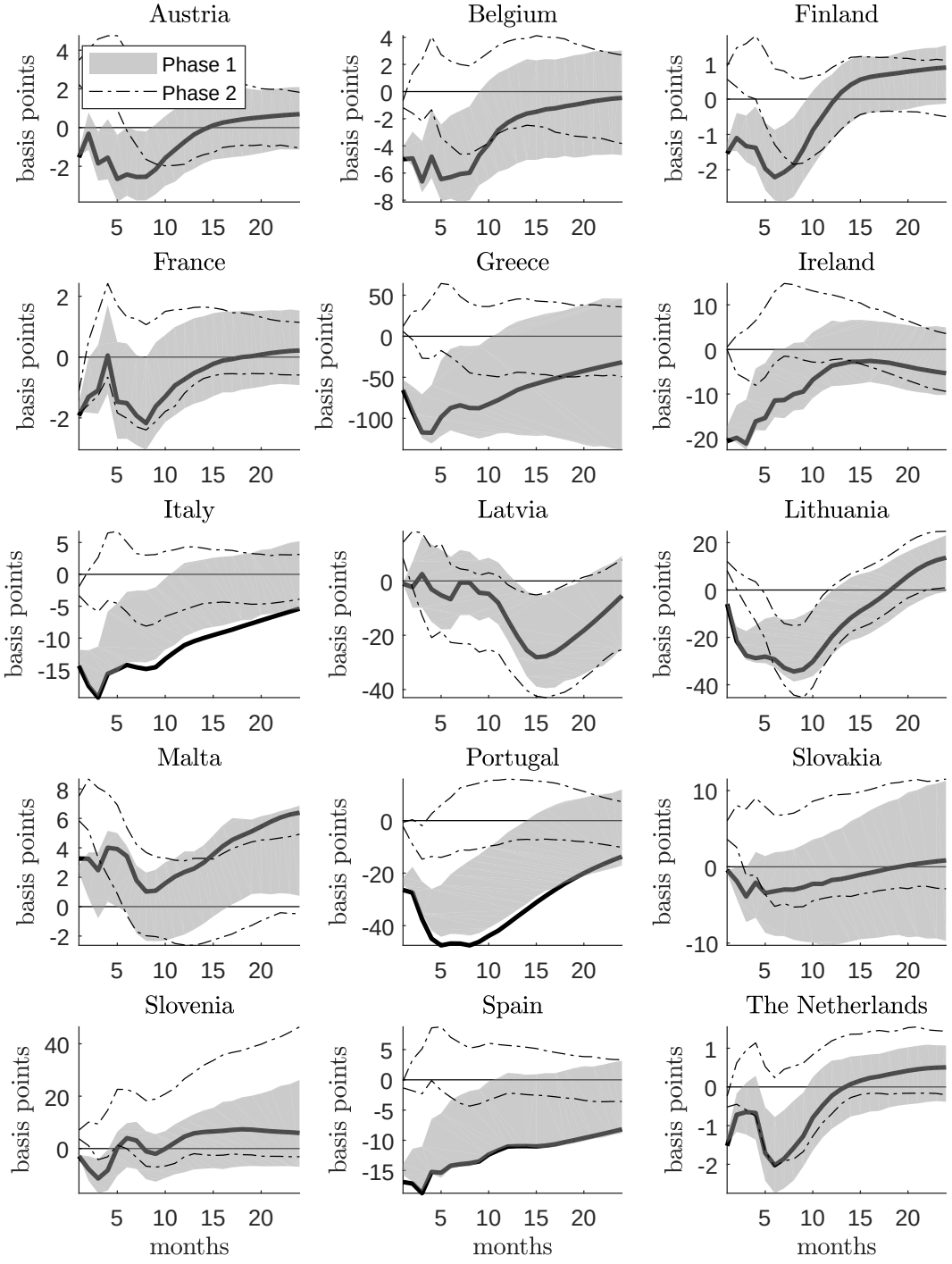
Figure C.2: Robustness: government consumption from Figure 5 using Bayesian estimation with eight lags



Notes: The figure shows the peak responses of country-specific government consumption after a one standard deviation expansionary monetary policy shock, along with 90% Bayesian credible sets obtained using 2000 posterior draws. The shaded area shows the pointwise median response for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the pointwise median response for a shock from the second phase. The peaks are reached after the following months from the shock (phase 1-2): Aut 26-7; Bel 6-6; Cyp 7-35; Est 11-30; Fin 28-22; Fra 3-4; Ger 33-1; Gre 7-7; Ire 18-2; Ita 4-6; Lat 12-29; Lit 8-34; Lux 8-7; Mal 9-7; Por 35-2; Svk 11-4; Svn 35-14; Spa 33-1; Nld 35-13.

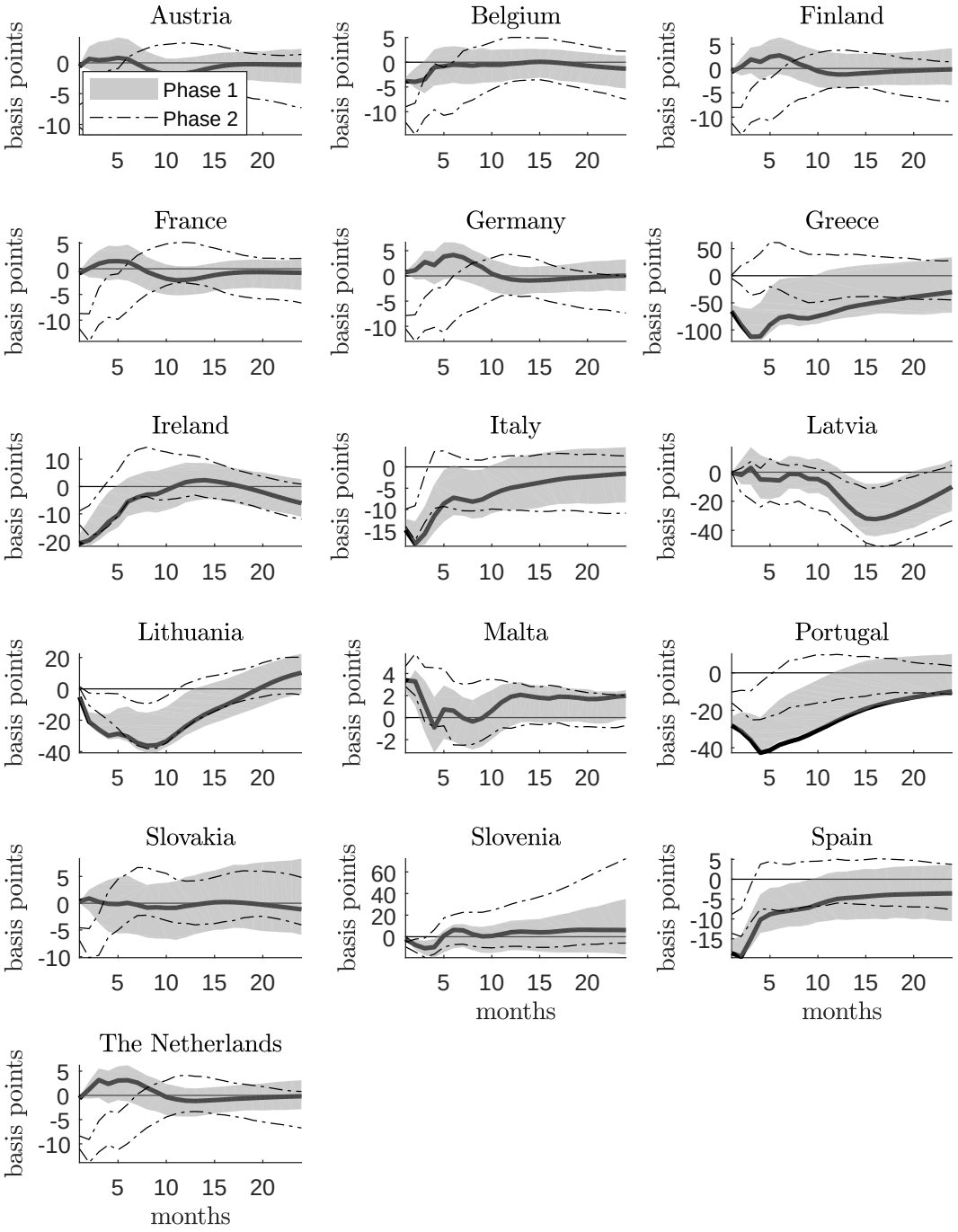
Appendix D : Responses behind the peak effects

Figure D.1: Spreads versus Germany on ten-year government bonds - impulse responses behind Figure 2



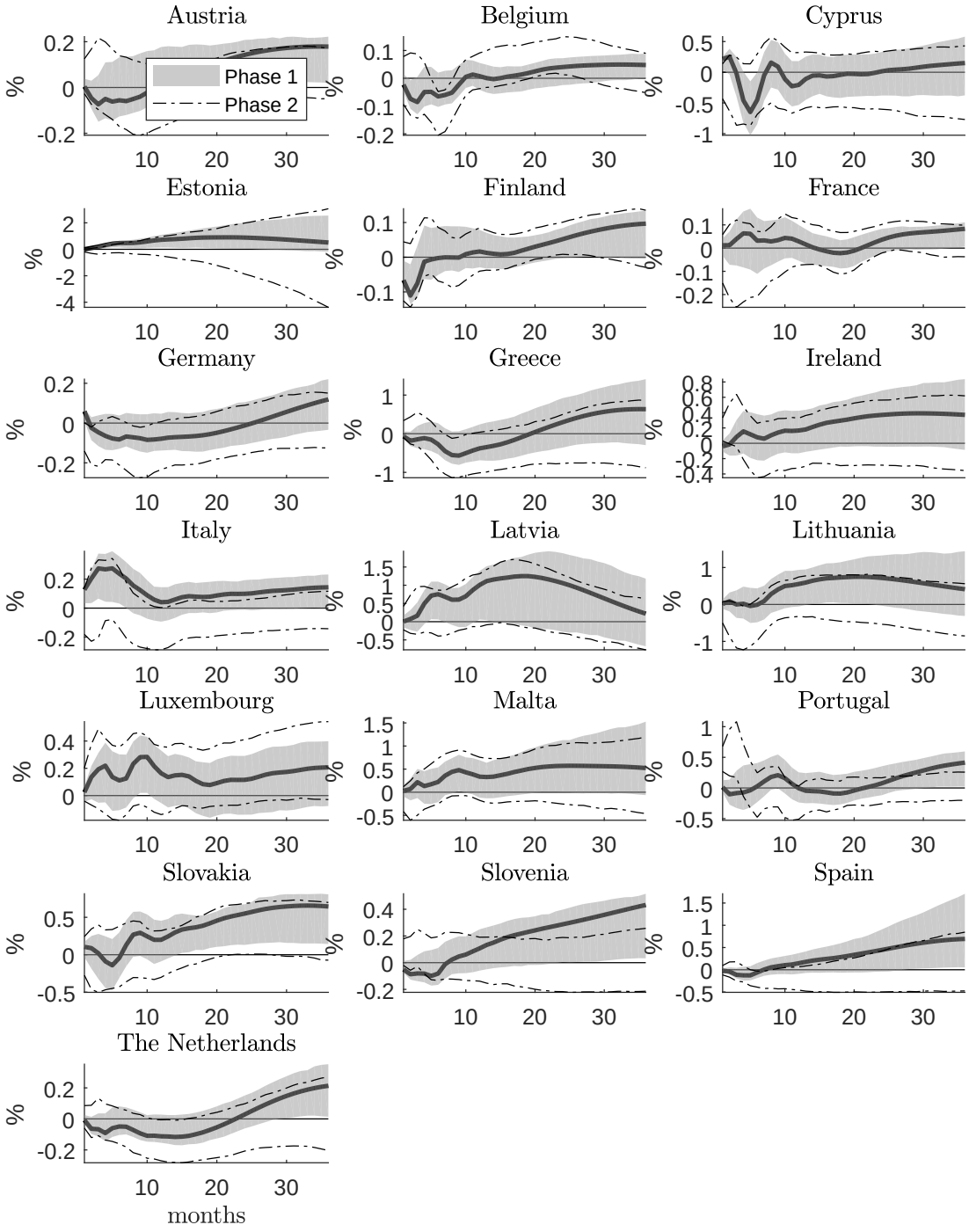
Notes: The figure shows the impulse responses of country-specific spreads versus Germany of ten-year government bonds after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure D.2: Yields on ten-year government bonds - impulse responses behind Figure 2



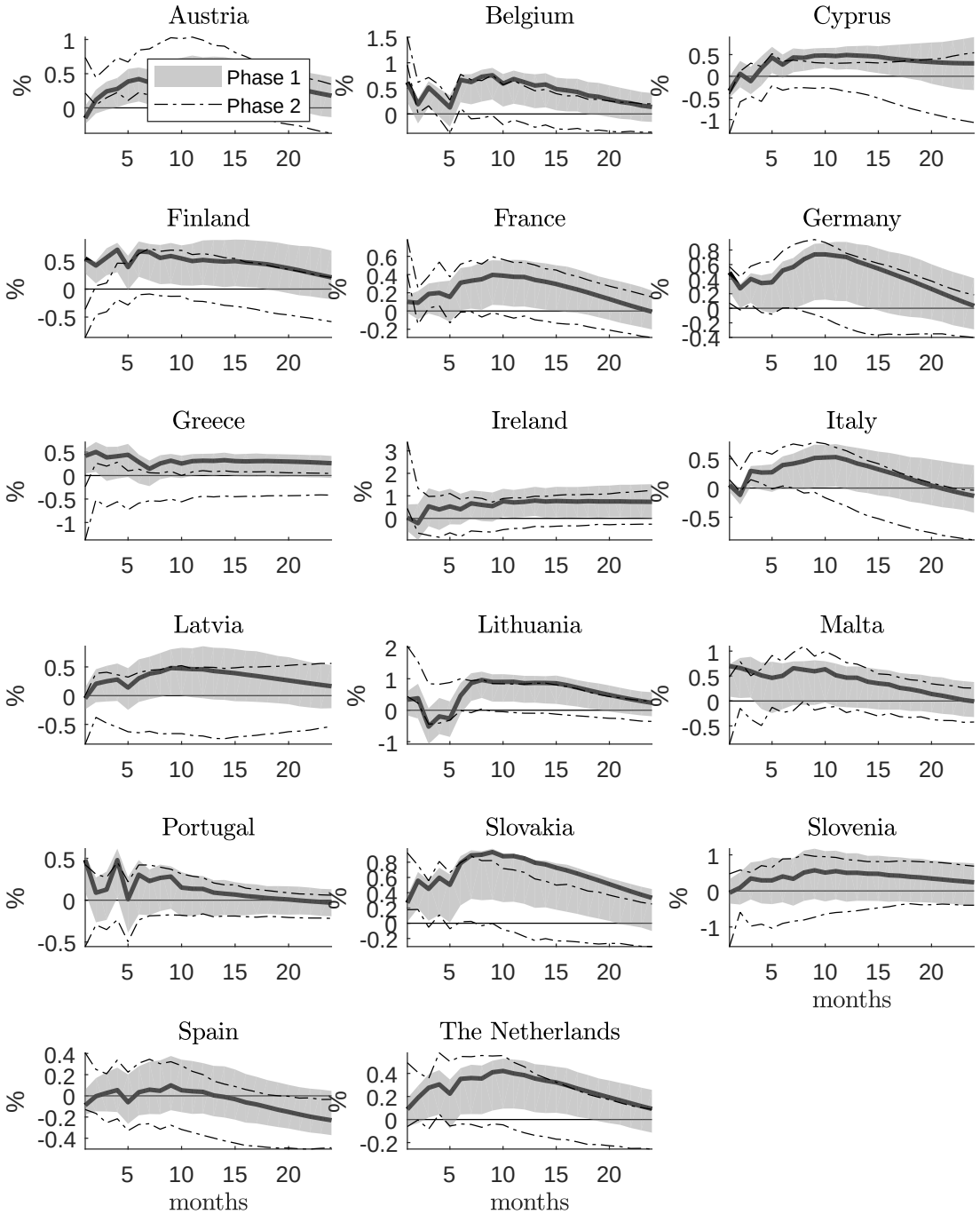
Notes: The figure shows the impulse responses of country-specific yields on ten-year government bonds after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure D.3: Government consumption - impulse responses behind Figure 5



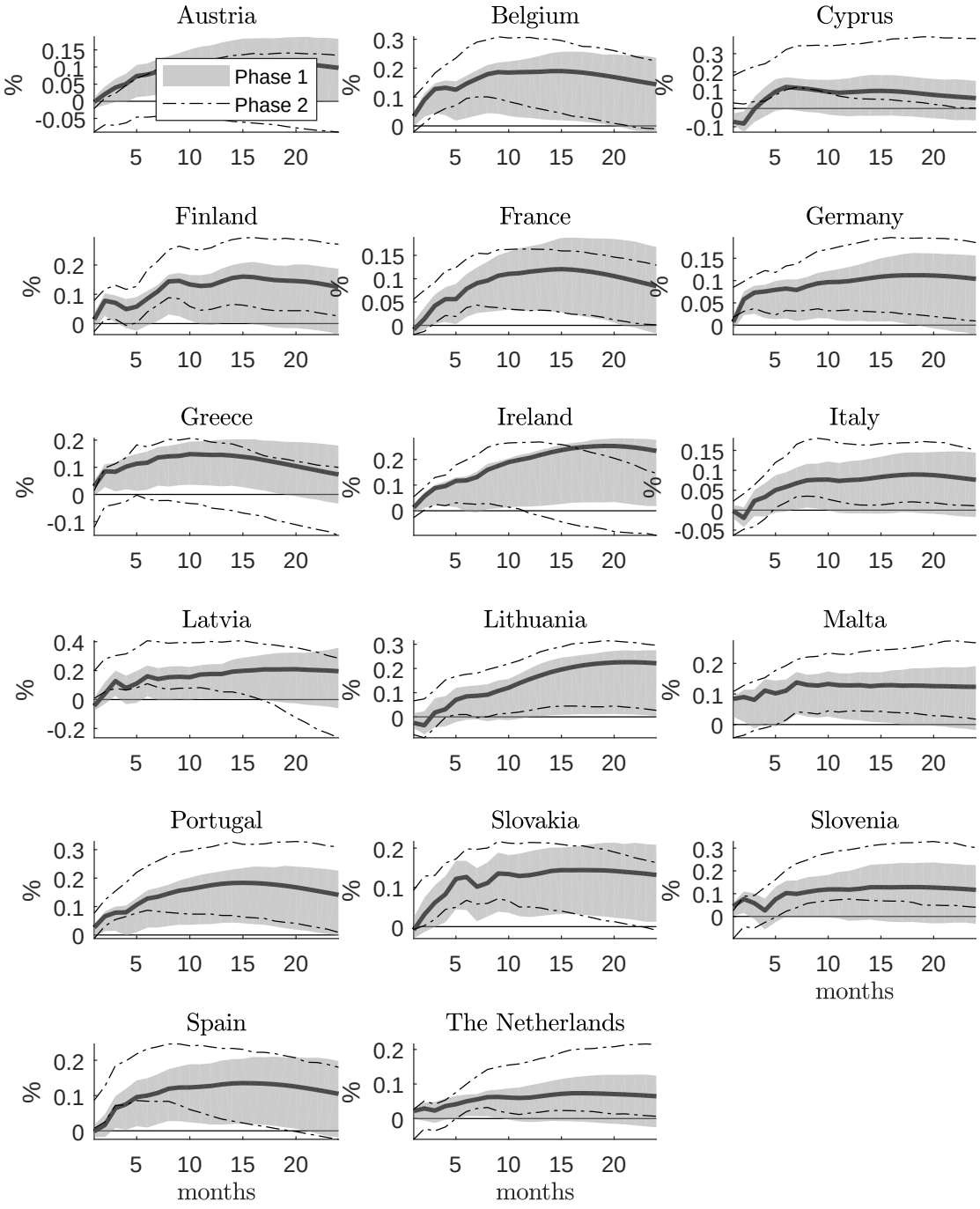
Notes: The figure shows the impulse responses of country-specific government consumption after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure D.4: Industrial production - impulse responses behind Figure 6



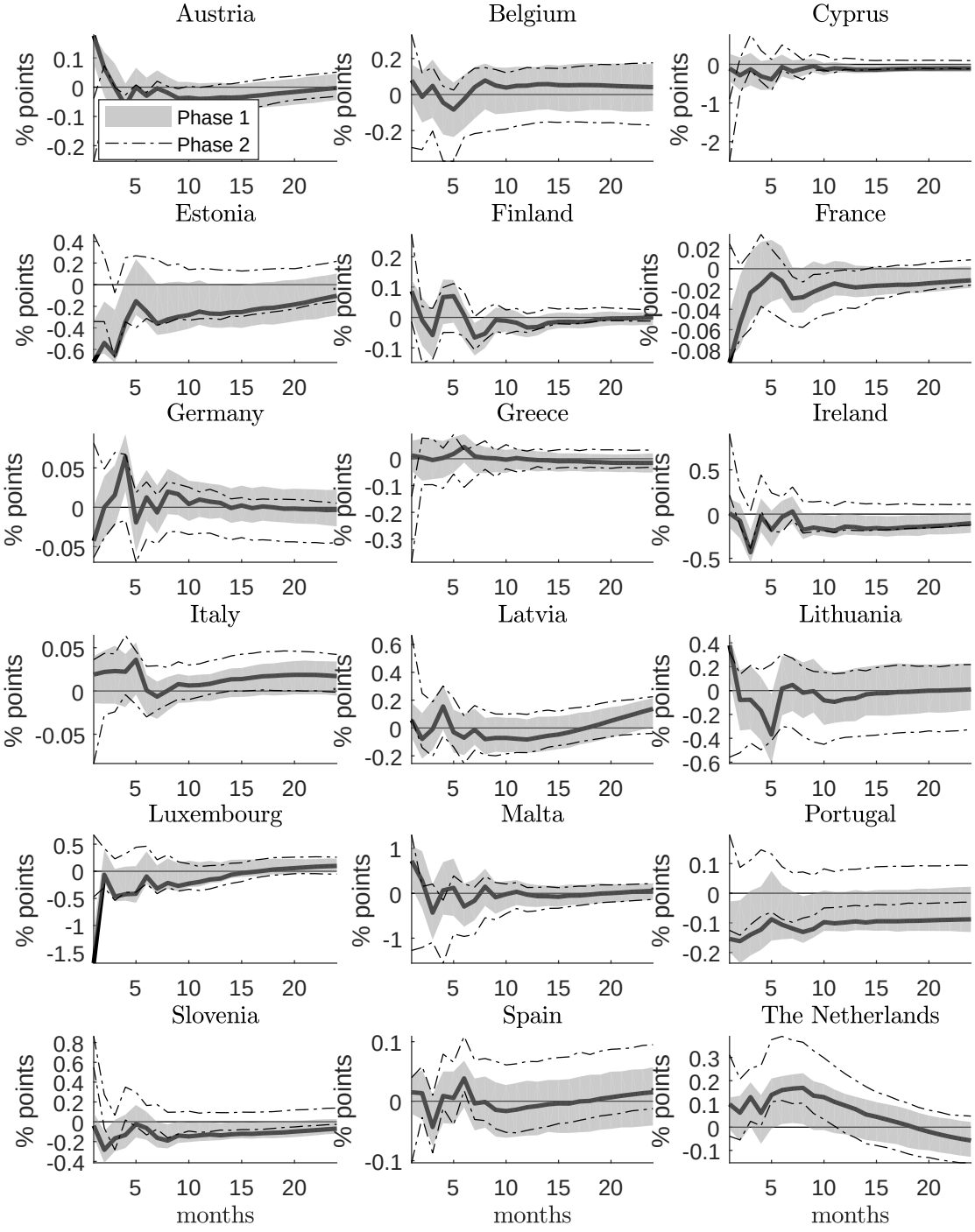
Notes: The figure shows the impulse responses of country-specific industrial production after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure D.5: Consumer price index - impulse responses behind Figure 6



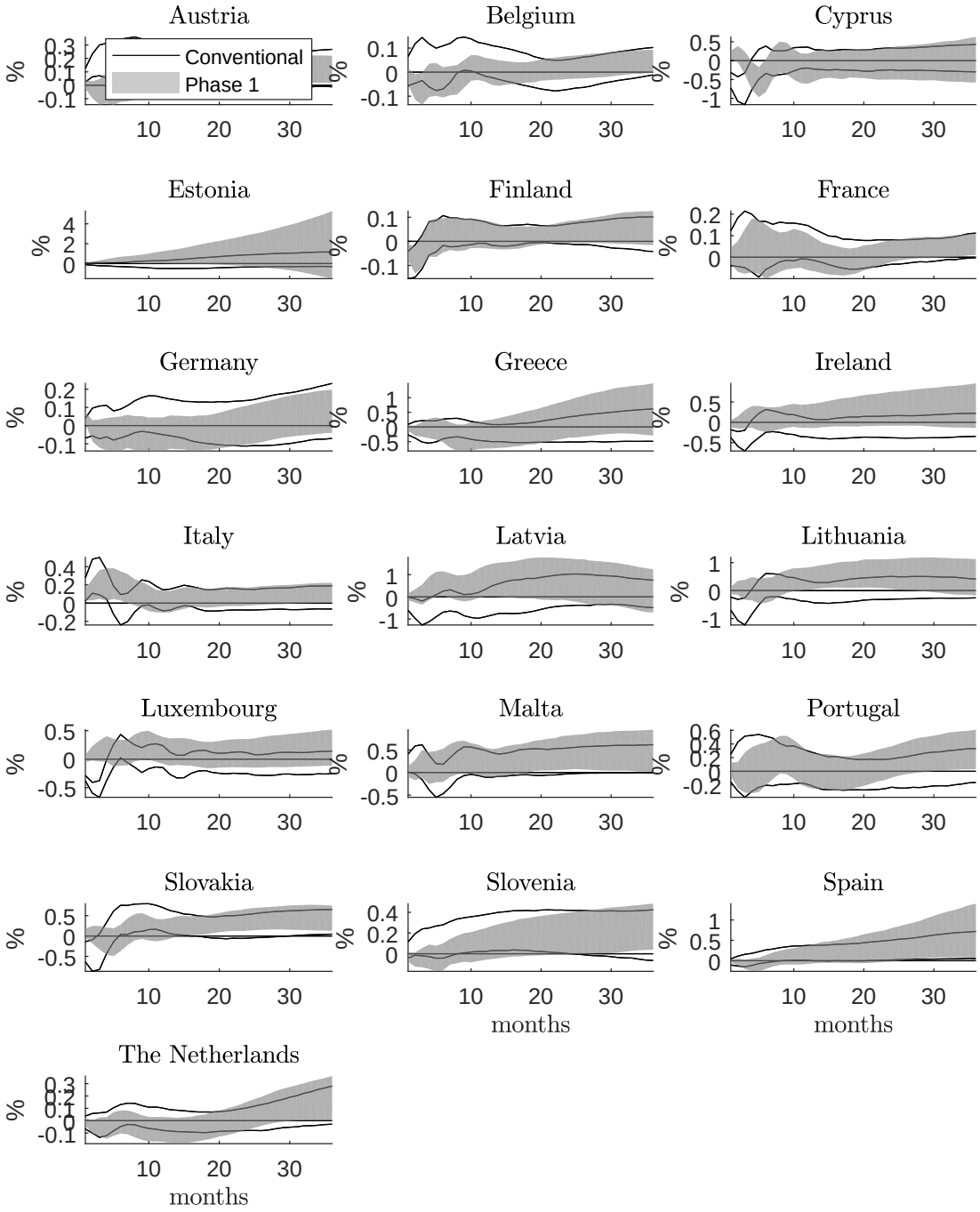
Notes: The figure shows the impulse responses of country-specific consumer price index after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure D.6: Net export - impulse responses behind Figure 8



Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure D.7: Government consumption - impulse responses behind Figure 11

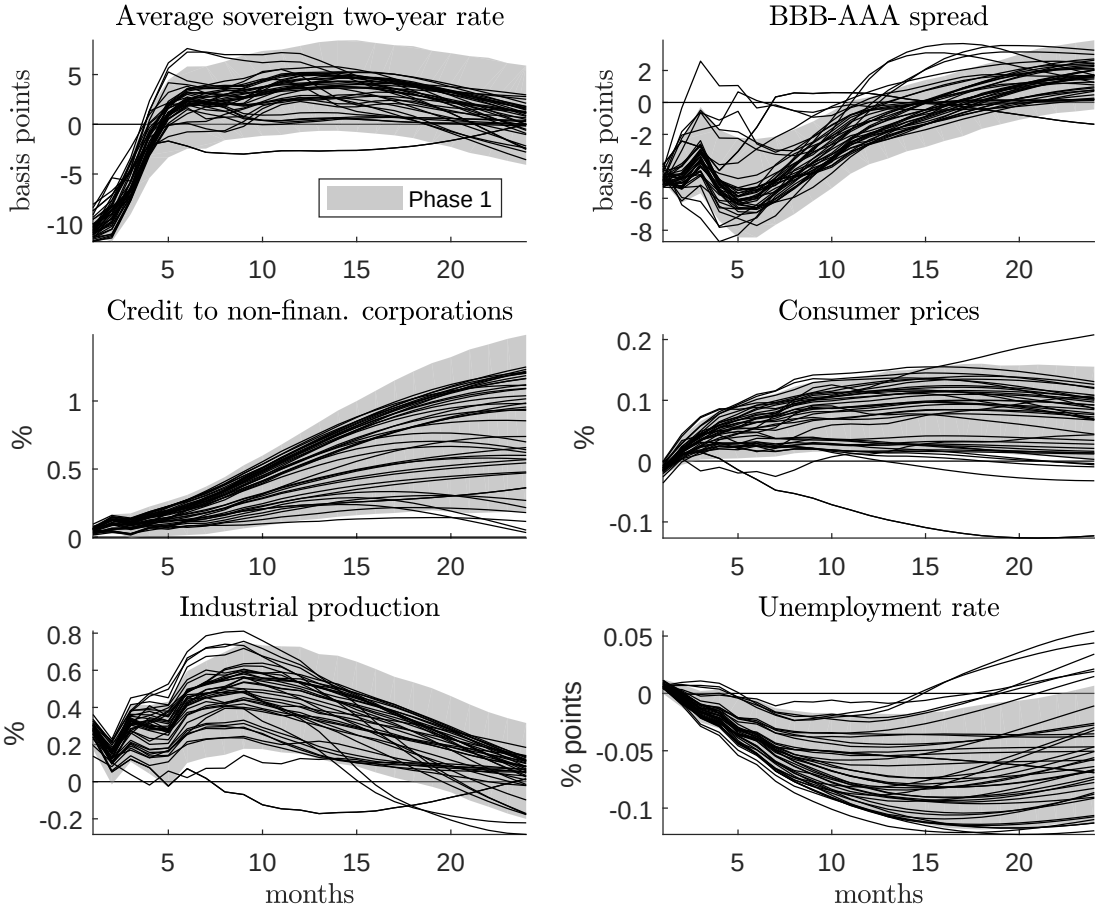


Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Appendix E : Sensitivity analysis

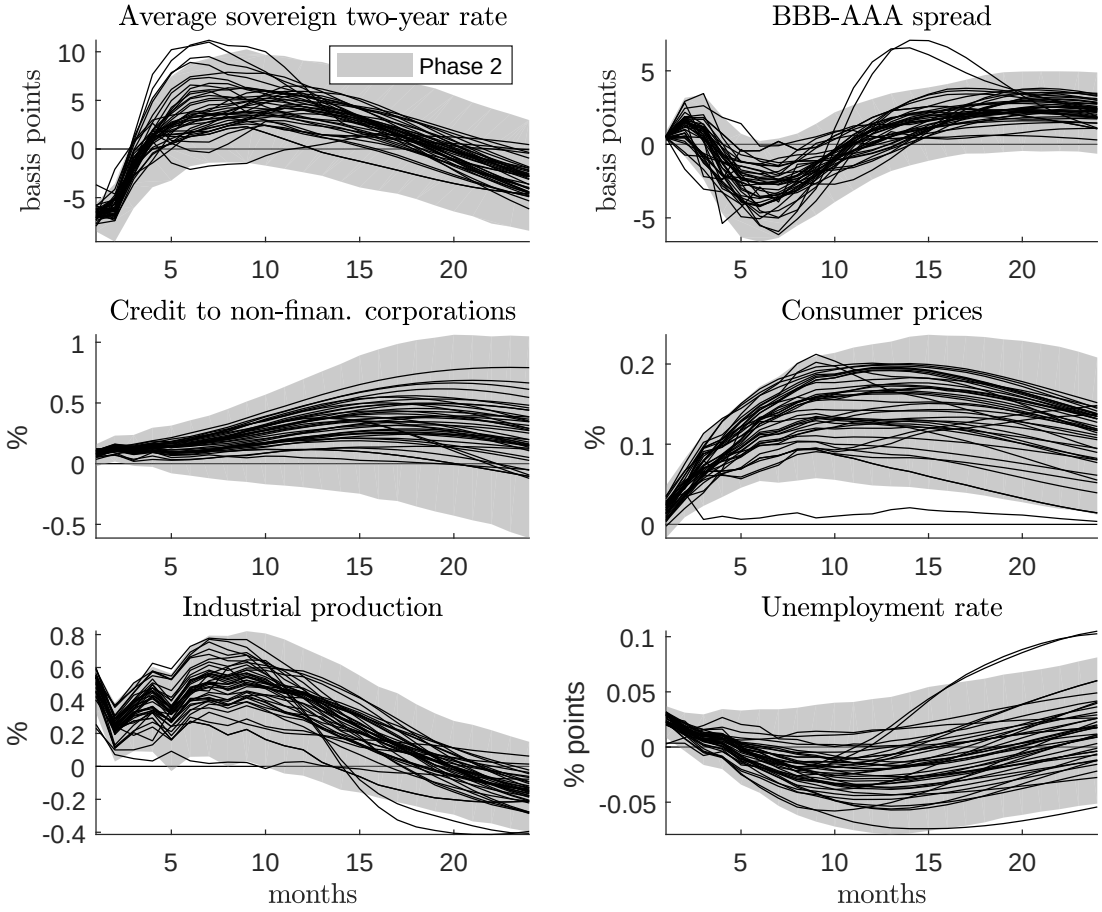
First, we look at the responses of the six baseline variables when adding the different marginal variables considered so far. Second, we increase the number of lags in the autoregressive component of the model from 5 to 8. Third, we replicate the analysis with eight lags using Bayesian estimation. Fourth, we estimate the reduced form model only on the period of unconventional monetary policy (2007M8-2016M11). Fifth, we compute impulse responses after winsorizing the instruments at 80% before identification. Sixth, we use the daily betas to construct the impulse vector as explained in footnote 11 in the paper. Seventh, we use a two-day event window for the construction of the proxy. Eighth, we use quarterly instead of monthly data. Ninth, we use only monthly VAR residuals in the estimation of the relative impulse vector. We replicate Figures 1 to 3 under the alternative model and data specifications. Finally, we construct three alternative proxies capturing specific aspects of ECB unconventional policy (credit easing, forward guidance, and quantitative easing), and a proxy merging phases 1 and 2, using either all yields or periphery yields. In the vast majority of cases, the responses are qualitatively the same as in the baseline model, and mostly also quantitatively similar.

Figure E.1: Robustness: baseline variables from Figure 1 when adding marginal variables (Phase I)



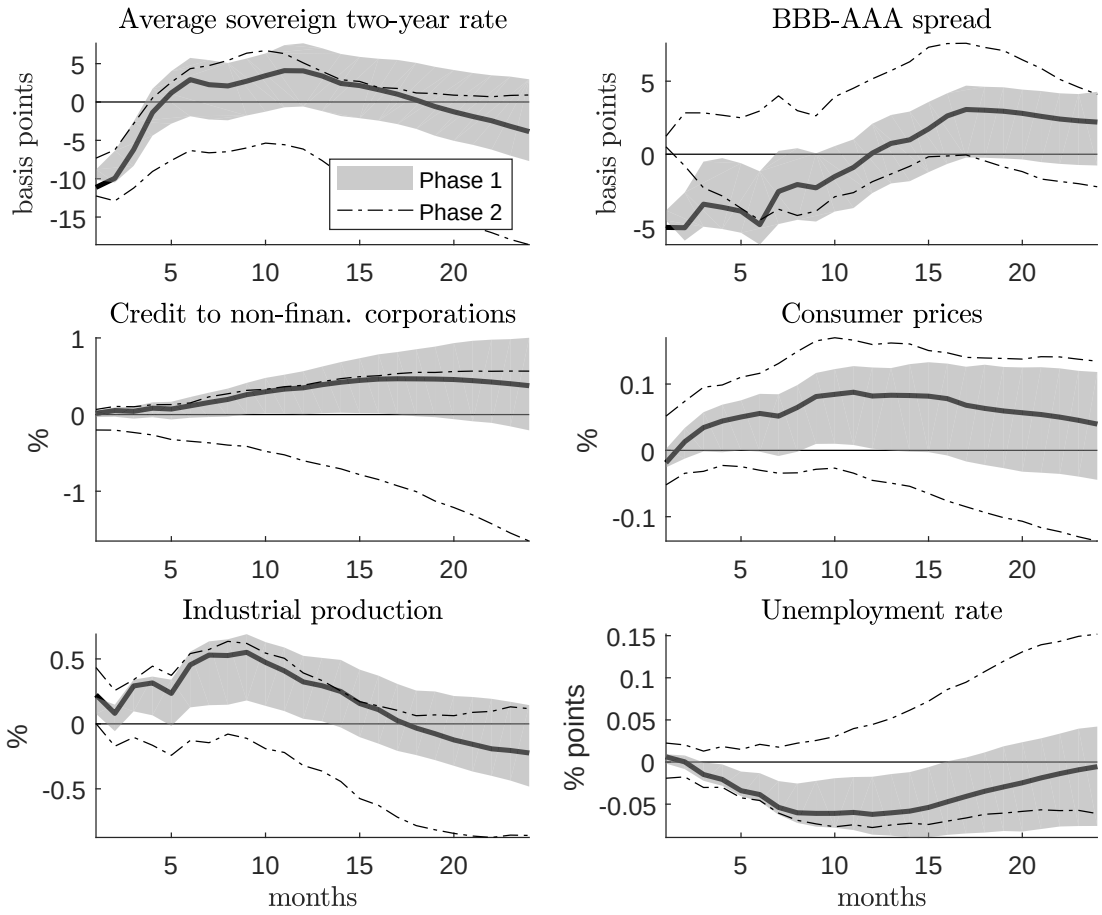
Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock. The shaded area shows the confidence band for a shock from the first phase of ECB unconventional monetary policy. The continuous lines show the point estimates of the impulse responses from the extended VARs from Figure 2 and Figure 3.

Figure E.2: Robustness: baseline variables from Figure 1 when adding marginal variables (Phase II)



Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock. The shaded area shows the confidence band for a shock from the second phase of ECB unconventional monetary policy. The continuous lines show the point estimates of the impulse responses from the extended VARs from Figure 2 and Figure 3.

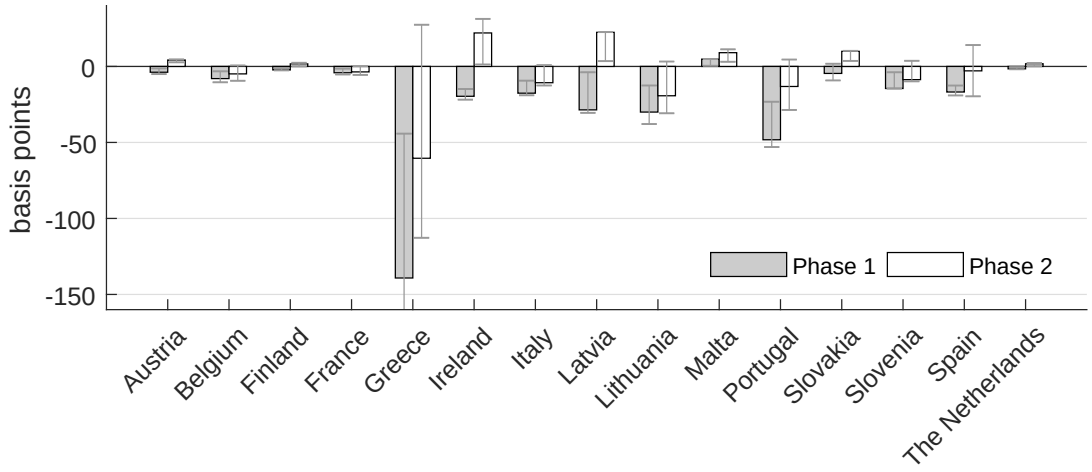
Figure E.3: Robustness: baseline variables from Figure 1 with eight lags rather than five



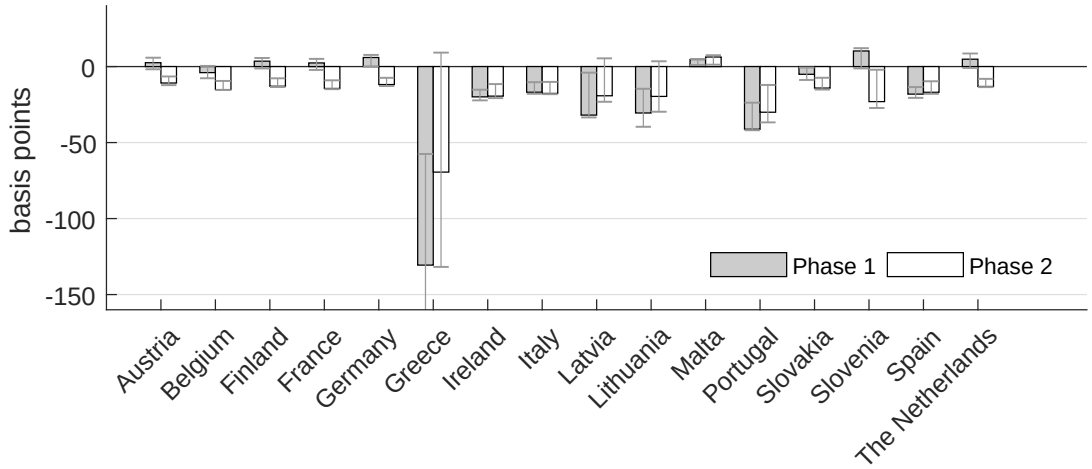
Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure E.4: Robustness: spreads and yields from Figure 2 with eight lags rather than five

(a) Spreads versus Germany

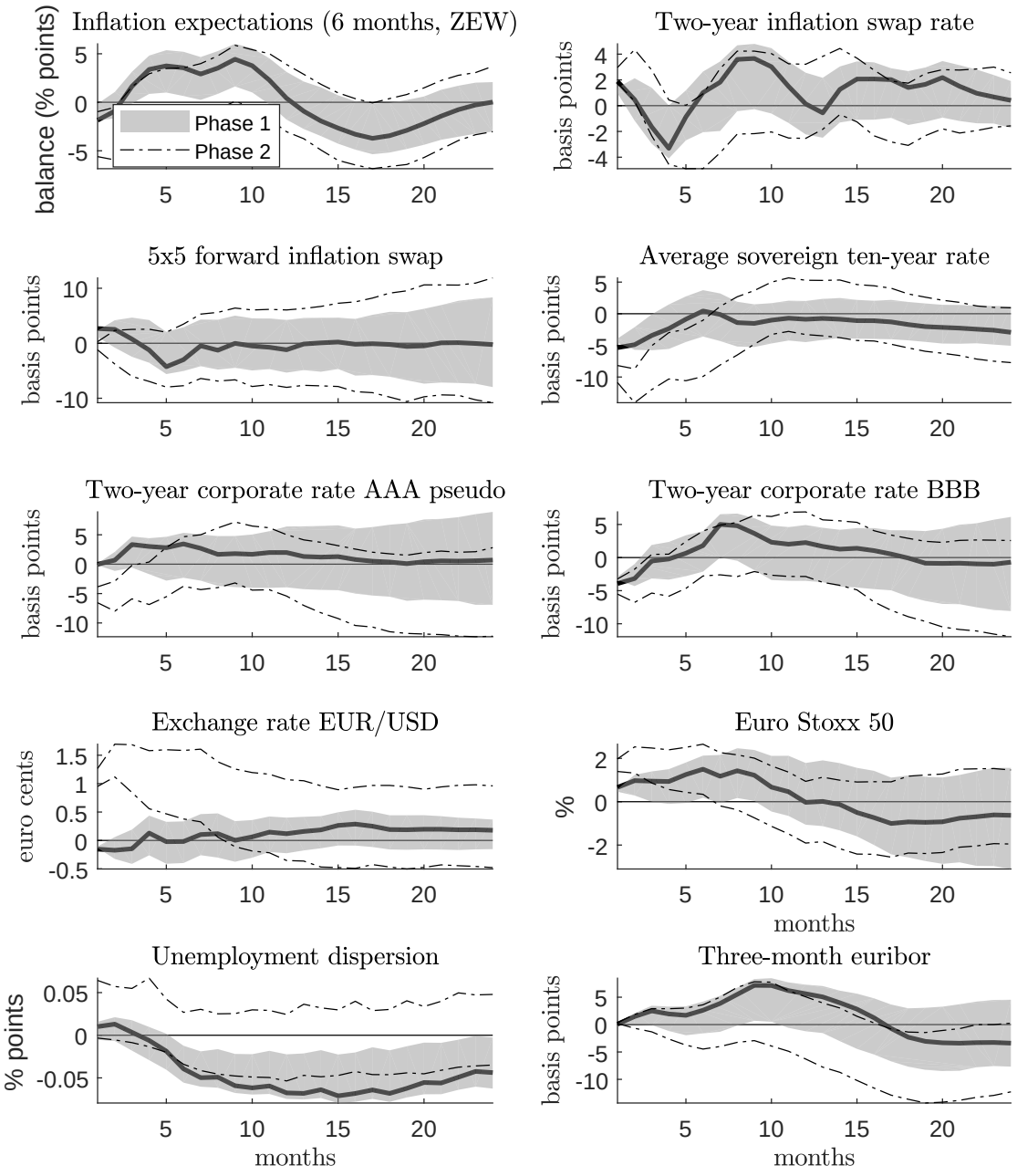


(b) Yields



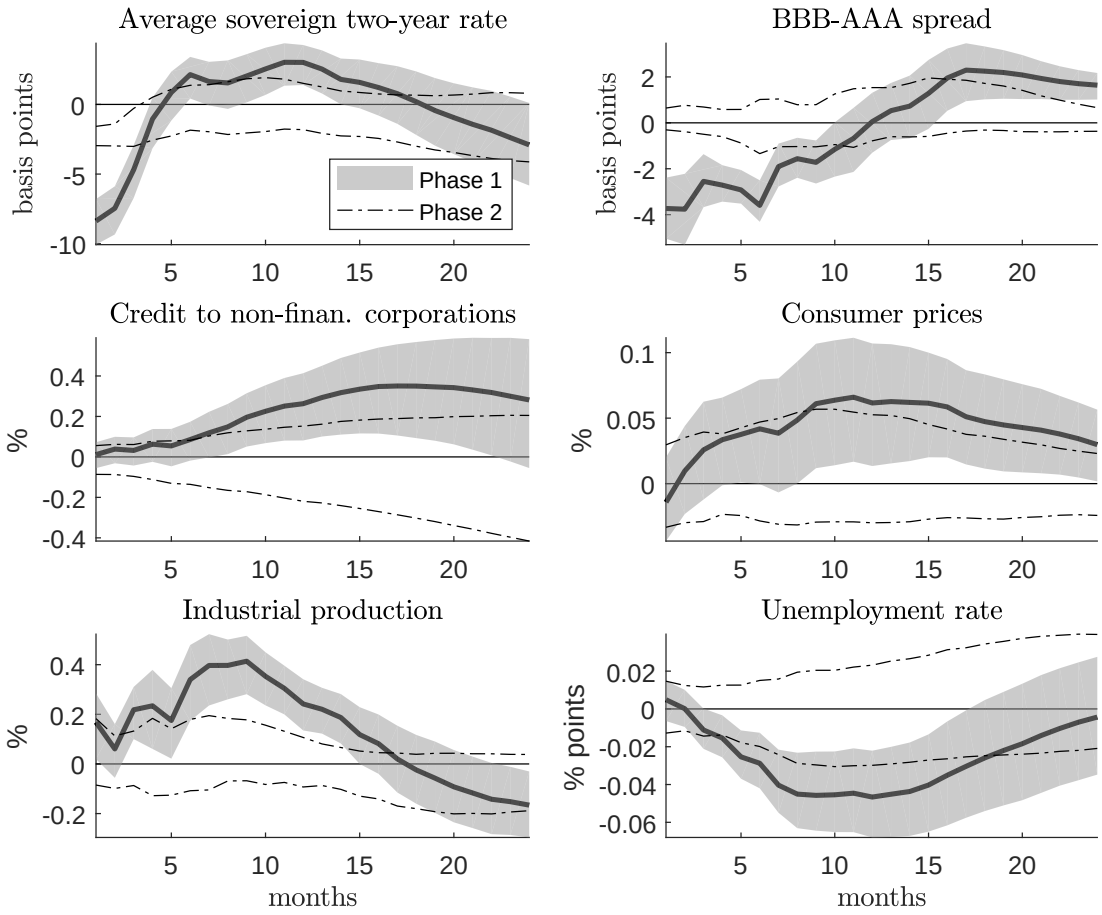
Notes: The figure shows the peak responses of ten-year country-specific sovereign spreads versus Germany (panel a) and ten-year government bond rates (panel b) after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the point estimate for a shock from the second phase. In panel *a*, the peaks are reached after the following months from the shock (phase 1-2): Aut 6-0; Bel 7-7; Fin 5-16; Fra 7-7; Gre 8-8; Ire 0-11; Ita 2-7; Lat 14-1; Lit 8-8; Mal 23-1; Por 6-6; Svk 7-1; Svn 2-3; Spa 0-23; Nld 5-16. In panel *b*, the peaks are reached after the following months from the shock (phase 1-2): Aut 5-1; Bel 7-1; Fin 4-1; Fra 5-1; Ger 5-1; Gre 8-8; Ire 0-0; Ita 1-1; Lat 15-18; Lit 8-7; Mal 1-1; Por 3-3; Svk 7-1; Svn 13-3; Spa 0-1; Nld 5-1.

Figure E.5: Robustness: other variables from Figure 3 with eight lags rather than five



Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

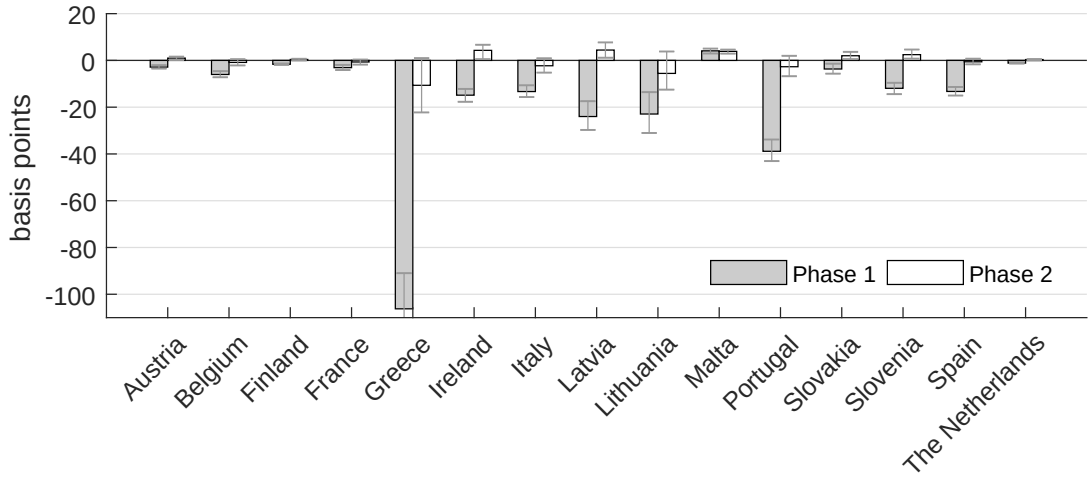
Figure E.6: Robustness: baseline variables from Figure 1 using Bayesian estimation with eight lags rather than five



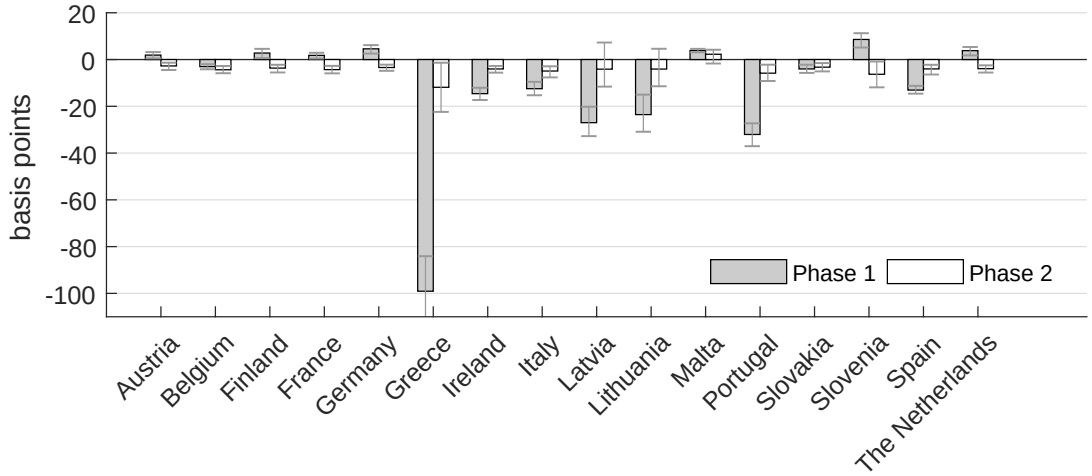
Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock, along with 90% credible sets obtained using 2000 posterior draws. The shaded area and the continuous line show the confidence band and the pointwise median response for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure E.7: Robustness: spreads and yields from Figure 2 using Bayesian estimation with eight lags rather than five

(a) Spreads versus Germany

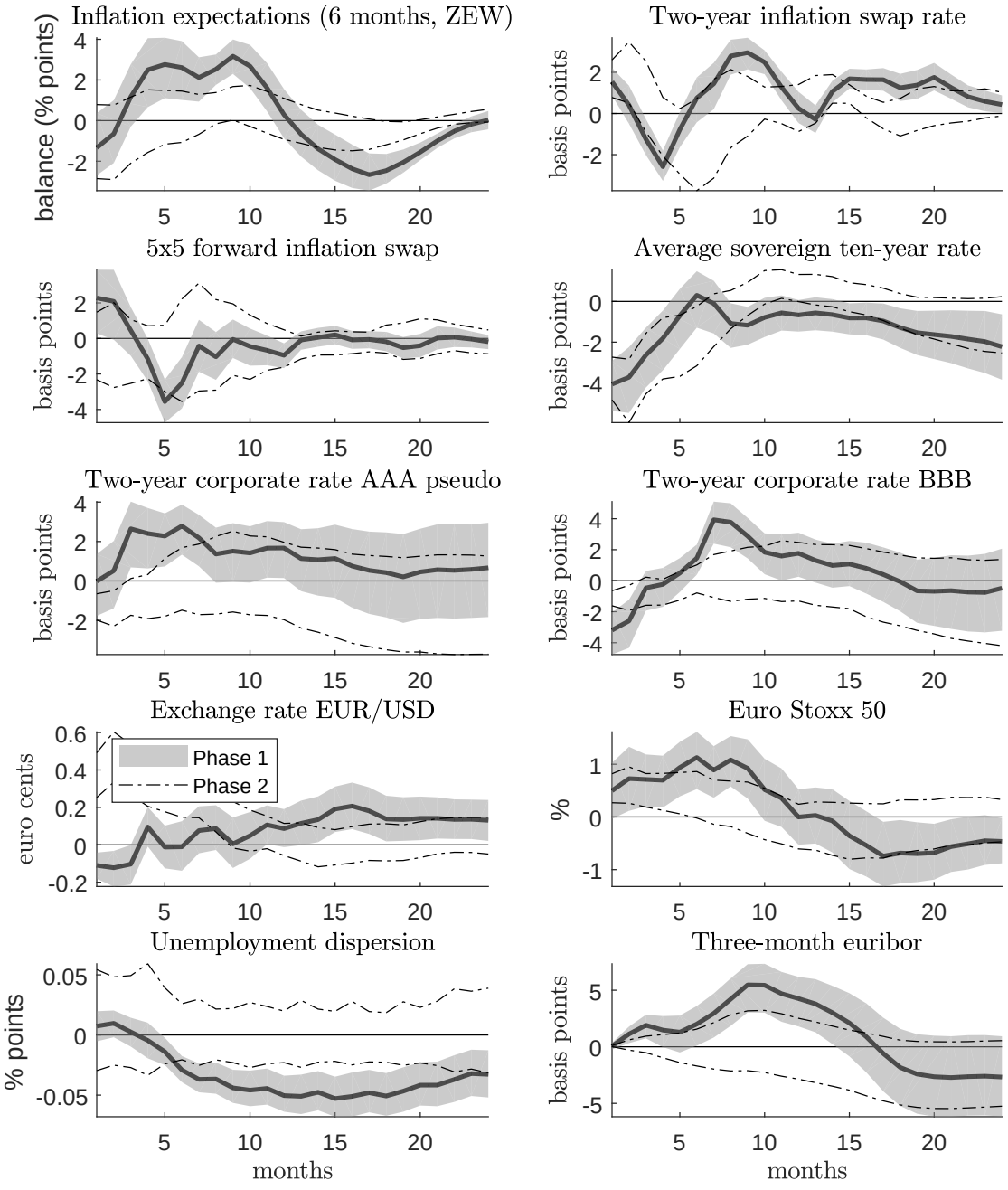


(b) Yields



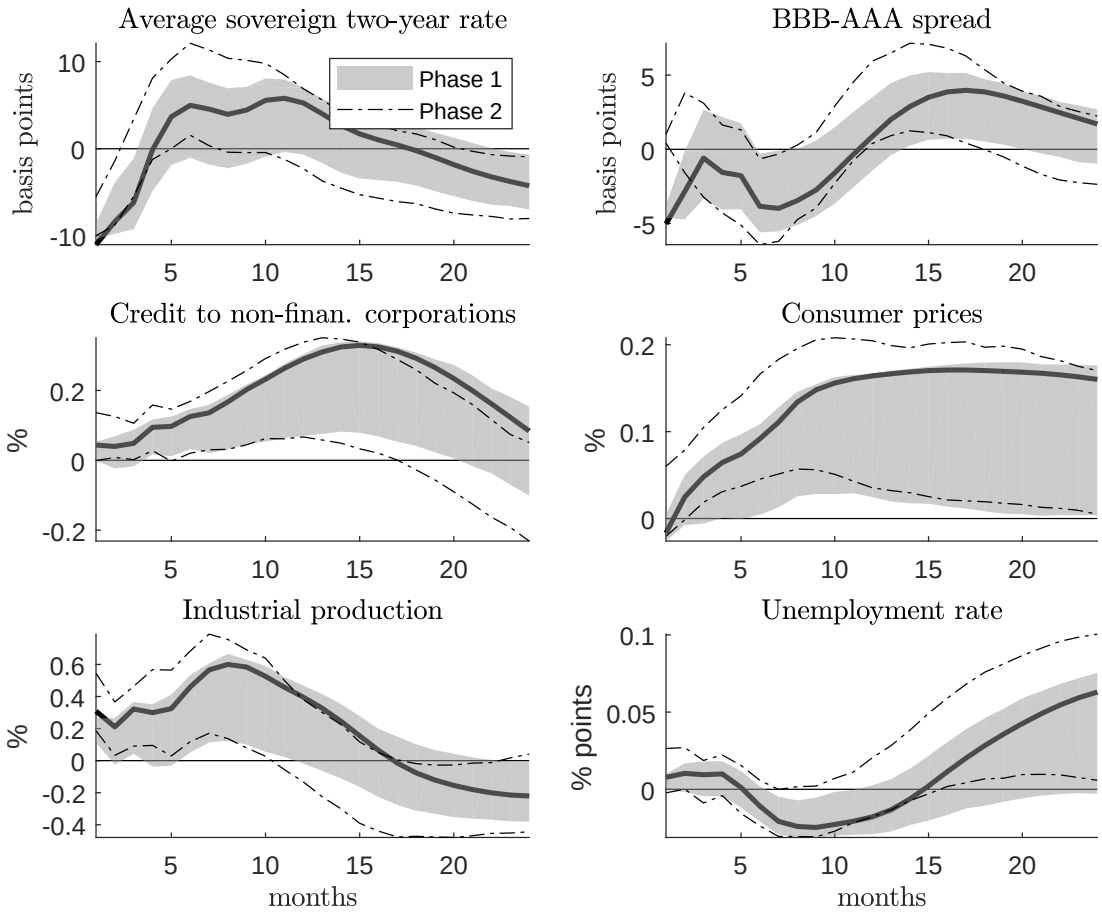
Notes: The figure shows the peak responses of ten-year country-specific sovereign spreads versus Germany (panel a) and ten-year government bond rates (panel b) after a one standard deviation expansionary monetary policy shock, along with 90% credible sets obtained using 2000 posterior draws. The shaded area shows the pointwise median response for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the pointwise median response for a shock from the second phase. In panel *a*, the peaks are reached after the following months from the shock (phase 1-2): Aut 7-0; Bel 7-7; Fin 5-16; Fra 7-7; Gre 8-8; Ire 0-11; Ita 2-7; Lat 14-1; Lit 8-8; Mal 23-1; Por 6-6; Svk 7-1; Svn 2-0; Spa 0-23; Nld 5-16. In panel *b*, the peaks are reached after the following months from the shock (phase 1-2): Aut 5-1; Bel 7-1; Fin 5-1; Fra 5-1; Ger 5-1; Gre 8-8; Ire 0-0; Ita 1-1; Lat 15-15; Lit 8-8; Mal 1-1; Por 3-3; Svk 7-1; Svn 13-3; Spa 0-1; Nld 5-1.

Figure E.8: Robustness: variables from Figure 3 using Bayesian estimation with eight lags rather than five



Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% credible sets obtained using 2000 posterior draws. The shaded area and the continuous line show the confidence band and the pointwise median response for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

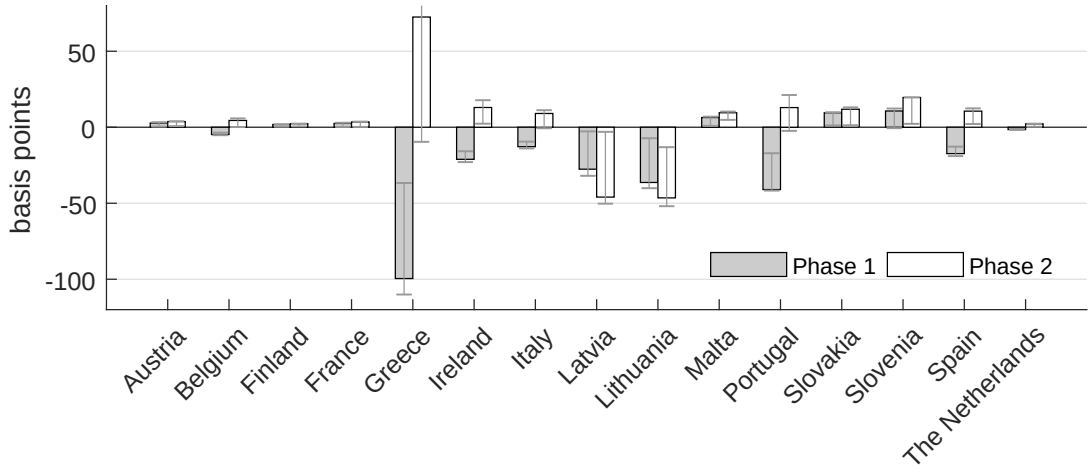
Figure E.9: Robustness: baseline variables from Figure 1 after estimating the VAR from August 2007



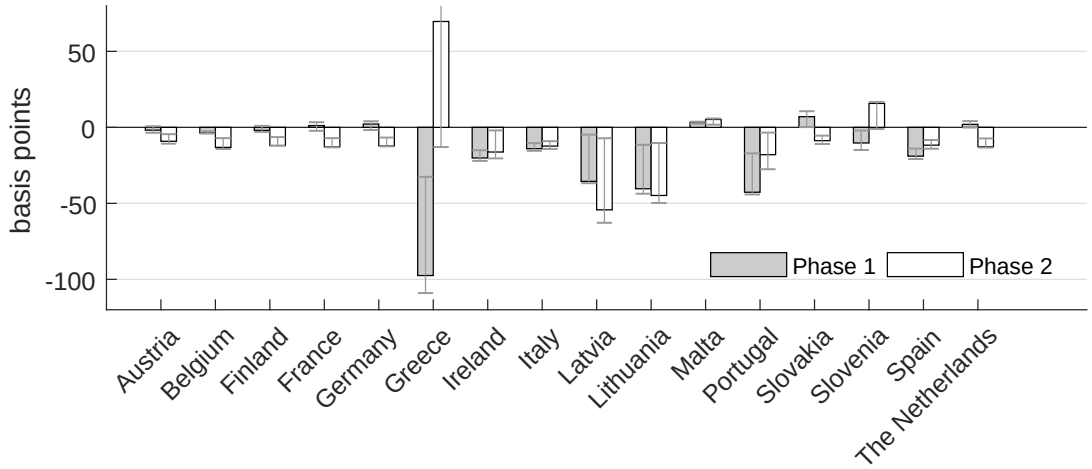
Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure E.10: Robustness: spreads and yields from Figure 2 after after estimating the VAR from August 2007

(a) Spreads versus Germany

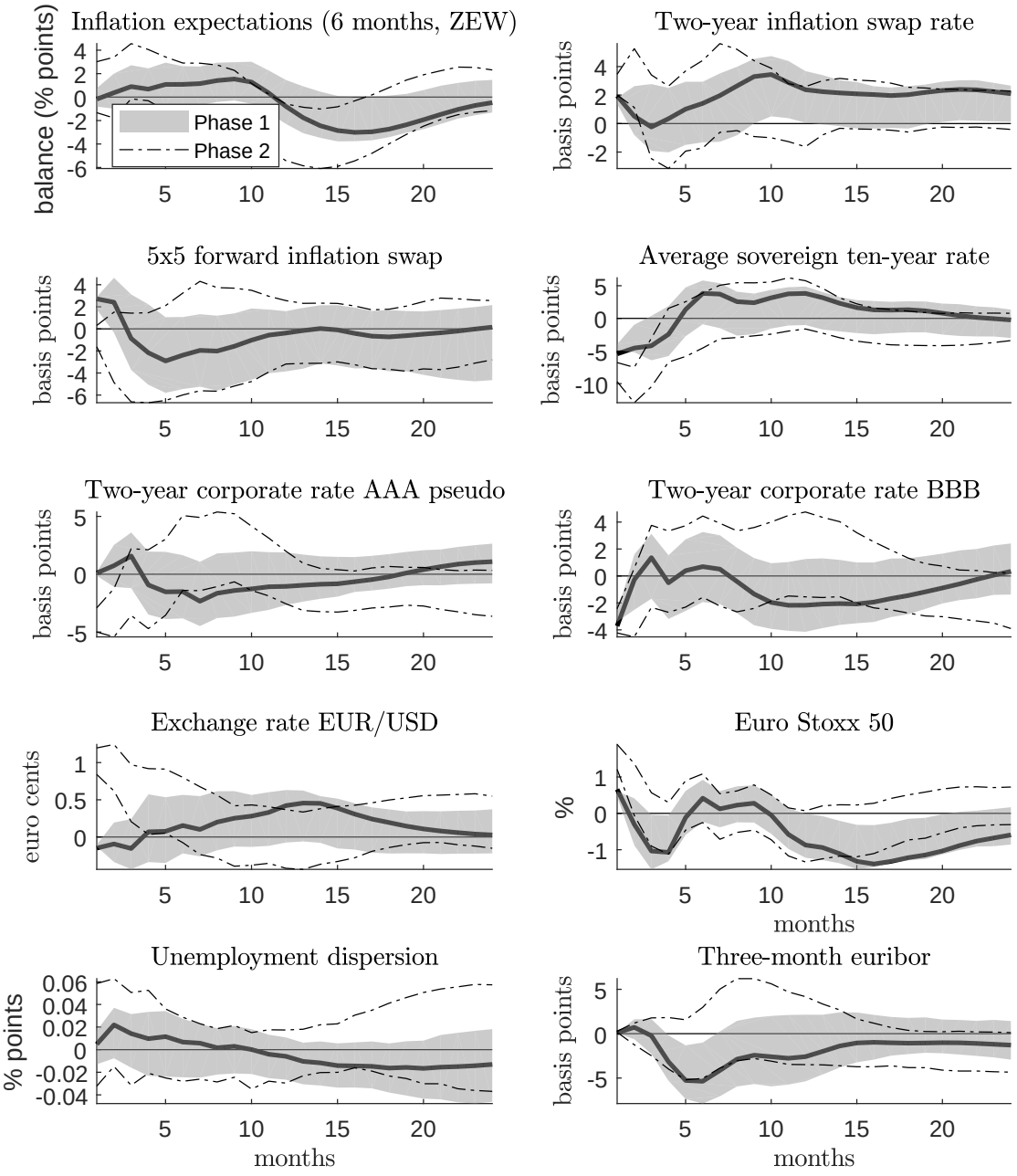


(b) Yields



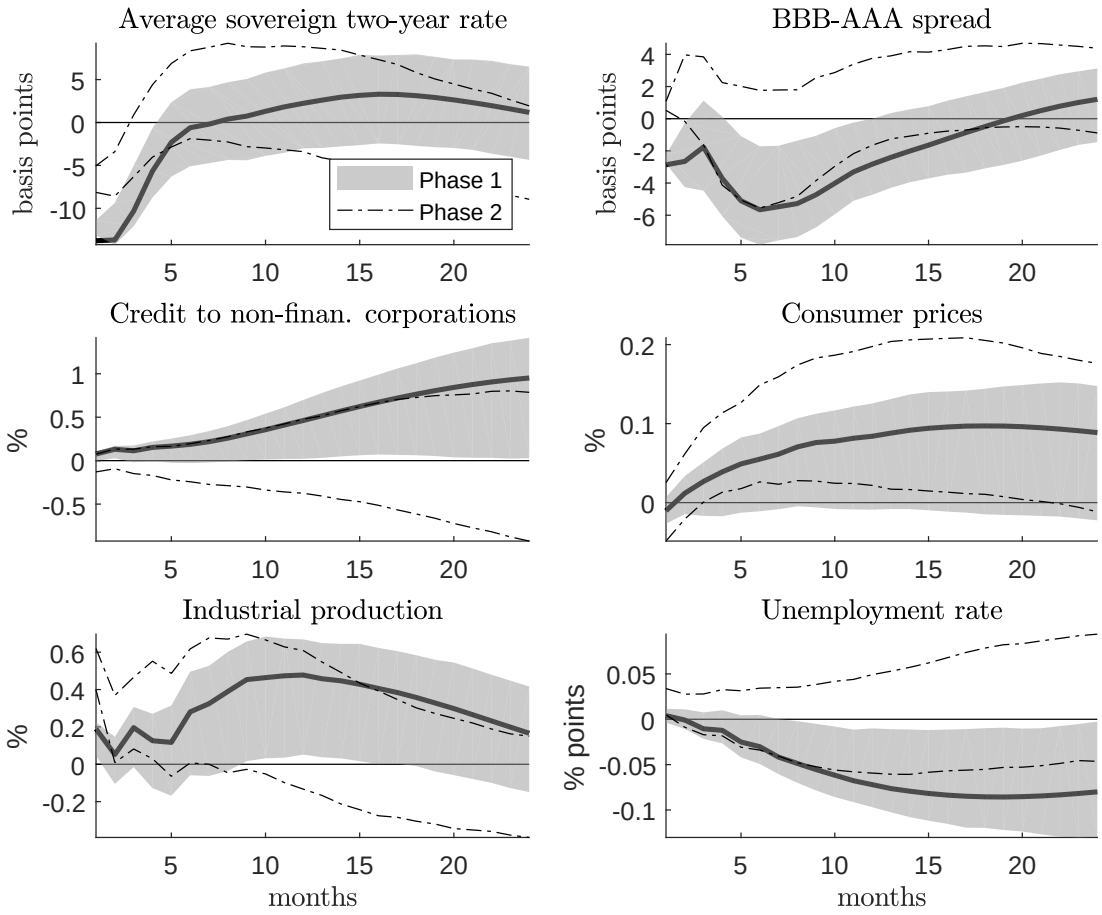
Notes: The figure shows the peak responses of ten-year country-specific sovereign spreads versus Germany (panel a) and ten-year government bond rates (panel b) after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the point estimate for a shock from the second phase. In panel *a*, the peaks are reached after the following months from the shock (phase 1-2): Aut 16-16; Bel 0-13; Fin 15-15; Fra 16-14; Gre 2-4; Ire 0-11; Ita 0-3; Lat 14-15; Lit 7-7; Mal 23-1; Por 3-13; Svk 18-16; Svn 18-4; Spa 0-3; Nld 0-14. In panel *b*, the peaks are reached after the following months from the shock (phase 1-2): Aut 23-1; Bel 0-1; Fin 15-1; Fra 5-1; Ger 6-1; Gre 2-4; Ire 0-2; Ita 0-0; Lat 15-15; Lit 7-7; Mal 0-1; Por 3-2; Svk 18-1; Svn 2-6; Spa 0-0; Nld 1-1.

Figure E.11: Robustness: other variables from Figure 3 after estimating the VAR from August 2007



Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

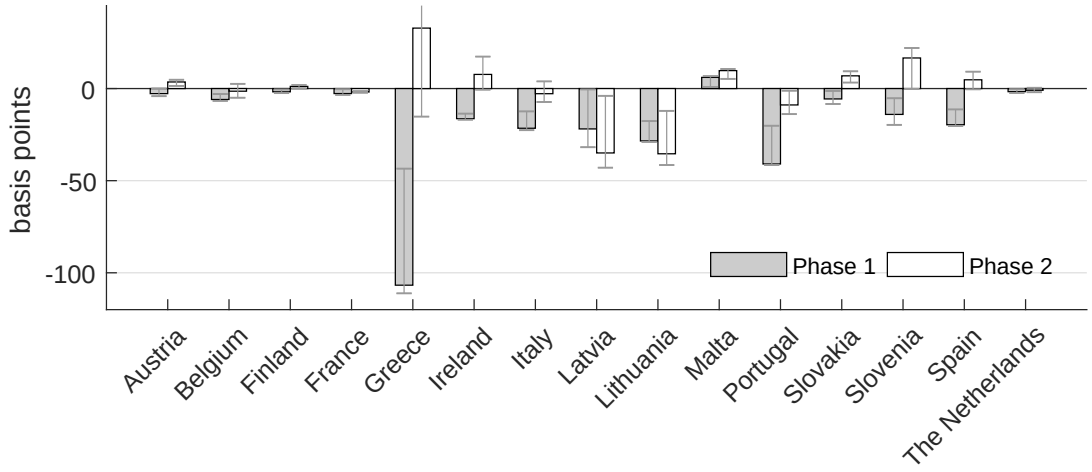
Figure E.12: Robustness: baseline variables from Figure 1 after a 80% winsorization of the external instruments



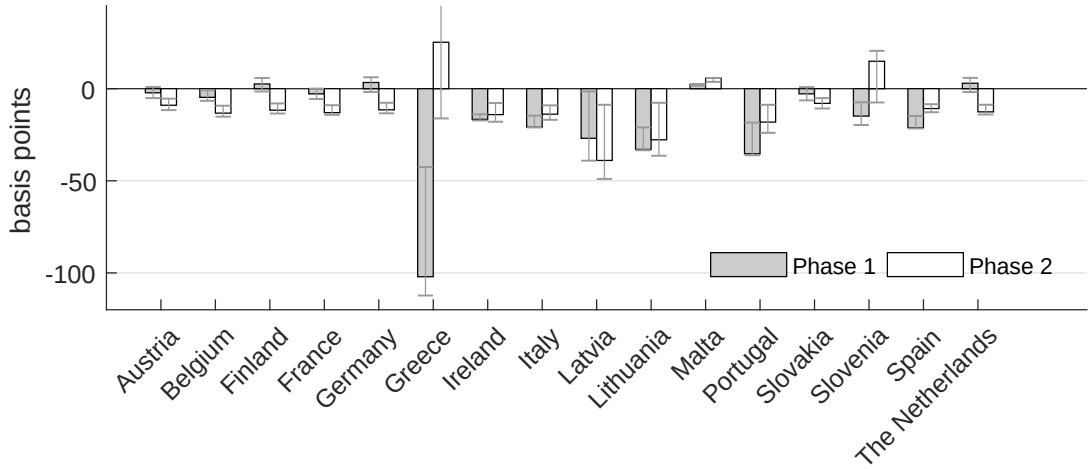
Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase. The 80% winsorization of the proxies is applied to the daily proxy before aggregation to the monthly frequency.

Figure E.13: Robustness: spreads and yields from Figure 2 after a 80% winsorization of the external instruments

(a) Spreads versus Germany

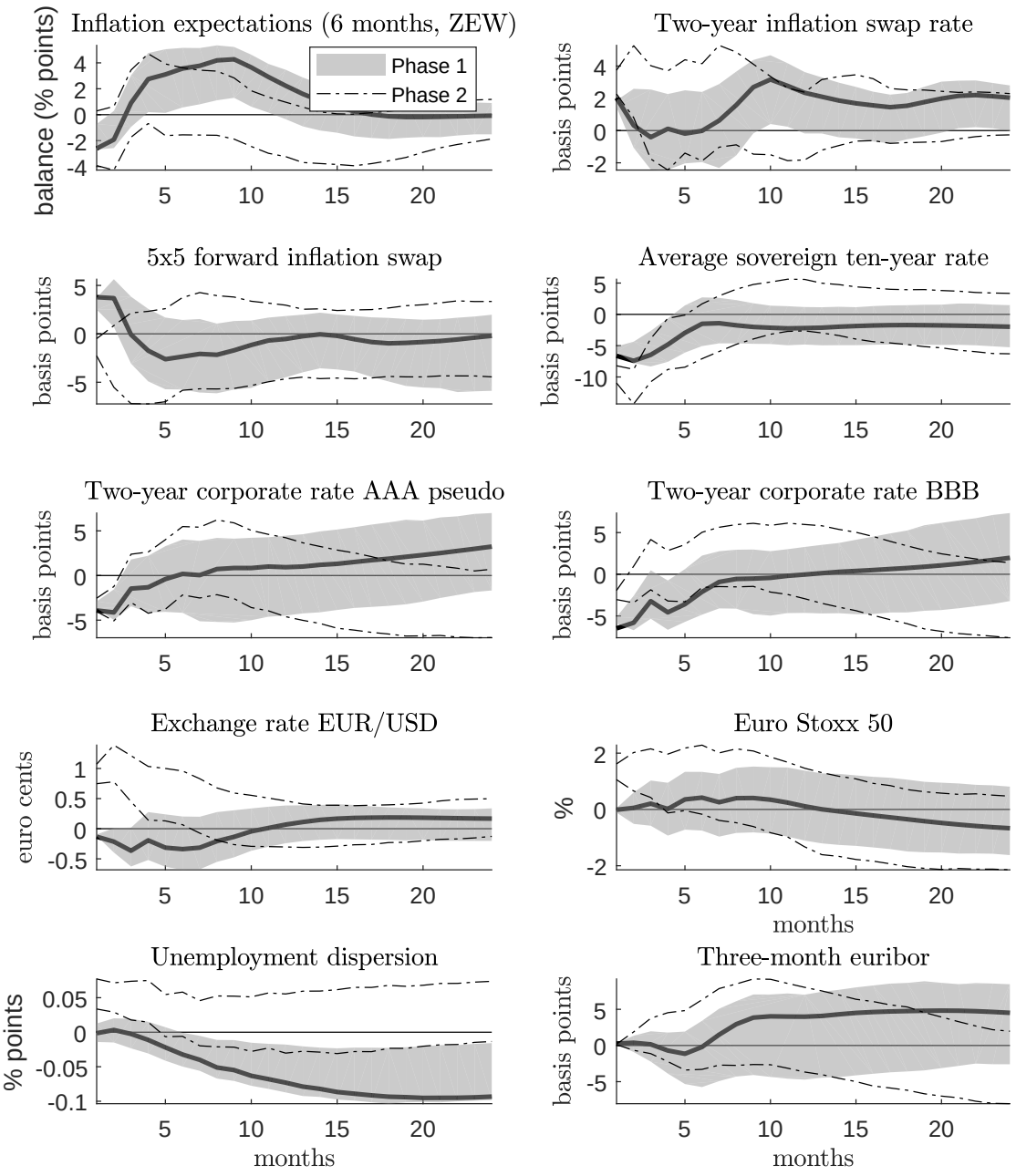


(b) Yields



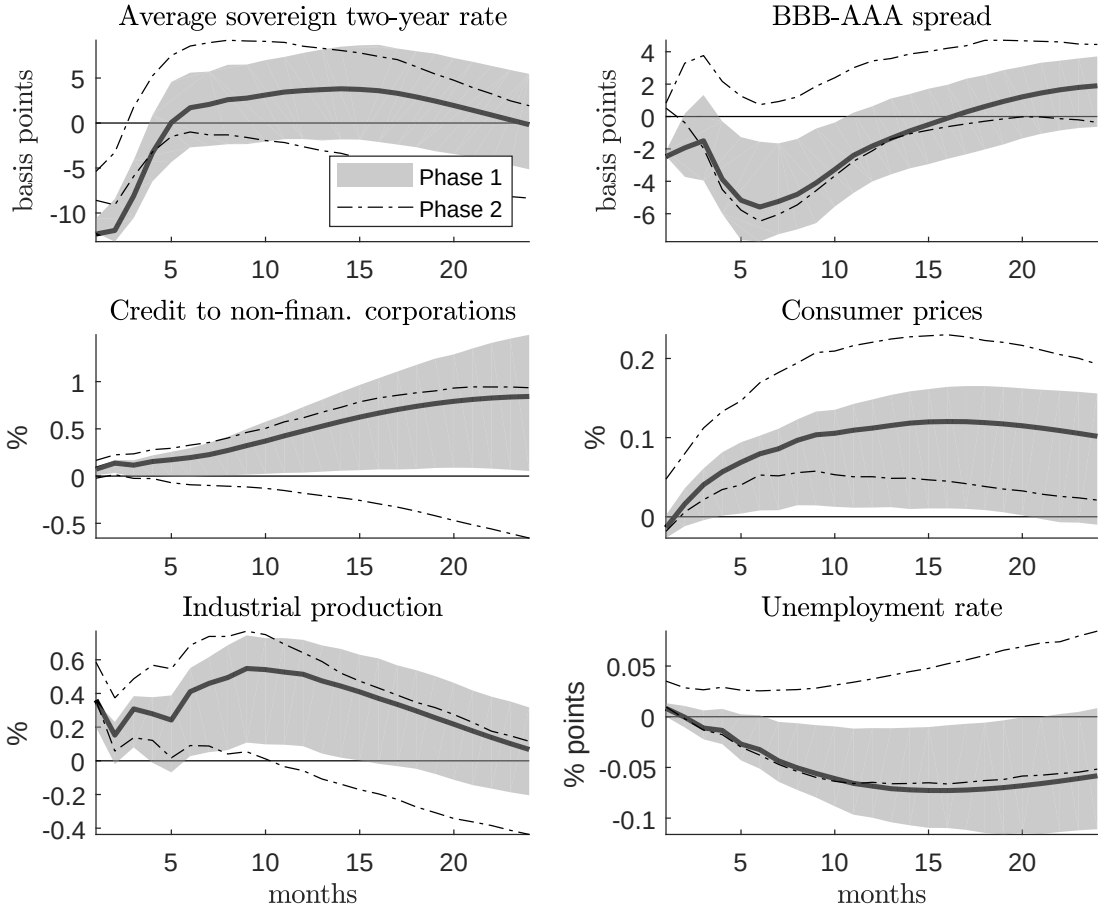
Notes: The figure shows the peak responses of ten-year country-specific sovereign spreads versus Germany (panel a) and ten-year government bond rates (panel b) after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the point estimate for a shock from the second phase. In panel *a*, the peaks are reached after the following months from the shock (phase 1-2): Aut 7-3; Bel 2-7; Fin 7-3; Fra 7-0; Gre 3-4; Ire 0-6; Ita 2-7; Lat 15-14; Lit 2-7; Mal 23-1; Por 4-2; Svk 2-1; Svn 2-4; Spa 2-3; Nld 6-5. In panel *b*, the peaks are reached after the following months from the shock (phase 1-2): Aut 10-1; Bel 2-1; Fin 5-1; Fra 10-1; Ger 5-1; Gre 3-4; Ire 0-1; Ita 1-1; Lat 15-15; Lit 2-7; Mal 0-0; Por 3-2; Svk 2-1; Svn 2-5; Spa 1-0; Nld 5-1.

Figure E.14: Robustness: other variables from Figure 3 after a 80% winsorization of the external instruments



Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

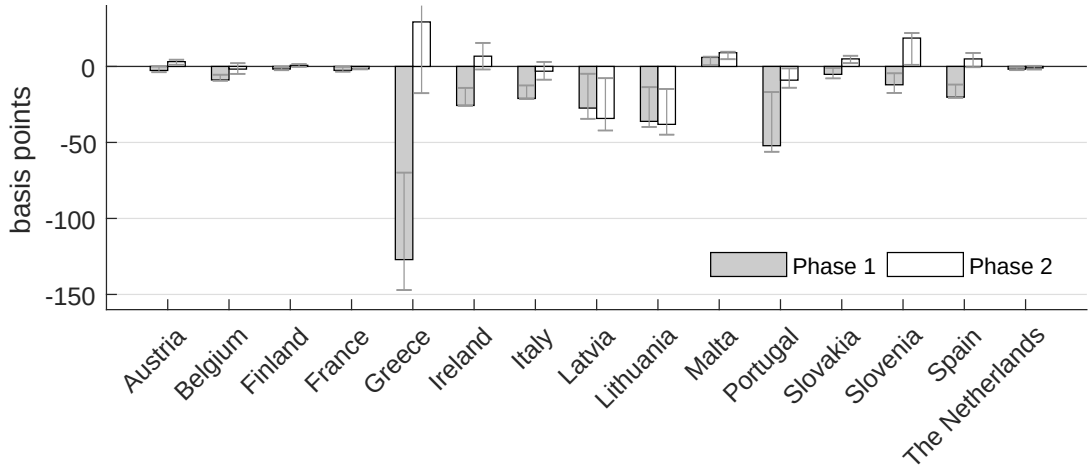
Figure E.15: Robustness: baseline variables from Figure 1, using the daily betas from footnote 11 in the paper



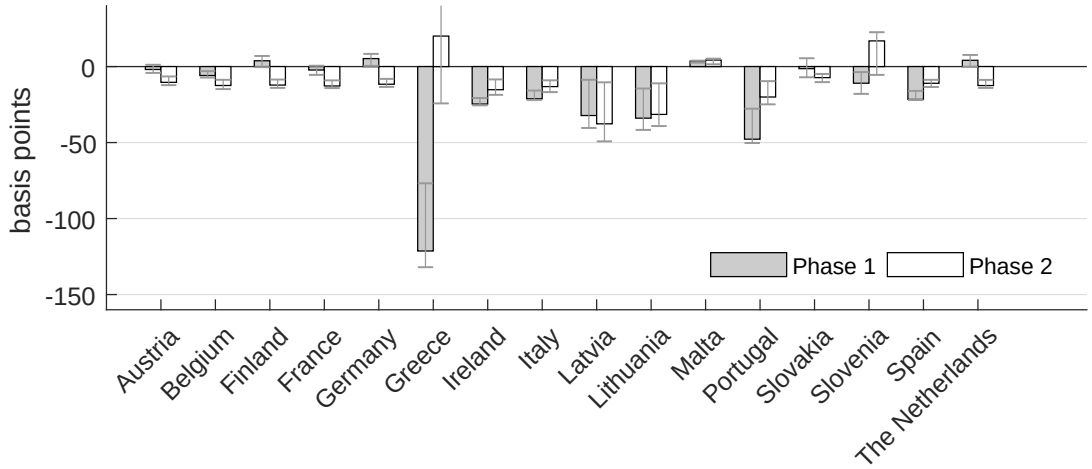
Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure E.16: Robustness: spreads and yields from Figure 2, using the daily betas from footnote 11 in the paper

(a) Spreads versus Germany

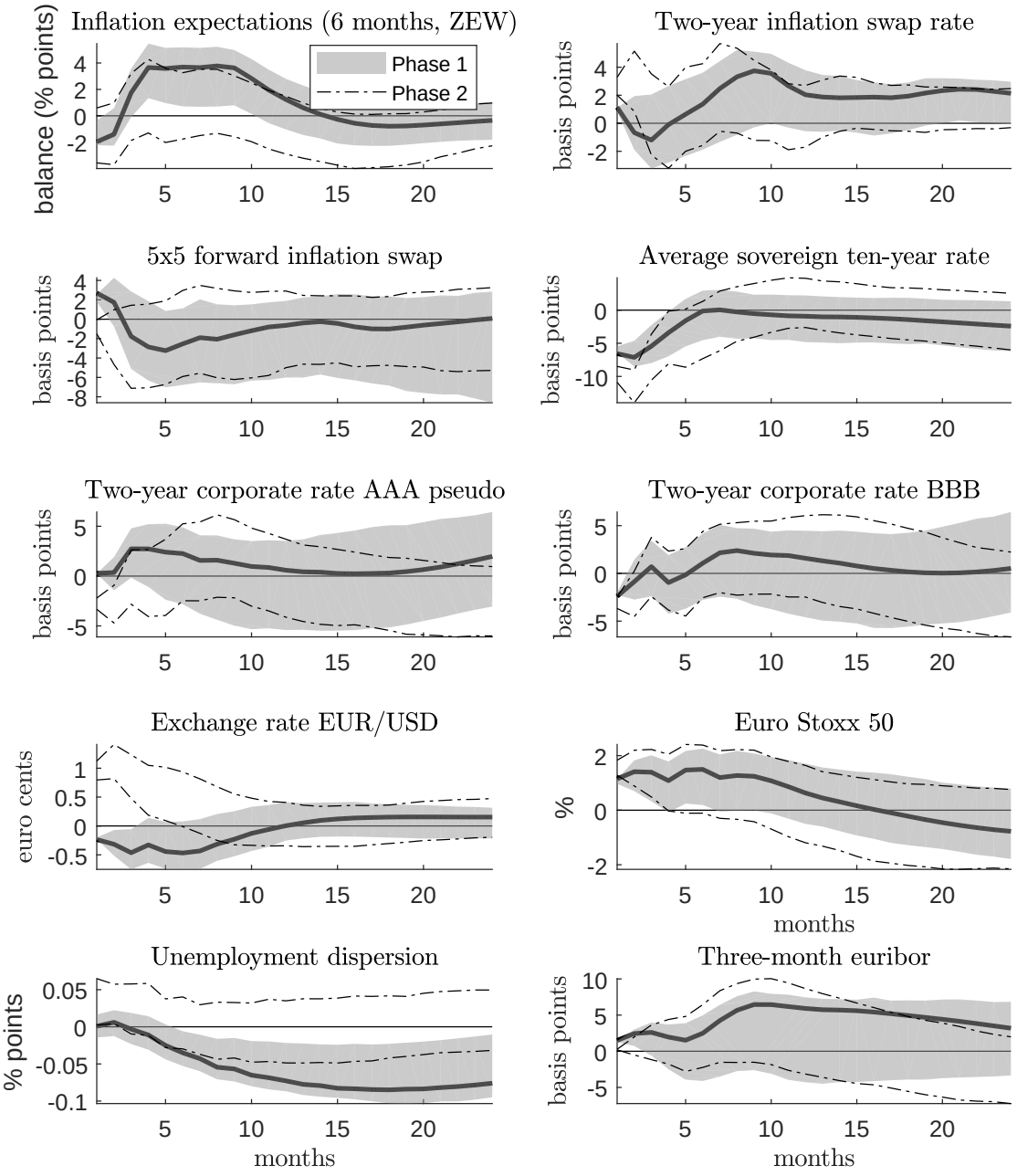


(b) Yields



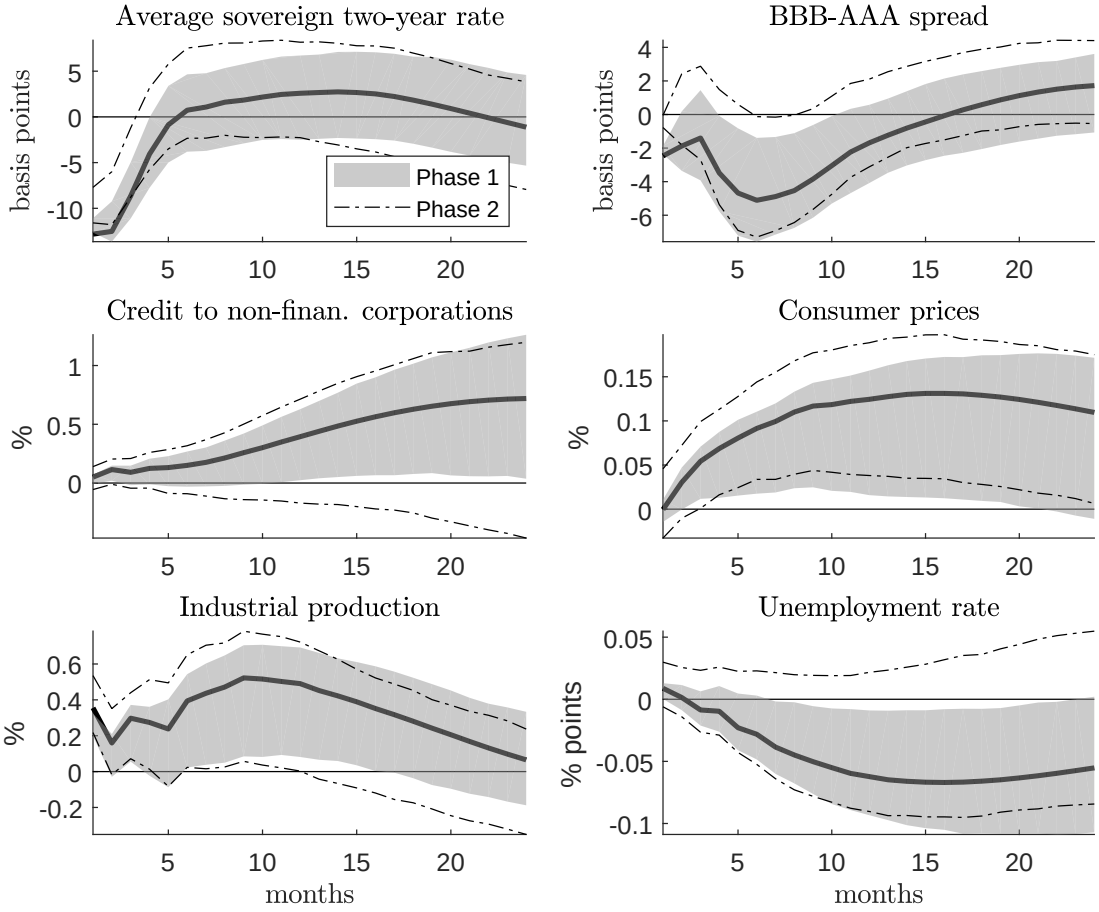
Notes: The figure shows the peak responses of ten-year country-specific sovereign spreads versus Germany (panel a) and ten-year government bond rates (panel b) after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the point estimate for a shock from the second phase. In panel *a*, the peaks are reached after the following months from the shock (phase 1-2): Aut 7-3; Bel 2-7; Fin 5-3; Fra 7-0; Gre 3-4; Ire 2-6; Ita 2-7; Lat 15-14; Lit 7-7; Mal 23-1; Por 7-2; Svk 2-1; Svn 2-4; Spa 2-3; Nld 5-5. In panel *b*, the peaks are reached after the following months from the shock (phase 1-2): Aut 10-1; Bel 1-1; Fin 5-1; Fra 11-1; Ger 5-1; Gre 2-4; Ire 0-1; Ita 1-1; Lat 15-15; Lit 8-7; Mal 0-1; Por 3-2; Svk 2-5; Svn 2-5; Spa 1-0; Nld 5-1.

Figure E.17: Robustness: other variables from Figure 3, using the daily betas from footnote 11 in the paper



Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

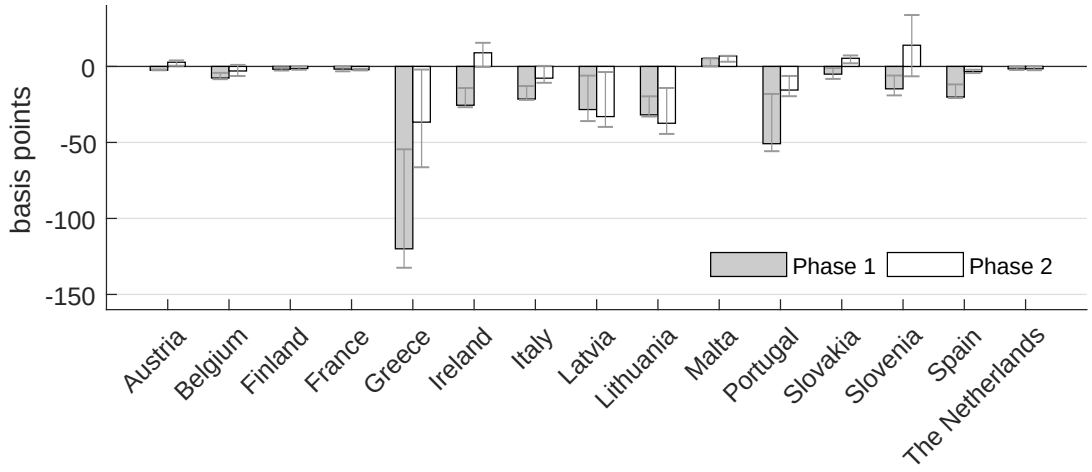
Figure E.18: Robustness: baseline variables from Figure 1, using a two day window around the events



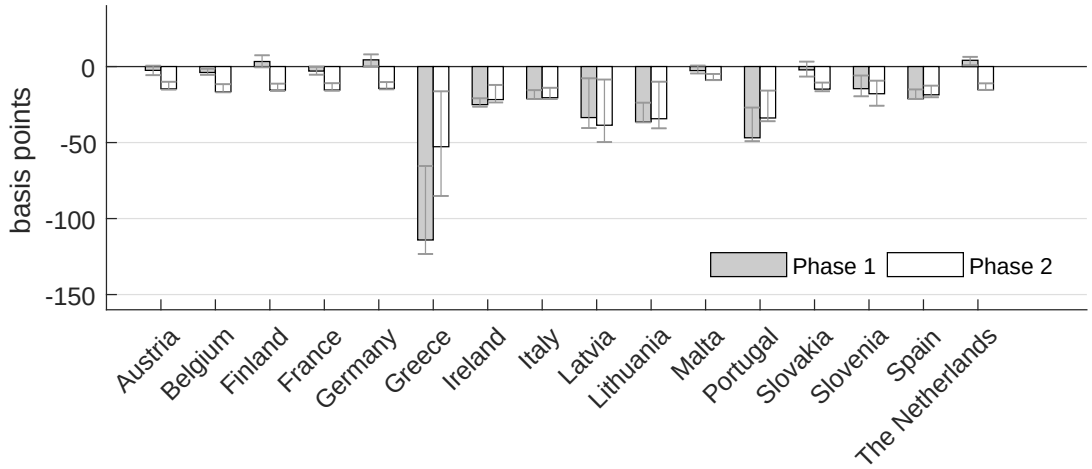
Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure E.19: Robustness: spreads and yields from Figure 2, using a two day window around the events

(a) Spreads versus Germany

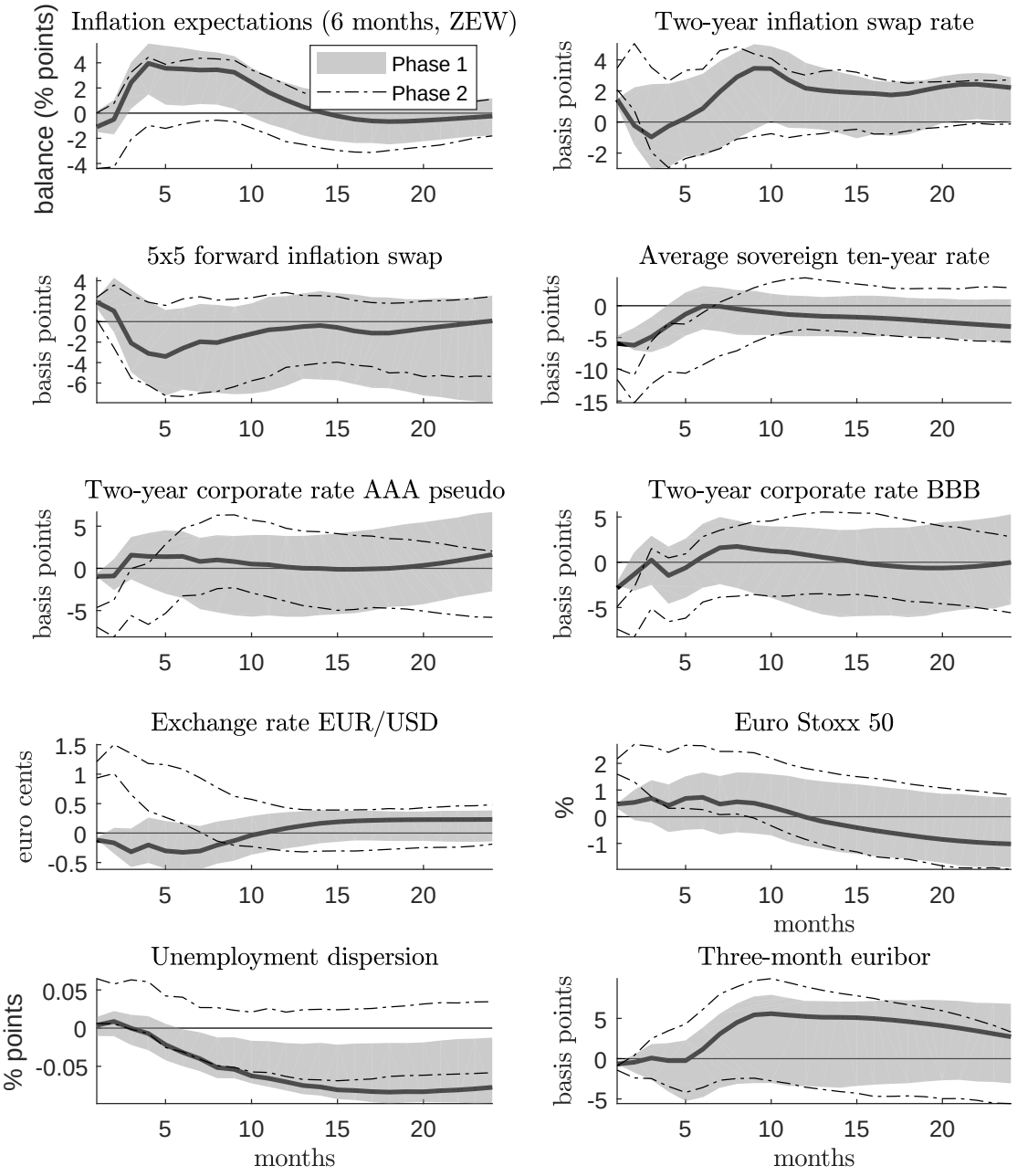


(b) Yields



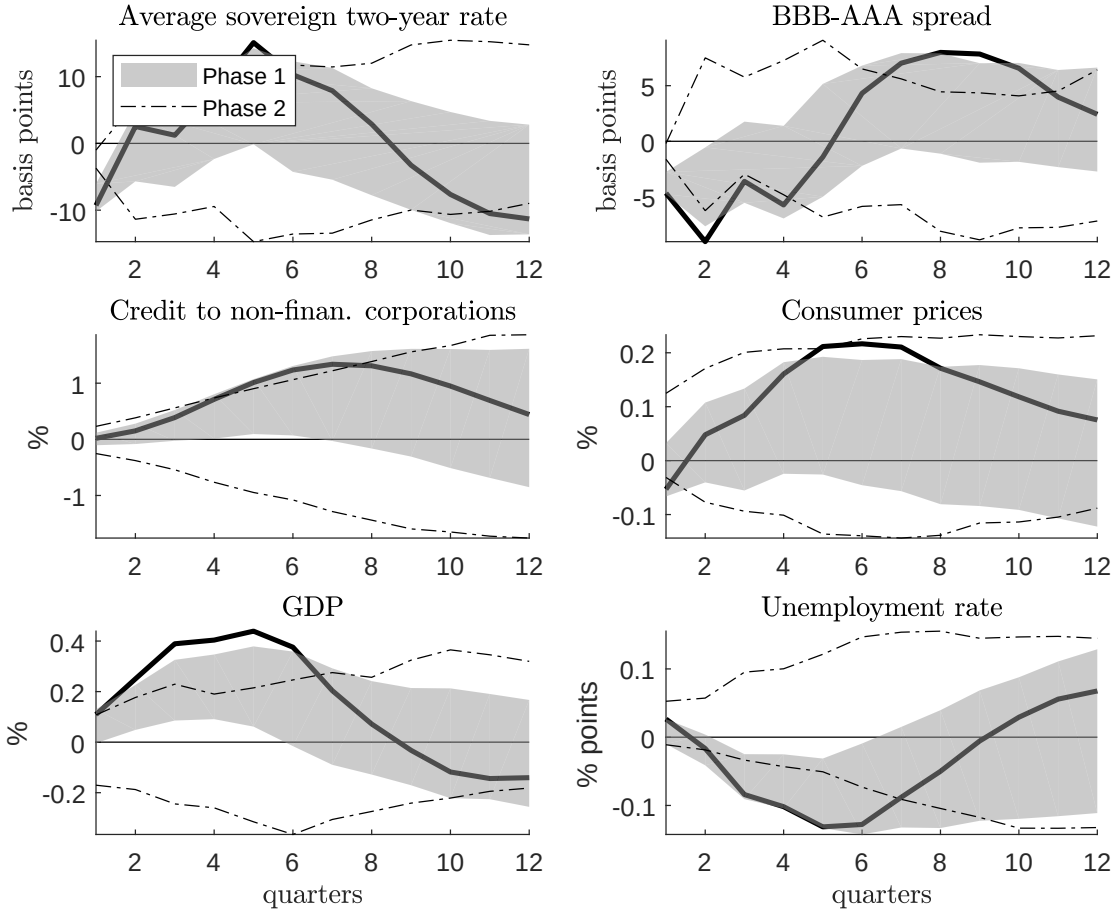
Notes: The figure shows the peak responses of ten-year country-specific sovereign spreads versus Germany (panel a) and ten-year government bond rates (panel b) after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the point estimate for a shock from the second phase. In panel *a*, the peaks are reached after the following months from the shock (phase 1-2): Aut 0-3; Bel 2-7; Fin 5-5; Fra 7-0; Gre 3-2; Ire 2-7; Ita 2-7; Lat 15-14; Lit 7-2; Mal 23-1; Por 7-2; Svk 2-1; Svn 2-13; Spa 2-0; Nld 5-5. In panel *b*, the peaks are reached after the following months from the shock (phase 1-2): Aut 11-1; Bel 1-1; Fin 5-1; Fra 11-1; Ger 5-1; Gre 2-2; Ire 0-1; Ita 1-1; Lat 15-15; Lit 2-7; Mal 3-1; Por 3-3; Svk 23-1; Svn 2-2; Spa 1-1; Nld 2-1.

Figure E.20: Robustness: other variables from Figure 3, using a two day window around the events



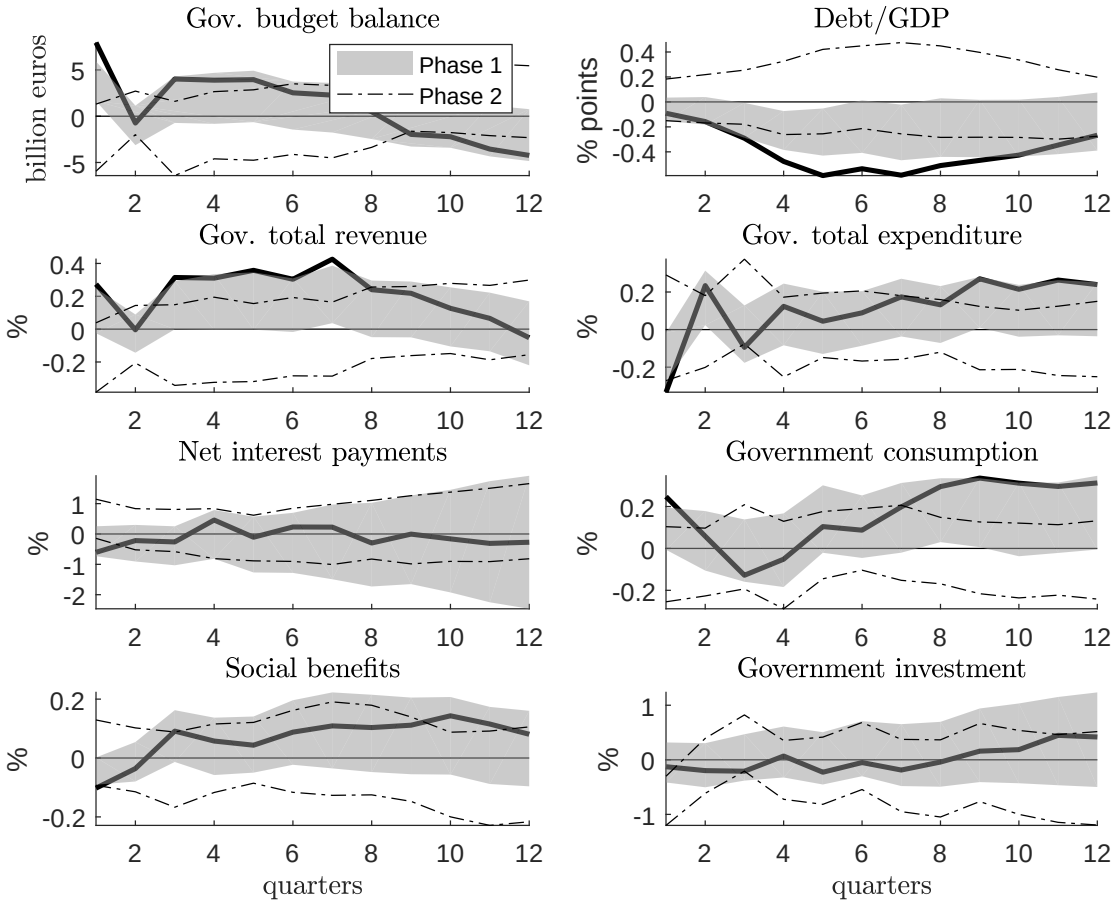
Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure E.21: Robustness: baseline model for the euro area, using quarterly data and four lags



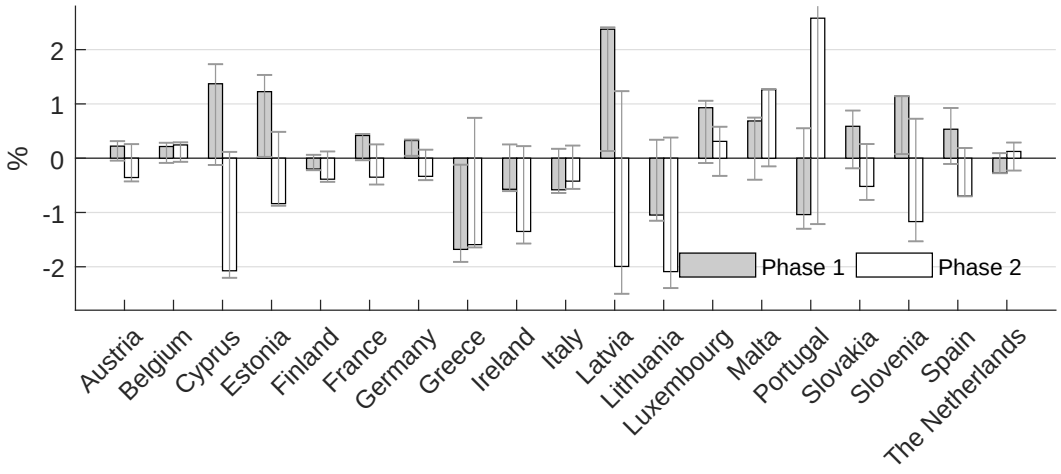
Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase. Relative to Figure 1 we replace industrial production with real GDP and and aggregate to quarterly frequency the remaining variables.

Figure E.22: Robustness: fiscal responses at the euro area level, using quarterly data and four lags



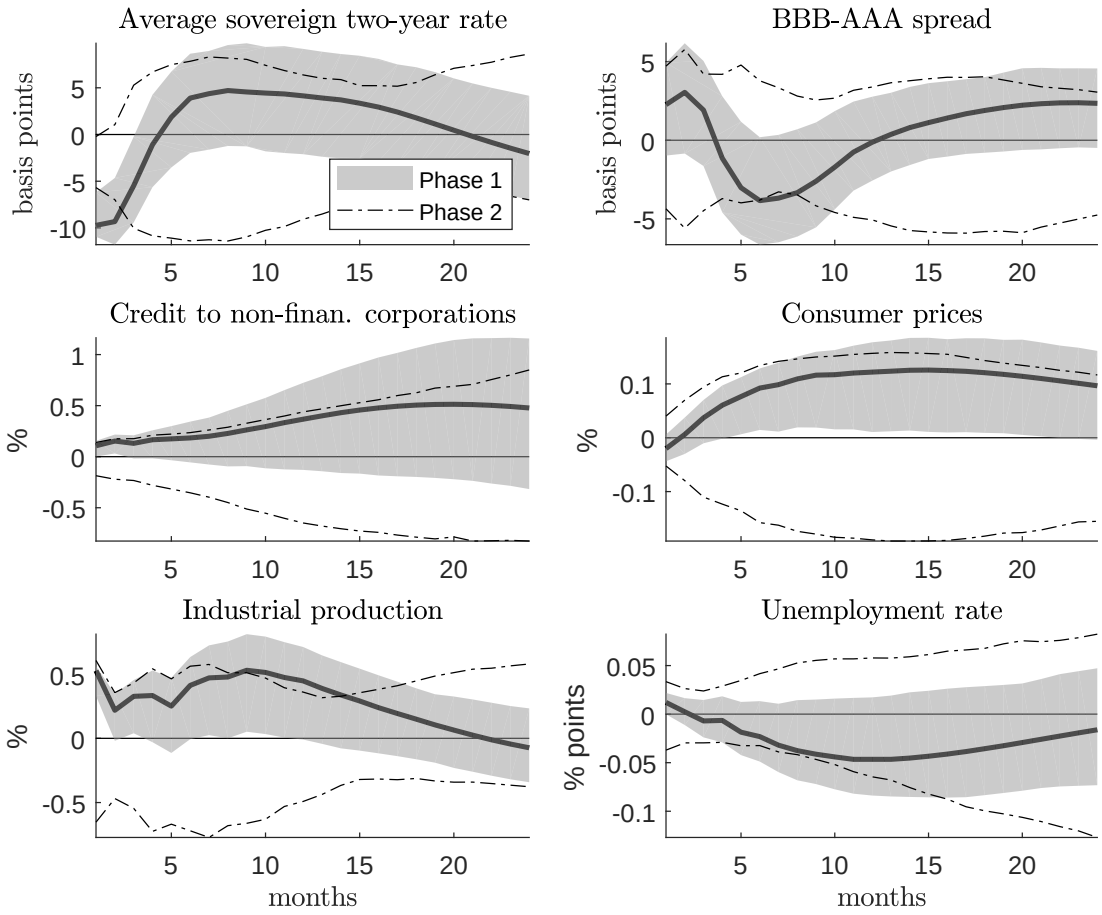
Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure E.23: Robustness: peak responses of government consumption, using quarterly data and four lags



Notes: The figure shows the peak responses of country-specific government consumption after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the point estimate for a shock from the second phase. The peaks are reached after the following quarters from the shock (phase 1-2): Aut 6-0; Bel 0-4; Cyp 0-0; Est 6-6; Fin 0-0; Fra 1-0; Ger 2-11; Gre 4-0; Ire 0-0; Ita 2-8; Lat 3-7; Lit 1-0; Lux 0-2; Mal 5-2; Por 3-0; Svk 11-9; Svn 11-0; Spa 9-3; Nld 3-7. Figure D.3 in the online appendix reports the full underlying impulse responses.

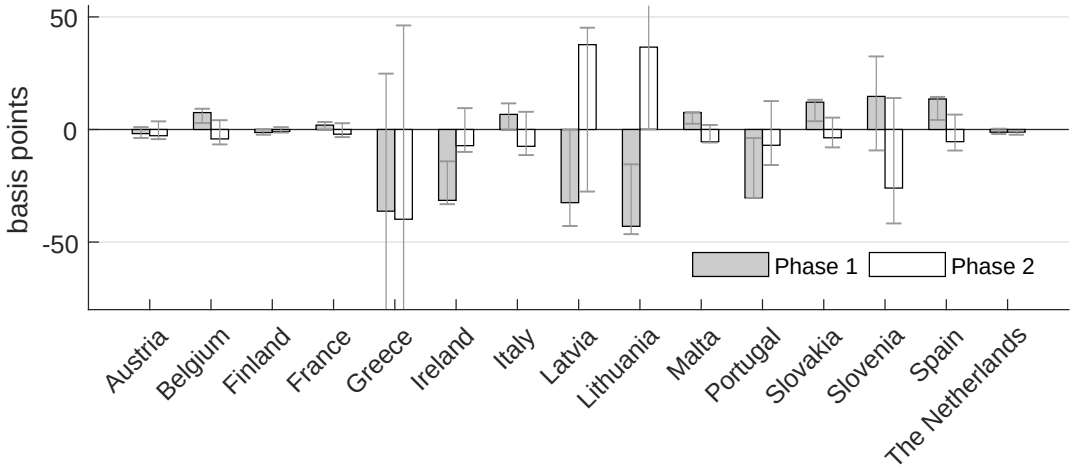
Figure E.24: Robustness: baseline variables from Figure 1, identifying the shocks only on monthly data



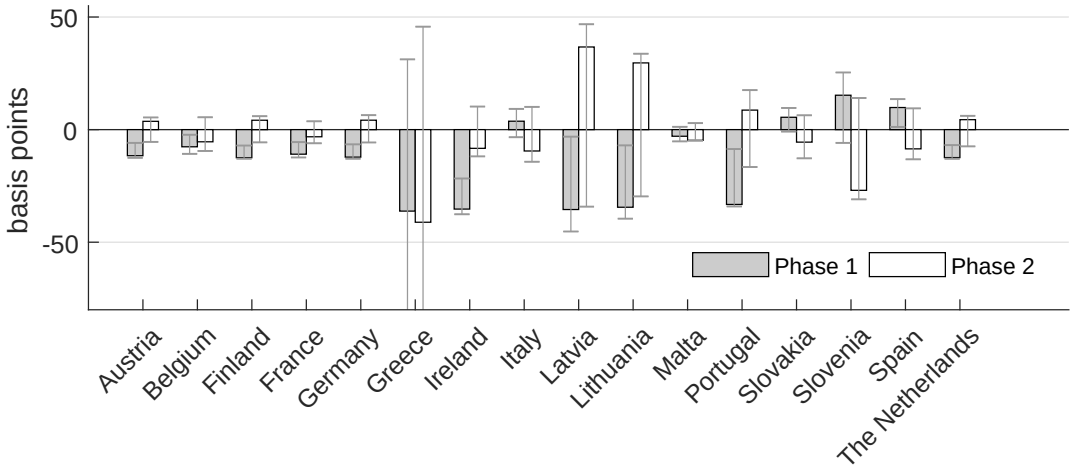
Notes: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure E.25: Robustness: spreads and yields from Figure 2, identifying the shocks only on monthly data

(a) Spreads versus Germany

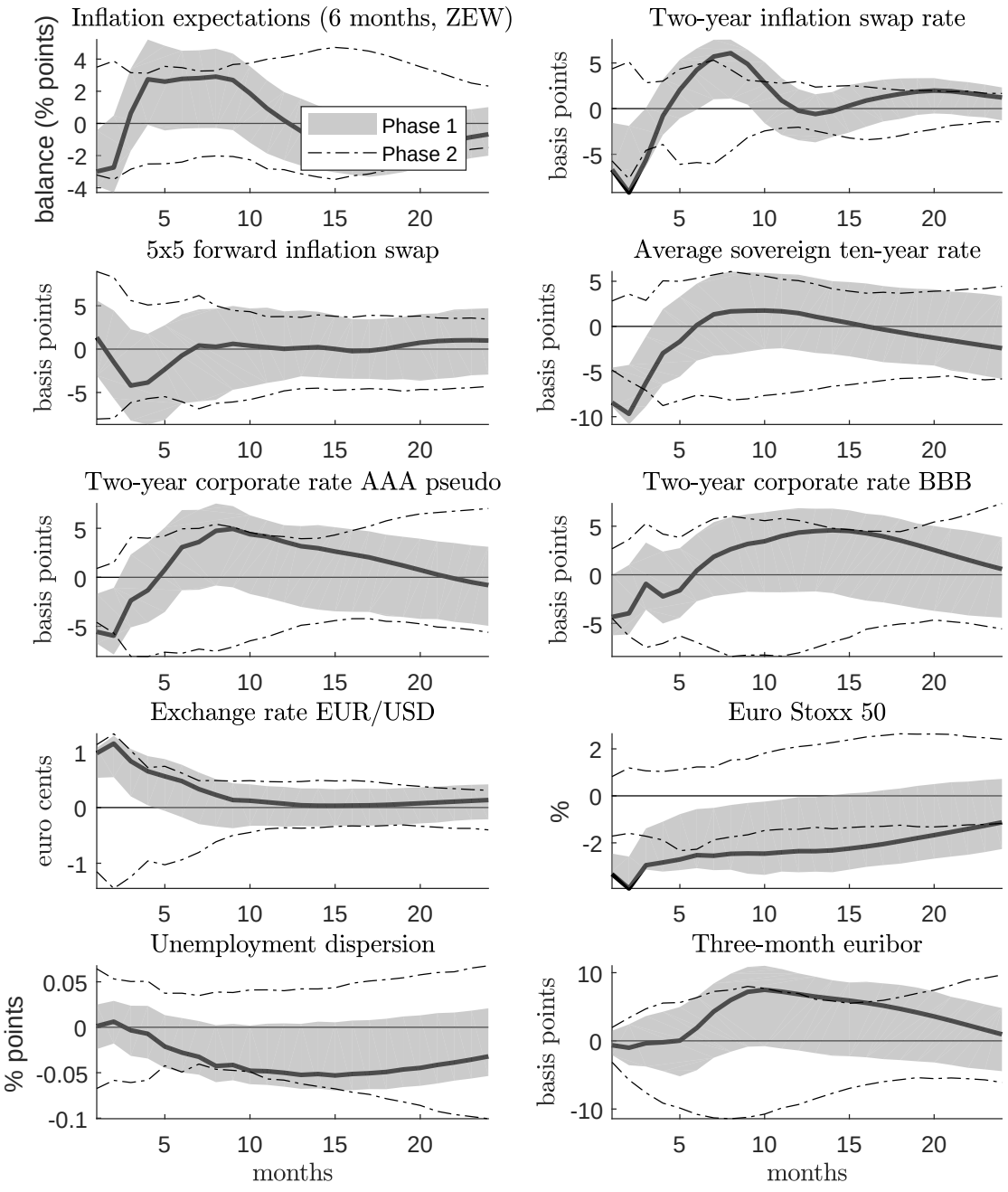


(b) Yields



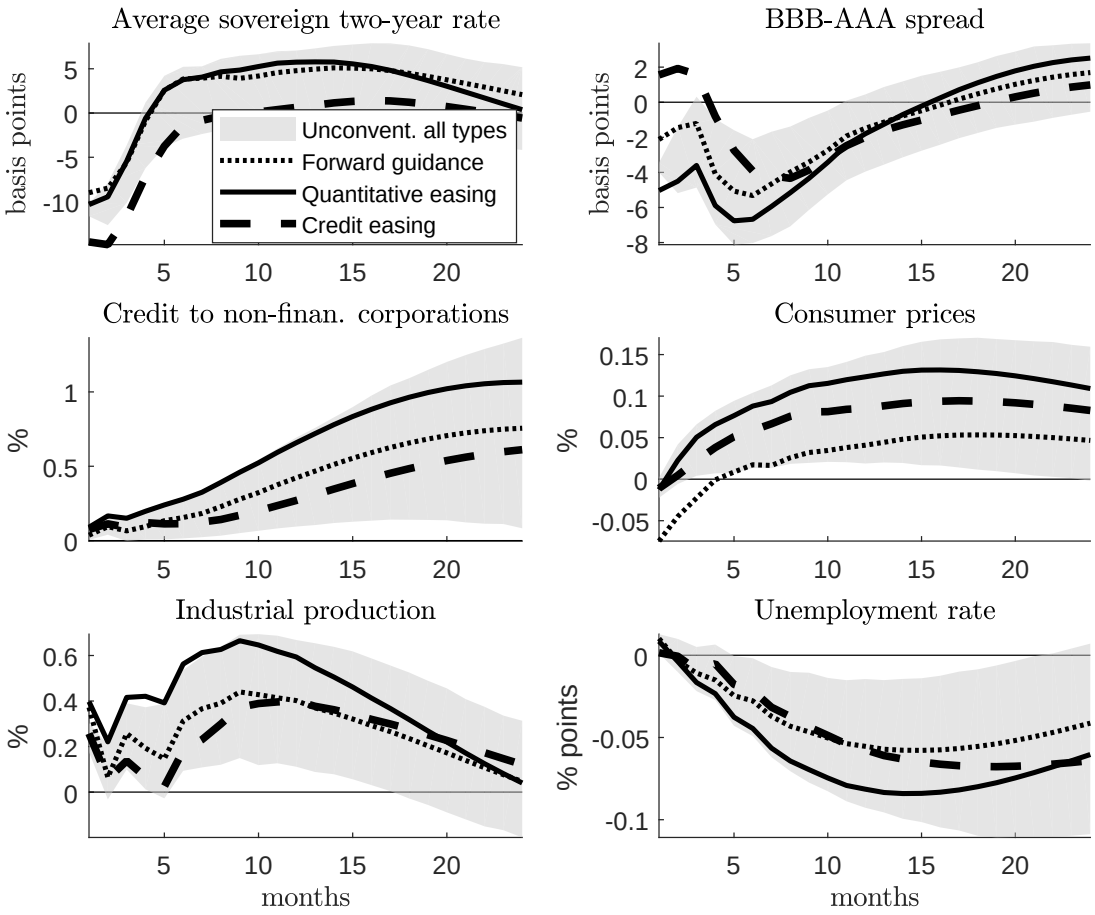
Notes: The figure shows the peak responses of ten-year country-specific sovereign spreads versus Germany (panel a) and ten-year government bond rates (panel b) after a one standard deviation expansionary monetary policy shock, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area shows the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the non-shaded area shows the point estimate for a shock from the second phase.

Figure E.26: Robustness: other variables from Figure 3, identifying the shocks only on monthly data



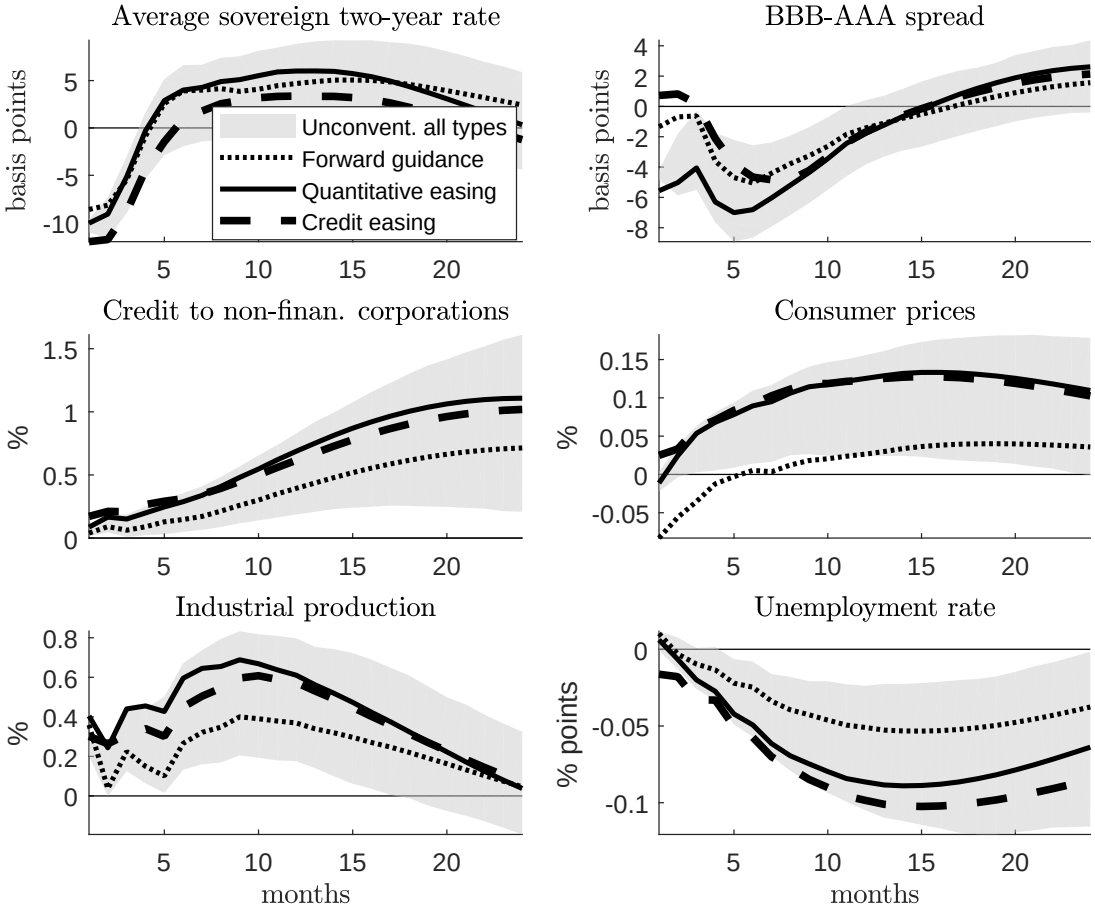
Notes: The figure shows the response to a one standard deviation expansionary monetary policy shock of variables individually added to the baseline VAR, along with 90% confidence bands obtained using 500 bootstrap replications. The shaded area and the continuous line show the confidence band and the point estimate for a shock from the first phase of ECB unconventional monetary policy, while the dashed lines show the confidence band for a shock from the second phase.

Figure E.27: Robustness: baseline variables from Figure 1. Instruments constructed on yields of all countries



Note: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock. The shaded area shows the 90% confidence bands obtained using 500 bootstrap replications when all unconventional monetary policy events are used to construct the instruments. The lines show the point estimates when using only the following events: forward guidance 03.03.2011, 09.06.2011, 04.08.2011, 06.10.2011, 06.06.2012, 06.12.2012, 02.05.2013, 04.07.2013, 08.11.2013, 21.07.2016, 08.09.2016, 20.10.2016, 08.12.2016; credit easing 22.08.2007, 28.03.2008, 29.09.2008, 08.10.2008, 15.10.2008, 07.05.2009, 03.12.2009, 04.03.2010, 28.07.2010, 03.03.2011, 04.08.2011, 06.10.2011, 08.12.2011, 21.12.2011, 09.02.2012, 28.02.2012, 22.03.2013, 05.06.2014, 03.07.2014, 31.08.2015, 10.03.2016, 03.05.2016 05.10.2016, 08.12.2016; quantitative easing 07.05.2009, 04.06.2009, 10.05.2010, 08.08.2011, 06.10.2011, 08.12.2011, 26.07.2012, 02.08.2012, 06.09.2012, 22.01.2015, 16.07.2015, 03.09.2015, 23.09.2015, 22.10.2015, 09.11.2015, 03.12.2015, 21.01.2016, 10.03.2016, 21.04.2016, 02.06.2016, 21.07.2016, 08.09.2016, 20.10.2016, 08.12.2016.

Figure E.28: Robustness: baseline variables from Figure 1. Instruments constructed on yields of periphery countries



Note: The figure shows the impulse responses of the variables in the baseline VAR after a one standard deviation expansionary monetary policy shock. The shaded area shows the 90% confidence bands obtained using 500 bootstrap replications when all unconventional monetary policy events are used to construct the instruments. The lines show the point estimates when using only the following events: forward guidance 03.03.2011, 09.06.2011, 04.08.2011, 06.10.2011, 06.06.2012, 06.12.2012, 02.05.2013, 04.07.2013, 08.11.2013, 21.07.2016, 08.09.2016, 20.10.2016, 08.12.2016; credit easing 22.08.2007, 28.03.2008, 29.09.2008, 08.10.2008, 15.10.2008, 07.05.2009, 03.12.2009, 04.03.2010, 28.07.2010, 03.03.2011, 04.08.2011, 06.10.2011, 08.12.2011, 21.12.2011, 09.02.2012, 28.02.2012, 22.03.2013, 05.06.2014, 03.07.2014, 31.08.2015, 10.03.2016, 03.05.2016 05.10.2016, 08.12.2016; quantitative easing 07.05.2009, 04.06.2009, 10.05.2010, 08.08.2011, 06.10.2011, 08.12.2011, 26.07.2012, 02.08.2012, 06.09.2012, 22.01.2015, 16.07.2015, 03.09.2015, 23.09.2015, 22.10.2015, 09.11.2015, 03.12.2015, 21.01.2016, 10.03.2016, 21.04.2016, 02.06.2016, 21.07.2016, 08.09.2016, 20.10.2016, 08.12.2016.

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