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How far does monetary policy reach? Evidence from factor-augmented vector autoregressions for Poland

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Mariusz Kapuściński

Economic Research Department
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Mariusz Kapuściński – Narodowy Bank Polski and Warsaw School of Economics;
mariusz.kapuscinski@nbp.pl

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Abstract

This study applies factor-augmented vector autoregressions to identify the effects of monetary policy shocks in a small, open, emerging market economy. It uses data on 132 variables for Poland, 'compressing' them to either structural (having an economic interpretation) or economically uninterpretable factors, also known as diffusion indices. The tightening of monetary policy is found to have broad, contractionary effects. Among other things, production, building permits, retail trade, employment, job offers, prices, wages, loans and stock prices decrease, unemployment and non-performing loans increase. However, a rise in the interest rate does not appear to be associated with an appreciation of the exchange rate. But this result is not robust among studies using vector autoregressions, which calls for a different strategy to identify the causal effect. As one of extensions, the effects of changes in global and foreign factors are investigated. Domestic prices are found to respond to global prices of commodities and foreign prices. Domestic production and interest rates – to their foreign counterparts.

JEL Codes: C38, C32, E43, E52

Keywords: factor analysis, vector autoregressions, factor-augmented vector autoregressions, high-frequency identification, monetary transmission mechanism

1 Introduction

In the basic new Keynesian model, as in Galí (2015), a central bank usually sets an interest rate according to a Taylor-type rule. The interest rate is changed when inflation deviates from the inflation target or/and when output deviates from potential output. In reality, central bankers make monetary policy decisions in a data-rich environment. They monitor a large number of variables. And results from a seminal study of Bernanke and Boivin (2003) for the Federal Reserve indicate that members of the Federal Open Market Committee consider more than inflation and output when they set a target for the federal funds rate. It should be taken into account in order to correctly identify an exogenous component of changes in interest rates (shocks/innovations) when investigating the effects of monetary policy.

The present study applies factor-augmented vector autoregressions (FAVARs) to identify the effects of monetary policy shocks in Poland, a small, open, emerging market economy. This framework allows to implicitly use a large number of variables in one model, combining factor analysis with vector autoregressions (VARs). 132 variables are 'compressed' into structural factors (having an economic interpretation), as in Belviso and Milani (2006), or into economically uninterpretable factors, as in Bernanke et al. (2005). Factors are also known as diffusion indices (Stock and Watson, 2002). Structural factors are obtained by extracting principal components from groups of variables related to economic concepts (real activity, inflation, credit, money, interest rates, financial market, expectations), economically uninterpretable factors – from all variables collected together. The study is the first to research into the monetary transmission mechanism in Poland using fully fledged FAVARs and, according to author's knowledge, the first to compare results from FAVARs with structural versus economically uninterpretable factors. These are its main contributions.

Not only do FAVARs facilitate better identification of monetary policy shocks, but they also have other advantages over standard VARs which, in order to preserve the degrees of freedom, usually contain explicitly only a few variables. First, a given concept can be proxied by many variables. It is usually not entirely clear which variable exactly should be used as a measure of, for example, output or inflation. And by applying factor analysis to many proxies one can get rid of measurement error. Second, impulse response functions can be calculated for all variables affected by factors. In principle, a researcher can avoid estimating many models with slightly different sets of variables (for example, replacing industrial production with its components) and risking the omitted variable bias.

Besides estimating both models with structural factors and economically uninterpretable factors, the study also carries out a thorough sensitivity analysis and makes extensions. As far as sensitivity analysis is concerned, different numbers of lags, measures of monetary policy and kinds of identification are checked. For extensions, a marginal contribution of domestic factors to standard VARs is analysed (as in Bernanke et al., 2005) and the effects of changes in global and foreign factors are investigated (as in Liu et al., 2014).

Results indicate that the tightening of monetary policy has broad, contractionary effects. Production, building permits, retail trade, employment, job offers, prices, wages, loans and stock prices decrease, unemployment and non-performing loans increase. However, the exchange rate does not appear to appreciate, as it should according to economic theory (precisely, according to uncovered interest parity, UIP). If anything, it depreciates. Some explanation for this result, supported by factor analysis, is that the economic contraction raises the risk premium, which compensates for higher interest on deposits. But that finding varies among studies using VARs, calling for a different strategy to identify the causal effect.

The results are robust with respect to different measures of monetary policy and identification schemes. On the other hand, 6 lags in a VAR – half of the baseline number, but a number larger than suggested by information criteria – are insufficient to adequately capture dynamic relationships between variables. A standard VAR, with differences of logarithms (logs) of industrial production, the CPI (consumer price index) and the REER (real effective exchange rate), and with the money market interest rate, gives a price puzzle (a rise in prices after an increase in the interest rate), which can be removed by the inclusion of two factors. Domestic prices respond to global prices of commodities and foreign prices. Domestic production and interest rates – to their foreign counterparts.

However, applied to data for Poland, FAVARs are no panacea. Models with structural and economically uninterpretable factors give qualitatively similar results, but the former do not appear to fully capture the effects on the labour market, and estimates from the latter are in most important cases imprecise. Using monthly data for the period between January 2001 and March 2017 in FAVARs with 12 lags, the degrees of freedom remain a tight constraint, and only 4 factors can be included in a given model. Therefore, in models with structural factors some variables need to be introduced separately by replacing other variables. In models with commodity price and foreign factors the number of lags needs to be reduced. Furthermore, the price puzzle from the standard VAR can also be removed by using high-frequency identification instead of identification by short-run, recursive restrictions.

The article is structured as follows. The second section reviews the literature. The third section describes the models. The fourth one – data. In the fifth section there are the results. The last section concludes.

2 Literature review

This study contributes to already quite extensive literature on the effects of monetary policy in Poland. However, it is the first one to analyse it within a fully fledged FAVAR framework. In the closest study, Balabanova and Brüggemann (2017) start from a standard VAR, with logs of industrial production, CPI, EURPLN exchange rate and with a money market interest rate. Then, they augment it with factors estimated either from 10 variables for 11 euro area economies or from 9 variables for the Czech Republic, Hungary and Slovakia, either as endogenous or as exogenous variables. In the baseline model they find a decrease in production, an appreciation of the exchange rate and no significant response of CPI after a monetary policy shock (a rise in the interest rate). However, inclusion of factors for the Czech Republic, Hungary and Slovakia as exogenous variables makes the response of CPI significant and negative.

In comparison to that study, this one extracts factors from domestic, not only foreign variables. Furthermore, here foreign factors are economically interpretable (foreign real activity factor, foreign inflation factor, foreign interest rates factor), so meaningful impulse responses to shocks to them can be, and are, calculated. And they are extracted from data for all European Union (EU) economies, as well as for the United States (US), Brazil, Russia, India and China. Also, this study uses a shorter sample – in Balabanova and Brüggemann (2017) it starts in January 1995 and ends in December 2013. On the one hand, the sample in the present study is more homogenous. On the other hand, it gives a smaller number of the degrees of freedom. Therefore, as mentioned above, in models with foreign factors the number of lags needs to be reduced, and they are not fully comparable with these without foreign factors. Finally, in this study variables are differenced if non-stationary, in Balabanova and Brüggemann (2017) – they are not. It again implies some trade-off – the risk of an omitted long-run relationship, mitigated by the large number of lags, versus the risk of capturing a spurious relationship.

Factors from 170 domestic variables, as well as from 198 foreign, euro area variables, are estimated and used in a FAVAR for Poland in Benkovskis et al. (2011). However, they investigate only the effects of euro area monetary policy shocks. They find that they are associated with the decrease in GDP (gross domestic product) in Poland. In comparison to this study, their factors are based on quarterly data (for the period between the second quarter of 1999 and the second quarter of 2010). They use more variables related to external trade (which is directly connected with the aim of their study) but, for example, no variables related to credit. In a more loosely related study, Bystrov (2014) augments a VAR, containing a money market interest rate and a spread on loans for house purchases, with factors extracted from 54 domestic variables. He finds a significant relationship between the money market interest rate and the spread, indicating an incomplete interest rate pass-through. Also, his results show that the spread responds to three factors: first with high loadings on exchange rates, stock market indices and CDS (credit default swap) spreads, second – on industrial production, employment and wages, third – on interest rates (other than the one used as a measure of monetary policy). Variables used to estimate factors in Bystrov (2014) cover similar concepts as these in this study, but a smaller number of variables is used for each concept. He also uses monthly data, but for a shorter period (January 2004-June 2014).

VARs for monetary policy analysis for Poland, without factors, are used in a number of studies. They differ with respect to the sets of variables, frequency and transformations of data, samples, inference (classical or Bayesian) and identification schemes. Usually they find a decrease in measures of real activity and inflation following a monetary policy shock. Findings on the response of the exchange rate are mixed. Standard references are studies conducted at Narodowy Bank Polski: Kapuściński et al. (2016), Kapuściński et al. (2014), Demchuk et al. (2012), Łyziak et al. (2011), Łyziak et al. (2008), and Pawłowska and Wróbel (2002). Arratibel and Michaelis (2013), and Darvas (2013) investigate how the monetary transmission mechanism in Poland has evolved over time, estimating VARs with time-varying coefficients. Postek (2011) uses non-linear VARs. Gajewski (2015) estimates more standard VARs, but focuses on regional differences in the effects of monetary policy shocks. Haug et al. (2013) analyse the effects of both monetary and fiscal policy.

Andrle et al. (2013) focus on variance decomposition between the effects of domestic and foreign shocks, but show responses to domestic monetary policy shocks as well. The focus on some other subject, showing the effects of monetary policy shocks at the same time, can also be found in Serwa and Wdowiński (2016), Górajski and Ulrichs (2016), and Bogusz et al. (2015) within the VAR framework, in Goczek and Partyka (2016) within the VECM (Vector Error Correction Model) framework, and in Dybka et al. (2017) within both frameworks. There is also a group of articles comparing the effects of monetary policy either within groups of post-transition economies (including Poland) or between them and developed economies. They usually use data from more distant periods. This group includes: Jarociński (2010), Gavin and Kemme (2009), Anzuini and Levy (2007), and Creel and Levasseur (2007).

Another group of articles related to this study uses factors estimated from large numbers of variables in forecasting exercises for Poland. Baranowski et al. (2010) find that economically uninterpretable factors reduce forecast errors for inflation, particularly at longer horizons. Szafrański (2011) finds a decrease in forecast errors at shorter horizons when using a structural factor related to other measures of inflation, and at longer horizons – when using a factor related to real activity. Szafranek (2017a) shows an improvement in inflation forecasts compared to a large number of benchmarks employing machine learning, with factor analysis as one of the steps in the analysis. Brzoza-Brzezina and Kotłowski (2009) use factor analysis to calculate the pure inflation rate. They find it to improve inflation forecasts and to be more responsive to monetary policy than standard measures of inflation. These results indicate that a large number of economic variables for Poland can be usefully summarised by factors extracted from them, at least for forecasting purposes. Similar findings of Stock and Watson (2002) for the US were used by Bernanke et al. (2005) as one of the arguments for studying the monetary transmission mechanism using FAVARs.

The last group of related articles investigates the role of commodity prices and foreign variables (among other factors) in explaining real activity, inflation and interest rates in Poland. Leszkiewicz-Kędzior (2015) and Socha (2014) find a strong relationship between global and domestic energy prices. Hałka and Szafrański (2015) find that factors in inflation common to Central and Eastern European economies explain 13% of inflation in Poland. According to Szafranek and Hałka (2017) deflation in Poland between 2014 and 2016 was driven mainly by commodity prices and foreign real activity. Such a relationship in general (a significant, positive relationship between inflation, and commodity prices and foreign real activity) was found in Hałka and Kotłowski (2016). Hałka and Szafranek (2016) point to large spillovers from inflation in the euro area to inflation in Poland. A significant role of commodity prices and foreign inflation in explaining the inflation in Poland was also found in Szafranek (2017b), a role of foreign inflation – in Hałka and Kotłowski (2013). Goczek and Mycielska (2013) find that interest rates in the euro area affect interest rates in Poland (and the relationship does not go the other way around). However, as they do not control for other variables affecting interest rates, their results are difficult to interpret. Results from this group of articles motivate using commodity price and foreign factors in extensions.

3 Models

The empirical analysis in this study is conducted in two steps. In the first step, a large number of observable variables is 'compressed' into a smaller number of unobservable factors, employing factor analysis. In the second step, these factors are used, together with one or a few observable factors, as endogenous variables in VARs.

As far as the first step is concerned, a general framework is the following. Let X_t^* denote a vector of global/foreign observable variables and X_t – a vector of domestic observable variables. They consist of different measures of key economic concepts. Let F_t^* and F_t be vectors of global/foreign and domestic unobservable factors, respectively. They are supposed to summarise information from X_t^* and X_t. Finally, let Y_t denote a vector of (domestic) observable factors. Y_t contains either variables without noise or variables in which noise might not be neglected when monetary policy decisions are made (see Amir Ahmadi and Uhlig, 2015). The relationship between observable variables and factors is the following:

$$\begin{bmatrix} X_t^* \\ X_t \\ Y_t \end{bmatrix} = \begin{bmatrix} \Lambda^* & 0 & 0 \\ 0 & \Lambda & \Lambda^Y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} F_t^* \\ F_t \\ Y_t \end{bmatrix} + \upsilon_t \tag{1}$$

where Λ^*, Λ and Λ^Y are matrices of factor loadings, and υ_t is a vector of error terms. According to this set of equations, global/foreign variables are restricted to be affected only by global/foreign factors, and domestic variables – by domestic factors, including observable ones.

In this study, global/foreign variables are divided into groups related to economic concepts, as in Liu et al. (2014). Each group is allowed to be affected only by one factor, having a structural interpretation. It means that the first equation from the matrix notation above can be expanded in the following way:

$$\begin{bmatrix} X_{1,t}^* \\ \vdots \\ X_{k,t}^* \end{bmatrix} = \begin{bmatrix} \Lambda_1^* & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \Lambda_k^* \end{bmatrix} \begin{bmatrix} F_{1,t}^* \\ \vdots \\ F_{k,t}^* \end{bmatrix} + \upsilon_{1,t} \tag{2}$$

where k is the number of global/foreign factors.

Domestic variables are also divided into groups connected with economic concepts. Each group is either allowed to be affected only by one, structural factor, as in Belviso and Milani (2006), or by many, economically uninterpretable factors, as in Bernanke et al. (2005). In the first approach, Λ^Y is restricted to 0, and the second equation from the matrix notation above has the following expansion:

$$\begin{bmatrix} X_{1,t} \\ \vdots \\ X_{l,t} \end{bmatrix} = \begin{bmatrix} \Lambda_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \Lambda_l \end{bmatrix} \begin{bmatrix} F_{1,t} \\ \vdots \\ F_{l,t} \end{bmatrix} + \upsilon_{2,t} \tag{3}$$

where l is the number of domestic factors.

Both global/foreign and domestic factors are estimated using principal components. However, the estimation of economically uninterpretable domestic factors requires additional steps. First, principal components are extracted from X_t. Let the vector C_t denote them. At this stage it is not explicitly taken into account that Y_t is observable. Nevertheless, under not very restrictive conditions, C_t includes both F_t and Y_t (see Stock and Watson, 2002). Then, $\hat{F}_t$ is obtained by rotating $\hat{C}_t$ to remove the effects of Y_t.

In practice, in order to be able to identify shocks by short-run, recursive restrictions in the second step of empirical analysis, variables from X_t are divided into slow-moving, which cannot be immediately affected by Y_t, and fast-moving, which can. Not only are principal components extracted from X_t, but also (separately) from slow-moving variables. Let them be denoted by the vector F_t^S. Next, $\hat{C}_t$ is regressed on $\hat{F}_t^S$ and Y_t, and factors estimated from X_t are rotated so that $F_t = \hat{C}_t - \hat{\beta} Y_t$, where β is the matrix of coefficients. Finally, factor loadings are estimated by regressing X_t on $\hat{F}_t$ and Y_t.[1]

In the second step, reduced-form VARs in the following general form are estimated:

$$\begin{bmatrix} F_t^* \\ F_t \\ Y_t \end{bmatrix} = \begin{bmatrix} B_{11}(L) & 0 & 0 \\ B_{21}(L) & B_{22}(L) & B_{23}(L) \\ B_{31}(L) & B_{32}(L) & B_{33}(L) \end{bmatrix} \begin{bmatrix} F_{t-1}^* \\ F_{t-1} \\ Y_{t-1} \end{bmatrix} + \varepsilon_t \tag{4}$$

where $B_{ij}(L)$ are matrices of coefficients ($i = 1 \ldots p$, $j = 1 \ldots p$, p is the number of endogenous variables in a VAR, L is a lag operator) and ε_t denotes a vector of error terms. According to the set of equations above, domestic factors are not allowed to affect foreign ones.

In extensions with global/foreign factors a seemingly unrelated regression estimation is employed, as it is more efficient in this case (see Enders, 2015). In the baseline models, sensitivity analysis and the remaining extensions $B_{11}(L)$ is restricted to 0 and VARs are estimated using ordinary least squares.

In all except two models shocks are identified by short-run, recursive restrictions.

[1] Bernanke et al. (2005) propose also an alternative approach: to extract factors from slow-moving and fast-moving variables separately, and order the former before, and the latter after, the observable factors in the Cholesky decomposition. However, similarly as in their study, in the present one it introduces collinearity between a measure of monetary policy and other interest rates, and destabilises the results. But when fast-moving interest rates and spreads are removed from the set of observable variables results are similar as when using the rotation of factors. Interestingly, they can also be largely replicated employing unrotated factors, but using generalised impulse response functions (insensitive to the ordering) instead of orthogonalised ones.

Global/foreign factors are, if included, ordered before domestic ones. Domestic, economically uninterpretable factors are ordered before Y_t. However, it should be noted that they can be affected immediately by Y_t, if they have non-zero factor loadings on it. The specifics of the ordering of domestic, structural factors shall be described in the next section. Of course, a given model always contains either structural or economically uninterpretable domestic factors, never both. In the remaining two models high-frequency identification is used. Specifically, monetary policy shocks from Kapuściński (2017), estimated similarly as in Gürkaynak et al. (2005), are employed as a measure of monetary policy. A similar approach is used, for example, in Barakchian and Crowe (2013).

4 Data

The set of variables applied to models described in the previous section consists of 135 domestic variables, 10 commodity price indices and 102 foreign series, comprising 3 variables for 34 economies. Domestic variables include 3 measures of monetary policy. The foreign economies are the following: the EU economies, the US, Brazil, Russia, India and China. The sample starts in January 2001 and ends in March 2017.

Variables in X_t are chosen to be similar as in Bernanke et al. (2005), but adapted to Poland and grouped as in Belviso and Milani (2006). They are supposed to cover information available to, and monitored by, members of the Monetary Policy Council (as reflected in Inflation Reports) and by the private sector, particularly by professional forecasters (as reflected, for example, in bulletins of commercial banks). The groups of variables are related to the following concepts:

- real activity – this group consists of measures of production, building permits, domestic and external trade, employment, unemployment, and job offers,
- inflation – comprises consumer and producer prices, prices in external trade, and wages,
- credit – includes loans, non-performing loans and spreads between interest rates on loans and the overnight money market interest rate,
- money – covers money supply, including divisia indices,
- interest rates – consists of money markets interest rates, government bond yields and interest rates on loans,
- financial market – comprises bilateral exchange rates (an increase means depreciation), effective exchange rates (an increase means appreciation), stock market indices, and dividend yield and price/earnings ratio,
- expectations – includes confidence indicators for industry and consumers, and spreads of money market interest rates and government bond yields versus the overnight money market interest rate.

One structural factor is estimated from each of these groups. They are given the following structural interpretations: the real activity factor, the inflation factor, the credit factor, the money factor, the interest rates factor, the financial market factor and the expectations factor, respectively, with such an ordering in a Cholesky decomposition. In practice, as shall be explained below in this section, only 4 factors are included in a given model. In an alternative approach, 4 economically uninterpretable factors are extracted from all variables collected together. For consistency, when economically uninterpretable factors are rotated, variables related to real activity, inflation, credit and money are used as slow-moving, variables related to interest rates, financial market and expectations – as fast-moving.

Compared to variables in Bernanke et al. (2005), for Poland data on capacity utilisation, personal income, duration of unemployment, hours of work and personal consumption expenditures are unavailable at a monthly frequency. Data on housing starts and new orders are not available for a large number of periods. Similarly for the components of the Purchasing Managers' Index (PMI) and for government bill yields, but these can be replaced with the components of the Business Climate Indicator (BCI) and by money market interest rates, respectively. Corporate bond yields, unavailable for any period, are replaced with interest rates on loans. Data on bank reserves and the monetary base adjusted for changes in the reserve requirement, also unavailable, could have been estimated. However, its use would not have brought much information, as in Poland the demand for reserves is driven mostly by the reserve requirement, and Narodowy Bank Polski adjusts the supply of reserves to the demand. Manufacturers' shipments of mobile homes do not seem to be relevant for Poland either. Instead, the set of variables is supplemented with the following series: production in construction, retail trade, quantities and prices in exports and imports, loans in foreign currencies (exchange rate adjusted), non-performing loans and divisia indices, not used in Bernanke et al. (2005). The components of aggregate variables, if employed, are also adapted to reporting in Poland (and, more generally, in the EU). The main innovation compared to Belviso and Milani (2006) is to add spreads between interest rates on loans and the overnight money market interest rate, to test for the financial accelerator.

In all except two models Y_t contains only the measure of monetary policy. The baseline measure in this study, for comparability with Bernanke et al. (2005) and Belviso and Milani (2006), is the overnight money market interest rate, WIBOR ON (Warsaw Interbank Offered Rate, Overnight). The volume-weighted overnight money market interest rate and an operating target of Narodowy Bank Polski, POLONIA (Polish Overnight Index Average), is available only since 2005. In sensitivity analysis WIBOR 1M, the 1-month money market interest rate, and monetary policy shocks from Kapuściński (2017) are checked. In the remaining two models, in the exercise analysing the marginal contribution of domestic factors to a standard VAR in extensions, Y_t consists of industrial production, CPI, WIBOR ON and REER, ordered in this way in the Cholesky decomposition. Such a set of variables in a VAR for monetary policy analysis is used, for example, in Peersman and Smets (2001).

X_t^* comprises commodity price indices calculated by the International Monetary Fund, and industrial production, CPI and 10-year government bond yields for the economies listed above. If unavailable, 10-year government bond yields are replaced with other interest rates. If missing only for some periods, the former are estimated using changes in the latter, assuming that they move proportionally.

On the one hand, the use of long-term instead of short-term interest rates in this study allows to capture the effects of forward guidance and asset purchases. On the other hand, long-term interest rates reflect also other factors (for example, the risk premium). A practical motive for not using short-term interest rates is to avoid having the same interest rate for the euro area economies. Liu et al. (2014) use short-term interest rates and more measures of real activity and inflation, but their set of economies is more global and contains only a few members of the euro area. Furthermore, the analysis of the international transmission of shocks is the very aim of their study. Here, it is only one of the extensions.

From each of these 4 groups (commodity price indices, industrial production, CPI, 10-year government bond yields) one structural factor is extracted, interpreted as: the commodity price factor, the foreign real activity factor, the foreign inflation factor and the foreign interest rates factor. The ordering in the Cholesky decomposition is the same as the ordering in which they are listed. In practice, either the first factor or the next three factors are used in a given model.

In general, 247 series are used. Variables are differenced if non-stationary and expressed in percent, or log-differenced if non-stationary and expressed in units other than percent. Results from unit root tests do not help much, as in many cases different tests find different orders of integration. Furthermore, their power is low, particularly for persistent processes (see, for example, DeJong et al., 1992). Instead, transformations are applied to make economic sense. For example, the log of industrial production should trend upwards, but its growth (log-differences) should be stationary. Eventually, transformations are similar as in Bernanke et al. (2005), with a few exceptions. First, job offers divided by registered unemployed persons are not used in log, since they are in percent. Second, building permits, unemployment rates and job offers divided by registered unemployment persons require (log-)differencing, as in Poland they are very slow-moving. Variables other than interest rates, spreads and financial market series are seasonally adjusted and, if necessary, calendar adjusted. (Log-)differenced variables are winsorised (the 5% extreme observations are replaced, 2.5% from each tail). The list of variables, together with sources and transformations, is shown in Table 1. The results from unit root tests and publicly available time series are provided in an online Appendix.[2]

When applying the data to the models, even using factor analysis to ‘compress’ variables, the number of degrees of freedom is a tight constraint. Between January 2001 and March 2017 there are 195 periods. VARs with stationary variables usually require a large number of lags, in order to mitigate the risk of omitting long-run relationship. Bernanke et al. (2005), and Belviso and Milani (2006) use 13 lags. In this study 12 lags are used in most models, even as in baseline models information criteria suggest 2-4 lags. 6 lags are checked in the sensitivity analysis. To keep the number of parameters below the number of periods divided by 3, as suggested by one of the rules of thumb

[2] Available at: `https://figshare.com/s/60ca26730a1712f6fe25`.

(see Ouliaris et al., 2016), only 5 variables can be used in a given model. In a FAVAR with high-frequency identification the number of lags needs to be reduced to 9 for the model to be stable. In models with the commodity price factor and in models with foreign factors 9 and 6 lags are used, respectively.

Summing up and supplementing the information above, endogenous variables in the first of baseline models with structural factors (FAVAR-BM, as Belviso and Milani) are the following: the real activity factor, the inflation factor, the credit factor, WIBOR ON and the financial market factor. In the remaining 3 ones, the credit factor is replaced with the money factor, the interest rates factor and the expectations factor, respectively. The baseline model with economically uninterpretable factors (FAVAR-BBE, as Bernanke, Boivin and Eliasz) uses 4 factors and WIBOR ON. In these models the number of lags is 12. Sensitivity analysis is conducted on the FAVAR-BM. First, the number of lags is reduced to 6. Second, WIBOR ON is replaced with either WIBOR 1M or monetary policy shocks (models with 12 and 9 lags, respectively). In the first extension, a standard VAR with log-differences of industrial production, the CPI and the REER, and with WIBOR ON is estimated, and then 1) extended with 2 factors, 2) WIBOR ON is replaced with monetary policy shocks. These models use respectively 12, 9 and 12 lags. Finally, in the second extension, the FAVAR-BM is extended 1) with the commodity price factor (9 lags), 2) the foreign factors (6 lags). In all except two models only the effects of monetary policy shocks are analysed. In models with global/foreign factors the focus is on the effects of commodity price, foreign real activity, foreign inflation and foreign interest rates shocks.

5 Results

5.1 Baseline results

5.1.1 Factor analysis

Starting with results from factor analysis, important for the interpretation of results from VARs, Figures 1-3 show factor loadings. Bars are ordered as variables in Table 1. Because series are standardised, loadings equal correlations between observable variables and unobservable factors. Usually they are considered to be significant if their absolute values are above 0.3-0.5.

In Figure 1 there are loadings on domestic, structural factors. The real activity factor positively affects measures of production, building permits, domestic and external trade, employment and job offers, and negatively affects unemployment. However, only absolute values of loadings of industrial production are above 0.5. The inflation factor is positively correlated with prices, particularly strongly with consumer prices, less with producer prices and much less with prices in external trade. Its correlation with wages is close to 0. Loadings of loans on the credit factor are positive, loadings of non-performing loans and loan spreads – negative, but absolute values of the negative ones are somewhat below 0.5. Money, interest rates and expectations factors correlate positively with all variables from which they are estimated. The financial market factor negatively affects bilateral exchange rates, and positively affects effective exchange rates and stock market indices. It is also, respectively, positively and negatively correlated with dividend yield and price/earnings ratio, though these relationships are relatively weak.

Interestingly, the financial market factor explains as much as 3/4 of the variability of the NEER and 2/3 of the variability of the WIG (Warszawski Indeks Gieldowy), a stock market index. Since it is associated with simultaneous appreciations of the former and increases in the latter (or depreciations and decreases, respectively), it might be related to the risk premium. If the exchange rate is driven mostly by the risk premium, that would explain a frequent finding that it depreciates after the tightening of monetary policy. This is because it is followed by economic contraction, which should increase the risk premium.[3] It does not necessarily mean that monetary policy does not affect the exchange rate also through different channels, possibly working in the opposite direction (as UIP or carry trade). However, a more careful identification strategy might be required for them not to be overshadowed by the effects through the risk premium.[4]

[3] An alternative interpretation is that not only income earned on deposits, but also on equities affects the exchange rate. And the economic contraction lowers profits and returns on equity, which compensates for higher interest on deposits.

[4] For example, Kapuściński (2017) finds an appreciation of the exchange rate following a surprise rise in the interest rate in Poland, focusing on responses in 30- and 60-minute windows around announcements of Monetary Policy Council's decisions.

Figure 2 shows loadings on domestic, economically uninterpretable factors after a rotation. Loadings on an observable factor, the WIBOR ON, are shown as well. Variables do not appear to endogenously group themselves in 'entering' factors. That would have made the latter de facto structural. If anything, the first two factors the most affect the variables related to credit. The first factor is negatively correlated with domestic currency loans and positively correlated with foreign currency loans, the second one is positively correlated with both. However, absolute values of loadings of domestic currency loans on the first factor are below 0.5. The third factor correlates the most with variables connected with the financial market – positively with bilateral exchange rates, negatively with effective exchange rates and stock market indices. Loadings on the fourth factor are the highest, and negative, for measures of money supply. WIBOR ON contemporaneously affects other interest rates (positively), but also variables related to expectations (negatively).

In Figure 3 there are loadings on global/foreign factors. All except one commodity price index, connected with prices of beverages, have loadings on the commodity price factor above 0.5. Almost all loadings of foreign industrial production, CPI and 10-year government bond yields, on foreign real activity, inflation and interest rates factors, respectively, are positive. Foreign factors have relatively weak effects on Brazil, Russia, India and China.

Figures 4-6 show factor scores with 68% confidence intervals. They were calculated using delete-d jacknife, with d equal to $\sqrt{n}$, where n is the number of observations. 1000 samples of d observations were randomly drawn and removed from all observations, and factors were extracted and scores were made using remaining observations. Confidence intervals are practically invisible. It suggests that uncertainty related to estimation of factors can be ignored. Therefore, standard, analytical confidence intervals are used in VAR analysis.

Figure 7 compares shares of the variability of each domestic variable explained by structural and economically uninterpretable factors. Structural factors (specifically, the real activity factor in this case) explain a much larger share of the variability of industrial production. On the other hand, economically uninterpretable factors are much better in explaining employment and unemployment. There are also significant differences for money supply in favour of structural factors, and for the PPI, foreign currency loans, loan spreads and confidence indicators in favour of economically uninterpretable factors.

At this point an important caveat should be made. FAVARs allow to analyse the effects of shocks on observable variables only through unobservable factors included in VARs. Their maximal number, for a given number of observations and lags, might be insufficient to capture some important relationships. Even for a 'right' (according to some criterion) number of factors some information is lost. It might be a measurement error, but also information measured reliably in a given variable, though not in any of the remaining variables. However, these components matter only when they are necessary to identify shocks or when shocks affect them, which does not seem very likely. In this study, results from factor analysis suggest that particularly the variability of employment and unemployment might be insufficiently explained by structural factors, and the variability of industrial production – by economically uninterpretable factors.

5.1.2 Vector autoregressions

Moving to results from VARs, Figure 8 shows responses of structural factors to a monetary policy impulse from the baseline FAVARs-BM, with 68% confidence intervals. Interpreting the results it should be noted that these factors have the mean 0, the standard deviation 1 and correspond to transformed variables. Following an increase in WIBOR ON, the interest rates factor increases, and the financial market and expectations factors decrease. Their responses are very quick, reaching peaks/troughs as early as immediately or after 1 month. There is also a decline in real activity, inflation and credit factors. The maximal effect on the first one occurs after 3 months, on the second and on the third one – after 15 months. The response of the money factor is less well-behaved. A trough negative response after 3 months is followed by an increase after 6 months and a more persistent decrease in the second year after the shock.[5]

Mostly for symmetry, in Figure 9 there are the responses of economically uninterpretable factors to a monetary policy shock from the baseline FAVAR-BBE. These factors have standard deviations different from 1 (although, loadings shown in Figure 2 were computed for standardised factors). Factor 1 increases, contributing to (among other things) an increase in foreign currency loans and a decrease in domestic currency loans. There is also a decline in factor 2, which lowers both domestic and foreign currency loans. After an increase in WIBOR ON the response of factor 3 (correlating positively with bilateral exchange rates, negatively with effective exchange rates and stock market indices) switches signs for 2 years. The effect on factor 4 is positive, contributing to a decrease in money supply. However, in this model each variable is affected by many factors and the net effects shall be known only after calculating impulse responses to the former (see below).

Figures 10-11 and 12-13 show responses of 30 (out of 132) variables to a monetary policy impulse, derived from responses of factors, from the baseline FAVARs-BM and the baseline FAVAR-BBE, respectively. Each response is computed as a sum of responses of factors ‘entering’ a given variable, multiplied by factor loadings. Furthermore, in order to restore original units, responses are multiplied by standard deviations of variables. Finally, responses of (log-)differenced variables are cumulated, so they are

[5]As mentioned, in FAVARs-BM real activity, inflation and financial market factors, and WIBOR ON are the ‘core’ variables, while credit, money, interest rates and expectations factors are introduced separately. Figure 8 shows impulse response functions of the ‘core’ variables from a model with the credit factor. However, their responses in the remaining models are similar.

comparable with these from VARs using non-stationary variables in (log-)levels, as usually in the literature. On the other hand, they are neither explicitly comparable with results from Bernanke et al. (2005), who go with responses of variables in logs further to levels, nor to these from Belviso and Milani (2006), who do not restore original units and do not cumulate responses of variables in differences. The online Appendix provides also non-cumulative impulse responses of differenced variables and responses of remaining 102 variables.

According to results from FAVAR-BM, following a 0.20 percentage point (1 standard deviation) increase in WIBOR ON, industrial production decreases (or increases after a decrease – models are linear). After 14 months it is lower by 0.81% (confidence interval: -1.60 – -0.01%), compared to a counterfactual without a shock. There is also a decline in production in construction, building permits and retail trade. Point estimates from FAVAR-BBE have the same sign, but are less precise. In both models employment decreases and unemployment increases. However, the effects according to results from FAVAR-BBE are much stronger. Job offers decline, with more precise estimates from FAVAR-BM. Differences in estimates appear to be related to differences in shares of the variability of variables explained by factors in the two approaches.

The point impulse response function for CPI is negative in both models. After 40 months consumer prices are lower by 0.21% (-0.47 – 0.05%), according to estimates from FAVAR-BM, which also in this case are more precise. In both models confidence intervals are on both sides of 0 for all horizons, though they are close to 0 from above in the model with structural factors, and responses of growth in prices are clearly statistically significant for many horizons. The annualised trough effect on growth in prices is at -0.17 percentage point (-0.26 – -0.08 percentage point) after 15 months. The response of PPI is similar as the response of CPI in FAVAR-BM, in FAVAR-BBE confidence intervals are very wide. On the other hand, FAVAR-BBE, better capturing the effects on the labour market, indicates a decrease in wages, while their response in FAVAR-BM is economically insignificant.

An increase in WIBOR ON is also associated with a decrease in loans. The effects arising from a decline in demand appear to be amplified by the supply-side effects through the financial accelerator – non-performing loans and loan spreads increase. Results from FAVAR-BBE, in contrast to these from FAVAR-BM, indicate some delay in the interest rate pass through (an initial negative response of spreads).

Estimates for responses of the measures of money supply are imprecise. Point impulse response functions are negative. Changes in WIBOR ON are transmitted to other money market interest rates, government bond yields and loan rates. However, point estimates differ between models. In FAVAR-BM they appear to be underestimated.

A monetary policy impulse depreciates the NEER and lowers the WIG index. As far as the response of the exchange rate is concerned, it might be that the effects through UIP are overshadowed by the effect through the risk premium, as discussed above. But this result is not robust among studies using VARs, which calls for a different strategy to identify the causal effect.[6] There is also a rise in dividend yield and a decline in price/earnings ratio. In FAVAR-BBE the effects are more persistent. But it should be noted that factors in both models explain only a small share of the variability of these 2 variables, except for dividend yield in FAVAR-BM.

Finally, the PMI, the consumer confidence indicator, and spreads of longer money market interest rates and government bond yields versus WIBOR ON decrease. The decrease in spreads is less persistent according to results from FAVAR-BBE.

In general, both FAVAR-BM and FAVAR-BBE indicate that the tightening of monetary policy has broad, contractionary effects. An increase in WIBOR is transmitted to other interest rates. Financial asset prices decrease, but, at a monthly frequency, the exchange rate does not appear to appreciate, as it should according to economic theory (specifically, according to UIP). If anything, it depreciates. The effects of the shock are amplified through the financial accelerator. In effect, measures of (current and expected) real economic activity and inflation decrease. It is associated with a decrease in credit and money, with more uncertainty related to the response of the latter. Results from models with structural and economically uninterpretable factors somewhat differ in the estimated strength of the effects and in the precision of the estimates.

5.2 Sensitivity analysis

Figures 14-16 show results from sensitivity analysis, in which FAVAR-BM is modified in 3 ways. In order to preserve space, only responses of 16 observable variables/factors to a monetary policy impulse are shown. Results from analogous exercises on FAVAR-BBE (with similar conclusions) are available in the online appendix.

When the original number of lags is reduced to 6, by as much as half but to a number remaining above suggested by information criteria, in most cases estimates are very imprecise (Figure 14). On the other hand, point impulse response functions have the same signs, though for consumer and producer prices it takes much more time to decrease. It appears that 6 lags are insufficient to adequately capture dynamic relationships between variables. However, taking into account that models use variables differenced if non-stationary (long-run relationship is not explicitly modelled), it is not very surprising and should not be interpreted as invalidating baseline results.

Baseline results do not change qualitatively when WIBOR 1M is used instead of WIBOR ON as a measure of monetary policy (Figure 15). When monetary policy shocks are identified using high-frequency identification instead of short-run, recursive restrictions (WIBOR ON is replaced with externally identified cumulative series of

[6] For example, Kapuściński et al. (2016) also find a depreciation in some models, but in other they do not. In Darvas (2013) there is a depreciation at the beginning and then an appreciation. Arratibel and Michaelis (2013) and Jarociński (2010) impose an appreciation by sign restrictions, hardly solving the problem.

shocks, residuals are still orthogonalised by a Cholesky decomposition, though), changes in results are minor (Figure 16). Estimates of responses of variables affected by the real activity factor are less precise. A decrease in prices starts later.

Summing up, baseline results appear to be robust to reasonable changes in original models. However, some subjective choices related to their specification affect the precision of estimates.

5.3 Extensions

In Figure 17 there are results from the first extension, which analyses a marginal contribution of domestic factors to standard VARs. It compares responses of production in industry, the CPI, measure of monetary policy and the REER to a monetary policy impulse from 4 models: the FAVAF-BM, a standard VAR (with production in industry, CPI, WIBOR ON and REER as endogenous variables, transformed for stationarity) and the standard VAR supplemented with 2 economically uninterpretable factors, or with high-frequency identification. Impulse response functions with confidence intervals are available in the online Appendix.

In results from the standard VAR there is a price puzzle (a rise in prices after an increase in the interest rate, see, for example, Sims, 1992). It can be removed by the inclusion of 2 economically uninterpretable factors. Inclusion of only 1 is insufficient, inclusion of as many as 3 does not change much. It might indicate that additional information, compared to the standard, 4-variable VAR for monetary policy analysis in an open economy, is required to correctly identify monetary policy shocks.[7] Responses of the remaining variables are qualitatively similar for FAVAR-BM, the standard VAR and the standard VAR supplemented with 2 factors.

However, the price puzzle can also be removed by using high-frequency identification instead of identification by short-run, recursive restrictions. It requires less effort related to data processing. Furthermore, if it properly removes the endogenous component of changes in interest rates, there is no threat of omitted variable bias (see Bishop and Tulip, 2017, for a formal derivation of this argument). On the other hand, impulse response functions from the model with high-frequency identification (including a response of the measure of monetary policy) are worryingly persistent. Externally identified series of shocks might need to be further cleaned, for example, as in Miranda-Agrippino and Ricco (2017).

Figures 18-21 show results from the second extension. The set of variables in FAVAR-BM is extended either with the commodity price factor or with foreign real activity, inflation and interest rates factors. The effects of shocks to these variables are investigated. Again, only responses of 16 observable variables/factors are shown,

[7] But the validity of such an interpretation is not clear-cut. Structural residuals from the 4-variable VAR are more correlated with high-frequency identified monetary policy shocks, which can serve as a benchmark (see Rudebusch, 1998), than these from the VAR additionally containing 2 factors.

and responses from FAVAR-BBE (with similar conclusions) are available in the online Appendix. It should be noted that these results are from models with probably an insufficient number of lags and should be treated with caution. In future research, their sensitivity can be analysed either using a larger number of lags when a sufficient number of observations is available or resigning from the variables unavailable before 2001 and extending the sample backwards.[8]

After an increase in commodity prices, domestic prices rise (Figure 18). In response, monetary policy is tightened. Similarly, there is an increase in domestic production following an increase in foreign real activity (Figure 19) and domestic prices rise after a rise in foreign prices (Figure 20). In these two cases the domestic interest rate also increases. It goes up after an increase in foreign interest rates as well (Figure 21). However, at least to some extent, it results from a (rather puzzling) rise in domestic prices following this shock. It might be because it is not clean from anticipatory changes in foreign interest rates related to expected inflation, which materialises (put differently, a foreign interest rates shock might not be correctly identified).

[8]It might be argued (rightly) that if global/foreign factors are significant, they should be included in baseline models, used to identify the effects of monetary policy shocks. However, sensitivity analysis shows that 6 lags, the maximum for a given number of observations and variables while keeping the number of degrees of freedom reasonable, are insufficient to this end. Fortunately, results from models with high-frequency identification, robust to an omission of variables in the information set of the central bank, are similar. But their sensitivity should be analysed having a sufficient number of additional observations.

6 Conclusion

This study applies FAVARs to identify the effects of monetary policy shocks on 132 variables in Poland. Compared to existing studies, it does so using a fully fledged version of this framework, and ‘compressing’ variables (separately) to both structural factors (as in Belviso and Milani, 2006) and economically uninterpretable factors (as in Bernanke et al., 2005). Sensitivity with respect to the specification of models is analysed, and the analysis is extended to check the marginal contribution of factors to standard VARs and the effects of changes in global/foreign factors.

The tightening of monetary policy is found to have broad, contractionary effects on different measures of, among other things, real activity, inflation, credit and stock prices. However, the exchange rate does not appreciate. It might be because the effects through a risk premium prevail, as suggested by results from factor analysis. But this finding varies among studies using VARs. It calls for a different strategy to identify the causal effect.

The results are robust, but some subjective choices related to the specification of models affect the precision of estimates. Information from two factors is sufficient to remove the price puzzle from standard VARs. Domestic prices respond to global prices of commodities and foreign prices. Domestic production and interest rates – to their foreign counterparts.

However, results somewhat differ depending on whether structural or economically uninterpretable factors are applied. Mainly with respect to the precision of estimates and the strength of the effects, though. Furthermore, even using factor analysis to ‘compress’ variables, a small number of observations remains constraining. And if the aim is to remove the price puzzle from the model with stationary variables, by better identifying monetary policy shocks, it can also be achieved by using high-frequency identification.[9] It requires less data processing, without a threat of omitted variable bias. On the other hand, FAVARs have also other advantages (as listed in the Introduction).

As far as policy implications are concerned, the study confirms an earlier finding that monetary policy does affect inflation in Poland. However, it should be noted that the quantitative effects are uncertain, as reflected by wide confidence intervals for the response of prices to a monetary policy impulse. For example, according to a point estimate, lowering inflation from 5 to 2.5% would require increasing the interest rate by 2.94 percentage points (more than 11 rises of 0.25 percentage point). But 68% confidence intervals span from 1.92 to 6.25 percentage points. Furthermore, the maximum effect of each interest rate rise would come after 15 months. Therefore, on the one hand gradualism (see Bernanke, 2004), on the other hand forward-lookingness

[9] In models with non-stationary variables, as in Kapuściński et al. (2016), the price puzzle rarely occurs.

appear to be required when making monetary policy decisions.

In future research, the set of variables can be extended with some important and interesting variables available only at a quarterly frequency, at least for some periods. They include GDP, house prices, bank profits, capital buffers and lending policy. Then, an expectation maximisation algorithm can be used to estimate factors. Variables can be grouped differently in structural factors, especially that, for example, labour market variables share only a limited part of their variability with measures of production. It could also be interesting to combine FAVARs with high-frequency identification and the approach of Romer and Romer (2004) to identify monetary policy shocks, by adding a forecast factor. A larger number of observations should also allow to estimate FAVARs with time-varying coefficients. Borio and Hofmann (2017) show that the effects of monetary shocks might differ depending on the initial level of interest rates. According to Auer et al. (2017) the role of global factors in explaining domestic inflation is increasing.

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Appendix

Table 1. Data

	Variable	Source	Transformation	Mnemonic code
Real activity				
1	Production in industry	Eurostat	dlog	pi
2	Production in industry – intermediate goods	Eurostat	dlog	pi_int
3	Production in industry – energy	Eurostat	dlog	pi_ene
4	Production in industry – capital goods	Eurostat	dlog	pi_cap
5	Production in industry – consumer goods	Eurostat	dlog	pi_con
6	Production in industry – durable consumer goods	Eurostat	dlog	pi_con_d
7	Production in industry – non-durable consumer goods	Eurostat	dlog	pi_con_nd
8	Production in industry – mining and quarrying	Eurostat	dlog	pi_min
9	Production in industry – manufacturing	Eurostat	dlog	pi_man
10	Production in industry – ele., gas, ste. and air con. sup.	Eurostat	dlog	pi_ele
11	Production in industry – wat. col., tre. and sup.	Eurostat	dlog	pi_wat
12	Production in construction	Eurostat	dlog	pc
13	Building permits	Eurostat	dlog	bp
14	Retail trade	Eurostat	dlog	rt
15	Exports	NBP	dlog	exp_q
16	Imports	NBP	dlog	imp_q
17	Average paid employment in ent. sec.	CSO of Poland	dlog	emp
18	Average paid employment in ent. sec. – ind.	CSO of Poland	dlog	emp_ind
19	Average paid employment in ent. sec. – con.	CSO of Poland	dlog	emp_con
20	Average paid employment in ent. sec. – ret. tra.	CSO of Poland	dlog	emp_rt
21	Unemployment rate – registered	CSO of Poland	d	une_reg
22	Unemployment rate – Labour Force Survey	Eurostat	d	une_lfs
23	Job offers	CSO of Poland	dlog	jo
24	Job offers/registered unemployed persons	CSO of Poland	d	jo_une_reg
Inflation				
25	CPI	NBP	dlog	cpi
26	Core CPI – net of administered prices	NBP	dlog	cpi_cor_a
27	Core CPI – net of most volatile prices	NBP	dlog	cpi_cor_mv
28	Core CPI – net of food and energy prices	NBP	dlog	cpi_cor_fe
29	Core CPI – 15% trimmed mean	NBP	dlog	cpi_cor_tm
30	HICP	Eurostat	dlog	hicp
31	HICP – food and non-alcoholic beverages	Eurostat	dlog	hicp_foo
32	HICP – alcoholic beverages, tobacco and narcotics	Eurostat	dlog	hicp_alc
33	HICP – clothing and footwear	Eurostat	dlog	hicp_clo
34	HICP – housing, water, electricity, gas and other fuels	Eurostat	dlog	hicp_hou
35	HICP – fur., hou. equ. and rou. hou. mai.	Eurostat	dlog	hicp_fur
36	HICP – health	Eurostat	dlog	hicp_hea
37	HICP – transport	Eurostat	dlog	hicp_tra
38	HICP – communications	Eurostat	dlog	hicp_com
39	HICP – recreation and culture	Eurostat	dlog	hicp_rec
40	HICP – education	Eurostat	dlog	hicp_edu
41	HICP – restaurants and hotels	Eurostat	dlog	hicp_res
42	HICP – goods	Eurostat	dlog	hicp_goo
43	HICP – services	Eurostat	dlog	hicp_ser
44	PPI	Eurostat	dlog	ppi
45	PPI – intermediate goods	Eurostat	dlog	ppi_int
46	PPI – energy	Eurostat	dlog	ppi_ene
47	PPI – capital goods	Eurostat	dlog	ppi_cap
48	PPI – consumer goods	Eurostat	dlog	ppi_con
49	PPI – durable consumer goods	Eurostat	dlog	ppi_con_d
50	PPI – non-durable consumer goods	Eurostat	dlog	ppi_con_nd
51	PPI – mining and quarrying	Eurostat	dlog	ppi_min
52	PPI – manufacturing	Eurostat	dlog	ppi_man
53	PPI – ele., gas, ste. and air con. sup.	Eurostat	dlog	ppi_ele
54	PPI – wat. col., tre. and sup.	Eurostat	dlog	ppi_wat
55	Price index in external trade – exports	CSO of Poland	dlog	exp_p
56	Price index in external trade – imports	CSO of Poland	dlog	imp_p
57	Average monthly gross wages and sal. in ent. sec.	CSO of Poland	dlog	wag
58	Average monthly gross wages and sal. in ent. sec. – ind.	CSO of Poland	dlog	wag_ind
59	Average monthly gross wages and sal. in ent. sec. – con.	CSO of Poland	dlog	wag_con
60	Average monthly gross wages and sal. in ent. sec. – ret. tra.	CSO of Poland	dlog	wag_rt
Credit				

61	Loans	NBP	dlog	loa
62	Loans – dom. cur.	NBP	dlog	loa_dc
63	Loans to non-fin. cor. – dom. cur.	NBP	dlog	loa_dc_nfc
64	Loans to non-fin. cor. – cur. acc. and wor. cap. – dom. cur.	NBP	dlog	loa_dc_nfc_ca
65	Loans to non-fin. cor. – investment – dom. cur.	NBP	dlog	loa_dc_nfc_inv
66	Loans to non-fin. cor. – purchase of real property – dom. cur.	NBP	dlog	loa_dc_nfc_prp
67	Loans to hou. – dom. cur.	NBP	dlog	loa_dc_h
68	Loans to hou. – consumer – dom. cur.	NBP	dlog	loa_dc_h_con
69	Loans to hou. – cur. acc., ind. ent. and far. – dom. cur.	NBP	dlog	loa_dc_h_ca
70	Loans to hou. – investment – dom. cur.	NBP	dlog	loa_dc_h_inv
71	Loans to hou. – purchase of real property – dom. cur.	NBP	dlog	loa_dc_h_prp
72	Loans – for. cur.	NBP	dlog	loa_fc
73	Loans to non-fin. cor. – for. cur.	NBP	dlog	loa_fc_nfc
74	Loans to non-fin. cor. – cur. acc. and wor. cap. – for. cur.	NBP	dlog	loa_fc_nfc_ca
75	Loans to non-fin. cor. – investment – for. cur.	NBP	dlog	loa_fc_nfc_inv
76	Loans to non-fin. cor. – purchase of real property – for. cur.	NBP	dlog	loa_fc_nfc_prp
77	Loans to hou. – for. cur.	NBP	dlog	loa_fc_h
78	Loans to hou. – consumer – for. cur.	NBP	dlog	loa_fc_h_con
79	Loans to hou. – cur. acc., ind. ent. and far. – for. cur.	NBP	dlog	loa_fc_h_ca
80	Loans to hou. – investment – for. cur.	NBP	dlog	loa_fc_h_inv
81	Loans to hou. – purchase of real property – for. cur.	NBP	dlog	loa_fc_h_prp
82	Non-performing loans/loans	NBP	d	npl
83	Interest rate on loans to hou. – consumption-WIBOR ON	NBP, Datastream		ir_con_spr
84	Interest rate on loans to hou. – house purchases-WIBOR ON	NBP, Datastream		ir_hp_spr
85	Interest rate on loans to non-fin. cor.-WIBOR ON	NBP, Datastream		ir_nfc_spr
Money				
86	Currency in circulation	NBP	dlog	cur
87	Overnight deposits and other liabilities	NBP	dlog	dep
88	M1	NBP	dlog	m1
89	M2-M1	NBP	dlog	m2_m1
90	M2	NBP	dlog	m2
91	M3-M2	NBP	dlog	m3_m2
92	M3	NBP	dlog	m3
93	M1 – divisia	NBP	dlog	m1_div
94	M2 – divisia	NBP	dlog	m2_div
95	M3 – divisia	NBP	dlog	m3_div
96	M2 – real	NBP	dlog	m2_rea
Interest rates				
97	WIBOR 3M	Datastream		wibor_3m
98	WIBOR 6M	Datastream		wibor_6m
99	WIBOR 1Y	Datastream		wibor_1y
100	Goverment bond yields 2Y	Datastream		gby_2y
101	Goverment bond yields 5Y	Datastream		gby_5y
102	Goverment bond yields 10Y	Datastream		gby_10y
103	Interest rate on loans to hou. – consumption	NBP		ir_con
104	Interest rate on loans to hou. – house purchases	NBP		ir_hp
105	Interest rate on loans to non-fin. cor.	NBP		ir_nfc
Financial market				
106	EURPLN exchange rate	Datastream	dlog	eurpln
107	USDPLN exchange rate	Datastream	dlog	usdpln
108	CHFPLN exchange rate	Datastream	dlog	chfpln
109	NEER	Eurostat	dlog	neer
110	REER	Eurostat	dlog	reer
111	WIG index	Datastream	dlog	wig
112	WIG-banking index	Datastream	dlog	wig_ban
113	WIG-construction index	Datastream	dlog	wig_con
114	WIG-food index	Datastream	dlog	wig_foo
115	WIG-IT index	Datastream	dlog	wig_it
116	WIG-telecom index	Datastream	dlog	wig_tel
117	WIG dividend yield	Datastream		wig_dy
118	WIG price/earnings	Datastream		wig_pe
Expectations				
119	PMI	Markit Economics		pmi
120	Assessment of order-book levels – ind.	Eurostat		ci_ind_ob
121	Assessment of export order-book levels – ind.	Eurostat		ci_ind_ob_e
122	Assessment of stocks of finished products – ind.	Eurostat		ci_ind_sto
123	Production expectations for the months ahead – ind.	Eurostat		ci_ind_pro
124	Selling price expectations for the months ahead – ind.	Eurostat		ci_ind_sp
125	Employment expectations for the months ahead – ind.	Eurostat		ci_ind_emp

126	Confidence indicator – con.	Eurostat		ci_con
127	WIBOR 3M-WIBOR ON	Datastream		wibor_3m_spr
128	WIBOR 6M-WIBOR ON	Datastream		wibor_6m_spr
129	WIBOR 1Y-WIBOR ON	Datastream		wibor_1y_spr
130	Goverment bond yields 2Y-WIBOR ON	Datastream		gby_2y_spr
131	Goverment bond yields 5Y-WIBOR ON	Datastream		gby_5y_spr
132	Goverment bond yields 10Y-WIBOR ON	Datastream		gby_10y_spr
Measures of monetary policy				
133	WIBOR ON	Datastream		wibor_on
134	WIBOR 1M	Datastream		wibor_1m
135	Monetary policy shock	Kapuściński (2017)		mps
Commodity prices				
136	All Commodity Price Index	IMF	dlog	pallfnf
137	Non-Fuel Price Index	IMF	dlog	pnfuel
138	Food and Beverage Price Index	IMF	dlog	pfandb
139	Food Price Index	IMF	dlog	pfood
140	Beverage Price Index	IMF	dlog	pbeve
141	Industrial Inputs Price Index	IMF	dlog	pindu
142	Agricultural Raw Materials Index	IMF	dlog	prawm
143	Metals Price Index	IMF	dlog	pmeta
144	Fuel Index	IMF	dlog	pnrg
145	Crude Oil, Price index	IMF	dlog	poilapsp
Real activity, foreign				
146	Production in industry – Austria	Datastream	dlog	pi_aus
147	Production in industry – Belgium	Datastream	dlog	pi_bel
148	Production in industry – Bulgaria	Datastream	dlog	pi_bul
149	Production in industry – Croatia	Datastream	dlog	pi_cro
150	Production in industry – Cyprus	Datastream	dlog	pi_cyp
151	Production in industry – Czech Republic	Datastream	dlog	pi_cr
152	Production in industry – Denmark	Datastream	dlog	pi_den
153	Production in industry – Estonia	Datastream	dlog	pi_est
154	Production in industry – Finland	Datastream	dlog	pi_fin
155	Production in industry – France	Datastream	dlog	pi_fra
156	Production in industry – Germany	Datastream	dlog	pi_ger
157	Production in industry – Greece	Datastream	dlog	pi_gre
158	Production in industry – Hungary	Datastream	dlog	pi_hun
159	Production in industry – Ireland	Datastream	dlog	pi_ire
160	Production in industry – Italy	Datastream	dlog	pi_ita
161	Production in industry – Latvia	Datastream	dlog	pi_lat
162	Production in industry – Lithuania	Datastream	dlog	pi_lit
163	Production in industry – Luxembourg	Datastream	dlog	pi_lux
164	Production in industry – Malta	Datastream	dlog	pi_mal
165	Production in industry – Netherlands	Datastream	dlog	pi_net
166	Production in industry – Portugal	Datastream	dlog	pi_por
167	Production in industry – Romania	Datastream	dlog	pi_rom
168	Production in industry – Slovakia	Datastream	dlog	pi_slova
169	Production in industry – Slovenia	Datastream	dlog	pi_slove
170	Production in industry – Spain	Datastream	dlog	pi_spa
171	Production in industry – Sweden	Datastream	dlog	pi_swe
172	Production in industry – United Kingdom	Datastream	dlog	pi_uk
173	Production in industry – Brazil	Datastream	dlog	pi_bra
174	Production in industry – Russia	Datastream	dlog	pi_rus
175	Production in industry – India	Datastream	dlog	pi_ind
176	Production in industry – China	Datastream	dlog	pi_chi
177	Production in industry – United States	Datastream	dlog	pi_us
Inflation, foreign				
178	CPI – Austria	Datastream	dlog	cpi_aus
179	CPI – Belgium	Datastream	dlog	cpi_bel
180	CPI – Bulgaria	Datastream	dlog	cpi_bul
181	CPI – Croatia	Datastream	dlog	cpi_cro
182	CPI – Cyprus	Datastream	dlog	cpi_cyp
183	CPI – Czech Republic	Datastream	dlog	cpi_cr
184	CPI – Denmark	Datastream	dlog	cpi_den
185	CPI – Estonia	Datastream	dlog	cpi_est
186	CPI – Finland	Datastream	dlog	cpi_fin
187	CPI – France	Datastream	dlog	cpi_fra
188	CPI – Germany	Datastream	dlog	cpi_ger
189	CPI – Greece	Datastream	dlog	cpi_gre
190	CPI – Hungary	Datastream	dlog	cpi_hun

191	CPI – Ireland	Datastream	dlog	cpi_ire
192	CPI – Italy	Datastream	dlog	cpi_ita
193	CPI – Latvia	Datastream	dlog	cpi_lat
194	CPI – Lithuania	Datastream	dlog	cpi_lit
195	CPI – Luxembourg	Datastream	dlog	cpi_lux
196	CPI – Malta	Datastream	dlog	cpi_mal
197	CPI – Netherlands	Datastream	dlog	cpi_net
198	CPI – Portugal	Datastream	dlog	cpi_por
199	CPI – Romania	Datastream	dlog	cpi_rom
200	CPI – Slovakia	Datastream	dlog	cpi_slova
201	CPI – Slovenia	Datastream	dlog	cpi_slove
202	CPI – Spain	Datastream	dlog	cpi_spa
203	CPI – Sweden	Datastream	dlog	cpi_swe
204	CPI – United Kingdom	Datastream	dlog	cpi_uk
205	CPI – Brazil	Datastream	dlog	cpi_bra
206	CPI – Russia	Datastream	dlog	cpi_rus
207	CPI – India	Datastream	dlog	cpi_ind
208	CPI – China	Datastream	dlog	cpi_chi
209	CPI – United States	Datastream	dlog	cpi_us
Interest rates, foreign				
210	Government bond yields – Austria	Datastream		gby_aus
211	Government bond yields – Belgium	Datastream		gby_bel
212	Government bond yields – Bulgaria	Datastream		gby_bul
213	Government bond yields – Croatia	Datastream		gby_cro
214	Government bond yields – Cyprus	Datastream		gby_cyp
215	Government bond yields – Czech Republic	Datastream		gby_cr
216	Government bond yields – Denmark	Datastream		gby_den
217	Government bond yields – Estonia	Datastream		gby_est
218	Government bond yields – Finland	Datastream		gby_fin
219	Government bond yields – France	Datastream		gby_fra
220	Government bond yields – Germany	Datastream		gby_ger
221	Government bond yields – Greece	Datastream		gby_gre
222	Government bond yields – Hungary	Datastream		gby_hun
223	Government bond yields – Ireland	Datastream		gby_ire
224	Government bond yields – Italy	Datastream		gby_ita
225	Government bond yields – Latvia	Datastream		gby_lat
226	Government bond yields – Lithuania	Datastream		gby_lit
227	Government bond yields – Luxembourg	Datastream		gby_lux
228	Government bond yields – Malta	Datastream		gby_mal
229	Government bond yields – Netherlands	Datastream		gby_net
230	Government bond yields – Portugal	Datastream		gby_por
231	Government bond yields – Romania	Datastream		gby_rom
232	Government bond yields – Slovakia	Datastream		gby_slova
233	Government bond yields – Slovenia	Datastream		gby_slove
234	Government bond yields – Spain	Datastream		gby_spa
235	Government bond yields – Sweden	Datastream		gby_swe
236	Government bond yields – United Kingdom	Datastream		gby_uk
237	Government bond yields – Brazil	Datastream		gby_bra
238	Government bond yields – Russia	Datastream		gby_rus
239	Government bond yields – India	Datastream		gby_ind
240	Government bond yields – China	Datastream		gby_chi
241	Government bond yields – United States	Datastream		gby_us

Figure 1. Factor loadings, structural factors

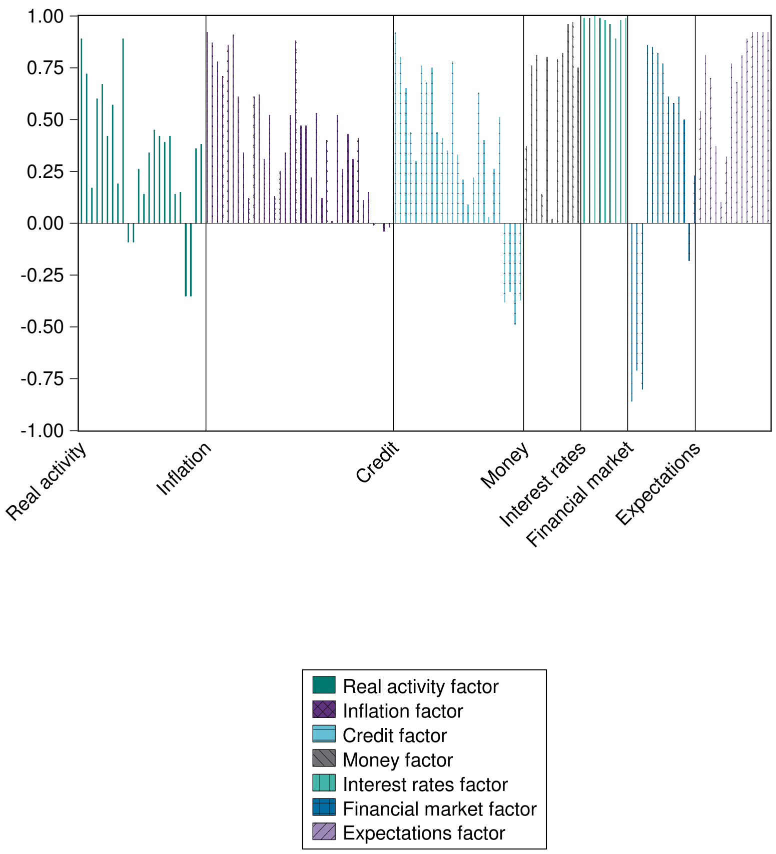


Figure 2. Factor loadings, economically uninterpretable factors

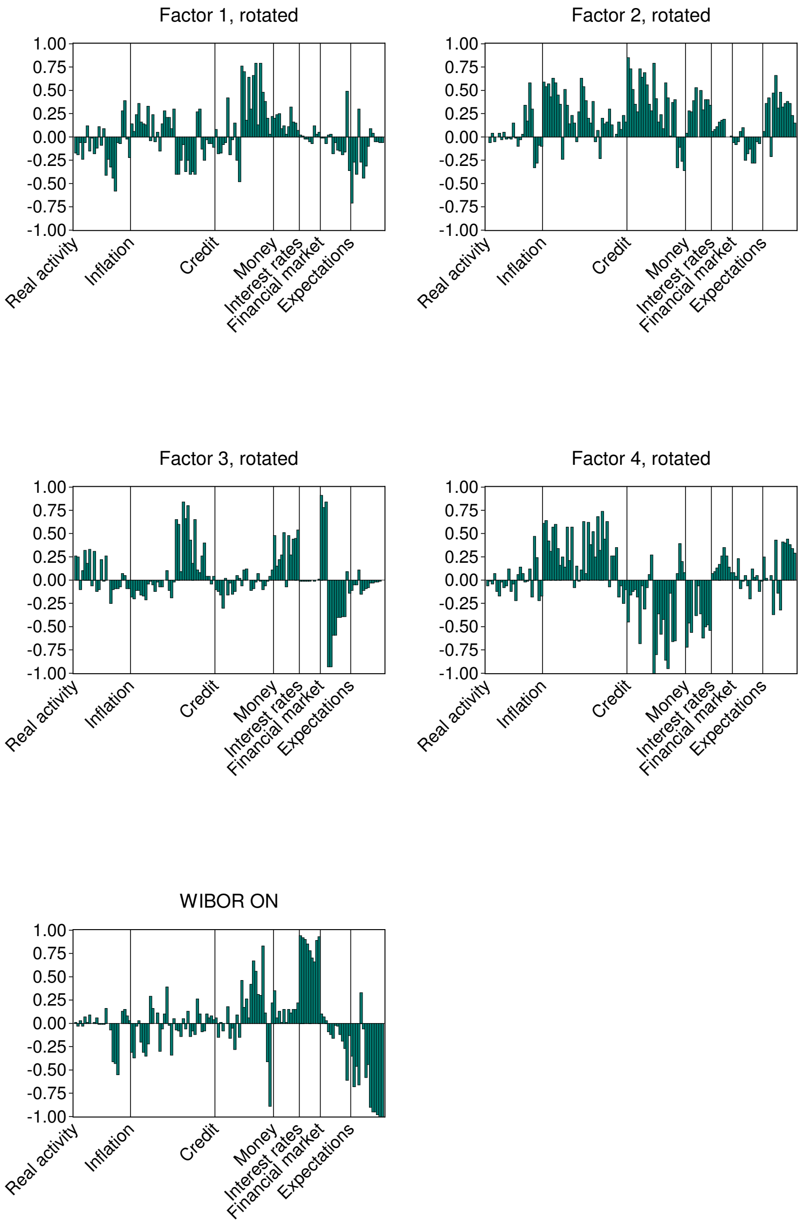


Figure 3. Factor loadings, commodity price and foreign factors

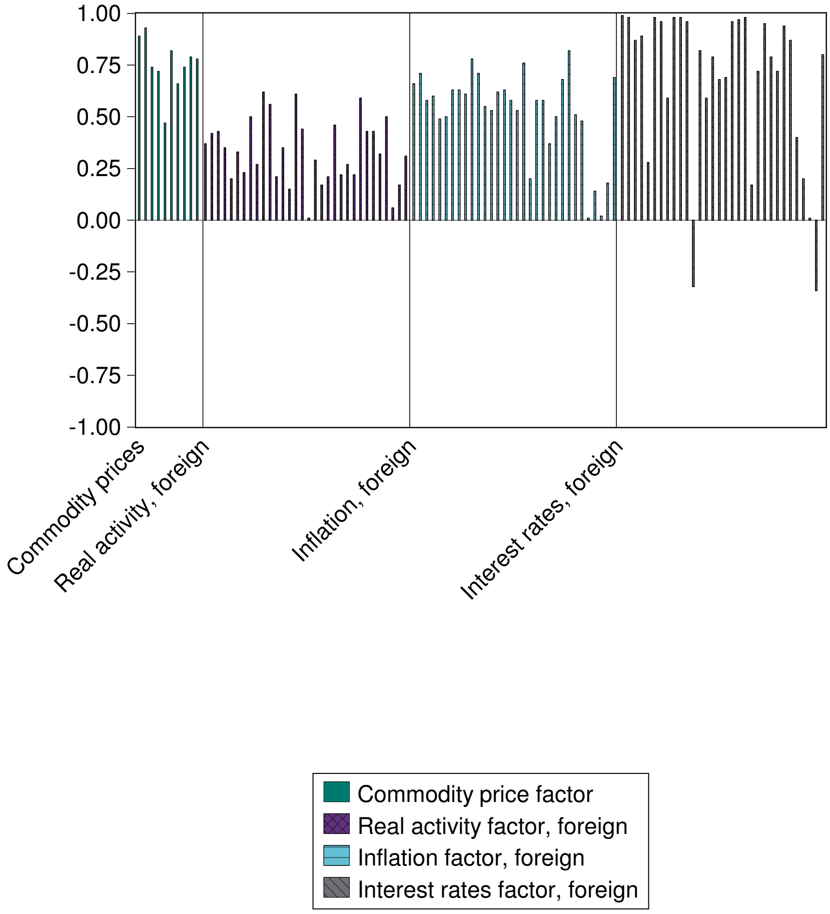


Figure 4. Factor scores and 68% confidence intervals, structural factors

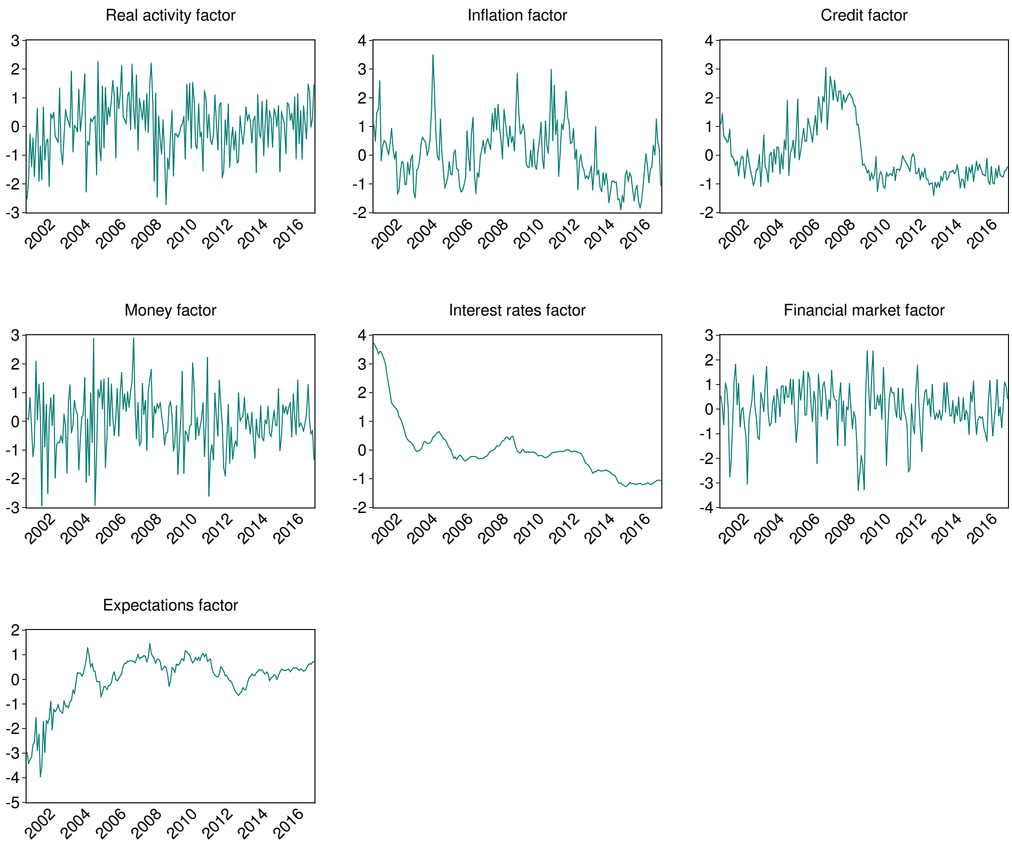


Figure 5. Factor scores and 68% confidence intervals, economically uninterpretable factors

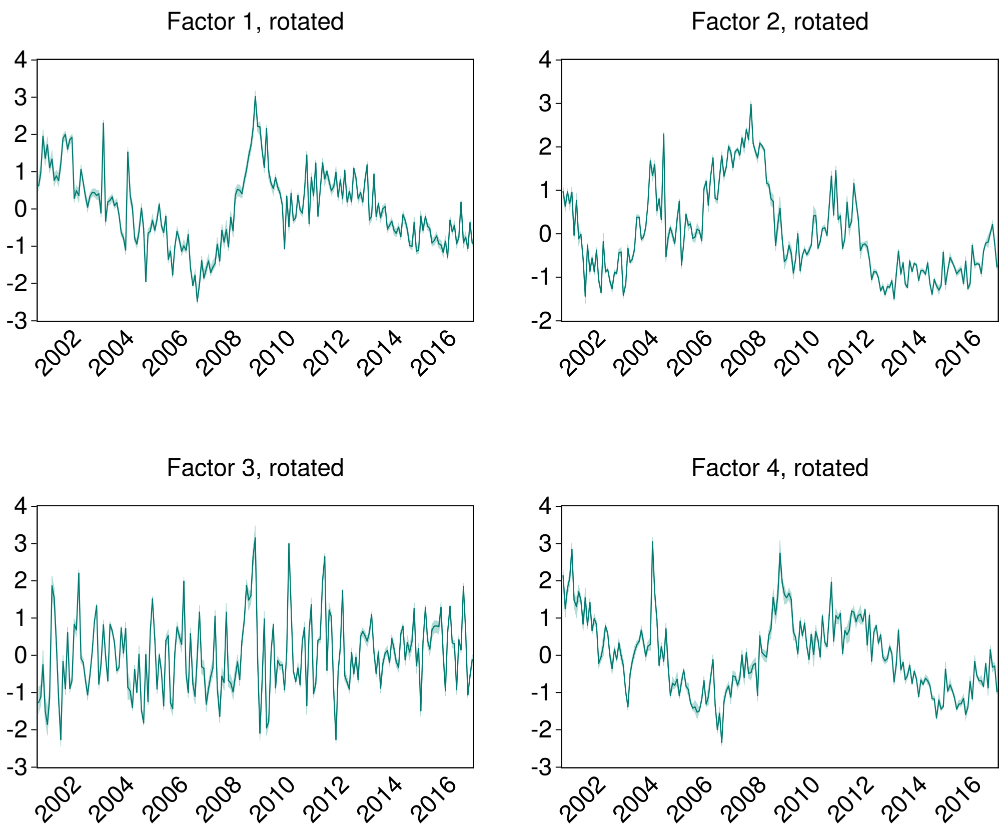


Figure 6. Factor scores and 68% confidence intervals, commodity price and foreign factors

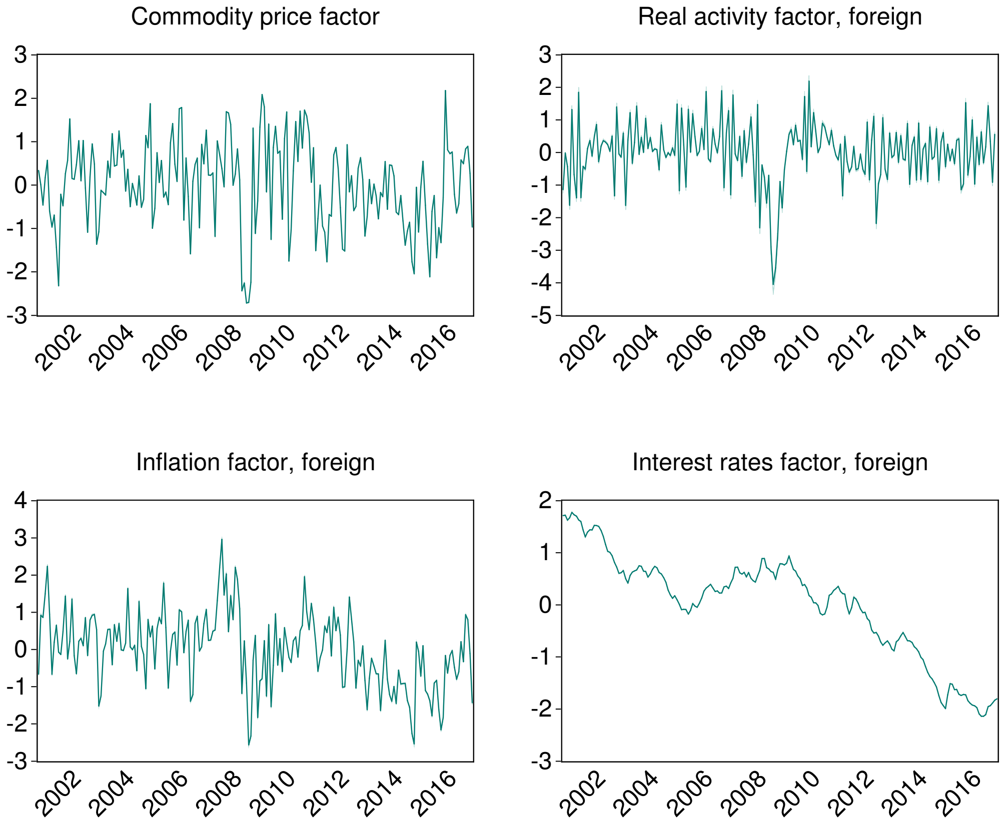


Figure 7. R-squared

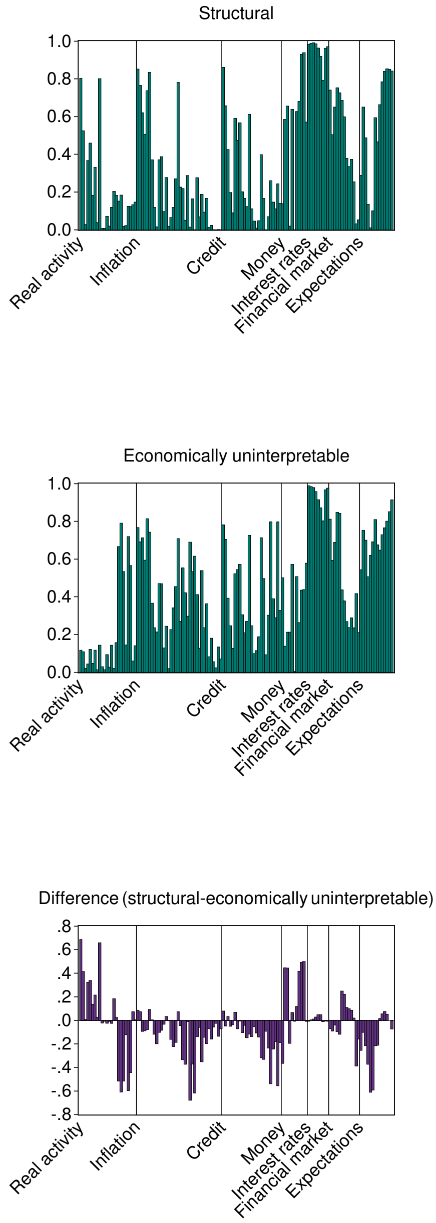


Figure 8. Responses to monetary policy impulse and 68% confidence intervals, FAVAR-BM

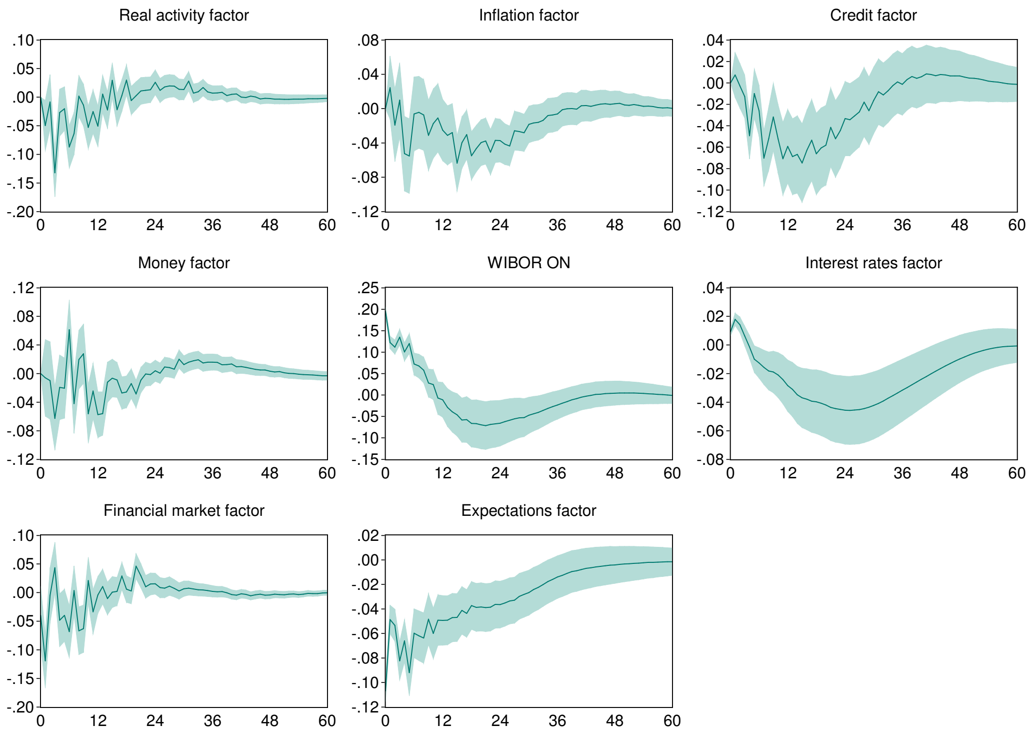


Figure 9. Responses to monetary policy impulse and 68% confidence intervals, FAVAR-BBE

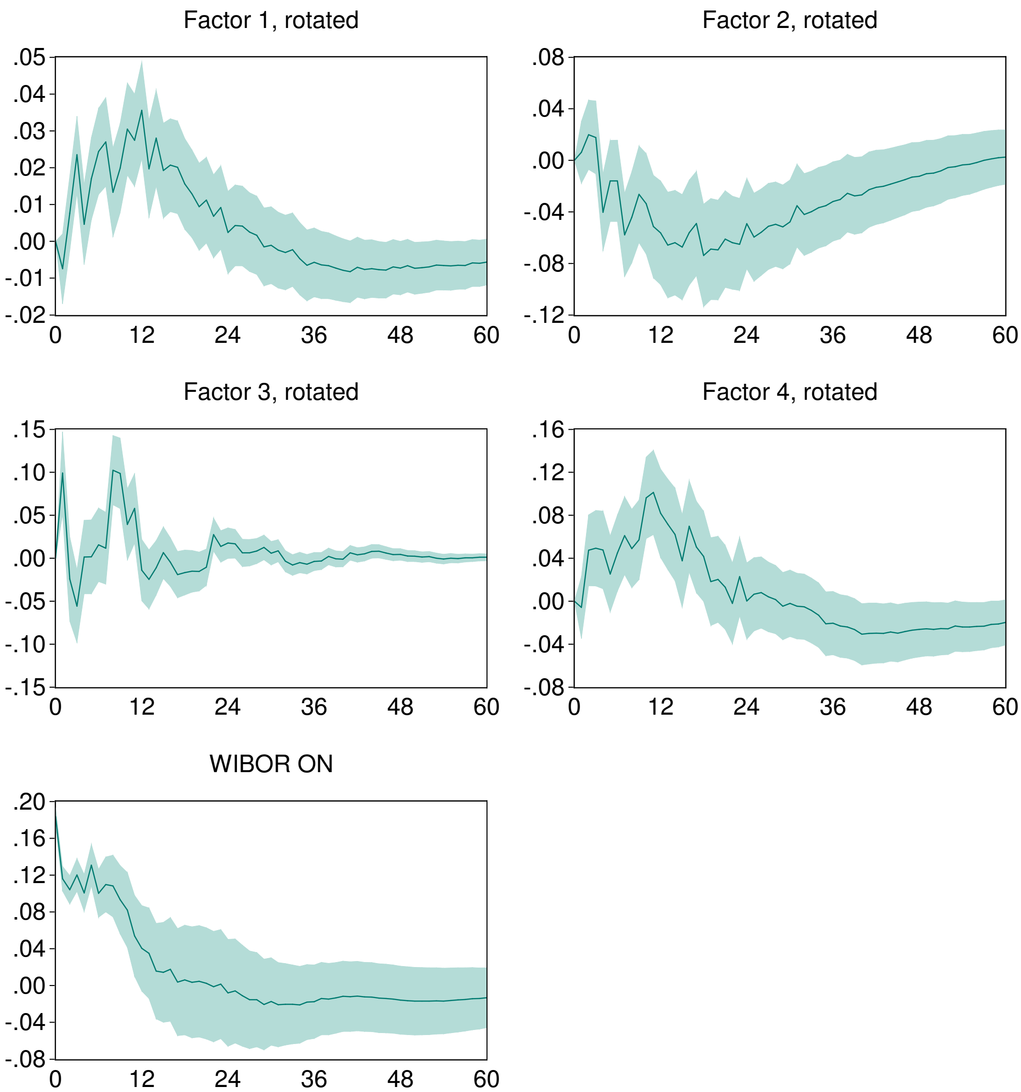


Figure 10. Responses to monetary policy impulse and 68% confidence intervals, FAVAR-BM

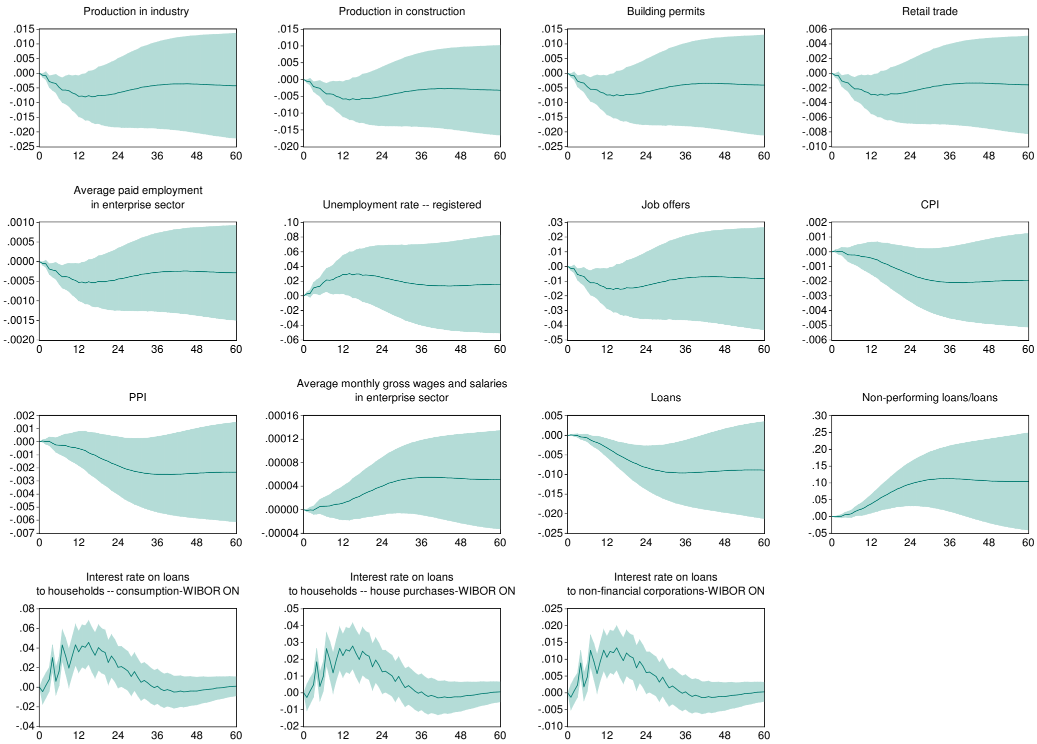


Figure 11. Responses to monetary policy impulse and 68% confidence intervals, FAVAR-BM

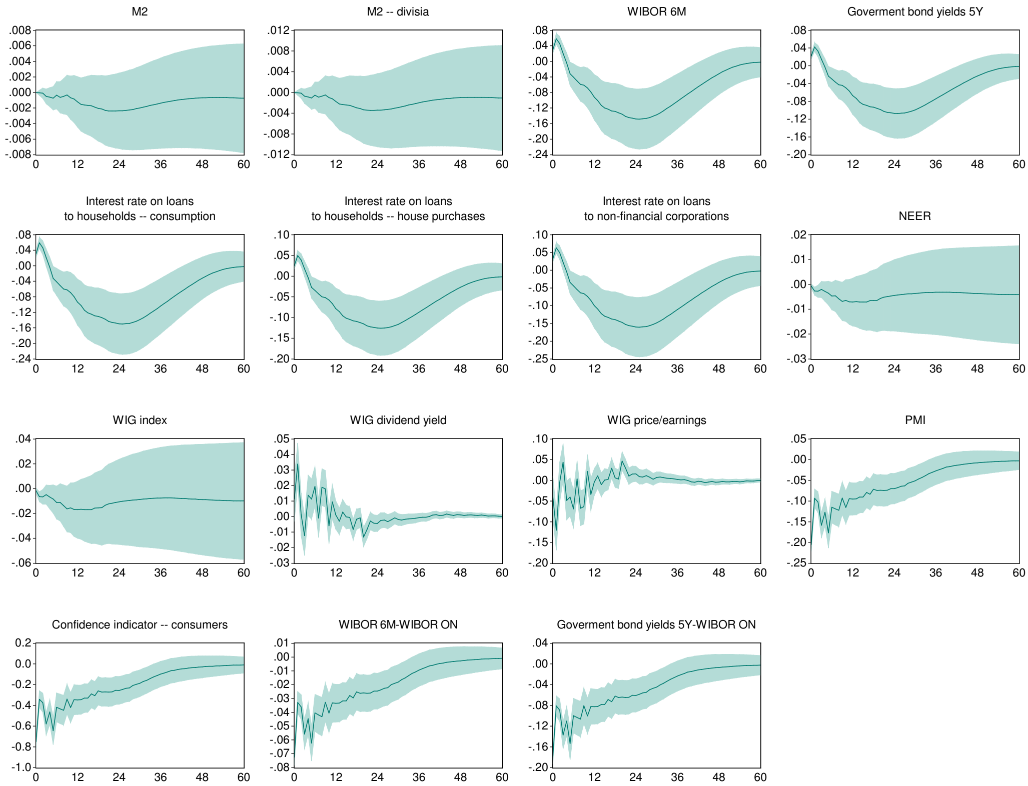


Figure 12. Responses to monetary policy impulse and 68% confidence intervals, FAVAR-BBE

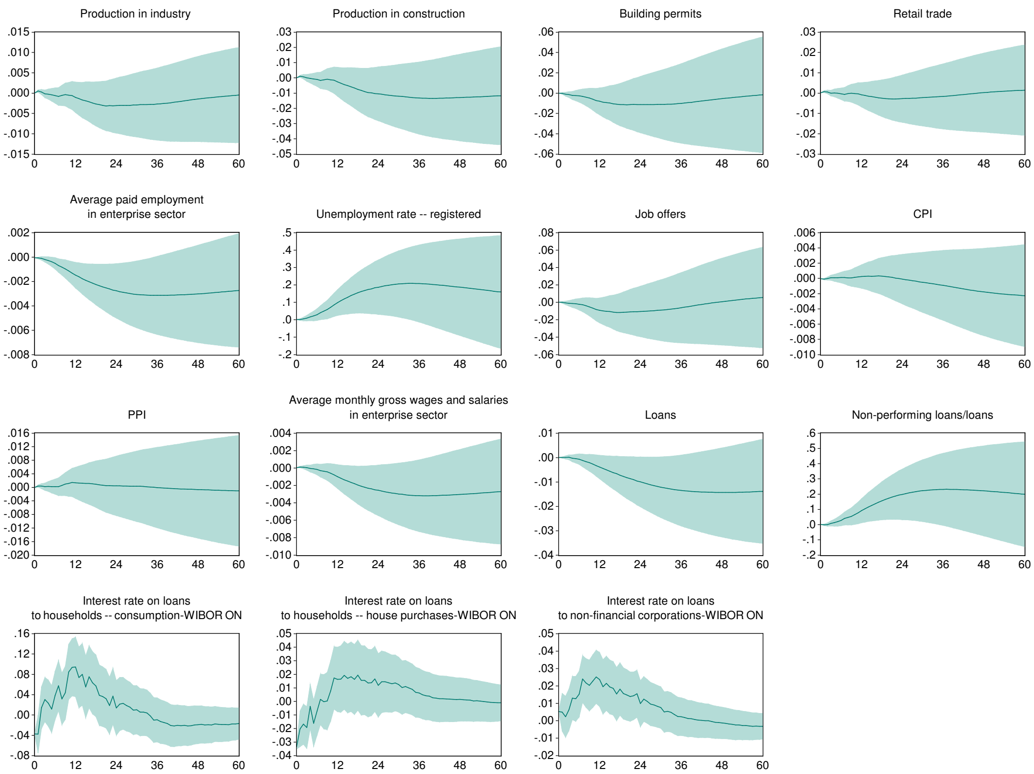


Figure 13. Responses to monetary policy impulse and 68% confidence intervals, FAVAR-BBE

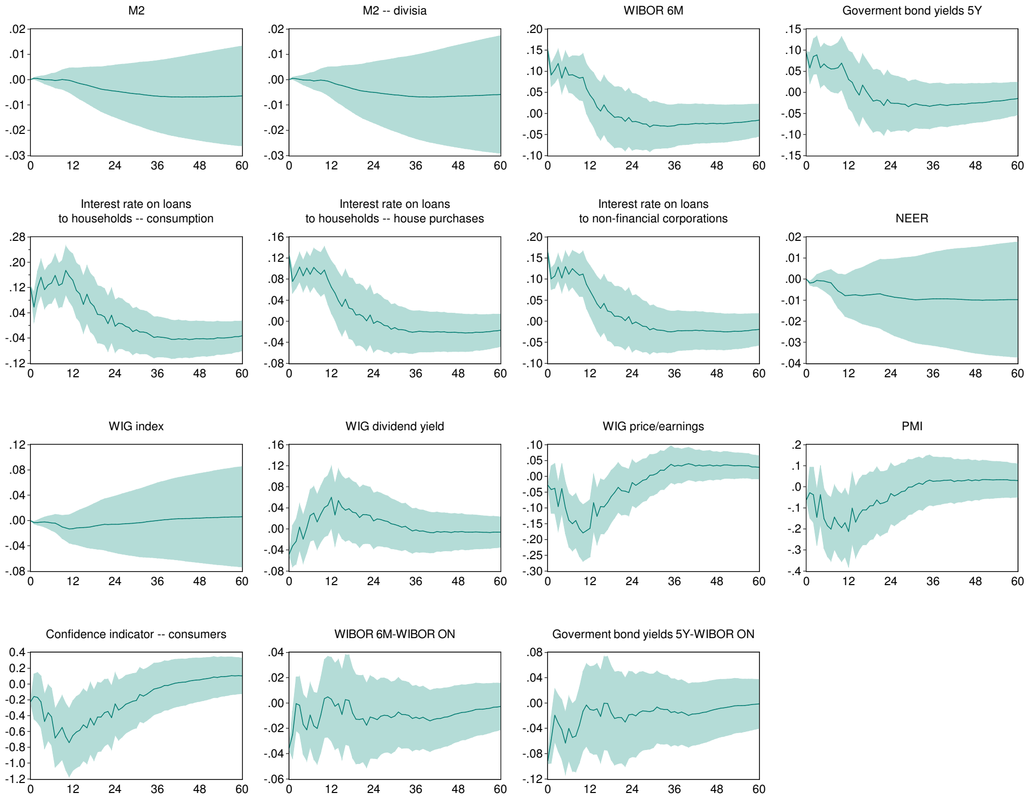


Figure 14. Responses to monetary policy impulse and 68% confidence intervals, FAVAR-BM, 6 lags

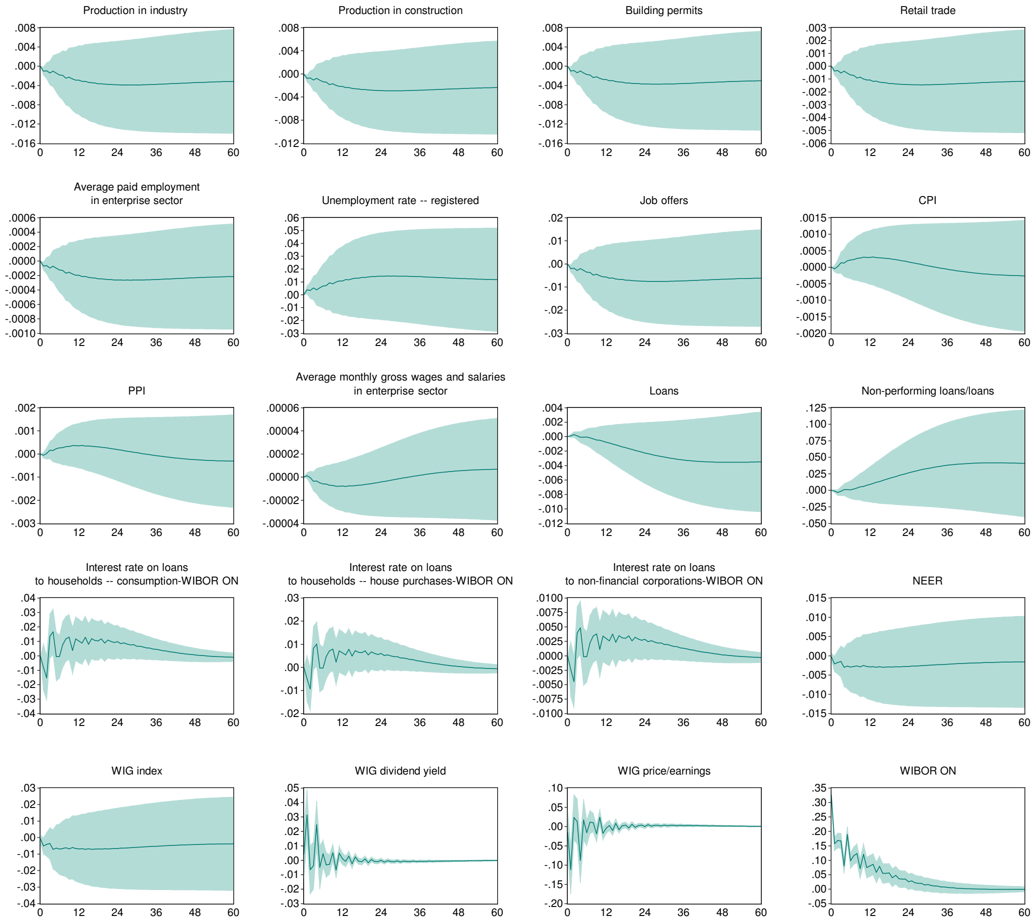


Figure 15. Responses to monetary policy impulse and 68% confidence intervals, FAVAR-BM, WIBOR 1M as measure of monetary policy

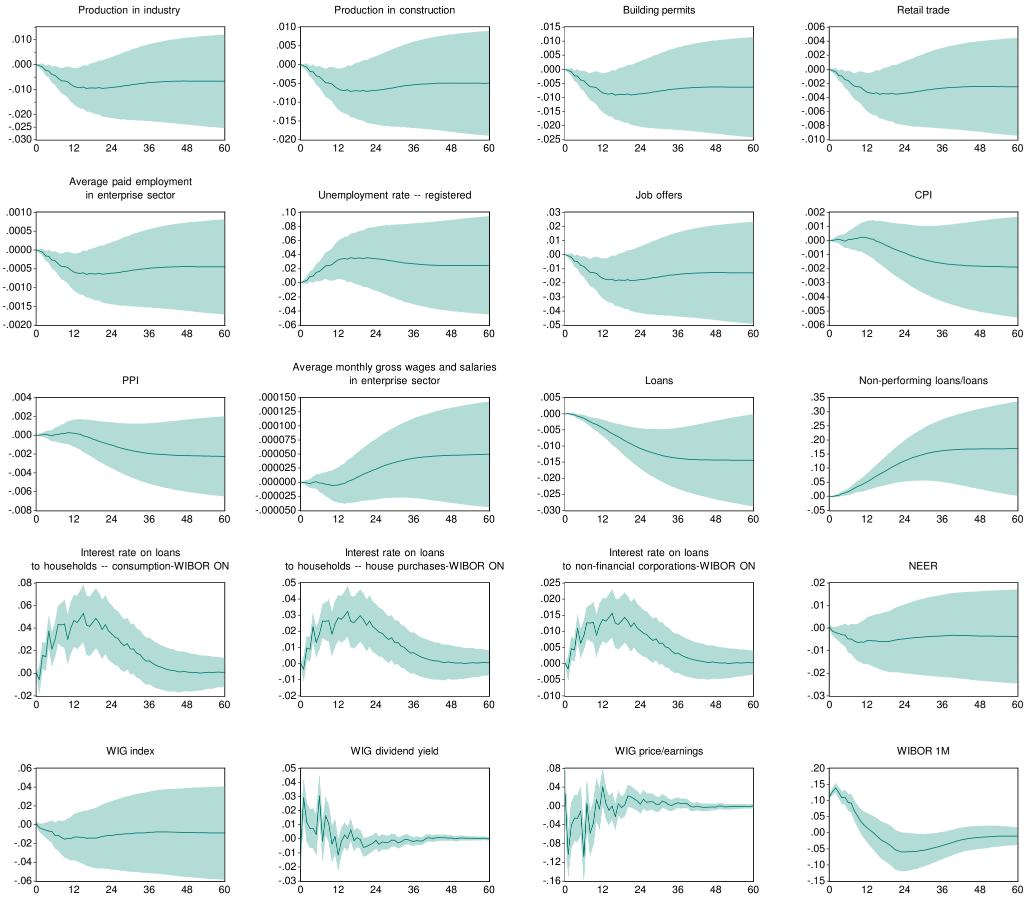


Figure 16. Responses to monetary policy impulse and 68% confidence intervals, FAVAR-BM, high-frequency identification

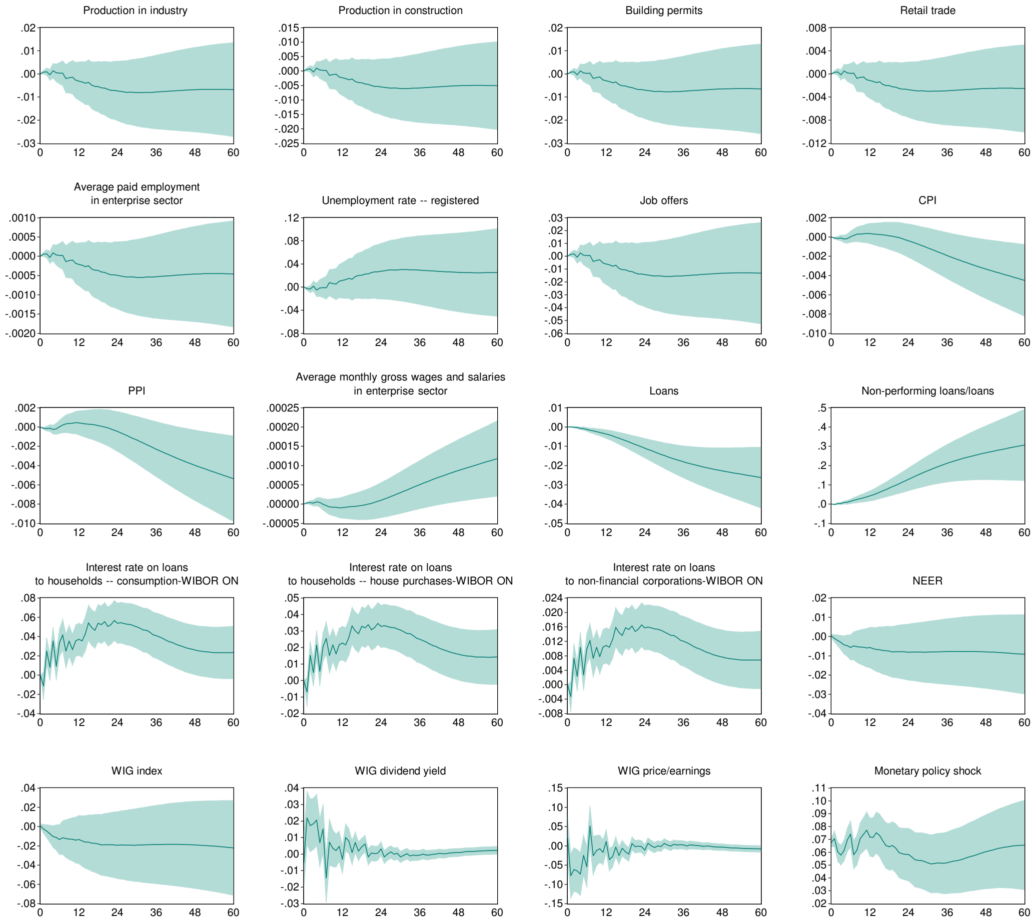


Figure 17. Responses to monetary policy impulse

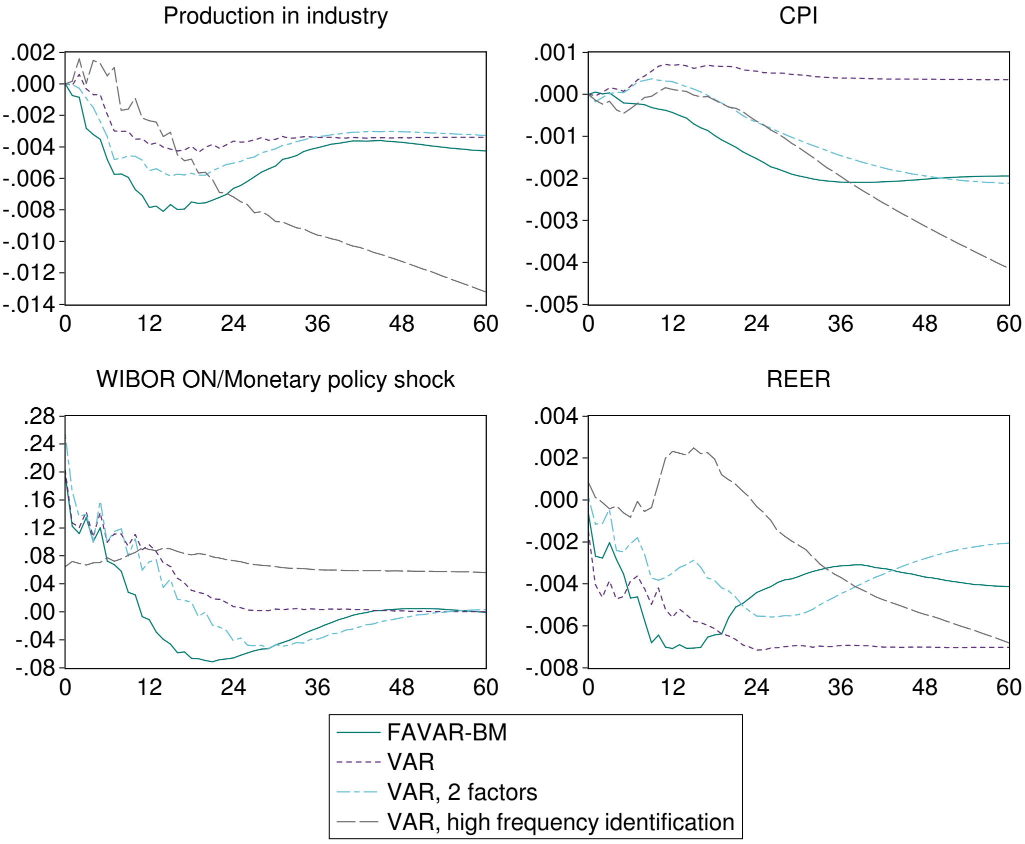


Figure 18. Responses to commodity price impulse and 68% confidence intervals, FAVAR-BM with commodity price factor

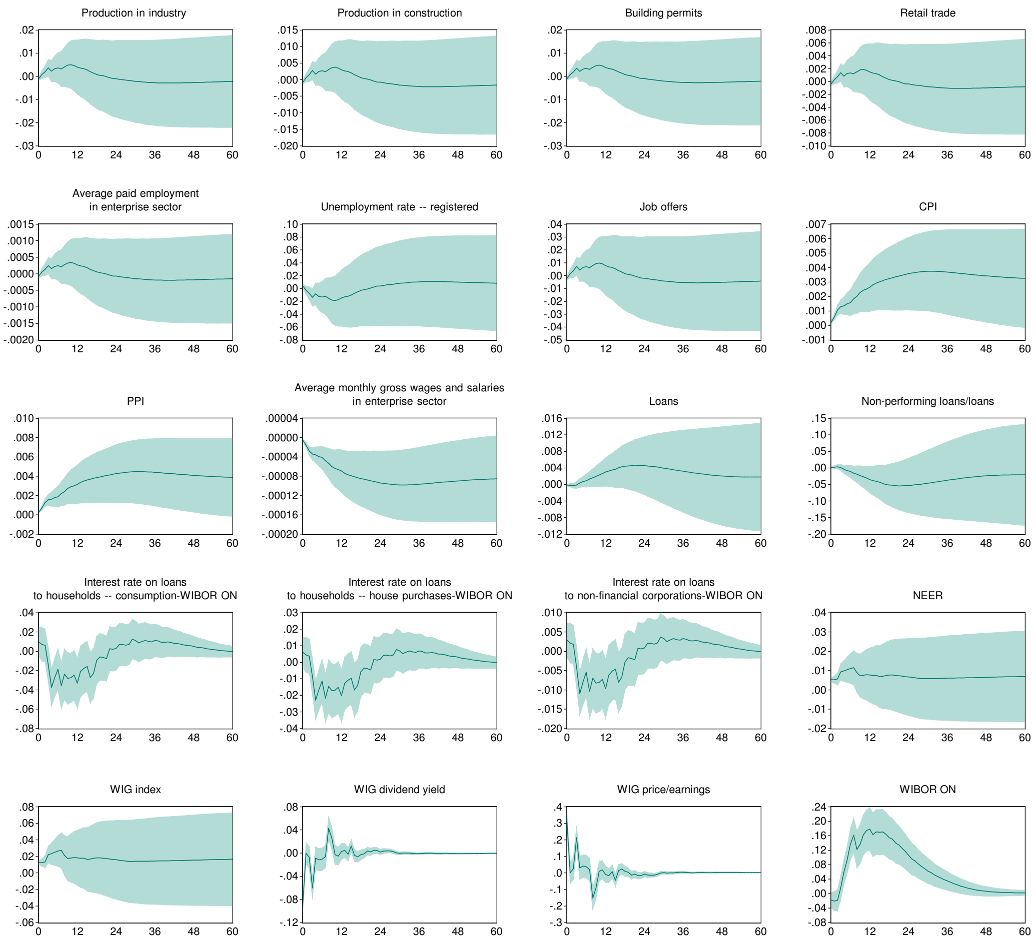


Figure 19. Responses to foreign real activity impulse and 68% confidence intervals, FAVAR-BM with foreign factors

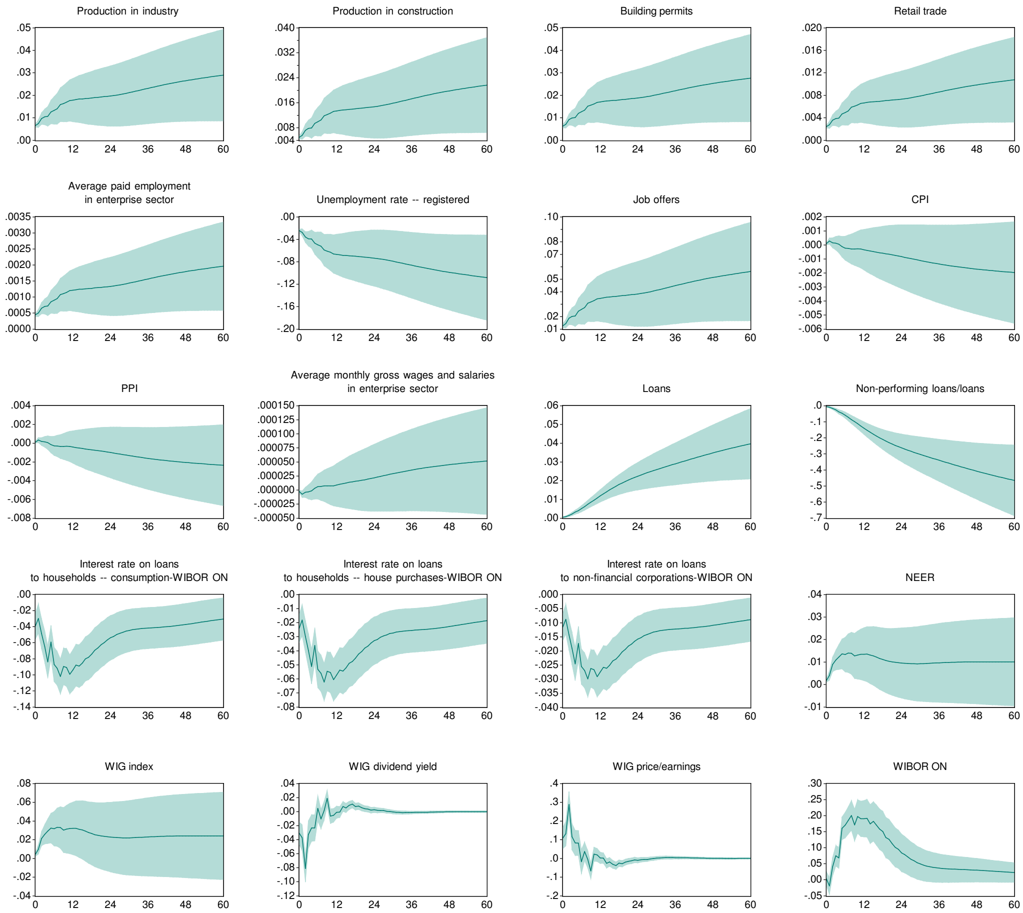


Figure 20. Responses to foreign inflation impulse and 68% CI, FAVAR-BM with foreign factors

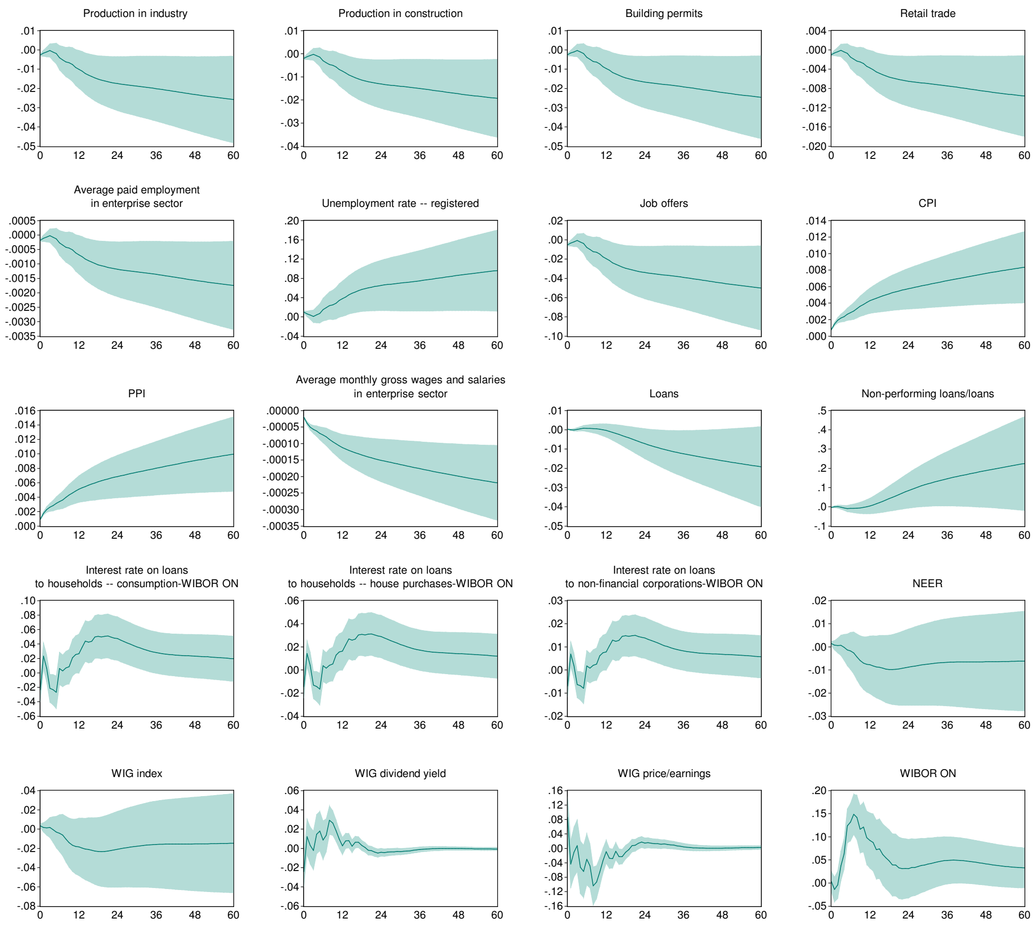
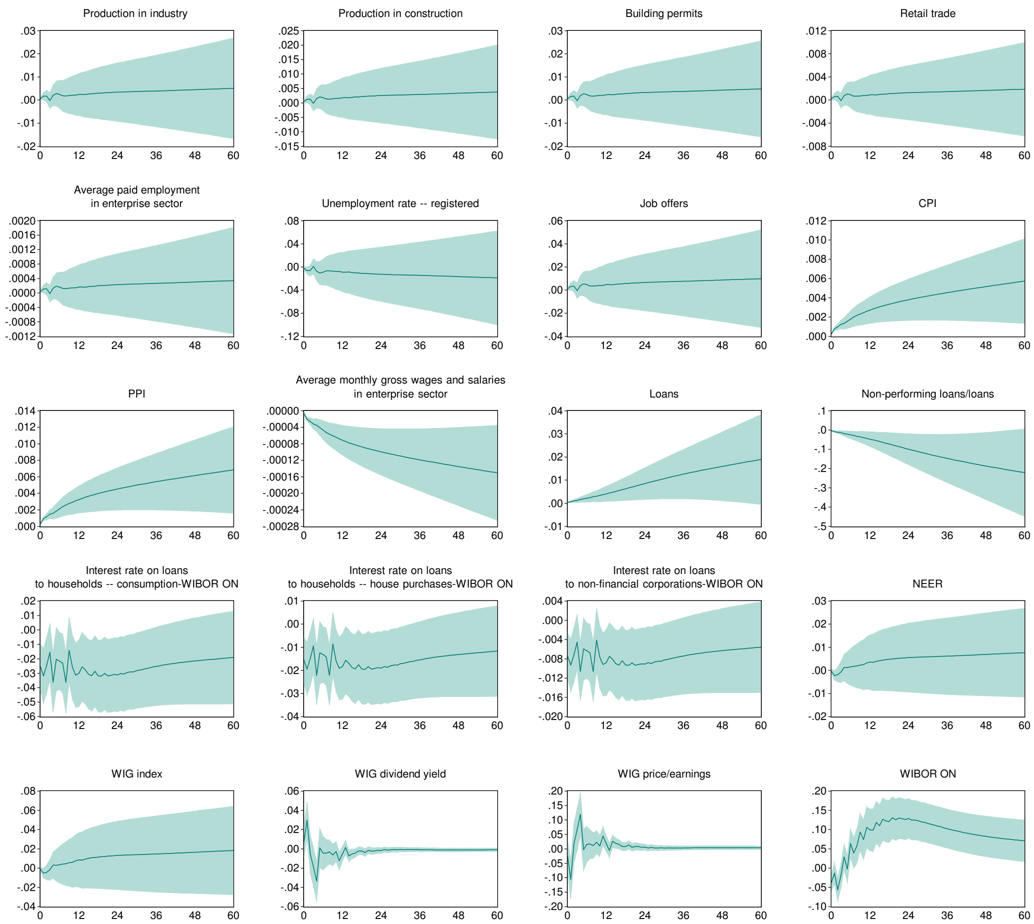


Figure 21. Responses to foreign interest rates impulse and 68% confidence intervals, FAVAR-BM with foreign factors



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