THE EFFECT OF CONVENTIONAL AND UNCONVENTIONAL EURO-AREA MONETARY POLICY ON MACROECONOMIC VARIABLES

ARNE HALBERSTADT* AND LEO KRIPPNER**

Abstract. We analyze the impact of monetary policy on macroeconomic variables in Germany in the years 1999 to 2015. For that, we apply a small-scale vector autoregression that allows for time variation in both structural relations and shocks. As monetary policy has been conducted also by means beyond policy rate setting since short term interest rates have approached the zero lower bound in 2011, we use the effective monetary stimulus measure (EMS-Q) of Krippner (2014) as monetary policy indicator: The EMS-Q is able to reflect the stance of monetary policy in times when the zero lower bound is binding. We find that most relationships between the macroeconomic variables and the EMS-Q have been relatively stable over the time from 1999 to 2015. Also time variation in the impulse responses is often found to be insignificant. For monetary policy shocks, in particular, we find on the one hand no significant time variation across non-zero lower bound and zero lower bound periods. On the other hand, however, the effects of monetary policy shocks on prices have become increasingly uncertain in recent years.

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1. Introduction

We analyze the impact of monetary policy on macroeconomic variables in Germany in the years 1999 to 2015. For that, we apply a small-scale vector autoregression that allows for time variation in both structural relations and shocks. As monetary policy has been conducted also by means beyond policy rate setting since short term interest rates have approached the zero lower bound in 2011, we use the effective monetary stimulus measure (EMS-Q) of Krippner (2014) as monetary policy indicator: The EMS-Q is able to reflect the stance of monetary policy in times the zero lower bound is binding.

The impact of monetary policy on macroeconomic variables is often analyzed in VARs featuring inflation (expectations), the output gap or the unemployment rate, and a short term interest rate (studies featuring time-varying parameters include Cogley and Sargent, 2005; Primiceri, 2005).This framework may need to be adjusted to analyze the most recent years, however, as short term interest rates approached the zero lower bound. The six months yield of German government bonds, for example, fell below 0.2% in November 2011 and has not exceeded this level since then. Meanwhile, the European Central Bank has loosened the monetary stance further by means of long term financing operations, forward guidance, and asset purchasing programs. This stimulus is not reflected by the short term rates which are bound to zero. The EMS-Q, contrarily, reflects the expansionary effect of the unconventional policy measures. It builds on the rational of a shadow short rate, i.e. the short rate that would prevail if investors do not have the option to hold cash instead of (possibly negative) interest rate bearing bonds (Krippner, 2012). The EMS-Q measure differs from the concept of the shadow short rate, as it contains information from the entire yield curve. Specifically, the EMS-Q is the integral over the difference of the zero-truncated path of short rate expectations relative to the neutral interest rate (Krippner, 2014). We check whether the EMS-Q is a suitable substitute for a short term interest rate as monetary policy indicator in an otherwise standard monetary policy VAR.

We mostly rely on German data, although our sample covers the time of the European Monetary Union (EMU). There is thus no independent German monetary policy to analyze. Our setup can rather be seen as a way to understand how the monetary policy of the ECB -which is actually targeted on Euro area aggregates- affects German macroeconomic variables. Although we do not impose any explicit structure in the VAR, this is clearly an auxiliary approach. It relies in the impulse response analysis on the assumption that the chosen German indicators are sufficiently similar interrelated with the monetary policy indicator as the target variables of the ECB. Instead of considering German data, we could take on an EMU-perspective, relying exclusively on EMU-data. However, approximately risk-free yield curve data is necessary for the estimation of the EMS-Q, and risk-free yields exhibit the highest correlation with the yield curve of German government bonds. If, alternatively, we take an entirely European perspective, we also would have to control for credit risk developments that influenced the funding conditions of companies in several EMU-countries in recent years.

The sample we consider covers the mid-2000s that are characterized by relatively stable economic and financial developments, but also the years of the global financial crisis and the euro-area debt crisis. Therefore, we apply a flexible modeling approach, namely the time-varying parameter VAR of Primiceri (2005). The setup allows to checking whether macroeconomic variables respond differently on monetary policy shocks in a zero lower bound environment than in a time of conventional monetary policy shocks.

A comparison of impulse responses from a VAR featuring the EMS-Q measure as monetary policy indicator and a VAR with a short term interest rate as policy indicator on the other hand indicates that the former setup is better able to deliver a reasonable description economic dynamics. This is true for the full sample covering the non-zero lower bound period and the zero lower bound period, but also for a sample covering solely the non-zero lower bound period.

For the VAR featuring the EMS-Q as monetary policy variable, there is little time variation detectable in the impulse response analysis. Often, time variation is found to be small and/or insignificant. Structural relations in the economy, for example between prices and output developments, have thus remained similar since 1999. Interestingly, this is by and large also true for monetary policy shocks, although monetary policy is conducted nowadays by other means than at the beginning of the sample. Monetary policy shocks are similar in size across the entire sample, and the difference in persistence is insignificant. Their effect on prices and output does not differ significantly across the sample. However, the impact of monetary policy shocks has become more uncertain in recent years: For recent years, we find that a surprisingly announced loosening of monetary policy does not affect price indices significantly anymore. Also the impact on industrial production becomes increasingly uncertain. This may reflect that firms become increasingly indifferent to changes in (monetary) refinancing conditions, because the refinancing conditions have been already extraordinary loose for some time.

In a counterfactual analysis, we consider hypothetical realizations of the state variables if no monetary policy shocks had occurred. Monetary policy shocks turn out to be expansionary for the most of the time since 2007. The impact of monetary policy shocks on macroeconomic variables is small in the considered time period: The price index's median counterfactual is estimated to deviate by $+/-0.13\%$ from realized values. The counterfactual indicator of the industrial production gap deviates up to 0.65% from realized values due to monetary policy shocks. Still, the deviation remains (slightly) insignificant.

Our study is related to the work of Wu and Xia (2014), who evaluate the effects of the unconventional monetary policy measures on the macroeconomy for the case of the Unites States. They rely on a constant parameter FAVAR for modelling the transmission of monetary policy shocks. While they test in a subsample analysis whether structural relations changed once the effective Federal Funds Rate approached the zero lower bound, we rather allow for potential time variation directly. Their findings broadly coincide with ours for German data: First, we can confirm that shock transmission became more uncertain in the zero lower bound period. Second, apart from the increased uncertainty, we also do not find indications for significant structural changes in how the macroeconomy is affected by monetary policy shocks.

Francis et al. (2014) discuss whether a shadow short rate is an appropriate indicator of monetary policy in VAR analyses in times in which short rates move close to the zero lower bound. They argue that this question is particularly relevant because the unobserved shadow short rate is not directly influenced by macroeconomic variables. This issue is alleviated by applying the EMS-Q as policy indicator, because the EMS-Q takes only those horizons of the shadow short rate expectations into account which are economically effective (Krippner, 2015). Francis et al. (2014) find that shadow short rates are generally able to serve as monetary policy indicators in zero lower bound periods if one considers a sample covering both a zero lower bound and a non-zero lower bound period. Our findings, obtained from using the EMS-Q measure as monetary policy indicator for both zero lower bound and non-zero lower bound periods, confirm their results. Furthermore, we find that the EMS-Q turns out to be a plausible indicator for monetary policy also in non-zero lower bound periods, in which it differs from the observed short rate as well.

We begin by briefly summarizing our modeling approach that is based on the time-varying parameter VAR featuring stochastic volatility of Primiceri (2005) (Section 2). There, we also provide details on the concept and the estimation of the EMS-Q measure. In Section 3, we provide some information about the data used in the analysis. Section 4 reports our results, including a discussion of an impulse response analysis and a counterfactual analysis. We evaluate the sensitivity of our results to variable selection in Section 6. Section 7 concludes.

2. The Model

The sample period that we consider suggest applying a flexible modeling approach: The sample covers the mid-2000s that are characterized by relatively stable economic and financial developments, but also the years of the global financial crisis and the euro-area debt crisis. Furthermore, we aim to analyze monetary policy shocks over both a non-zero lower bound period in which monetary policy was conducted by interest rate settings and a zero lower bound period in which central banks applied unconventional measures: In recent years, announcements of asset purchasing programs, amply long term lending facilities and the like represent major monetary policy surprises. On the one hand, Krippner (2014) argues that the EMS-Q measure is able to represent the monetary stance consistently over both periods in which the zero lower bound is binding and periods in which it is not binding. Therefore, we do not necessarily have to consider the transition to the zero lower bound period as a regime shift (Francis et al., 2014). On the other hand, the consistency does not generally imply that the impact of shocks to macroeconomic variables is the same in both phases. A certain scale of easing may still cause different macroeconomic responses whether it takes place within normal macroeconomic conditions or in a low interest rate environment. A time-varying parameter approach featuring stochastic volatility is especially favorable in the case of smooth changes of structural relations. Time-varying parameters in the VAR equation control for gradual changes in structural relationships over time. Stochastic volatility in the shocks takes into account that the impact of unexpected deviations of variable realizations may diverge between, for example, the non-zero lower bound period and the zero lower bound period.

Our model approach thus allows to find whether there were significant changes in the way monetary policy shocks affect the economy or not. For a sample covering also the zero lower bound period in the U.S., Francis et al. (2014) find ambiguous evidence for parameter stability depending on the monetary policy indicator incorporated in the VAR. For German data, there is little comparable evidence available to the best of our knowledge. Evidence on time variation in macro-financial data as it is considered here is either rather peripherally covered in cross country studies (Del Negro and Otrok, 2008) or the time variation is analyzed with a focus on other areas of the economy (for instance, an analysis of time variation in fiscal multipliers is provided by Berg, 2014).

2.1. **Primiceri (2005).** In the following, we describe the TVP-VAR of Primiceri (2005) that we use for estimating the time-varying dynamics of our state vector y_t which contains four variables (see Section 3 for a description of the data). We briefly summarize the model description and the prior specification of Primiceri (2005) and refer to his paper for a detailed discussion and a documentation of the estimation procedure. We consider a VAR process of the form:

$$y_t = c_t + B_{1,t}y_{t-1} + \ldots + B_{k,t}y_{t-k} + u_t. \tag{1}$$

The coefficients $B_{i,t}$, $i = 1, \ldots, k$ and the innovations u_t can vary over time. The variance covariance matrix of the residuals u_t, Ω_t, can be decomposed,

$$A_t \Omega_t A_t = \Sigma_t \Sigma_t', \tag{2}$$

where A_t is a lower triangular matrix with elements $\alpha_{ii,t}$ in the lower triangle and ones on the main diagonal. Σ_t is a diagonal matrix with the time-varying elements $\sigma_{1,t}, \ldots, \sigma_{n,t}$ on its main diagonal.

The number of parameters to be estimated is kept small by assuming that the time variation of the parameters can be described by (geometric) random walks, i.e.

$$B_t = B_{t-1} + \nu_t, \tag{3}$$

$$\alpha_t = \alpha_{t-1} + \zeta_t, \tag{4}$$

$$log(\sigma_t) = log(\sigma_{t-1}) + \eta_t. \tag{5}$$

Here, B_t represents the vectorized matrix of coefficients $B_{1,t}, \ldots, B_{k,t}$, and the vectors α_t and σ_t contain the free or nonzero elements of A_t or Σ_t, respectively. The residuals' variances are assumed to be normally distributed and uncorrelated with each other.

2.2. **Priors and Initializations.** Our prior specifications are widely in line with those in Primiceri (2005). We also use a training sample, from February 1992 to December 1998, to define priors. Korobilis (2014) stresses that a training sample specification has particularly in case of time-varying parameter models the advantage of numerical stability. OLS point estimates of parameters on the training sample are used as hyperparameters.

The prior distribution of the coefficient matrix of the VAR equation, $B_{i,t}$, is assumed to be normal, and its first two moments are set equal to the OLS estimates on the training sample:

$B_0 \sim N(\hat{B}_{TS}, 5 * V(\hat{B}_{TS}))$.

The prior distribution of σ_t, the diagonal elements of the variance matrix of the VAR equation, is normal with the mean of the corresponding training sample OLS-estimate and a diagonal variance matrix:

$log(\sigma_0) \sim N(log(\hat{\sigma}_{TS}), 5 * I_n)$.

Equivalently, for the prior distribution of A_t, we assume

$A_0 \sim N(\hat{A}_{TS}, 5 * V(\hat{A}_{TS}))$,

where $V(\hat{A}_{TS})$ is the variance of $\hat{A}_{TS}$ in the training sample.

For S and Q, the variance covariance matrices of ζ_t and $B_{i,t}$, respectively, inverse-Wishart distributions are assumed:

$S \sim iW(k_S^2 * 5 * V(\hat{A}_{TS}), 5)$,

$Q \sim iW(k_Q^2 * 69 * V(\hat{B}_{TS}), 69)$,

because we incorporate four state variables, and $\hat{B}_{TS}$ has 68 elements. For W, the variance covariance matrices of η_t, we assume an inverse-Gamma distribution:

$W \sim iG(k_W^2 * 5 * I_n, 5)$.

For simplifying the estimation, we also adapt the assumption that S has a block structure as in Primiceri (2005).

The prior beliefs about time variation in the covariance matrix of the processes of Q, α_t and $log(\sigma_t)$ are set as in Primiceri (2005), $k_Q = 0.01$,

$k_S = 0.1$ and $k_W = 0.01$. We find that the results are only negligibly affected by moderate changes in these parameters. Primiceri (2005) documents thoroughly that the posterior inference is not very sensitive to choices of these hyperparameters.

3. Data

Generally, we aim to set up a small-scale VAR for analyzing monetary policy shocks. We hence need a monetary policy measure, a measure of deviations of realized output from potential output, and an inflation measure. As we want to apply the model to recent German data, we have to take into account two restrictions: First, the German reunification in 1990 and the beginning of the European Monetary Union (EMU) in 1999 represent two meaningful structural breaks that could be taken as starting points of the analysis. The potential sample is thus not particularly long for a macroeconomic study, and we therefore consider only data that is available in a monthly frequency. Second, the monetary policy rates of the ECB do not fully reflect the stance of monetary policy in recent years: While the ECB's key interest rates have approached the lower bound, the ECB provided further monetary easing for example by means of forward guidance, long term refinancing operations and asset purchasing programs. Therefore, we incorporate the effective monetary stimulus measure (EMS-Q) instead of a short term interest rate as an indicator of the monetary policy stance (see Krippner, 2014).

The monthly frequency of the data restrains us from using the output gap as a measure of deviations of realized output from potential output. As a monthly proxy for an output measure, we take industrial production (see, for example, Clarida et al., 1998). According to the German Federal Statistical Office, industrial production had a share of 25.9% at GDP in 2014. We use the deviation of the annual growth rate of industrial production from its time-varying trend as it is obtained from the Hodrick-Prescott filter (Engel and West, 2006; Taylor and Davradakis, 2006).[1] As suggested by Ravn and Uhlig (2001), we apply a smoothing parameter of 129600 for a series of monthly observations.

For inflation, a broad price measure such as the harmonized consumer price index (HCPI) would be the obvious choice. We deviate from that, as the application of the HCPI would eventually imply rather imprecise results in the shock analysis (see Section 6 for details). Instead, we use a producer price index for commercial goods sold in inland (PPIIN). As we incorporate industrial production instead of overall output, it is reasonable to choose a producer price index on commercial goods instead of an overall price index analogously. By focusing on goods sold within the country, we

[1] Alternatively to the application of the Hodrick-Prescott filter, one can use a quadratic time trend to detrend the data, as it is done in the aforementioned study of Clarida et al. (1998).

can control at least in part for exchange rate effects on the price index. The effects of a monetary policy shock on exchange rates are itself found to be puzzling in some vector autoregression analyses, particularly in case of Germany (Sims, 1992; Grilli and Roubini, 1996), and a puzzling depreciation of the exchange rate in response to a monetary policy shock can support the incidence of a price puzzle, i.e. a positive response of the price index to a contractionary monetary policy shock. Even with sign restrictions, the counterintuitive responses of exchange rates do not generally vanish (Scholl and Uhlig, 2008). Other studies approach them by incorporating the exchange rate directly into the VAR (Elbourne and de Haan, 2009). This can be particularly favorable for countries whose central banks target the exchange rate (which is not the case for both the monetary authorities in the times considered here), but we avoid this for keeping the dimension of the model small. Technically, the PPIIN is considerable more volatile than the consumer price index, as markets for commercial goods are more price sensitive than the markets for goods considered for the CPI. Overall, however, the aggregated increase of both price indices reached since the beginning of the EMU is similar. The price data as well as the industrial production data is taken from the German Federal Statistical Office.

We follow Sims (1992) and Christiano et al. (1996) by also including a commodity price index into the model. As these authors point out, the rational of including commodity prices is to take into account anticipated inflationary pressure that is not yet reflected in the other variables of a small-scale VAR. This would eventually help to alleviate the price puzzle. We choose to incorporate the commodity price index of the IMF on metals (CPM).[2] One advantage of the CPM as an indicator for inflationary pressure over alternative candidates (such as survey data on inflation expectations) is its availability in monthly frequency for the entire sample.

We incorporate the EMS-Q measure as a fourth state variable. However, we confront this setup with a rather standard setup featuring a short rate as monetary policy indicator. In that case, we take the three-months EA-OIS swap rate that is actually also used for the estimation of the EMS-Q. The EMS-Q measure is estimated as described in Krippner (2014) based on both a short term OIS rate and on zero coupon yields on German government bonds. The OIS swap rate with three months to maturity is an EMU-wide short rate and serves as a proxy for a common policy rate. We take the OIS swap rate data from Bloomberg. For longer maturities, the yields of German government bonds represent a measure of risk-free rates in the Euro area. The government bond yields are estimated with the Nelson-Siegel-Svensson method and can be downloaded from Bundesbank's web page. We apply the maturities of 6 months, and 1, 2, 3, 5, 7, 10 and 30 years to maturity. The three-months OIS swap rate and the EMS-Q measure are plotted in Figure

[2]Incorporating another commodity price index, particularly the index on agricultural goods, leads to very similar results. For the commodity price data, see http://www.imf.org/external/np/res/commod/index.aspx.

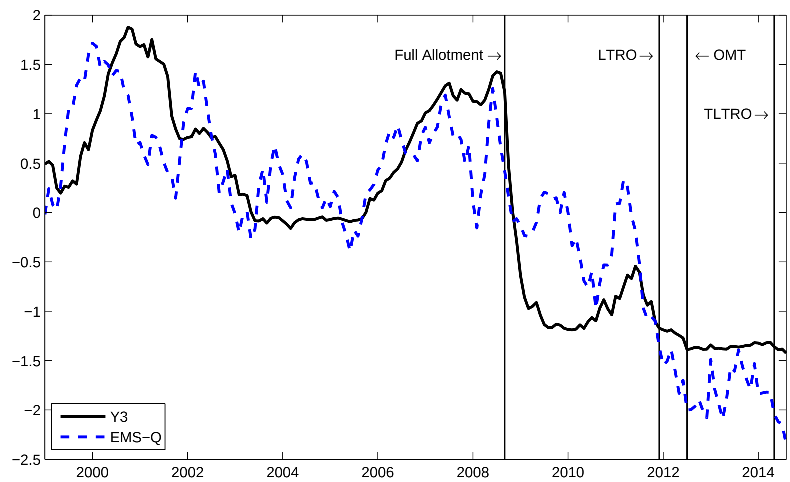

Figure 1: The short rate and the EMS-Q measure, both standardized to have mean zero and unit variance.

1. For ease of comparison, both series are standardized to have zero mean and unit variance and the sign of the EMS-Q is reversed (as compared to Krippner (2014)). We consider the EMS-Q with reversed sign throughout the paper to alleviate the comparison to the short rate. The development of the EMS-Q measure differs from the short rate also in times the zero lower bound was not binding, as it contains more directly information about the long end of the yield curve. This also explains why the EMS-Q indicates a remarkably slower loosening than the short rate in the time from 2009 to 2011. Long term yields did not decline as fast short term yields, letting the term spread of the yield curve steeply increase. The rapid decline of interest rates in 2008 brought the short rate already close to the zero lower bound. The short rate eventually fell below 10 basis points at the end of July 2012, around the ECB's announcement of the Outright Monetary Transactions (OMT) programme. Since then, it has not moved by much. The EMS-Q reflects the loosening by unconventional measures: The announcements of the LTRO in December 2011, of the OMT-programme in summer 2012, and of the targeted LTRO and the ABS purchasing programme in June 2014 caused obvious drops of the EMS-Q indicator.

Specifically, we choose April 1993 as starting point of the training sample. Our actual estimation sample coincides with the time of the EMU and hence starts in January 1999. The last observation is of Mai 2015. The PPIIN, the CPM, and the industrial production gap are considered in annual growth rates (these series are plotted in Figure 8 in Appendix A). All variables, including also the EMS-Q, are standardized to have mean zero and unit variance. We apply $k = 4$ lags in the VAR-equation (Equation 1). Overall, we draw 30000 times from the Gibbs sampler. The first 20000 draws are removed as burn-in.

We identify shocks in the VAR in a fairly standard way, namely we assume a recursive ordering of shocks. Hence, the ordering of variables matters. As the price measures and the gap in industrial production are ordered ahead of the monetary policy indicator, they can only react with a lag to a monetary policy shock. In the same vein, shocks to inflation or the industrial production gap can affect the monetary policy indicator contemporaneously. The CPM is ordered directly after the PPIIN because it is used as a proxy for anticipated inflation. Anyway, one may argue that the CPM index should be ordered after the indicator for industrial production, because commodity prices can react immediately to monetary policy shocks. Such a change, however, does not change the results as they are presented in the next section significantly.

4. Results

The application of a time-varying parameter model allows us to consider whether uncertainty about the variables in the VAR has changed in the last 17 years. Plots of Σ_t in Figure 2 indicate small time variation in the forecast error variances. They also show the forecast error variances of a more standard VAR including the short rate as the policy indicator (black lines). The forecast error variance of the short rate spiked at the beginning of the 2000s and at the high points of crisis in 2007 and 2011.

Naturally, the short rate volatility remained at zero in recent years, because the short rate got stuck at the zero lower bound. Using on one rate at the short end of the maturity spectrum disregards monetary stimulus that is caused by changes in the term structure through non-standard policies such as asset purchasing programs. The forecast error variance of the short rate is thus at the end of the sample as low as in the mid-2000s, a period of tranquil economic and financial developments. The forecast error variance of the EMS-Q remained relatively stable over the entire sample (upper right panel). Inferring from the EMS-Q variance, there is hence no distinct time variation in the size of the shocks across the times of conventional monetary policy and unconventional monetary policies at the end of the sample.

The difference in the variances of the two monetary policy indicators induces also deviations in other state variables' variances: Whereas Σ_t itself is diagonal, A_t is not (see Equation 2). Like Primiceri (2005) stresses, this setup allows innovations of one variable to have time-varying effects on other variables through A_t. Each variable's variance indicates a reduction from the heights in 2009 and 2010 towards levels close to the pre-crisis observations.

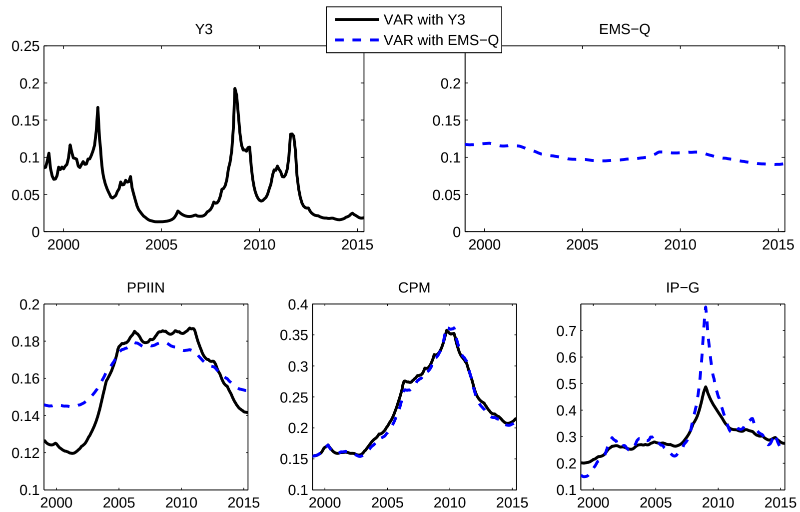

Figure 2: Posterior means of the time-varying standard deviation of the forecast residuals of the VAR. Blue-dashed lines refer to a VAR featuring the EMS-Q as monetary policy indicator; black lines refer to a VAR with the short rate instead of the EMS-Q measure.

4.1. **Impulse Response Functions.** In some VAR-studies, the response of inflation to an expansionary monetary policy shock is found to be negative. This pattern is contradictory to theoretic arguments. Authors describing this "price puzzle" provide explanations for its emergence (Sims, 1992; Bernanke et al., 2005): Not all information that is relevant for the transmission of a monetary policy shock may be incorporated in a small-scale VAR, and hence a monetary policy shock cannot be identified correctly. Particularly, as Sims (1992) and Bernanke et al. (2005) describe, monetary tightening may be a reaction of the central bank to higher inflation expectations, and increased inflation expectations may lead to higher inflation if the monetary policy response is not strong enough. Therefore, various ways to control for omitted information about expectations were proposed in the literature to thwart the price puzzle (for a meta-analysis of different approaches to counteract the price puzzle, see Rusnak et al., 2011). In our four variable VAR, neither the inclusion of a common factor extracted from a broad macroeconomic data set (Bernanke et al., 2005) nor the addition of a measure of inflation expectations (Castelnuovo and Surico, 2010) has proven to be successful. However, other remedies like the incorporation of commodity prices do help alleviating the price puzzle in the medium run. Generally, there are other possible reasons for the emergence of a price puzzle that we have not approached, like a change in the monetary policy regime, the cost channel, or the application of an inappropriate method of shock identification (Rusnak et al., 2011).

Whether the price puzzle can be considered to be solved or not depends, naturally, on the exact definition of the phenomenon. For example, Bernanke et al. (2005) report that the price puzzle disappears by the inclusion of a common factor. Their impulse response of prices to a monetary policy shock, however, is still positive for about 12 months before turning negative (see Bernanke et al. (2005), Figure 2). Rusnak et al. (2011) consider a positive response of inflation over 12 months as a medium-run price puzzle.

We consider first impulse responses of the variables in the VAR to a monetary policy shock. The scale of the response is hardly interpretable, as the data is standardized to have zero mean and unit variance. Hence, the values on the ordinates of Figures 3 to 6 report the responses of series to a shock as measured in standard deviations of these series. We report impulse responses for three different points in time, namely for January 2000, January 2007 and January 2014. There is no specific reason for this choice, except that it picks one observation from the beginning, one from the middle, and one from the end of the sample. Rather incidentally, however, the size of monetary policy shocks is relatively similar at each point in time. For the three years under consideration, time variation in the impulse responses of monetary policy shocks thus rather originates from time variation in the propagation mechanism than from differing impulses.

In order to motivate the application of the EMS-Q as monetary policy indicator, we compare the impulse responses of a VAR featuring the EMS-Q as policy variable with those of a more standard version with the three month OIS swap rate instead of the EMS-Q measure as monetary policy indicator, keeping all else equal. We consider this comparison for two different samples, namely a sample in which the zero lower bound was not binding (1999-2008), and a sample covering also the most recent years in which the zero lower bound is binding (1999-2015).

Figure3 provides the impulse responses for the non-zero lower bound period. A small price puzzle is visible, as prices increase for about a year after the shock occurred. However, the PPIIN turns negative in the medium term, and this backlash is (marginally) statistically significant. Contrarily, the reaction of industrial production is not plausible in any period or horizon under consideration: Industrial production expands significantly in response to monetary tightening. After one year, its response turns highly insignificant. On this sample, we thus do not obtain plausible results from small-scale VAR featuring the short term interest rate as monetary policy indicator.

The immediate response of the PPIIN to a tightening monetary shock is also uncertain if one applies the EMS-Q as policy indicator (Figure5). The drop in prices over the medium term, however, is stronger and more significant as compared to the setup featuring the short rate. Furthermore,

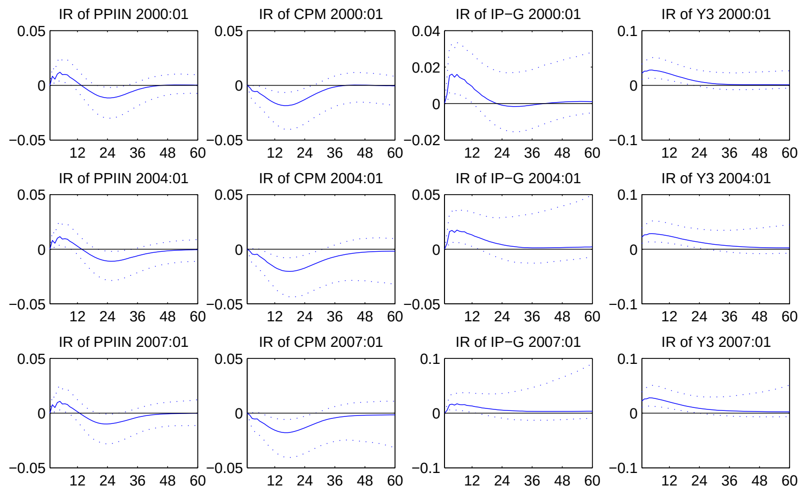

Figure 3: Impulse responses to a shock on the short term interest rate from a non-zero lower bound sample (1999-2008). The upper row depicts the responses in January 2000, the middle row those in January 2004, and the lower row those from January 2007. Dashed lines indicate 16% and 84% confidence intervals.

industrial production reacts as expected and decreases significantly in response to a tightening shock in all periods. Overall, the EMS-Q appears to be a more suitable indicator of monetary policy in this period in which the zero lower bound is not binding.

We consider now the entire sample that is available, namely from January 1999 to May 2015, covering both a non-zero lower bound period and a period in which the zero lower bound is binding. Impulse responses of the setup featuring the short rate turn out to be similar to those from the non-zero lower bound sample. The error bands are not so wide, but particularly the reaction of industrial production to tightening shocks remains implausible at all point in time (Figure 4).

Also for the full sample lasting until Mai 2015, the setup featuring the EMS-Q as policy indicator provides plausible results as we will discuss in the following in more detail. The comparison of results of alternative monetary policy indicators for both the NZLB sample and the NZLB/ZLB sample indicates thus the usefulness of the EMS-Q as monetary policy indicator in different interest rate environments.

We begin the discussion of the results of the VAR featuring the EMS-Q for the entire sample with considering the size and persistence of the policy shocks. There is no significant time variation observable in the impulse responses of EMS-Q over time. However, median values indicate that the

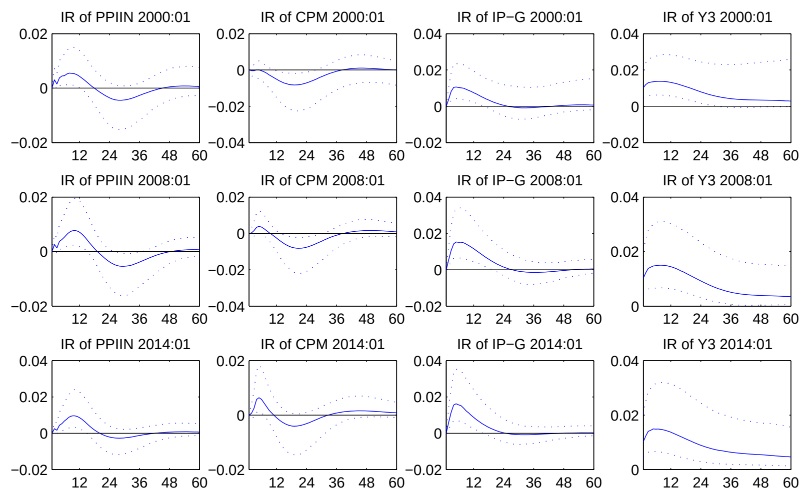

Figure 4: Impulse responses to a shock on the short term interest rate from a sample covering both a non-zero lower bound period and a period in which the zero lower bound is binding (1999-2015). The upper row depicts the responses in January 2000, the middle row those in January 2008, and the lower row those from January 2014. Dashed lines indicate 16% and 84% confidence intervals.

EMS-Q's reaction to an EMS-Q shock may be more persistent at the end of the sample. Its impulse response turns insignificant after about four years at the beginning of the sample, while it is still marginally significantly different from zero after five years in 2014 (Figure 6). The difference in persistence could reflect differences in monetary policy shocks in the early 2000s and in recent years: In the first years of the EMU, typical monetary policy shocks were surprising changes in the policy rate. Changes in the policy rate may motivate agents to adapt their expectations about the future path of monetary policy. The rate itself, however, has a short maturity. Contrarily, unconventional monetary policy instruments such as forward guidance aim to adjust the monetary stance explicitly for an extended period of time. Shocks may thus have become more persistent because the means applied for monetary policy implementation in recent years target implicitly or explicitly on a longer horizon than the traditional policy rate setting.

The immediate response of the PPIIN to an EMS-Q shock is uncertain (see first column of Figure 6). After the economy has adjusted, prices recede in the medium term. This reaction is significant in 2000 and 2008. In January 2014, the backlash into positive values does not become significant on a 16% level anymore. This absence of significance is caused by both widened error bands and a lower median response. Although monetary

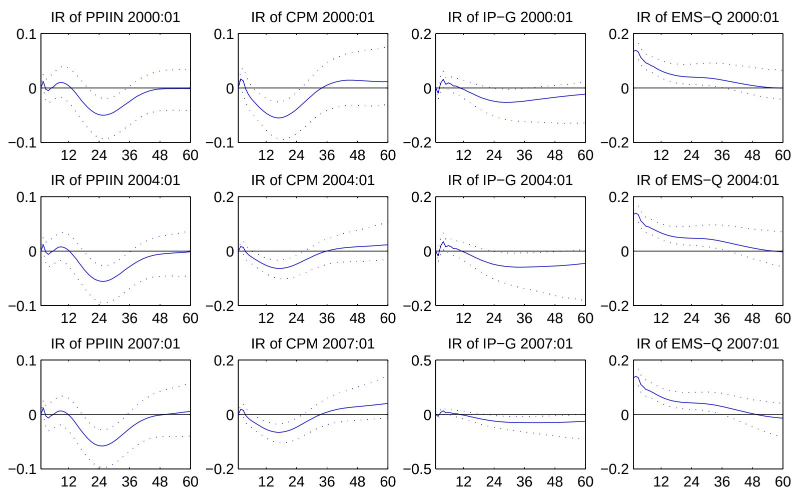

Figure 5: Impulse responses to a shock on the short term interest rate from a sample covering both a non-zero lower bound period and a period in which the zero lower bound is binding (1999-2015). The upper row depicts the responses in January 2000, the middle row those in January 2008, and the lower row those from January 2014. Dashed lines indicate 16% and 84% confidence intervals.

policy shocks are per se more persistent in 2014 than in the first half of the sample, their impact on inflation has weakened at last. Also Wu and Xia (2014), who compare impulse responses estimated on a long sample with those estimated on a sample solely covering the zero lower bound period in the United States, find a higher uncertainty of the responses in recent years.

The impulse responses of the commodity price index CPM are similar to the responses of PPIIN, both in significance and in shape. Also in amplitude they are similar. Sims (1992) and Christiano et al. (1996) argue that it is unconvincing that a monetary policy shock in one country affects a global commodity price index significantly, but they also stress the actual purpose of a commodity price index in a small-scale VAR, namely to control for expected price developments. The response directs into the expected direction in the medium term. The similarity of the responses of CPM and PPIIN indicates that this estimated pattern could be representative for a price measure's reaction to a monetary policy shock in this setup.

Counterintuitively, the industrial production increases in response to a tightening shock for the first months. After about a year, however, the impulse response turns significantly negative in the years 2000 and 2008. The effects of a monetary policy shocks on industrial production become also more uncertain at the end of the sample: Its impulse response is insignificant

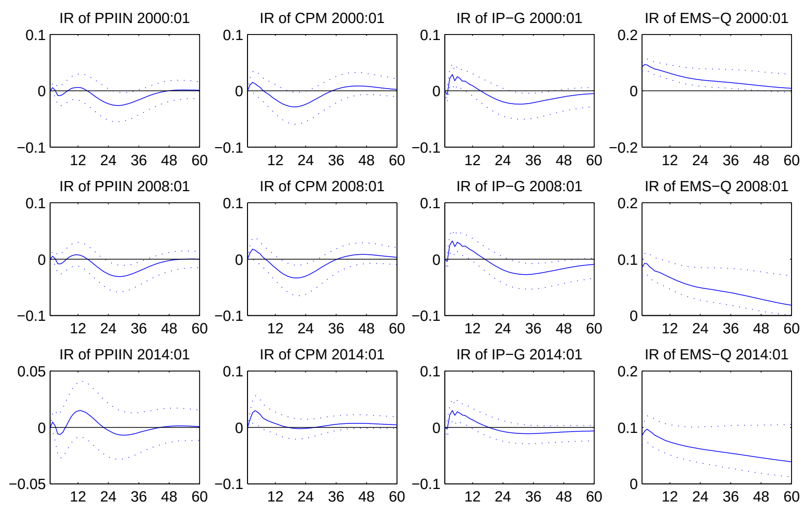

Figure 6: Impulse responses to a shock on the EMS-Q measure. The upper row depicts the responses in January 2000, the middle row those in January 2008, and the lower row those from January 2014. Dashed lines indicate 16% and 84% confidence intervals.

over almost all horizons in 2014. Firms thus appear not to change the size of their production once surprising changes in the (monetary) refinancing conditions are observed. This may be due to the extraordinary low interest rates already faced by companies in their investment decisions or it may be due to structural relations that are beyond the dimension of the VAR.

Impulse responses to shocks on other variables than the monetary policy indicator are often found to not varying by much over time: Shocks on inflation, in particular, are found to have very similar effects on all other variables over the entire sample. The sample may be too short for finding major changes in the interrelation of macroeconomic variables like output and price measures. If considerable time variation reveals in median responses, it is often resulting from high estimation uncertainty.

5. Counterfactual Analysis

We consider now how much of the development of the EMS-Q can be attributed to monetary policy surprises. For that, we derive a counterfactual path of the EMS-Q assuming that no monetary policy shocks have occurred.

Monetary policy shocks are estimated to be mostly, but not always expansionary over the last years (Figure 7). Particularly between 2007 and 2008 and at the beginning of 2011, the monetary policy surprises turn out

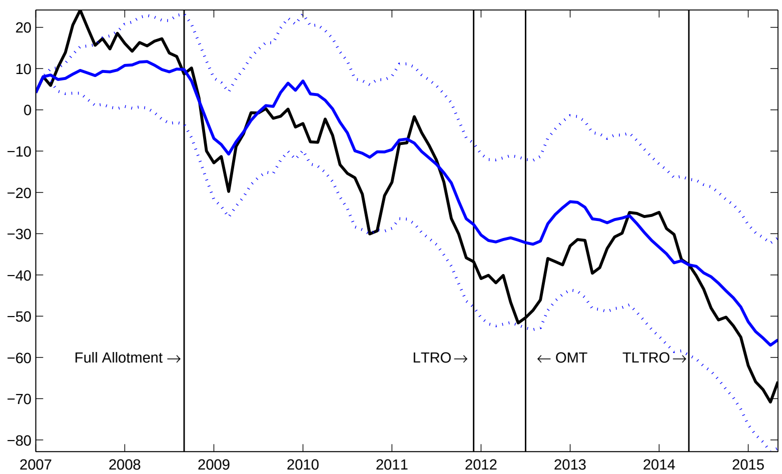

Figure 7: Counterfactual analysis: Realized EMS-Q (black line) and the counterfactual indicator (blue line) assuming no monetary policy shocks had occurred. Dashed lines indicate 16% and 84% confidence intervals.

to be rather contractive. These periods were high points of the financial crisis and the European debt crisis, in which uncertainty about the future economic and financial developments promptly drove up yields of the entire maturity spectrum. This caused the EMS-Q to rise temporarily. Also at the end of 2013, shocks became neutral relative to the expected stance. Global yields increased in 2013 in response to the Fed's announcement to tapering its bond purchases, and market participants prepared for a less expansionary monetary policy stance. This may also have influenced expectations about future yields in Germany. The central bank may not have intended to be less expansionary in those times. But the EMS-Q reflects information from the entire yield curve, and longer yields are not under direct control of the central bank. In Mai 2015, the last month of the sample, the counterfactual index of EMS-Q exceeds the realized value by 10. Significant deviations from realized EMS-Q occurred in 2007 and 2010.

The impact of monetary policy shocks on other variables is small. The counterfactual index of PPIIN deviates at most by $+/-0.12\%$ from realized PPIIN in the time from 2007 to 2014. Also the deviation at the end of the sample is negligible in size and insignificant. For an overview of the counterfactual paths of PPIIN and all other variables if no monetary policy shocks occurred, see Figure 9 in Appendix B.The industrial production gap was only temporarily significantly influenced by monetary policy surprises, particularly in 2007, when EMS-Q shocks happened to be significantly restrictive. However, the deviation of the median counterfactual does not exceed 0.65% and remains statistically insignificant in most times.

6. Alternative Specifications

We consider now whether our results are sensitive to the variable selection. While keeping the setup generally similar (a price measure, a proxy for inflation expectations, an economic activity measure, and a monetary policy measure), we replace once each of the variables by an alternative indicator.

The effective monetary stimulus measure can be decomposed into a part that contains stimulus provided by risk-neutral expectations about future short rates (EMS-P) and another part that reflects stimulus provided by lower term premiums (EMS-RP, namely the difference of EMS-Q and EMS-P. Hence, incorporating the EMS-P or the EMS-RP as monetary policy indicator would generally allow us to identifying the size of stimulus provided by either steering interest rate expectations or by dampening term premiums of long term yields, respectively. However, the results are inconclusive, because the estimation uncertainty is very high. Particularly the setup with the EMS-RP leads to highly uncertain impulse responses. Eventually, the stimulus contained in both components needs to be considered together to finding material monetary policy effects on macroeconomic variables. Like for the other setups, Table D in Appendix D contains a stylized overview of the results for these setups.

Another possible monetary policy indicator is the shadow short rate (SSR, see Krippner, 2013). The SSR does not reflect information from the long end of the yield curve directly and thus differs conceptually from the EMS-Q. The implications of a surprising monetary tightening for the economy are, nevertheless, largely comparable: The price measures' impulse responses have similar patterns as in the setup with the EMS-Q (see Figure 10 in Appendix C). Though, the contraction in the industrial production gap remains insignificant over all horizons.

The harmonized consumer price index (HCPI) provides a broader measure of price developments. If we replace the PPIIN by annual growth rates of the HCPI, taken from Eurostat, impulse responses remain in some cases insignificant over all horizons (see Figure 11 in Appendix C). The implications of a surprising monetary tightening for the economy are, nevertheless, largely comparable, if one solely compares the sign of the median responses which often point into the same direction as in the approach with the EMS-Q.

Eventually, we use the commodity price index CPM as an instrument to incorporate anticipated inflation. Straightforwardly, a measure of inflation expectations could serve the same purpose. Therefore, we replace the CPM by inflation expectations taken from the Consensus Forecast survey. The frequency of the data depends on both the expectation horizon and the observation period and varies between one month and six months. For each observation period, we take the mean over the observation horizons (from current year to six-to-ten years ahead). By aggregating over all horizons available, we obtain a more frequent measure as if we had only taken long-term forecasts into account. Nevertheless, the volatility is low compared to the other variables in the VAR. This may be one reason why impulse response estimates are very uncertain. At most points in time, the impulse response of inflation expectations to an EMS-Q shock is not significant at any horizon. Also the impact on other variables is found to be less significant in this setup (see Figure 12 in Appendix C).

Instead of the industrial production gap, the unemployment rate (from the German Federal Statistical Office) can be used as an indicator for economic activity. The unemployment rate increases significantly when a monetary policy shock occurs. Prices decrease significantly in the medium term in response to a tightening shock in the years 2000 and 2008, but not in 2014. We obtain thus broadly similar results as from the specification with industrial production.

It is also possible to derive qualitatively similar results in a three-variable VAR in PPIIN, a macroeconomic factor and the EMS-Q. A factor has the advantage that it incorporates information from a (possibly) broad macroeconomic data set in a VAR of limited dimensions. Typical misidentifications of monetary policy shocks that are caused by a negligence of expectations can be alleviated in this way (Bernanke et al., 2005). We take the first principal component as factor. It is extracted from a panel of 74 macroeconomic series describing the labor market, industrial production, prices, surveys and financial developments. The underlying series are transformed, orthogonalized to the EMS-Q and standardized to have zero mean and unit variance. The resulting impulse responses from a VAR with a factor as economic activity indicator conform with those from the four-variable VAR (see Figure 13 in Appendix C). Prices and the macroeconomic factors decrease in response to surprising tightening of monetary policy, albeit only marginally significantly. Interestingly, also the application of the EMS-Q appears to help to incorporating expectations into the small-scale VAR that are relevant for inferring appropriately price reactions to monetary policy surprises. This becomes obvious by comparing the results to those from a VAR featuring the PPIIN, the macroeconomic factor and the short term interest rate as policy indicator (Figure 14 in Appendix C). Whereas the response of the macroeconomic factor to a monetary policy shock is very similar in both setups, the response of the PPIIN remains insignificant at all horizons. Hence, the EMS-Q may incorporate information about (expected) inflation that helps obtaining plausible impulse responses of prices to monetary policy shocks.

Eventually, the impulse responses resulting from alternative variable sets mostly differ in their significance. The median responses are overall similarly shaped. The variable set PPIIN, CPM, industrial production gap and EMS-Q appears thus to be one admissible representation of the economy in a small-scale VAR for the considered sample.

7. Concluding Remarks

We use the effective monetary stimulus measure (EMS-Q) for analyzing the effects of the common European monetary policy on German macroeconomic variables in the time of the European Monetary Union. As the EMS-Q reflects monetary stimulus by interest rate cuts and unconventional instruments, its application enables us to cover also the recent years in which short term interest rates were bound to zero. We estimate a time-varying VAR to understand whether the effects of monetary stimulus have changed over time.

Our results indicate that monetary policy shocks are expansionary for the most of the time since 2007. Their impact on macroeconomic variables is often rather uncertain according to this study. Also the time variation detected in impulse responses is often found to be modest or insignificant. Hence, major changes in the relation of macroeconomic key variables are not detectable during the transition from the outgoing Great Moderation to the Global Financial Crisis. Also the impact of monetary policy shocks to macroeconomic variables does not vary significantly over the sample period. We thus do not find significant structural differences in the way that conventional or unconventional monetary policy shocks affect the economy. Nevertheless, the impact of monetary policy shocks to macroeconomic variables may have changed in previous years, anyway: Although time variation in impulse responses of macroeconomic indicators is mostly not significant, the results indicate that the impact of monetary policy has become increasingly uncertain in recent years.

These results have to be interpreted against the background of some limitations of the setup of the analysis: First, our results describe principally only sectorial developments since we apply variables from the production sector rather than the broadest price and output measures available. Since industrial production represents a significant share of overall economic activity, this limitation may be innocuous. Also, given that the price index PPIIN behaves in a similar way as the global commodity price index in the impulse response analysis, reassures us that our data selection does not deliver solely sector-specific evidence. Second, the German macroeconomic variables used in this setup are obviously not those indicators that the ECB primarily targets in its conduct of a common European monetary policy. The results of our impulse response analysis have therefore to be seen as a sign for how monetary policy is transmitted to the German economy, and not how effective the ECB's monetary policy is in general.

Appendix A. Data

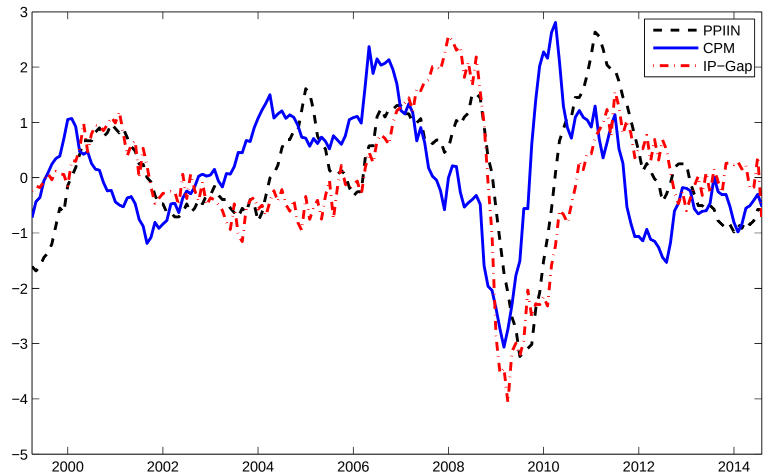

Figure 8: The price indices PPIIN and CPM and the industrial production gap are considered in annual growth rates in this analysis. This figure shows the standardized series for the main estimation sample starting in January 1999.

Appendix B. Counterfactual Analysis

Appendix C. Impulse Responses of Alternative Specifications

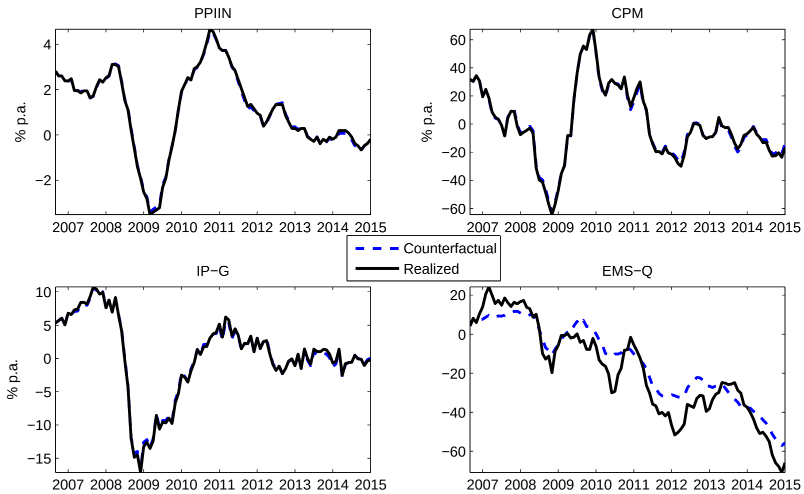

Figure 9: Realized EMS-Q (black line) and counterfactual of EMS-Q if no monetary policy shocks had occurred (blue line). Dashed lines indicate 16% and 84% confidence intervals.

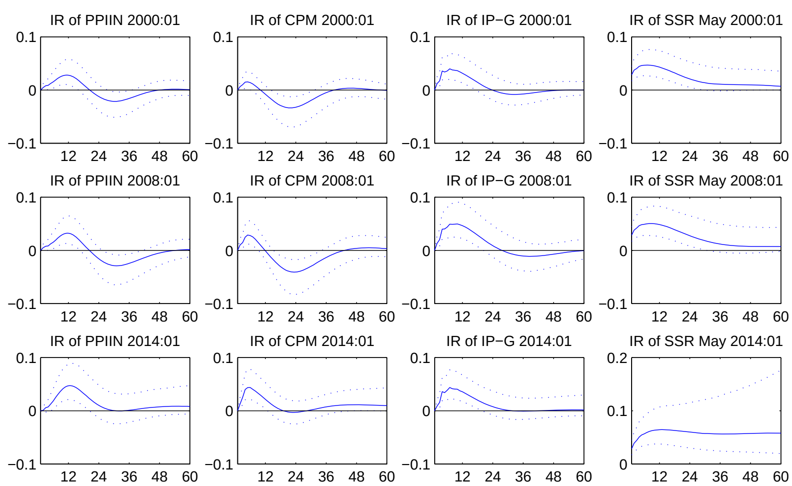

Figure 10: Impulse responses to a shock on the shadow short rate. Dashed lines indicate 16% and 84% confidence intervals.

Appendix D. Summary table

Table 1. Alternative model specifications: The table summarizes the results of impulse responses to a monetary policy shock to alternative specifications of the VAR. Checks indicate, in the first to rows, the actual sample, and otherwise whether a certain variable reacts significantly with the expected sign to a monetary policy shocks. A variable that reacts significantly, but implausibly, is marked with a cross. Insignificant responses are labelled by a 0. Commodity prices are incorporated as a control variable, but their responses are of no interest for our analysis (∅).

		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
1999-2008															√	√					
1999-2015		√	√	√	√	√	√	√	√	√	√	√	√	√			√	√	√	√	√
Variable type	Name																				
Prices:	PPIIN	0	√		0	√	0	√	√	√	×	0	√	0	√	√	0	√	0	√	√
	HCPI			0																	
Inflation Expect.	Survey (CF)	0																			
	Commodity prices		∅	∅	∅	∅		∅	∅	∅				∅	∅	∅		∅	∅	∅	∅
Real economy	IP	0			0	×	√	√	√	√	×	√		×	×	√					
	Macro factor												√				0	0	0	0	0
	Unemployment		√																		
Policy variable/s	Policy rate													√	√		√		√		
	SSR																			√	
	EMS(3)-Q							√													
	EMS(10)-Q								√												
	EMS(30)-Q	√	√	√			√			√						√		√			
	EMS(3)-P																				
	EMS(10)-P																				
	EMS(30)-P				√						√		√								√
	EMS(3)-RP																				
	EMS(10)-RP																				
	EMS(30)-RP					√						√									√
Counterfactual	Sign	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√	√	√	×
	CF significance	0	0	0	√	0	0	0	0	0	√	0	0	√			√	0	√	√	0

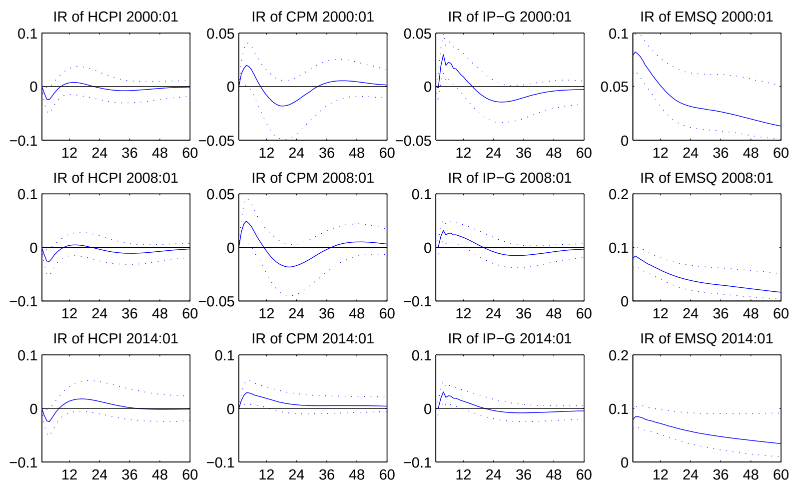

Figure 11: Impulse responses to a shock on EMS-Q in a VAR setup featuring the HCPI as price index. Dashed lines indicate 16% and 84% confidence intervals.

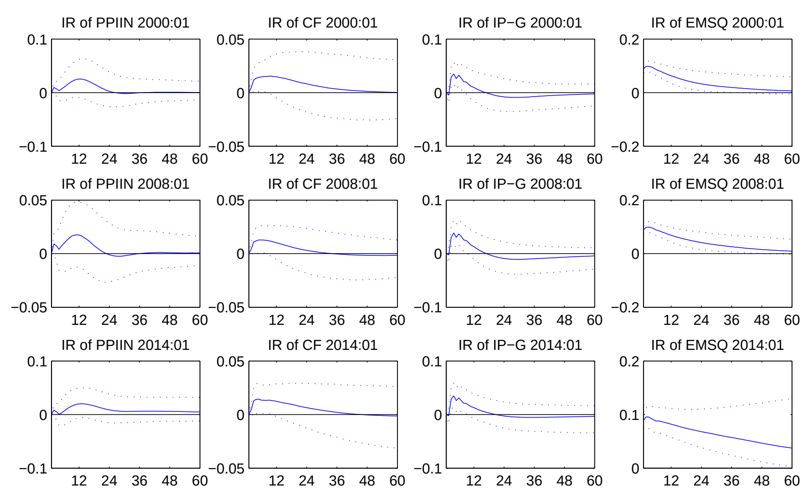

Figure 12: Impulse responses to a shock on EMS-Q in a VAR setup featuring a survey-based indicator for inflation expectations (CF). Dashed lines indicate 16% and 84% confidence intervals.

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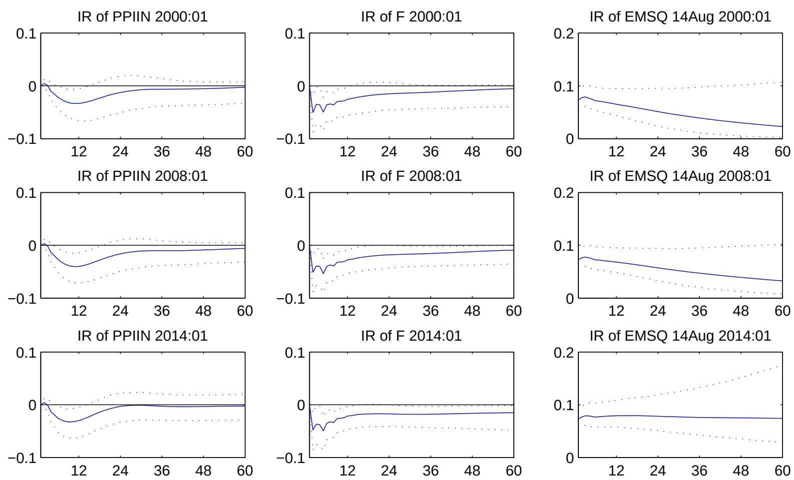

Figure 13: Impulse responses to a shock on EMS-Q in a three-variable VAR featuring a macroeconomic factor (F) as an economic indicator. Dashed lines indicate 16% and 84% confidence intervals.

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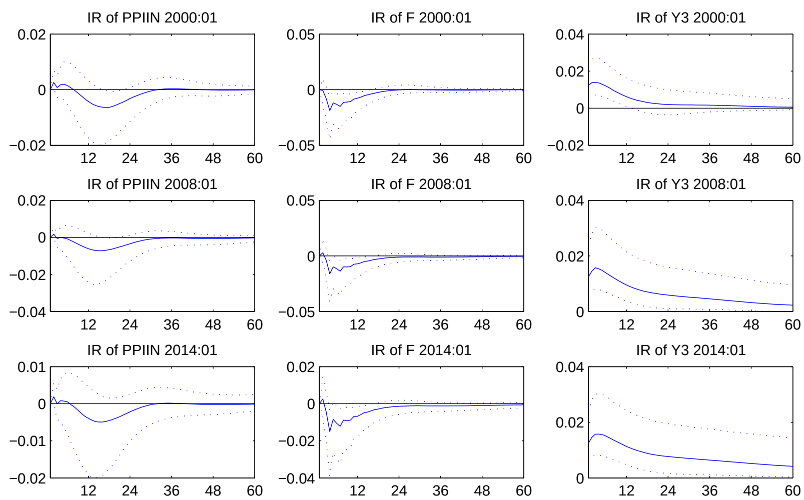

Figure 14: Impulse responses to a shock on EMS-Q in a three-variable VAR featuring a macroeconomic factor (F) as an economic indicator. Dashed lines indicate 16% and 84% confidence intervals.

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* Deutsche Bundesbank

** Reserve Bank of New Zealand