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What simple econometric analysis will tell us about the relationship between macroeconomic variables, stock market indices, and the activity of the banking sector?

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Abstract

The main goal of macroprudential policy is to reduce the systematic risk and the macroeconomic costs of financial instabilities. After the financial crisis of 2008, the macroprudential framework has been developed. In the paper we test the role of the banking sector's activity in the strength of the causal relationships between the real sector and the financial system. One of the main goals of macroprudential framework is to reduce the credit supply and strengthen the financial system. We examine the strength of the relationship between several macroeconomic variables, such as industrial production, the interest rate, stock market values, the unemployment rate, and particularly the volume of credit to the non-financial sector. The empirical analyses are performed with reference to three economies: Poland, Germany, and the United Kingdom. Substantial diversity of sources of economic growth as well as the size of the financial system in the case of the countries in question allows for a better understanding of the connections between the financial sector and the real sector. Moreover, each of them experienced the 2008 crisis in a different way.

Keyword: VAR, IRF, Granger causality, business cycle, credit cycle

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1. Introduction

The most important lesson learnt during the global financial crisis in the 2000s is that financial stability can no longer be treated as an outcome of efficient conduct only of monetary policy. Consequently, the stable financial system with a resilient banking system required a reorganization of the regulatory framework on both levels; international and domestic. These attempts resulted in the tempering of micro-prudential regulations, but also with a new construct called macroprudential policy.

The main goal of macroprudential policy is to reduce systematic risk and the macroeconomic costs of financial instabilities. Macroprudential policy is also recognized as a necessary element to fill the gap between monetary policy and the traditional micro-prudential regulations of financial institutions (mainly banks). Before 2008, regulatory authorities were focused on systemic risk and on monitoring financial institutions individually. Connections between the real economy and the financial system that become evident particularly during financial crises would be harmless in the future if the infrastructure of the financial system were strong. But if big financial institutions are fragile or highly leveraged, it can make the system more vulnerable to shocks. These can easily spread from one institution to another. As a consequence of this financial distress, an economic downturn or even a severe recession may occur.

As it is stated on the IMF site, policymakers need to take a broader approach to safeguard the financial system as a whole[1] and macroprudential policy may help them achieve this goal. Governments globally have been trying to regulate the system and have created macroprudential regulations and authorities. Macroprudential authorities monitor the financial system and identify risks and vulnerabilities. In the European Union separate entities were designed to focus on macroprudential policies. In the European Central Bank Governing Council, the Macroprudential Forum and Financial Stability Committee were established. Moreover, another entity called the European Systemic Risk Board (ESRB) was created as well as the nationally (locally) designated authorities for each of 28 members. Usually, the domestic macroprudential authority is the central bank or a financial supervisory authority. The ESRB developed five main objectives executed by macroprudential tools. According to the recommendations of the ESRB, from 4 April 2013,[2] the most important objective is to reduce excessive credit growth and leverage. It is executed by banks, which need to meet appropriate capital requirements such as countercyclical capital buffer, loan-to-value (LTV), and loan-to-income (LTI) ratios. The second objective is to reduce excessive maturity mismatch and improve market illiquidity. Macroprudential regulatory authorities created restrictions on funding sources, margins and haircut requirements, and made adjustments to liquidity ratios. The third objective is the improvement of the resilience of financial infrastructure. To achieve that goal, the ESRB increased the disclosure of financial infrastructure and regulated the structural systemic risk buffer. Local macroprudential authorities have been implementing ESRB objectives but have also been developing tools specified for the structure of their economies. In Germany BaFin (Bundesanstalt für Finanzdienstleistungsaufsicht or the Federal Financial Supervisory Authority) oversees the implementation of the Basel packages and monitors the countercyclical capital buffer. In the United Kingdom, there are two institutions devoted to monitoring financial stability, namely the Bank of England and the Financial Policy Committee.

[1] https://www.imf.org/en/Publications/SPROLLs/Macroprudential-Policy#sort=%40imfdate%20descending.

[2] Recommendation from European Systemic Risk Board from 4th April 2013, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2013:170:0001:0019:EN:PDF.

In Poland, there is the Financial Stability Committee supervised by the Minister of Finance. The macroprudential authorities monitor the situation in each country in collaboration with the monetary policy authorities.

Monetary policy refers to the actions of central banks to influence the economy and the money supply in particular countries. Its tools are used to manage price stability and inflation; however, banks' decisions may have an impact on the financial stability through their effects on asset prices. Successful implementation of monetary policy requires an accurate understanding of how fast the effects of a given policy would influence the economy and how large those effects would be. The process which describes changes in how monetary policy influences other sectors of the economy is called the transmission mechanism. There are five channels of the monetary transmission mechanism: influencing economic growth through interest rates, exchange rates, asset prices, credit, and balance sheets. The transmission mechanism can be split into two parts. The first part involves the propagation of changes in monetary policy through the financial system. It explains how changes in the market operations of central banks affect the money market, which directly affects the spending decisions of households and firms. It can be measured by the relationship between the bond market and the bank loan market (short-term money market rates affect long-term bond rates), and the marginal cost of credit funding (banks' borrowing rates are affected). The second part of the transmission mechanism describes how monetary policy shocks affect the real economy through the financial system.

The paper aims to analyse the nature of interactions between the production sector and the financial sector of the economy before and after the creation of the macroprudential framework. We present empirical investigations of the impact of credit to the non-financial sector on a set of macroeconomic variables. Since both the financial cycle and the business cycle are linked, we analyse the strength of the relationship and infer which economic cycle plays the leading role. Additionally, we investigate how the role of credit to the non-financial sector evolved during the period from January 2000 to December 2019, namely, before and after implementation of the macroprudential framework. After the global financial crisis, governments started to implement macroprudential policies. It is interesting to have an insight into how these policies changed the connections and dynamics of the basic macroeconomic variables.

The methodology applied in the paper utilizes vector autoregression models (VAR) with an analysis of impulse response functions as the most important outcome. It will allow to explore the short-term dynamic relationships within multiple time series. We also report the results of the F-type testing procedure of the Granger causality; see: Granger (1969).

We have formulated the following research hypotheses:

H01: Credit to the non-financial sector has an empirically important impact on the dynamics of key macroeconomic variables.

H02: Credit to the non-financial sector constitutes the Granger causality for the stock market, industrial production, the unemployment rate, and the interest rate.

H03: Developed economies with larger service sectors are more resilient to the impact of credit shocks to the non-financial sector.

The analyses will be performed with reference to three European economies, i.e. Poland, Germany and the United Kingdom. The motivation for choosing these economies is that they are relatively different with respect to development, sources of growth, and observed process of recovery from the global financial crisis. In particular, the highly developed German economy is the largest one in the European Union. It is also an example of one of the biggest exporters globally and the biggest in the European Union. The mainstay of Germany's economy is manufacturing, with a large volume of exports, mainly of vehicles, machinery, chemical goods, electronic products, electrical equipment, and pharmaceuticals. The service sector contributes around 70% of the total GDP, industry 29.1%, and agriculture 0.9%. Germany experienced a mild recession after the global financial crisis. Poland is a small, open and emerging economy. The service sector contributes 62.3% of total GDP, industry 34.2%, and agriculture 3.5%. Poland also avoided recession throughout the financial crisis. The United Kingdom is an example of a highly developed and advanced economy. It serves as the second financial sector in the world. Consequently, the global financial crisis affected it strongly. In the United Kingdom, the service sector contributes around 80.2% of the total GDP, industry 19.2%, and agriculture 0.6%. The United Kingdom experienced a severe recession after the financial crisis.

The paper is organized as follows. The second section presents a literature overview focused on macroprudential and monetary policy. The third section presents the methodology applied in the paper. The next sections present our empirical results and our comments and conclusions.

2. Literature review

Research on the monetary policy and transmission mechanism and its influence on the business cycle has been conducted for many decades, resulting in a vast literature on the role of the credit channel and the nature of the pass-through effect. The empirical macroeconomic perspective is also very important, since there was always a strong belief about the existence of linkages between the real economy and the financial system (see: Bussière et al. 2020). This point of view was formulated initially by Fisher (1933), who created a debt deflation theory. He analysed the US economy when it was facing the serious consequences of the Great Depression in the 1930s. The theory states that when the real value of debt is rising (due to deflation), this forces people to default on their consumer loans. As a consequence, there is distress in the economy and the value of assets decline, which may predict recession. After Fisher, there was a long break in the research into the role of debt in the economy. In the 1990s Ben Bernake started to do research into the role of credit in growth fluctuations. He studied the role of the credit channel in the Monetary Policy Transmission Mechanism (see: e.g. Bernanke, Gertler 1995). Important considerations about the role of credit in the economy were also defined by Hyman Minsky (see: Minsky 1982). He proposed a concept of the financial instability hypothesis (FIH). In the heart of Minsky's theory lies the conviction that financing will precede production in one point. To increase production, financing is necessary. However, the financing of production and innovations is mostly sponsored by credit (Minsky 1992). There is nothing bad in using credit to finance the allocation of production factors; however, when borrowers and lenders decide to take a greater risk, this may be the reason for financial bubbles (see: Lenart, Pipień 2017). Credit availability is determined by risk and profitability to the lending institutions. The lower the risk and the greater profitability to lenders, the more loans banks are willing to give. Investment risk is then reduced because the values of real estate properties and expected rates of return are increasing. However, when the peak of the economic cycle turns, the assets and investments may decline in value. The moment when the finance bubble bursts is called the Minsky Moment. During this time the financial system moves from stability to instability. There is the moment when over-debt market participants start to sell their assets to meet their obligations. As a consequence, a fall in the asset prices in the market occurs. To manage the instability, Minsky suggested that governments should regulate markets to avoid financial fluctuations. He proposed that regulation should prevent speculative lending, banks should have certain liquidity in cash reserves, and there should be strict requirements for mortgage lending. Hence Minsky's works seem pioneering for macroprudential policy regulations.

In spite of the fact that banks play only the role of financial intermediaries, monetary policy has a substantial impact on their activity. If the economic environment is favourable, customers are more willing to spend and consequently the demand for credit grows. This is advantageous for banks, as it leads to more loans being provided and an increase in interest income. As a consequence of credit growth, there can be observed an increase in spending and investment. It can increase income levels in the economy and stimulate higher GDP growth and faster productivity growth. On the other hand, if there is an economic downturn, the amount of credit decreases, resulting in a much longer recession.

Analyses of the strength of the relationship between the business and credit cycle have recently been the subject of many research projects. This is represented by a broad stream of literature on the interactions between the real sector of the economy and the banking (financial) system. Empirical research into the financial cycle has become very popular over the last 20 years (see: Borio, Furfine, Lowe 2001; Danielsson, Shin, Zigrand 2004; Kashyap, Stein 2004; Brunnermeier et al. 2009; Adrian, Shin 2010). The main motivation for these studies was to put forward empirically supported hypotheses about important factors determining the cyclical nature of activity in the financial system. Since the ESRB aims at reducing excessive credit growth (by developing a macroprudential framework), there is interest in the credit cycle. Nowadays the financial sector cannot leverage the credit in the economy to stimulate a general expansion of economic activity.

One of the macroprudential policy tools requires control of the countercyclical capital buffers on the bank's lending. The results of analysis of the effects of this tool were discussed by Drehmann et al. (2010). The paper provided a simulation of how the countercyclical capital buffer designed in the Basel III package regulation could affect bank lending activity. According to the results, managing the countercyclical buffer can help to reduce credit growth during booms. Another study focusing on the impact of macroprudential policies and their interaction with the monetary policy was conducted by Gambacorta and Murcia (2018. The researchers used credit registry data for eight economies (Argentina, Brazil, Canada, Chile, Colombia, Mexico, Peru, and the United States). They found out that a tightening in macroprudential policies reduces the credit growth by 4.2% after three months and 7.2% after one year. As the conclusion of the work, they state that macroprudential policy can dampen the credit cycle and reduce risk in the banking sector. They also found that some tools are effective in a short time (polices focused on curbing the cycle), while others are effective in long term (capital bank requirements). The effectiveness of macroprudential tools on credit growth is affected by the contemporaneous use of monetary policy. Macroprudential tools that acted as a complement to the monetary policies (imputed in the same direction) were relatively more effective. Research on macroprudential policies in emerging markets was conducted by Moreno (2011). As is well known, there are significant differences between developed and emerging markets. The challenges faced by these economies respectively are also different. Moreno in his research noticed that there are only three types of financial and macroeconomic risk for small open emerging market economies. The first type is related to fluctuation and contagion from international markets, such as volatility in foreign currency liquidity and the financial effects of rising fiscal burdens. The second one results from the amount of domestic credit and market risks. Rapid credit growth can cause booms in asset prices and financial bubbles. The third category is impulses of response from international developed markets. The macroeconomic effects of macroprudential policy were analysed by Richter, Schularick and Shim (2018). The researchers focused on empirical analyses of the impact of changes in maximum loan-to--value (LTV) ratios on output and inflation. The most important research question of this work was how macroprudential policies interact with the core objectives of monetary policy to stabilize prices and output. Richter, Schularick and Shim (2018) used a large database of 56 countries with quarterly time series for 20 years. They showed that changes in maximum LTV ratios appear to have relatively modest effects on the economy, output and inflation. Larger effects of tightening (than loosening) LTV were observed in emerging market economies. The effects of LTV changes on inflation tend to be negligible. For more than a two-year horizon, the mean output effect of a 10 percentage point change in maximum LTV ratios corresponds roughly to that of a 25 basis point change in policy rates. The authors also provide evidence that changes in LTV have substantial effects on credit growth and house prices. Moreover, they suggest that in a developed economy the central bank would just use macroprudential tools to manage financial stability. Aikman (2016) developed research into the impact of the monetary and macroprudential policies in the United Kingdom between the 1950s and 1980s. The authors estimated the impulse response functions to the two policy shocks augmented by forecasts. They found that effective monitoring of macroprudential measures and credit controls allowed the credit cycle to be managed. Furthermore, the researchers found empirical evidence for an effect of credit controls on the price level in the UK. Other researchers that analysed the impact of changes in macroprudential and macroeconomic policies are Kim and Mehrotra (2017), who took into account the responses of credit, output and inflation for shocks of macroprudential and monetary policies. They used data for four countries in the APAC (Asia-Pacific Countries) region using VAR models and found a negative effect of changes in macroprudential policies on output and on inflation.

Another empirical analysis demonstrated that an increase in capital buffer impacts the real economy in the short and in the long run. The correlation between shocks from the capital buffer and economic activity is positive. Moreover, implementation of the macroprudential policy caused a positive impact on the stability of the financial system in Poland. The researchers also confirmed that capital buffer policy dominates over traditional interest rate policy in the long run (see: Dybka et al. 2017).

The role of debt in the economy is significant; the amount of credit in the economy depends on the monetary policy and the macroprudential policy. The macroprudential topic was studied in literature from manifold perspectives. Some researchers focused on specific tools, while others focused on the macroeconomic perspective or on particular regions and countries.

3. Model specification, datasets and preliminary descriptive analyses

The methodology applied in this paper is built on the basis of a stable Vector Autoregression model (VAR), commonly used in empirical research (Buckle et al. 2007). Our empirical analyses rely on investigation of impulse response functions (IRF) as well as on the Granger causality test. Let's consider the VAR model is represented as (see Osińska 2006):

$$\mathrm{A(B)}\, z_t = \varepsilon_t$$

where $\mathrm{A(B)} = I - A_1 B - A_2 B^2 \ldots . - A_q B^q$

The standard representation of a VAR model as a moving average MA(∞) process is denoted:

$$z_t = A^{-1}(B)\varepsilon_t = \psi(B)\varepsilon_t = \varepsilon_t + \sum_{i=1}^{\infty}\psi_i\varepsilon_{t-i}$$

where $\psi_i = \sum_{j=1}^{i} A_j \psi_{i-j}$, $\psi_0 = I_n$.

Let us consider that the covariance matrix is given as:

$$\sum_{\varepsilon\varepsilon} = E(\varepsilon_t\varepsilon_t')$$

If we transform the z_t equation into recursive VMA is denoted as:

$$z_t = \sum_{i=0}^{\infty}\psi_i S(S^{-1}\varepsilon_{t-i}) = \sum_{i=0}^{\infty}\Phi_i\xi_{t-i}$$

We would receive the direction of dependence. Verification of the Granger causality test is performed in a standard way using test *F*. Granger causality for VAR models is given (see Koop 2009):

$$Y_t = \alpha_1 + \delta_1 t + \rho_{11}Y_{t-1} + \ldots\ldots + \rho_{1p}Y_{t-p} + \varepsilon_t$$

We report values of *F*-statistics as well as p-values of zero restrictions corresponding to the causal relationship of each single variable with a group of all remaining ones analysed in the VAR system. The *F*-statistics is given (see Koop 2009):

$$F = \frac{(R_{UR}^2 - R_R^2)/r}{(1 - R_{UR}^2)/(T - k - 1)}$$

The analyses are based on the monthly data for three European economies: Poland, Germany and the United Kingdom. In order to check the role of credit in the problem of description of dynamics of analysed categories we build two competing VAR models and estimated them for each country. In Table 1 we present these two basic model specifications. In the first model (denoted by M1) we analyse the variability of the following macroeconomic variables: the closing values of the stock market index, industrial production, the unemployment rate and the interest rate. In the second model (denoted by M2) we extend the model M1 by including the variable of credit to the non-financial sector.

The data were collected from various sources; however, for each country we chose the period to cover an interval from January 2000 to December 2019, resulting in 228 observations for each time series. The unemployment rate and industrial production were taken from Eurostat. The closing values of daily stock indices were downloaded from the website: investing.com. Interest rates and the amount of total credit to the non-financial sector were downloaded from the websites of national banks.

Descriptive statistics for raw data as well as for differences of logarithms of raw data are summarized in Table 2.

The first variables are closing values of domestic stock market indices. In the case of Poland, we chose the WIG20 index, representing the performance of the twenty largest companies on the Warsaw Stock Exchange. In the case of Germany, we analyse the DAX index, which is constructed as a portfolio of the thirty largest companies on the Frankfurt Stock Exchange, while in the case of the UK, the FTSE100 index was analysed. The FTSE100 contains the capitalization of the hundred largest companies on the London Stock Exchange. Initially, we rely on daily data, making the usual adjustments to monthly frequency by calculating the average of the daily closing values observed within a particular month. There was positive excess kurtosis for the WIG20, DAX and FTSE100. This means that all capital markets had distribution with fat tails and had bigger volatility. As per Figure 1, in 2008 all indices broke down due to the response to the financial crisis. The DAX and FTSE100 had their peak values after the financial crisis. The DAX had its peak in January 2018 and the FTSE100 had its peak in May 2018. The WIG20 had its peak in October 2007.

Industrial production measures the change in the volume of production output. The data is unadjusted and in monthly intervals. The base year is 2015, which means that industrial production was equal to 100 in all economies. In Poland and in the United Kingdom industrial production is characterized by strong seasonality. German industrial production does not depend on season so much.

As a variable that describes the labour market, the standard unemployment rate was used. In Poland, the highest unemployment level was reached in February 2004, with the rate reaching 21%, while the lowest unemployment was in November 2019 at 2.8%. In Germany the highest unemployment was reached in June 2005, with the rate at 11.24% and the lowest in May, June, and October 2019 at 3.00%. In the United Kingdom the highest unemployment was reached in August 2011, with the rate at 8.50 %, while the lowest was in November 2019 at 3.50%.

In the case of each country we chose the 1 month interest rate. Consequently, for Poland we analyse WIBOR1M, for Germany EURIBOR1M, while for the United Kingdom the LIBOR1M instruments. Prior to the global financial crisis in 2008, the level of interest rates were relatively similar, reaching values around 6.00% in the case of all the analysed economies. After 2008 the interest rates were lowered. In the Eurozone they have had negative values since 2015. Poland lowered interest rates to 1.60% in January 2018.

In order to meet the research objectives stated in the paper, the most important variable in the model is the total amount of credit issued to the non-financial sector. As we can see on the graphs in Figure 1, growth in the amount of credit to the non-financial sector varied between countries. In Poland, the amount of credit to the non-financial sector was increasing constantly after the financial crisis. In Germany, the amount of credit to the non-financial sector was on a similar level. No rapid changes were observed in the amount of credit in the United Kingdom and a credit crunch could be observed after 2008. However, since the end of the downturn the amount of credit has been increasing.

In Figure 1, the dynamics of the raw time series is presented. As can be seen, the dynamics of the raw data represent a seasonality and trend pattern. Consequently, the analysed series were transformed by natural logarithm transformation. Models were also built for annual differences (i.e. the difference between the value corresponding to a particular month and the value corresponding to the analogous month in the previous year). In Germany there have been negative interest rates since March 2015. To calculate the logarithm, all observations of Euribor were increased by 0.05. This allowed us to have only positive values in the database. Figure 2 presents the plots for annual differences of logarithms of all analysed categories.

To confirm the stationarity of time series, an Augmented Dickey and Fuller test (ADF) was performed (Dickey, Fuller 1979). The ADF test statistics and corresponding p-values are summarized in Table 3.

4. Empirical results

4.1. Estimation of VAR models

In applications of VAR models it is extremely important to specify an appropriate lag structure, by determining the q parameter that fits the data best. The literature provides various choices to identify the optimal lag length; however, there are three basic information criteria widely used in econometric analyses: the Akaike information criterion (AIC) (Akaike 1973), the Hannan-Quinn information criterion (HQ) (Hannan, Quinn 1979) and the Bayesian information criterion (BIC) (Schwarz 1978). In this paper the selection of optimal lag length was restricted between one and ten months. For each lag length, the information criteria (AIC, HQ, BIC) were calculated in order to generate a ranking of competing VAR structures. For a better insight into the comparison of the models, a correlation matrix of ranks was also calculated.

In Table 4 we present the results of the analysis of the optimum lag length for model M1. In the case of Poland, the preferred lag length based on AIC seems to be $q = 6$ months. According to the HQ and BIC criteria, only $q = 2$ lagged months is necessary. Also in this case there is a very weak correlation between the ranks generated by AIC and HQ and (0.01). The ranks generated by AIC and BIC are also weakly correlated. The correlation of ranks resulting from the HQ and BIC criteria indicates some accordance. In the case of Germany, for M1 (where the variable representing credit dynamics is excluded) AIC criteria indicate $q = 5$ months for optimum lag length. HQ criteria suggested $q = 3$ months lag length. Based on Bayesian criteria, the estimated model should have a lag length of $q = 2$ months. For Germany the results obtained for M1 demonstrate a weak negative correlation between pairs: AIC-HQ (-0.48) and AIC-BIC (-0.35). There is a strong correlation between ranks generated by HQ and BIC criteria (0.87). For the United Kingdom in M1 variable the preferred lag length based on AIC was $q = 8$ months. According to the HQ criterium, $q = 2$ would be optimal and $q = 1$ month with respect to BIC. For the United Kingdom in M1 there is a very weak positive correlation between pairs: AIC-HQ (0.10) and AIC-BIC (0.05). There is a very strong correlation between HQ and BIC (0.99).

Table 5 presents an analysis of the optimum lag length criterium for models M2, which is an extension of model M1, where the credit to the non-financial sector is included in the system. In the case of Poland, based on AIC criteria the optimal lag length seems to be $q = 4$ months. The HQ and BIC criteria preferred $q = 2$ months lag length. Correlation coefficients for M2 in Poland among the criteria were relatively weak for AIC-HQ (-0.26) and AIC-BIC (-0.27). We report a strong correlation between HQ and BIC (0.92). In Germany for M2 AIC indicates $q = 5$ months as an optimal lag length, while HQ only $q = 2$ months. Based on BIC, M2 should be estimated only with a lag length of $q = 1$ month. Again, there is a weak positive correlation between the ranks AIC and HQ (0.12) and also between AIC and BIC (0.09). There is almost a perfect correlation between HQ and BIC (0.99), which explains why those criteria were the first or the second in the ranking.

For the UK dataset it is preferred, according to AIC criteria, to estimate model M2 based on q = 9. Contrary to AIC criteria, in the United Kingdom in M2, HQ and BIC suggested a lag length of q = 2 months and q = 1 month, respectively. In the United Kingdom in M2 the correlation coefficient was negatively correlated for AIC-HQ (-0.58) and AIC-BIC (-0.59). There was a very strong correlation between HQ and BIC (0.99), which explains why those criteria were first or second in the ranking.

The results presented above show that there is no unequivocal empirical evidence in favour of any lag length. In both models AIC supported richer parameterization, indicating a much greater lag length than HQ and BIC. HQ and BIC preferred a smaller optimal lag length (between 1–3 months). Correlation coefficients of ranks differ among models depending on the existence of the credit dynamics variable in the system. There is always a positive, strong correlation between HQ and BIC. The correlation between HQ or BIC and AIC was weak and sometimes even negative. Most importantly, the credit variable included in the model has an impact on inference about the optimal lag length.

We proposed for our research a lag length of q = 2. First of all, lag length $q = 2$ was always on the first or on the second position (based on HQ and BIC) in every country. Choosing a lag length of $q = 2$ is a compromise between the AIC, HQ and BIC criteria.

In the next step we performed an additional analysis of VAR's residuals given q = 2 testing for autocorrelation and stationarity. In Table 6 we reported matrixes of cross-correlation for Poland Germany and the United Kingdom for M1 and M2. We have also reported the summary of the results of Augmented Dickey and Fuller for models residuals (see Dickey, Fuller 1979). In Table 7 we reported test statistics for the ADF test and the p-value for the ADF test. The p-values we reported were very small (< 2.2e-16). According to the critical value of the ADF test and it's p-value, all residuals were stationary. We have also reported the Durbin and Watson test (DW test) (Durbin, Watson 1950, 1951). The results for each model's residuals are listed in Table 8. We reported in Table 8 the test statistic for Durbin and Watson and the p-value. The residuals for each M1 in Poland, Germany and in the United Kingdom were positively correlated. The highest autocorrelation in residuals was in Germany (1.9054) and the weakest autocorrelation in residuals was in the United Kingdom (1.9825). The residuals for each M2 in Poland, Germany and the United Kingdom were also positively correlated. The highest autocorrelation in residuals was in Germany (1.8898) and the weakest autocorrelation in residuals was in the United Kingdom (1.9596). Adding credit to the non-financial sector increased autocorrelation in the models.

4.2. Analysis of the Granger causality

Table 9 shows the results of existence of the Granger causality performed in the case of both models.

In the case of M1 for Poland the stock market variable may determine the future values of industrial production, the unemployment rate and the interest rate. In M2 dependence is similar as in M1, which means that the WIG20 may be the Granger causality for macroeconomic variables. For industrial production in M1 the null hypothesis cannot be rejected at any reasonable significance level. Industrial production does not cause any remaining categories analysed in models. However, after including the credit variable to the model, the resulting p-value of an appropriate causality test is much lower. In M1 the F-statistic and p-value for the unemployment rate was 0.14. Consequently, the null hypothesis cannot be rejected at a reasonable significance level. Again, including the credit variable to the model changes substantially the results of causality testing as the p-value has decreased to 0.005. The unemployment rate may be the Granger causality of the stock market index, industrial production, interest rate and credit to the non-financial sector in M2. For the interest rate in M1 and in M2, the null hypothesis cannot be rejected at any reasonable significance level. Credit to the non-financial sector may be the Granger causality for the stock market, industrial production, the unemployment rate and the interest rate as we report the p-value for F-test at the level 0.01. The existence of the variable describing banking sector activity in the model changes inference about causality, as we obtained much lower p-values of appropriate tests performed for industrial production, the unemployment rate and the interest rate. In Poland, between January 2000 and December 2019, the role of credit in forecasting macroeconomic variables was significant.

In the case of M1 and M2 in Germany, the stock market variable may be the Granger causality for industrial production, the unemployment rate, the interest rate and credit to the non-financial sector. In M1 industrial production had a p-value 0.1, so it may be the Granger causality. After adding the credit variable to the model, the p-value decreased to 0.05. Industrial production in M2 may be useful in forecasting other macroeconomics variables. Since the F-test statistic's p-value for the unemployment rate had values for M1 0.28 and M2 0.21, the null hypothesis cannot be rejected at any reasonable significance level. The interest rate in Germany in M1 and M2 may be the Granger causality for the stock market, industrial production, the unemployment rate and credit to the non-financial sector. The p-value of the F-statistic for credit to the non-financial sector variable was 0.35, which means that the null hypothesis cannot be rejected at any reasonable significance level. From this it follows that the amount of credit in Germany may be not useful to forecast other variables. However, adding the credit variable to the model lowered the p-values of statistics for industrial production and the unemployment rate.

In model M1 for the United Kingdom the stock market may be the Granger causality for industrial production, the unemployment rate and the interest rate. After adding the credit variable to the model the p-value of the F-statistic for the FTSE100 has increased to 0.04. However, the p-value was small, so the null hypothesis can be rejected. It means that the FTSE100 may be the Granger causality for macroeconomic variables in the United Kingdom. F-test statistic's p-value for industrial production in M1 was 0.12. There is no reason to reject the null hypothesis at any reasonable significance level. Industrial production does not cause any remaining categories analysed in models. After adding the credit variable to the model, the p-value decreased to 0.07. In the case of M1 and M2, the unemployment rate may be the Granger causality for the stock market, industrial production, the interest rate and credit to the non-financial sector. The F-test statistic's p-value for the interest rate had in both models values of 0.27; the null hypothesis cannot be rejected at any reasonable significance level. Credit to the non-financial sector may be the Granger causality for other macroeconomic variables because the p-value for the F-test was 0.08. Adding the credit variable to the model decreased the p-values of the statistics for industrial production and the unemployment rate. In the United Kingdom in the period between January 2000 and December 2019, the role of credit in the forecasting of macroeconomic variables was significant.

In the case of all countries in question, adding the credit variable to the model decreased the p-values of the macroeconomic variables. The impact of the credit variable in forecasting the stock market, industrial production, the unemployment rate, and the interest rate was significant in Poland and the United Kingdom The role of the credit variable in forecasting the stock market, industrial production, the unemployment rate, and the interest rate was not statically significant in Germany.

4.3. Analysis of the impulse response functions

In this section, we summarize analyses of estimation of the impulse response functions (IRF) for both models M1 and M2. We estimated IRF for VAR models on the basis of the maximum likelihood estimates of parameters and report 95% confidence intervals approximated by the bootstrap method. The analysed horizon was set to 36 months. The analyses were conducted in three time periods: 1) January 2000 – December 2019; 2), January 2000 – December 2008; 3) January 2009 – December 2019. All models were estimated for each time period with lag length $q = 2$. The reason for the selection of those three time intervals was an easy comparison of the connections between macroeconomic variables before and after the financial crisis. The financial crisis was an incentive for the creation of an advanced macroprudential framework. The macroprudential framework has an impact on credit to the non-financial sector.

Figures 3 and 4 show impulse response functions for the whole analysed period from January 2000 to December 2019 in Poland. In M1 the stock market index (WIG20) had a negative influence on industrial production and no influence on the unemployment rate and the interest rate. In M2 shocks from the stock market had a negative impact on industrial production and credit to the non-financial sector. The influence on the unemployment rate was positive. There was no connection between the stock market and the interest rate. In M1 shocks from industrial production had a positive impact on the unemployment rate and the interest rate. There was no influence on the stock market. In M2 industrial production positively influenced the unemployment rate, the interest rate and credit to the non--financial sector. There was no influence on the stock market. In M1, shocks from the unemployment rate had a negative impact on the interest rate. In M2, the unemployment rate had a negative influence on the interest rate and a positive influence one on credit to the non-financial sector. In M1, the interest rate did not influence any of the variables. In M2, shocks from the interest rate influenced credit to the non-financial sector negatively. Shocks from credit to the non-financial sector had no impact on Poland's economy in the period between January 2000 and December 2019.

In Figures 5 and 6 we show impulse response functions for the period between January 2000 and December 2008 in Poland. In M1, shocks from the stock market index had a positive impact on industrial production. In M2, the stock market index had a negative influence on industrial production, the interest rate, and credit to the non-financial sector. There was no influence on the unemployment rate. In M1, shocks from industrial production had no impact on the stock market and the interest rate. There was a negative influence on the unemployment rate. In M2, shocks from industrial production had a negative impact on the unemployment rate and the interest rate. In M2, shocks from industrial production had a positive impact on credit to the non-financial sector. There was no impact on the stock market. In M1, the unemployment rate had no influence on any of the variables. In M2, shocks from the unemployment rate had a negative impact on the interest rate and on credit to the non--financial sector. The unemployment rate had no impact on the stock market and industrial production. In M1 the interest rate had no influence on any macroeconomic variable. In M2 the interest rate had a negative impact on credit to the non-financial sector. Shocks from credit to the non-financial sector had no impact on the Polish economy between January 2000 and December 2008.

In Figures 7 and 8 we summarized impulse response functions for the period between January 2009 and December 2019 in Poland. In M1, the stock market index had no impact on industrial production, the unemployment rate, and the interest rate. In M2, the stock market index had a negative influence on the unemployment rate and on credit to the non-financial sector. Shocks from the stock market had a positive impact on the interest rate and no impact on industrial production. In M1 industrial production had a positive impact on the unemployment rate and the interest rate. There was no impact on the stock market. In M2 shocks from industrial production had a positive influence on the unemployment rate, the interest rate and on credit to the non-financial sector from industrial production. In M1 the unemployment rate and the interest rate did not impact any of the variables. In M2 the interest rate negatively influenced credit to the non-financial sector. Shocks from credit to the non-financial sector had no impact on the Polish economy in the period between January 2009 and December 2019.

Figures 9 and 10 demonstrate impulse response functions for the period between January 2000 and December 2019 for Germany. In M1 the stock market index (DAX) had a positive influence on industrial production and the interest rate. In M1 the stock market had a negative influence on the unemployment rate. In M2 shocks from the stock market had a positive impact on industrial production and the interest rate. As figures show the stock market negatively influenced the unemployment rate and credit to the non-financial sector. In M1 shocks from industrial production had a positive impact on the stock market, the unemployment rate and the interest rate. In M2 shocks from industrial production had a positive impact on the stock market, the unemployment rate, the interest rate and credit to the non-financial sector. In M1 the unemployment rate did not influence any of the variables in the model. In M2 shocks from the unemployment rate had a positive impact on the interest rate and a negative impact on credit to the non-financial sector. In M1 the interest rate did not influence any of the macroeconomic variables. In M2 the interest rate had only a negative impact on credit to the non-financial sector. Impulses from credit to the non-financial sector did not have any impact on variables from the model.

In Figures 11 and 12 there are impulse response functions for the period between January 2000 and December 2008 in Germany. In M1, shocks from the stock market index (DAX) had a positive influence on industrial production and a negative influence on the unemployment rate. There was no impact on the interest rate. In M2, the stock market had a negative influence on the unemployment rate and on credit to the non-financial sector. There was a positive influence from the DAX on industrial production. In M1, industrial production had a negative impact on the unemployment rate and a positive impact on the interest rate. There was no impact on the stock market. In M2 industrial production had no impact on the stock market and the unemployment rate. Shocks from industrial production had a positive influence on the interest rate and a negative one on credit to the non--financial sector. In M1 the unemployment rate negatively influenced the interest rate. There was no impact on the stock market and industrial production. In M2 shocks from the unemployment rate had a negative impact on the interest rate and credit to the non-financial sector. There was no impact on the stock market and industrial production. In M1 shocks from the interest rate did not influence any of the variables. In M2 the interest rate had a negative impact only on credit to the non-financial sector. Shocks from credit to the non-financial sector did not have any impact on the German economy in the period between January 2000 and December 2008. Adding the credit variable to the models changed the dynamics and the connections between the variables.

In Figures 13 and 14 we put impulse response functions for the period between January 2009 and December 2019 in Germany. In M1 the stock market index (DAX) had a positive influence on industrial production, the unemployment rate and the interest rate. In M2, shocks from the DAX had a positive influence on industrial production, the unemployment rate, and the interest rate. No impact on credit to the non-financial sector was observed. In M1 shocks from industrial production had a positive impact on the unemployment rate and the interest rate. No impact on the DAX was observed. In M2 industrial production had a positive impact on the stock market, the unemployment rate, the interest rate, and credit to the non-financial sector. In M1 the unemployment rate positively influenced the interest rate. There was no influence on other variables. In M2 the unemployment rate positively influenced the interest rate and negatively influenced credit to the non-financial sector. No influence on the stock market and industrial production was observed. In M1 the interest rate did not influence any of the variables. In M2 shocks from the interest rate had a negative impact on credit to the non-financial sector. Shocks from credit to the non-financial sector did not have any impact on the German economy in the period between January 2009 and December 2019. However, adding the credit variable to the model changed relationships within variables.

In Figures 24 and 25 there are summarized impulse response functions for the period between January 2000 and December 2019 in the United Kingdom. In M1 shocks from the stock market index had a positive impact on industrial production. In M2 shocks from the stock market index had a negative impact on industrial production. In M1 shocks from the FTSE had a negative impact on the unemployment rate and the interest rate. In M2 shocks from the stock market had a negative impact on the unemployment rate, the interest rate and credit to the non-financial sector. In M1 industrial production positively influenced the interest rate. There was no correlation between impulses from industrial production and the stock market. There was no correlation between impulses from industrial production and the unemployment rate either. In M2 industrial production had a positive impact on the unemployment rate, the interest rate, and credit to the non-financial sector. In M2 there was no impact from shocks of industrial production on the stock market. In M1 the unemployment rate had a negative impact on the interest rate. Shocks from the unemployment rate did not have any impact on the stock market and industrial production. In M2 shocks from the unemployment rate had a negative impact on the interest rate and credit to the non-financial sector. The unemployment rate did not influence the stock market and industrial production in M2. In M1 the interest rate did not influence any of the variables. In M2 the interest rate had a positive impact only on credit to the non--financial sector. Impulses from credit to the non-financial sector did not have any impact on the United Kingdom's economy in the period between January 2000 and December 2019.

Figures 17 and 18 contain the impulse response functions for the period between January 2000 and December 2008 in the United Kingdom. In M1 the stock market had a positive influence on industrial production and a negative influence on the unemployment rate. No impact on the interest rate was observed. In M2 shocks from the stock market had a positive influence on industrial production. The impact on the unemployment rate and credit to the non-financial sector was negative. No influence on the interest rate was observed. In M1 industrial production had a positive influence on the unemployment rate and the interest rate. There was no influence on the stock market. In M2 there was a positive impact on the unemployment rate, interest rate and credit to the non-financial sector. There was no influence on the stock market. In M1 the unemployment rate had only a negative impact on the interest rate. In M2 the unemployment rate had only a negative impact on the interest rate. In both models no impact on any other variables was observed. In M1 and M2, the interest rate did not influence any of the variables. Shocks from credit to the non-financial sector had no influence on the UK's economy in the period between January 2000 and December 2008. Including the credit variable to the model did not change the strength of connections between the variables.

Figures 19 and 20 summarize the impulse response functions for the period between January 2009 and December 2019 in the UK. In M1, shocks from the stock the market had a positive impact on industrial production. The stock market did not influence the unemployment rate and the interest rate. In M2, the stock market's influence on industrial production was positive. Shocks from the stock market had a negative impact on the unemployment rate, the interest rate, and credit to the non-financial sector. In M1, shocks from industrial production had a positive influence on the unemployment rate and the interest rate. There was no impact on the stock market index. In M2, shocks from industrial production had a positive impact on the interest rate and a negative impact on the unemployment rate. There was no influence on the stock market and credit to the non-financial sector. In M1, shocks from the unemployment rate had a positive impact on the interest rate. There was no impact on the stock market and industrial production. In M2, shocks from the unemployment rate had a positive impact on the interest rate and a negative impact on credit to the non-financial sector. In M1, the interest rate had no impact on any variables. Impulses from credit to the non-financial sector had no impact on the United Kingdom's economy between January 2009 and December 2019.

The analyses were conducted in three areas. The first area is the model without and with the credit variable. Shocks from credit to the non-financial sector had no influence on the Polish, German and the British's economies respectively in any of the investigated period. In the second area were differed effects between connections of macroeconomic variables in models without credit and with credit, adding the credit variable to the model changed relationships within variables in Poland and in Germany. The third area of the analysis was the period before and after the financial crisis. There were no significant changes of relationships between variables in the period before and after the crisis.

5. Conclusions

The main goal of this paper was to investigate the interactions between macroeconomic variables before and after the implementation of a macroprudential framework. We investigated the following macroeconomics variables; the stock market, industrial production, the unemployment rate, the interest rate and the amount of credit to the non-financial sector. We performed analysis for three European economies; those of Poland, Germany, and the United Kingdom respectively. The substantial diversity of sources of economic growth as well as the size of the financial system in the case of those countries allowed us to have broad results about credit supply within the macroprudential framework.

The estimated VAR models were estimated correctly, as we performed some checks in the residuals. We can conclude that the results we obtained are adequate and maybe used in future research.

The first hypothesis was: credit to the non-financial sector has an empirically important impact on the dynamics of key macroeconomic variables. This hypothesis can be accepted, which was proven during the research. Adding the credit variable to the models changed the dynamics and the connections between the macroeconomics variables. Our empirical research confirmed that there is a significant role of credit in the economy. Models with credit to the non-financial sector had higher autocorrelation in the residuals. The role of credit in the impulse response analysis was not always statistically significant. However, adding the credit variable to M1 changed the strength of the shocks and the period in which the impact was observed in the economies in question. We can conclude, therefore, that credit to the non-financial sector may have a significant impact on economic growth and the business cycle.

The second hypothesis was: credit to the non-financial sector constitutes the Granger causality for the stock market, industrial production, the unemployment rate, and the interest rate. The hypothesis cannot be accepted, yet cannot be rejected either due to the inconclusiveness of the results. The credit variable may be the Granger cause for Poland and the United Kingdom. In Germany, the credit variable is not the Granger cause for the macroeconomics variable. However, it is very interesting that in all countries, adding the credit variable to the model decreased the p-values of the macroeconomic variables.

The third hypothesis was: developed economies with larger service sectors are more resilient to the impact of credit shocks to the non-financial sector. In Germany which is a developed country with a high industry/GDP ratio, financial stability was the highest. In the United Kingdom, where the service/GDP ratio is the highest, the impact of credit was the strongest. During the research it was demonstrated that the credit variable had a significant impact on fluctuations during the business cycle in Poland and the UK. Credit to the non-financial sector has an impact on macroeconomic conditions and stimulated the economies of those countries.

The macroprudential framework is still dynamically developing. We can conclude that the macroprudential framework works well; however, it should be tested in the economic downturn as well. After 2008 we did not observe any financial crisis or downturn. After the crisis, all the central banks lowered interest rates, which was a common approach aimed at fostering economic recovery. Lower interest rates stimulated credit growth, which can be the cause of an increase in industrial production. We believe that the crisis which occurred due to the COVID pandemic in 2020 would be a good test of the use of macroprudential regulations, as credit growth can be observed in 2020. However, additional research is needed to confirm our hypothesis.

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Appendix

Table 1

VAR models build for research

Country	Model M1	Model M2
Poland Germany United Kingdom	stock market industrial production unemployment rate interest rate	stock market industrial production unemployment rate interest rate amount of credit to the non- -financial sector

Table 2

Descriptive statistics for raw data and differed logarithm for Poland, Germany and the United Kingdom

	Time series	Mean	Standard deviation	Minimum	Maximum	Excess kurtosis
Poland	WIG20	2199	580.27	1074	3826	3.23
	diff(log(WIG20))	0.0078	0.2502	-0.7407	0.4975	3.248
	Industrial production	82.7	32.06	26.2	182.9	2.62
	diff(log(Industrial production))	0.024	0.1373	-0.321	0.434	2.881
	Unemployment rate	11.22	5.43	2.80	21.0	1.83
	diff(log(Unemployment rate))	-0.08396	0.1658	-0.4018	0.29399	2.068
	WIBOR1M	5.19	4.32	1.56	19.00	6.27
	diff(log(WIBOR1M))	-0.12615	0.2654	-0.65925	0.36536	2.1175
	Credit	651377	352659.4	177351	1260694	1.521438
	diff(log Credit))	0.09765	0.074045	0.01019	0.32088	3.989452
Germany	DAX	7439.60	2880.80	2491.05	13270.66	2.12
	diff(log(DAX))	0.0280	0.2323	-0.7594	0.4537	3.353
	Industrial production	94.67	10.49	69.20	120.90	2.86
	diff(log(Industrial production))	0.0170	0.0730	-0.2074	0.2150	3.329
	Unemployment rate	6.79	2.44	3.00	11.24	1.79
	diff(log(Unemployment rate))	-0.04824	0.957	-0.25131	0.15484	2.215
	EURIBOR1M	1.57	1.75	-0.46	5.02	1.77
	diff(log(EURIBOR1M))	-0.21022	0.4863	-1.74611	0.63573	3.5463
	Credit	3138	142.12	2922	3523	2.51
	diff(log Credit))	0.00812	0.0158	-0.04149	0.054007	4.0904
United Kingdom	FTSE100	5867.37	1004.08	3614.48	7666.57	2.27
	diff(log(FTSE100))	0.0065	0.1509	-0.4366	0.4039	3.6066
	Industrial production	98.85	18.64	46.80	134.60	3.14
	diff(log(Industrial production))	0.0006	0.0903	-0.3269	0.3114	5.1663
	Unemployment rate	5.67	1.34	3.50	8.50	2.17
	diff(log(Unemployment rate))	-0.01863	0.1146	-0.25951	0.41224	5.0865
	Libor1M	1.96	1.94	0.15	6.68	2.70
	diff(log(Libor1M))	-0.05572	0.717	-2.74975	1.22534	4.729
	Credit	120371	18204.6	84207	153925	1.99
	diff(log Credit))	0.028619	0.072	-0.17622	0.109677	3.027

Table 3
Augmented Dickey and Fuller Test for differed and logarithmic macroeconomic variables

	Poland	**Germany**	**United Kingdom**
Stock market	-3.148 (7.73E-06)	-3.253 (3.43E-04)	-3.089 (1.19E-07)
Industrial production	-4.250 (3.92E-06)	-5.808 (2.20E-16)	-7.275 (2.03E-12)
Unemployment rate	-1.922 (2.20E-16)	-2.271 (1.01E-03)	-2.283 (2.56E-11)
Interest rate	-2.612 (2.69E-16)	-2.5204 (3.38E-05)	-2.416 (1.38E-04)
Credit to the non-financial sector	-1.2673 (1.36E-02)	-2.706 (3.67E-01)	-1.415 (2.29E-02)

Note: in brackets p-values.

Table 4
Analyses of information criteria for models M1 (credit variables excluded) in the case of Poland, Germany and the United Kingdom

Analyses of fitting the model based on information criterium											
Poland_VAR_ without_credit				**Germany_VAR_ without_credit**				**United Kingdom_VAR_ without_credit**			
lags	**AIC**	**HQ**	**BIC**	**lags**	**AIC**	**HQ**	**BIC**	**lags**	**AIC**	**HQ**	**BIC**
1	-23.71	-23.58	-23.40	1	-21.26	-21.14	-20.95	1	-21.86	-21.74	-21.55
2	-24.26	-24.03	-23.70	2	-21.52	-21.29	-20.96	2	-21.99	-21.76	-21.43
3	-24.27	-23.94	-23.46	3	-21.63	-21.30	-20.82	3	-21.96	-21.64	-21.16
4	-24.34	-23.92	-23.29	4	-21.57	-21.15	-20.52	4	-21.99	-21.57	-20.94
5	-24.34	-23.81	-23.03	5	-21.70	-21.17	-20.39	5	-21.97	-21.44	-20.67
6	-24.39	-23.76	-22.84	6	-21.67	-21.04	-20.11	6	-21.95	-21.32	-20.40
7	-24.35	-23.62	-22.55	7	-21.63	-20.90	-19.83	7	-21.99	-21.26	-20.19
8	-24.32	-23.49	-22.27	8	-21.57	-20.74	-19.52	8	-22.01	-21.18	-19.96
9	-24.32	-23.39	-22.02	9	-21.60	-20.67	-19.30	9	-21.92	-20.99	-19.62
10	-24.24	-23.21	-21.69	10	-21.57	-20.55	-19.03	10	-21.90	-20.87	-19.35
Ranking based on information criterium											
ranking	**AIC**	**HQ**	**BIC**	**ranking**	**AIC**	**HQ**	**BIC**	**ranking**	**AIC**	**HQ**	**BIC**
I	6	2	2	I	5	3	2	I	8	2	1
II	7	3	3	II	6	2	1	II	4	1	2
III	4	4	1	III	7	5	3	III	2	3	3
IV	5	5	4	IV	3	4	4	IV	7	4	4
V	9	6	5	V	9	1	5	V	5	5	5
VI	8	7	6	VI	10	6	6	VI	3	6	6
VII	3	1	7	VII	4	7	7	VII	6	7	7
VIII	2	8	8	VIII	8	8	8	VIII	9	8	8
IX	10	9	9	IX	2	9	9	IX	10	9	9
X	1	10	10	X	1	10	10	X	1	10	10
Correlation of rankings											
	AIC	**HQ**	**BIC**		**AIC**	**HQ**	**BIC**		**AIC**	**HQ**	**BIC**
AIC	1	0.01	-0.19	AIC	1	-0.48	-0.35	AIC	1	0.10	0.05
HQ	0.01	1	0.71	HQ	-0.48	1	0.87	HQ	0.10	1	0.99
BIC	-0.19	0.71	1	BIC	-0.35	0.87	1	BIC	0.05	0.99	1

Table 5
Analyses of information criteria for models M2 (credit variables included) in the case of Poland, Germany and the United Kingdom

Analyses of fitting the model based on information criterium											
Poland_VAR_ with_credit				**Germany_VAR_ with_credit**				**United Kingdom_VAR_ with_credit**			
lags	**AIC**	**HQ**	**BIC**	**lags**	**AIC**	**HQ**	**BIC**	**lags**	**AIC**	**HQ**	**BIC**
1	-32.34	-32.15	-31.87	1	-31.36	-31.18	-30.90	1	-30.66	-30.47	-30.19
2	-32.87	-32.52	-32.01	2	-31.57	-31.22	-30.71	2	-30.83	-30.49	-29.98
3	-32.85	-32.35	-31.61	3	-31.67	-31.16	-30.42	3	-30.95	-30.45	-29.71
4	-32.89	-32.23	-31.26	4	-31.64	-30.98	-30.01	4	-31.01	-30.35	-29.38
5	-32.83	-32.01	-30.81	5	-31.74	-30.92	-29.72	5	-30.96	-30.15	-28.94
6	-32.88	-31.91	-30.48	6	-31.66	-30.69	-29.26	6	-30.91	-29.94	-28.51
7	-32.88	-31.75	-30.09	7	-31.62	-30.49	-28.83	7	-30.98	-29.85	-28.18
8	-32.89	-31.60	-29.71	8	-31.53	-30.24	-28.35	8	-31.04	-29.75	-27.86
9	-32.88	-31.44	-29.31	9	-31.61	-30.16	-28.03	9	-31.04	-29.60	-27.47
10	-32.82	-31.22	-28.86	10	-31.53	-29.93	-27.57	10	-30.95	-29.35	-26.99
Ranking based on information criterium											
ranking	**AIC**	**HQ**	**BIC**	**ranking**	**AIC**	**HQ**	**BIC**	**ranking**	**AIC**	**HQ**	**BIC**
I	4	2	2	I	5	2	1	I	9	2	1
II	8	3	1	II	3	1	2	II	8	1	2
III	6	4	3	III	6	3	3	III	4	3	3
IV	7	1	4	IV	4	4	4	IV	7	4	4
V	9	5	5	V	7	5	5	V	5	5	5
VI	2	6	6	VI	9	6	6	VI	3	6	6
VII	3	7	7	VII	2	7	7	VII	10	7	7
VIII	5	8	8	VIII	10	8	8	VIII	6	8	8
IX	10	9	9	IX	8	9	9	IX	2	9	9
X	1	10	10	X	1	10	10	X	1	10	10
Correlation of rankings											
	AIC	**HQ**	**BIC**		**AIC**	**HQ**	**BIC**		**AIC**	**HQ**	**BIC**
AIC	1	-0.26	-0.27	AIC	1	0.12	0.09	AIC	1	-0.58	-0.59
HQ	-0.26	1	0.92	HQ	0.12	1	0.99	HQ	-0.58	1	0.99
BIC	-0.27	0.92	1	BIC	0.09	0.99	1	BIC	-0.59	0.99	1

Table 6
Matrixes of cross-correlation for Poland, Germany and the United Kingdom for M1 and M2

Poland M1				**Poland M2**				
1				1				
-0.05765	1			-0.04101	1			
0.005309	0.017263	1		0.025119	0.009787	1		
-0.01929	0.024745	-0.04558	1	-0.03768	0.031248	-0.03854	1	
				-0.07426	-0.05977	0.037378	0.039409	1
Germany M1				**Germany M2**				
1				1				
0.199827	1			0.196462	1			
-0.06161	0.035657	1		-0.0633	0.025518	1		
0.011409	0.041737	0.135051	1	0.016257	0.049405	0.136632	1	
				-0.06617	-0.01328	-0.05732	-0.06763	1
United Kingdom M1				**United Kingdom M2**				
1				1	-0.01333			
0.010943	1			-0.01333	1			
-0.10334	0.004102	1		-0.09439	0.015119	1		
-0.24837	0.116944	-0.0354	1	-0.23106	0.150522	-0.05777	1	
				-0.06858	0.175777	-0.01722	0.30609	1

Table 7

Augmented Dickey-Fuller test statistics for residuals of VAR without credit variables

		Poland Model M1	**Poland Model M2**	**Germany Model M1**	**Germany Model M2**	**United Kingdom Model M1**	**United Kingdom Model M2**
Stock market	ADF	-11.27	-11.69	-11.02	-10.99	-10.99	-10.736
	p-value	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Industrial production	ADF	-11.88	-11.57	-12.62	-12.470	-11.31	-11.04
	p-value	< 2.2e-16	<2.2e-16	< 2.2e-16	<2.2e-16	<2.2e-16	< 2.2e-16
Unemployment rate	ADF	-9.75	-9.82	-11.78	-11.830	-10.37	-10.48
	p-value	< 2.2e-16	< 2.2e-16	<2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Interest rate	ADF	-10.67	-10.75	-8.19	-8.230	-10.32	-10.21
	p-value	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Credit to the non-financial sector	ADF	X	-10.68	X	-11.860	X	-10.21
	p-value	X	<2.2e-16	X	< 2.2e-16	X	< 2.2e-16

Table 8
Durbin and Watson statistics for residuals of VAR without credit variables

	Poland Model M1	**Poland Model M2**	**Germany Model M1**	**Germany Model M2**	**United Kingdom Model M1**	**United Kingdom Model M2**
DW	1.9643	1.9131	1.9054	1.8898	1.9825	1.9596
p-value	0.395	0.2576	0.2371	0.2027	0.4473	0.3817

Table 9
The Granger causality value of F-statics and p-values for VAR models

Poland Model M1	**Poland Model M2**	**Germany Model M1**	**Germany Model M2**	**United Kingdom Model M1**	**United Kingdom Model M2**
Stock market	Stock market	Stock market	Stock market	Stock market	Stock market
Industrial production	Industrial production	Industrial production	Industrial production	Industrial production	Industrial production
Unemployment rate	Unemployment rate	Unemployment rate	Unemployment rate	Unemployment rate	Unemployment rate
Interest rate	Interest rate	Interest rate	Interest rate	Interest rate	Interest rate
	Credit to the non-financial sector		Credit to the non-financial sector		Credit to the non-financial sector
F-statics 3.9002	F-statics 3.8543	F-statics 5.0925	F-statics 4.0818	F-statics 5.6372	F-statics 4.6184
p-value 2.2e-16	p-value 2.2e-16	p-value 2.2e-16	p-value 2.2e-16	p-value 2.2e-16	p-value 0.04
Industrial production	Industrial production	Industrial production	Industrial production	Industrial production	Industrial production
Stock market	Stock market	Stock market	Stock market	Stock market	Stock market
Unemployment rate	Unemployment rate	Unemployment rate	Unemployment rate	Unemployment rate	Unemployment rate
Interest rate	Interest rate	Interest rate	Interest rate	Interest rate	Interest rate
	Credit to the non-financial sector		Credit to the non-financial sector		Credit to the non-financial sector
F-statics 0.58282	F-statics 1.0214	F-statics 1.7761	F-statics 1.8521	F-statics 2.5941	F-statics 1.9809
p-value 0.67	p-value 0.25	p-value 0.1	p-value 0.05	p-value 0.12	p-value 0.07

Table 9, cont'd

Poland Model M1	Poland Model M2	Germany Model M1	Germany Model M2	United Kingdom Model M1	United Kingdom Model M2
Unemployment rate Stock market Industrial production Interest rate	Unemployment rate Stock market Industrial production Interest rate Credit to the non-financial sector	Unemployment rate Stock market Industrial production Interest rate	Unemployment rate Stock market Industrial production Interest rate Credit to the non-financial sector	Unemployment rate Stock market Industrial production Interest rate	Unemployment rate Stock market Industrial production Interest rate Credit to the non-financial sector
F-statics 1.8977 p-value 0.14	F-statics 2.7351 p-value 2.2e-16	F-statics 1.1452 p-value 0.28	F-statics 1.1148 p-value 0.21	F-statics 1.9857 p-value 0.02	F-statics 3.6122 p-value 2.2e-16
Interest rate Stock market Industrial production Unemployment rate	Interest rate Stock market Industrial production Unemployment rate Credit to the non-financial sector	Interest rate Stock market Industrial production Unemployment rate	Interest rate Stock market Industrial production Unemployment rate Credit to the non-financial sector	Interest rate Stock market Industrial production Unemployment rate	Interest rate Stock market Industrial production Unemployment rate Credit to the non-financial sector
F-statics 1.7319 p-value 0.09	F-statics 1.4552 p-value 0.11	F-statics 3.9859 p-value 0.01	F-statics 3.0279 p-value 0.01	F-statics 1.253 p-value 0.27	F-statics 1.9516 p-value 0.27
	Credit to the non-financial sector Stock market Industrial production Unemployment rate Interest rate		Credit to the non-financial sector Stock market Industrial production Unemployment rate Interest rate		Credit to the non-financial sector Stock market Industrial production Unemployment rate Interest rate
	F-statics 1.7388 p-value 0.10		F-statics 1.0137 p-value 0.35		F-statics 4.237 p-value 0.08

Figure 1

Plots of macroeconomics variables in Poland, Germany and the United Kingdom for the period between January 2000 and December 2019; T = 228 observations

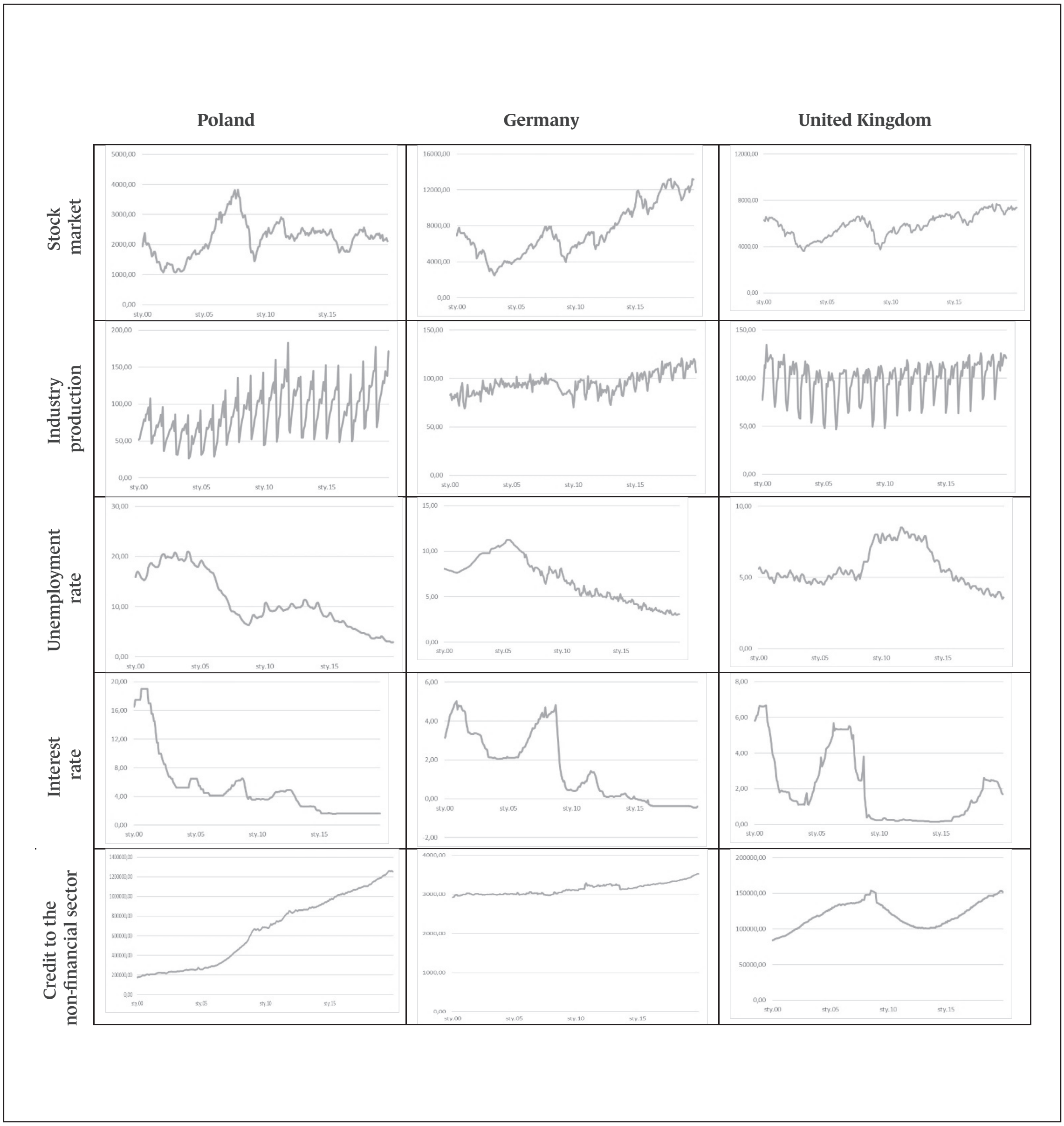

Figure 2
Plots of first differences of logarithms of macroeconomics variables in Poland, Germany and the United Kingdom for the period between January 2000 and December 2019; T = 225 observations

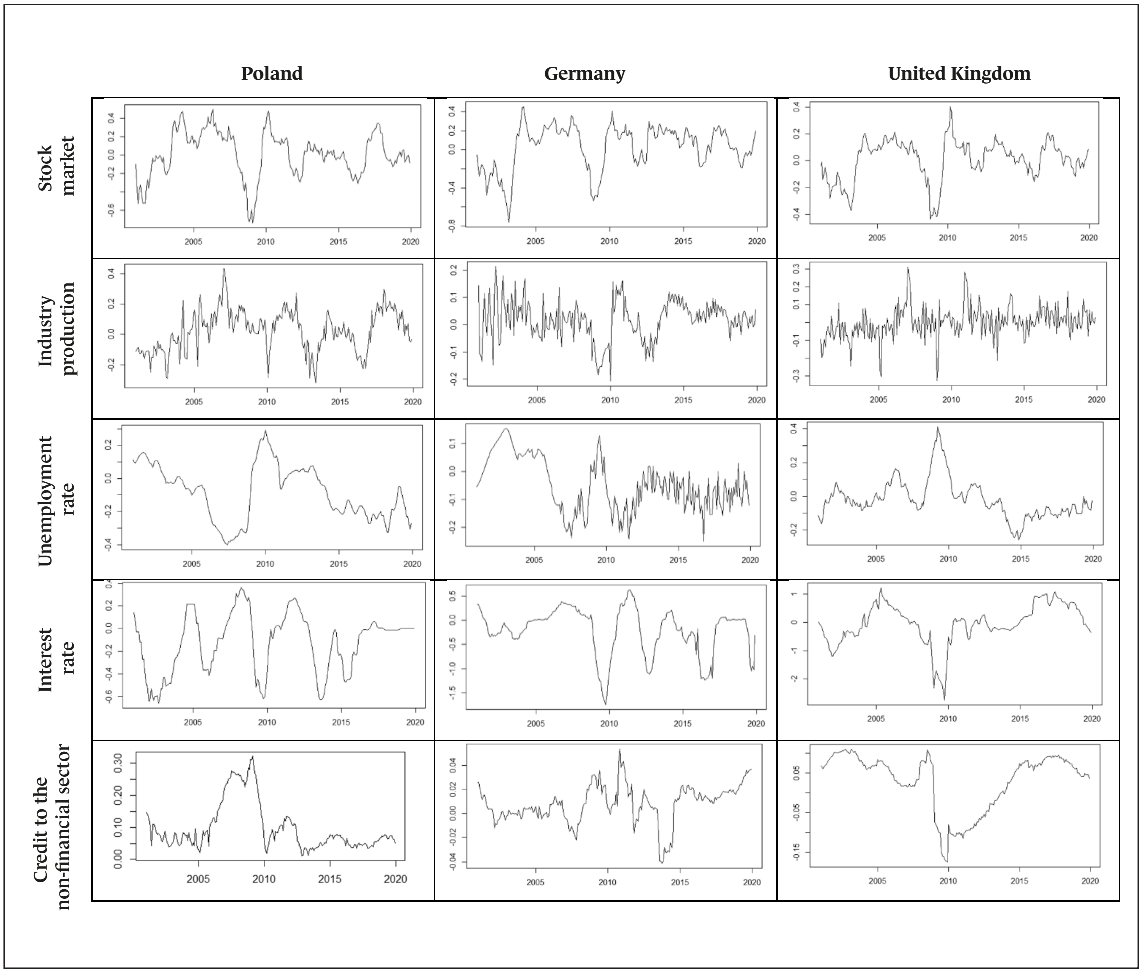

Figure 3

Impulse response function Poland VAR model M1 for the period between January 2000 and December 2019

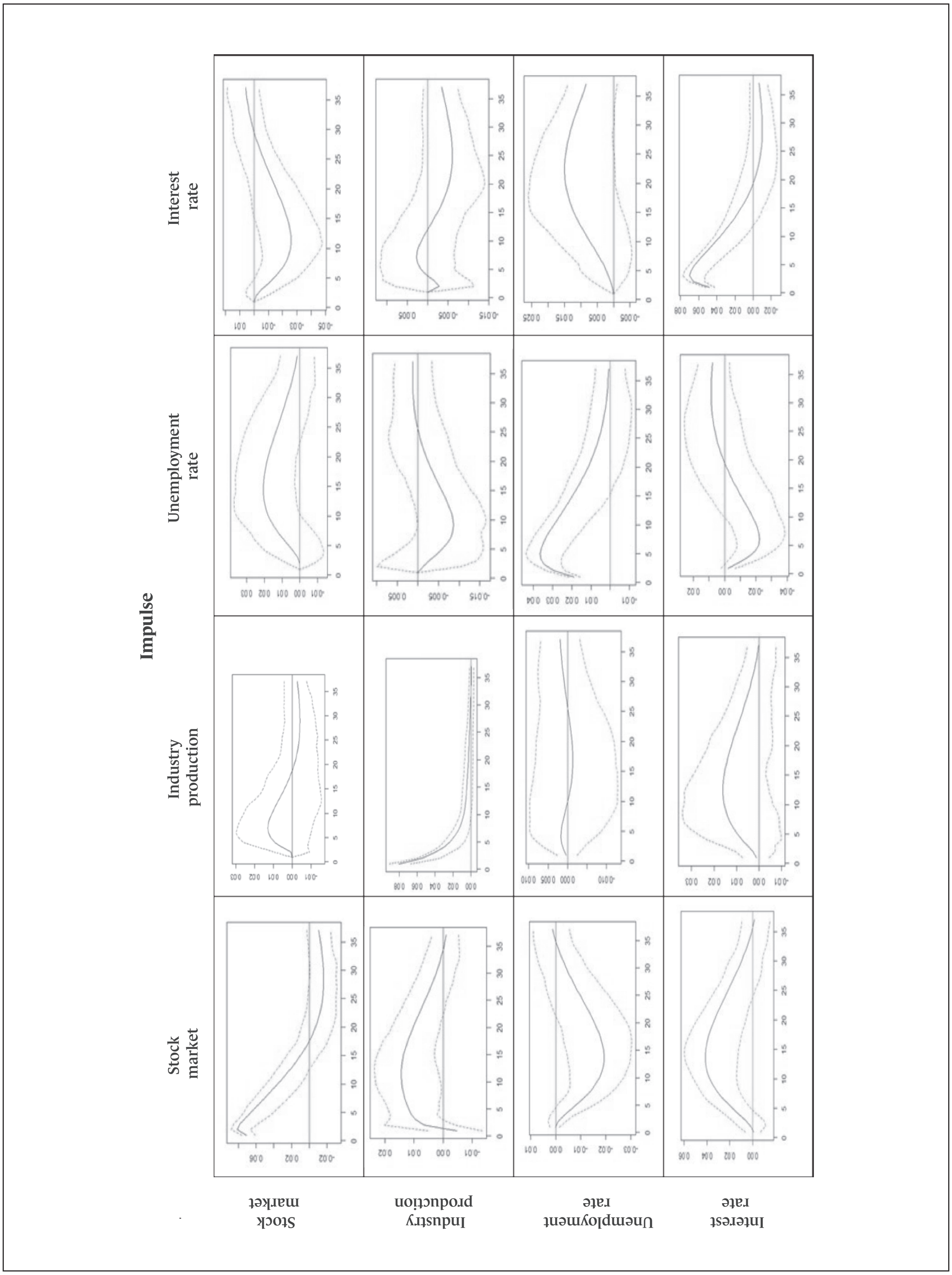

Figure 4

Impulse response function Poland VAR model M2 for the period between January 2000 and December 2019

Figure 5

Impulse response function Poland VAR model M1 for the period between January 2000 and December 2008

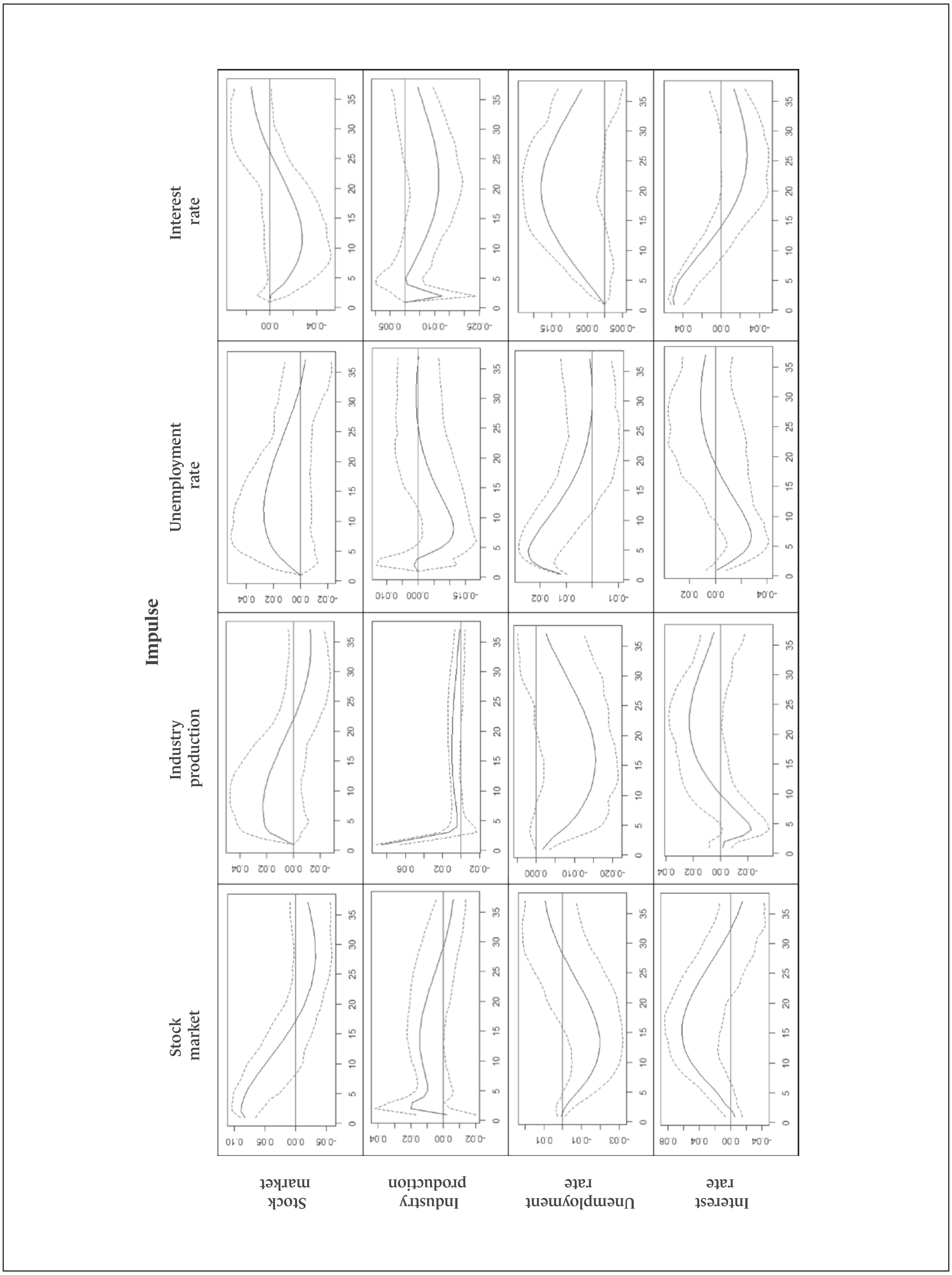

Figure 6

Impulse response function Poland VAR model M2 for the period between January 2000 and December 2008

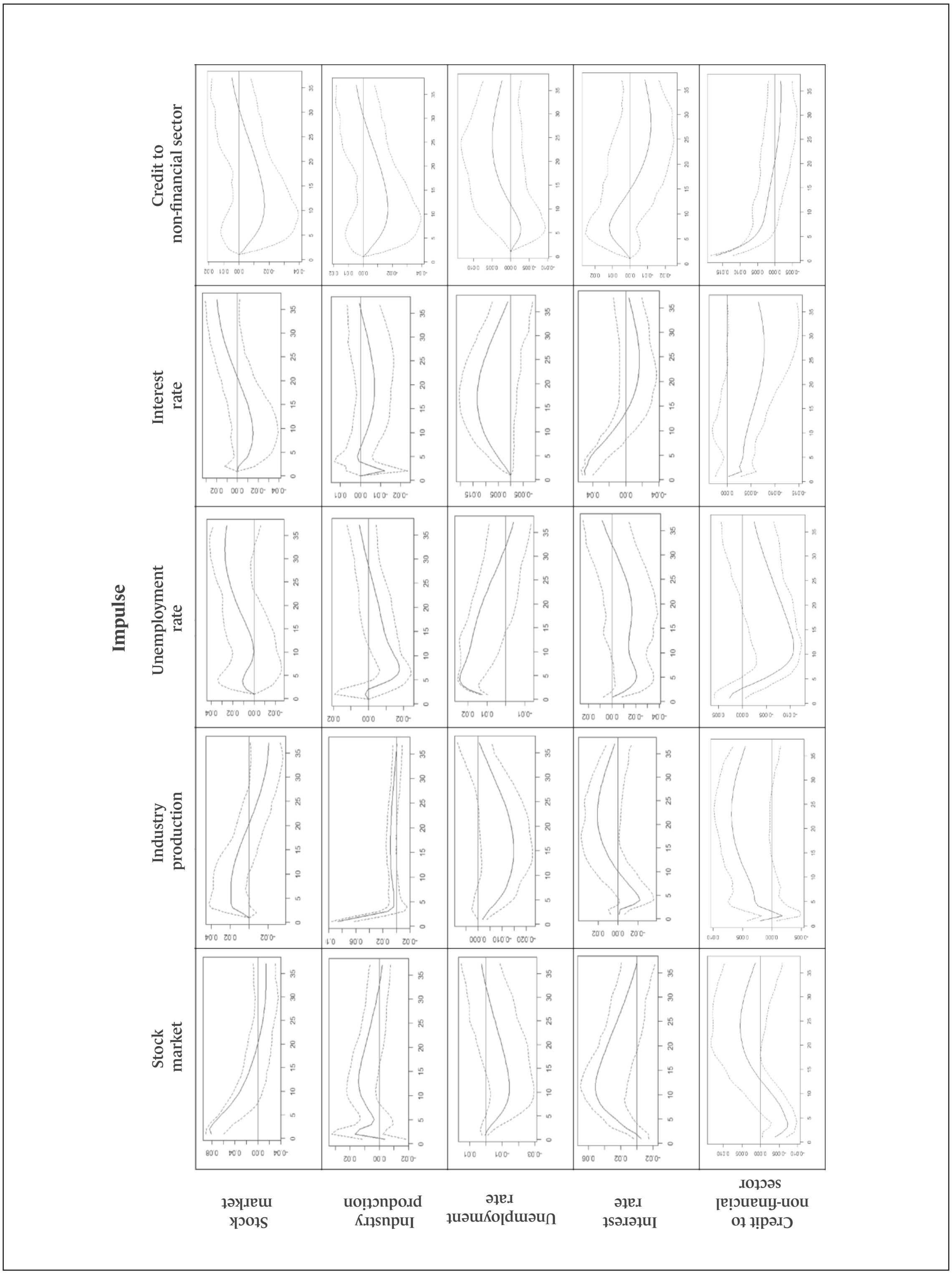

Figure 7

Impulse response function Poland VAR model M1 for the period between January 2009 and December 2019

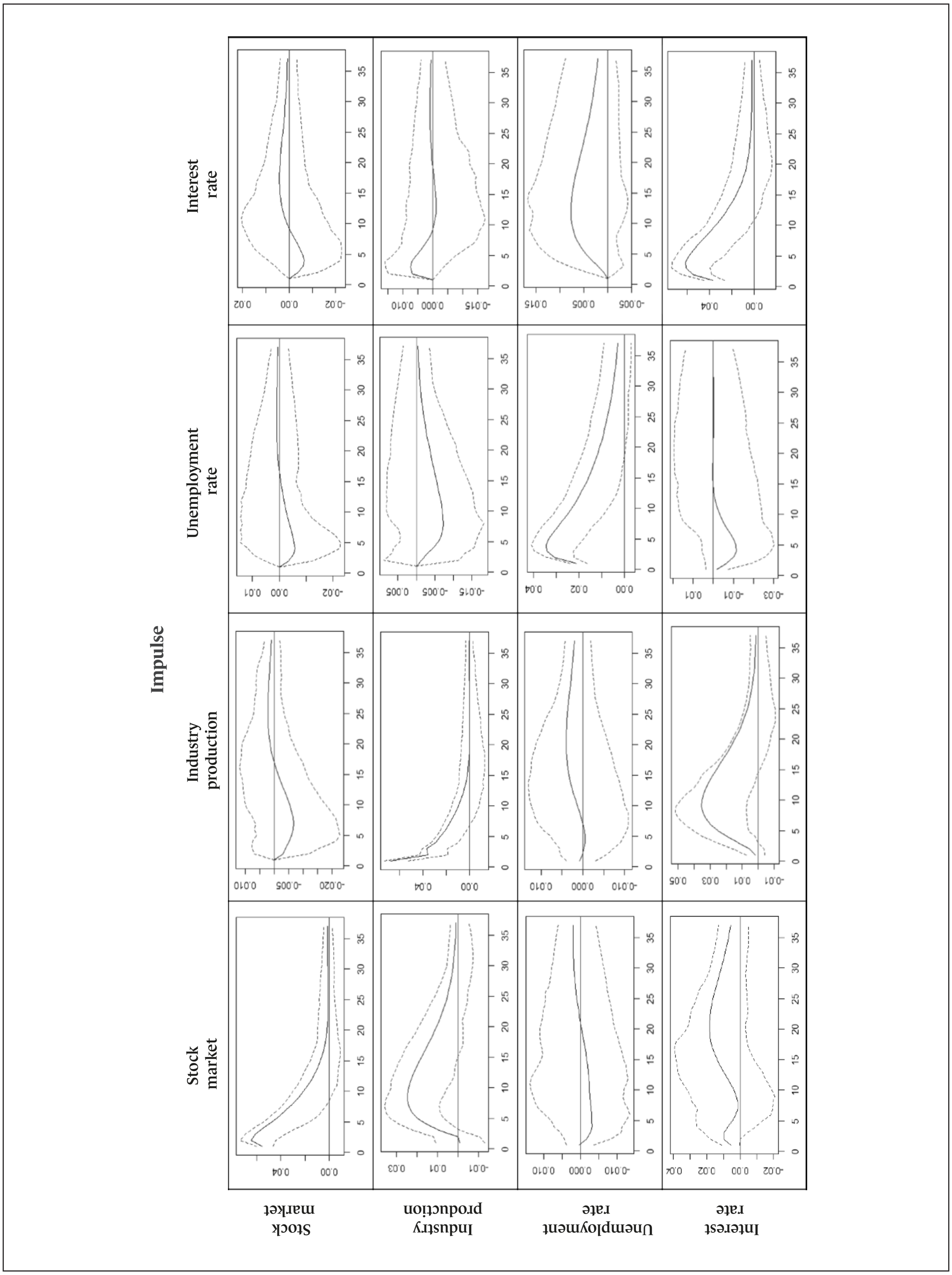

Figure 8

Impulse response function for Poland VAR model M2 for the period between January 2009 and December 2019

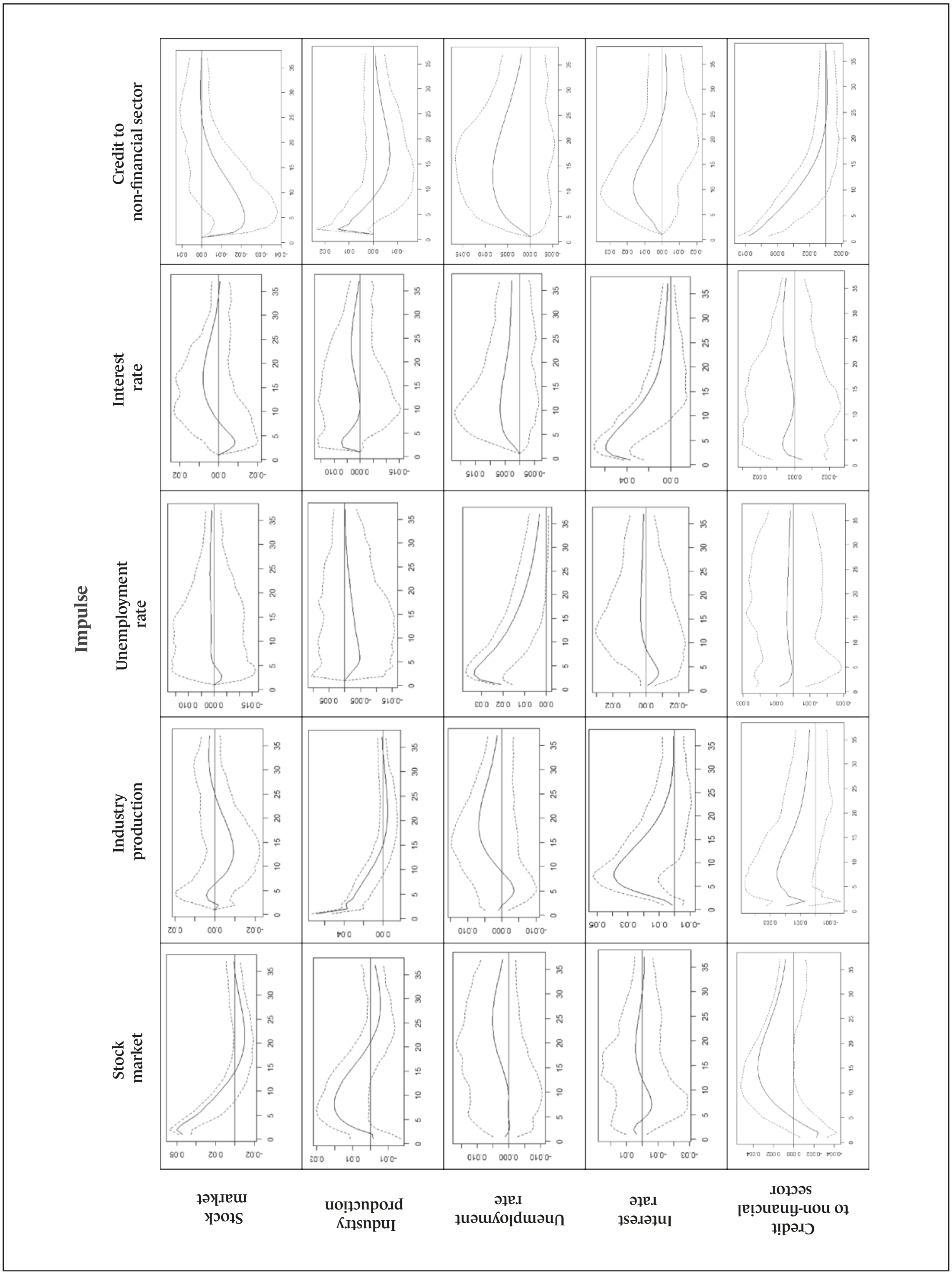

Figure 9

Impulse response function Germany VAR model M1 for the period between January 2000 and December 2019

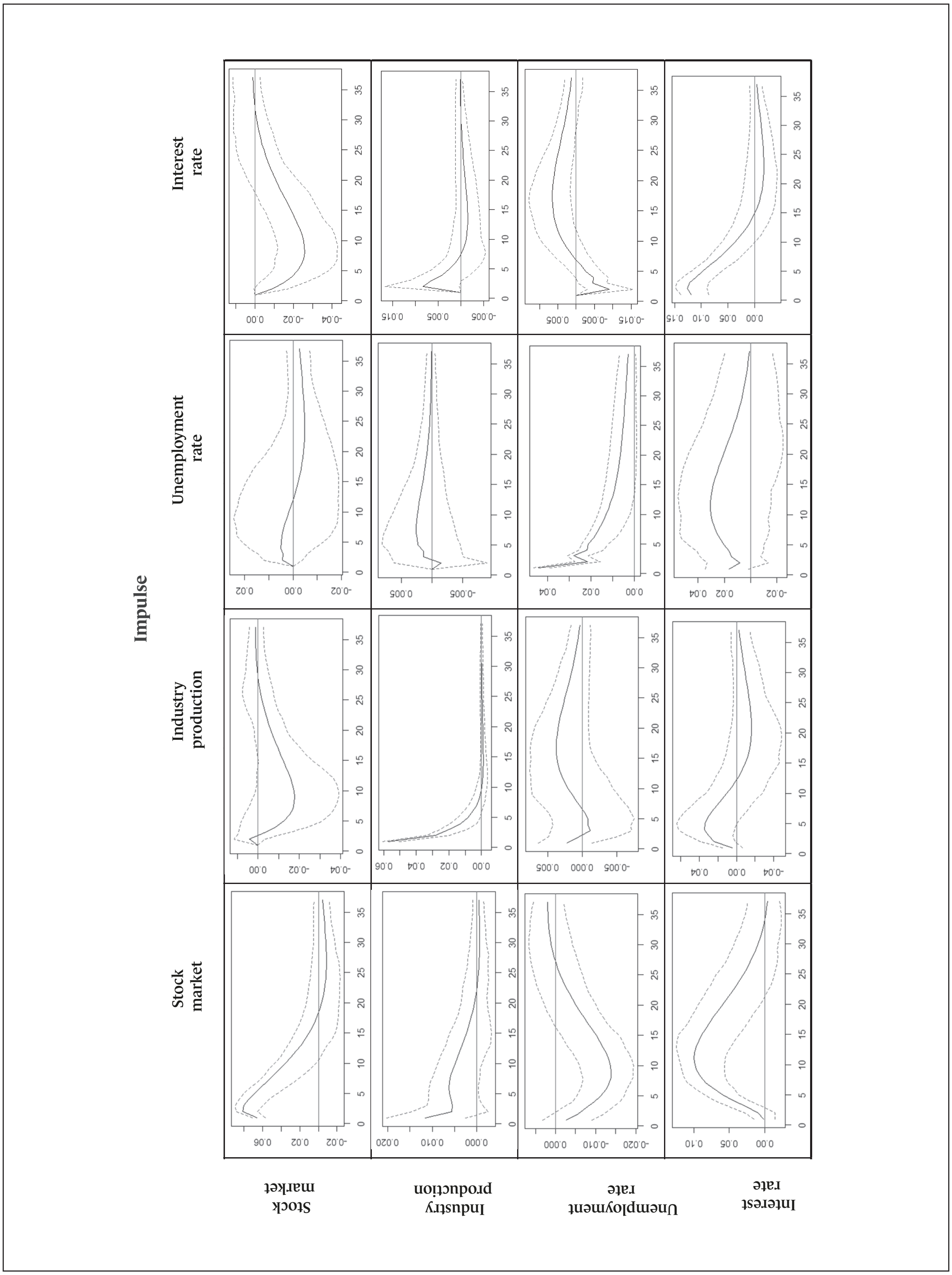

Figure 10

Impulse response function Germany VAR model M2 for the period between January 2000 and December 2019

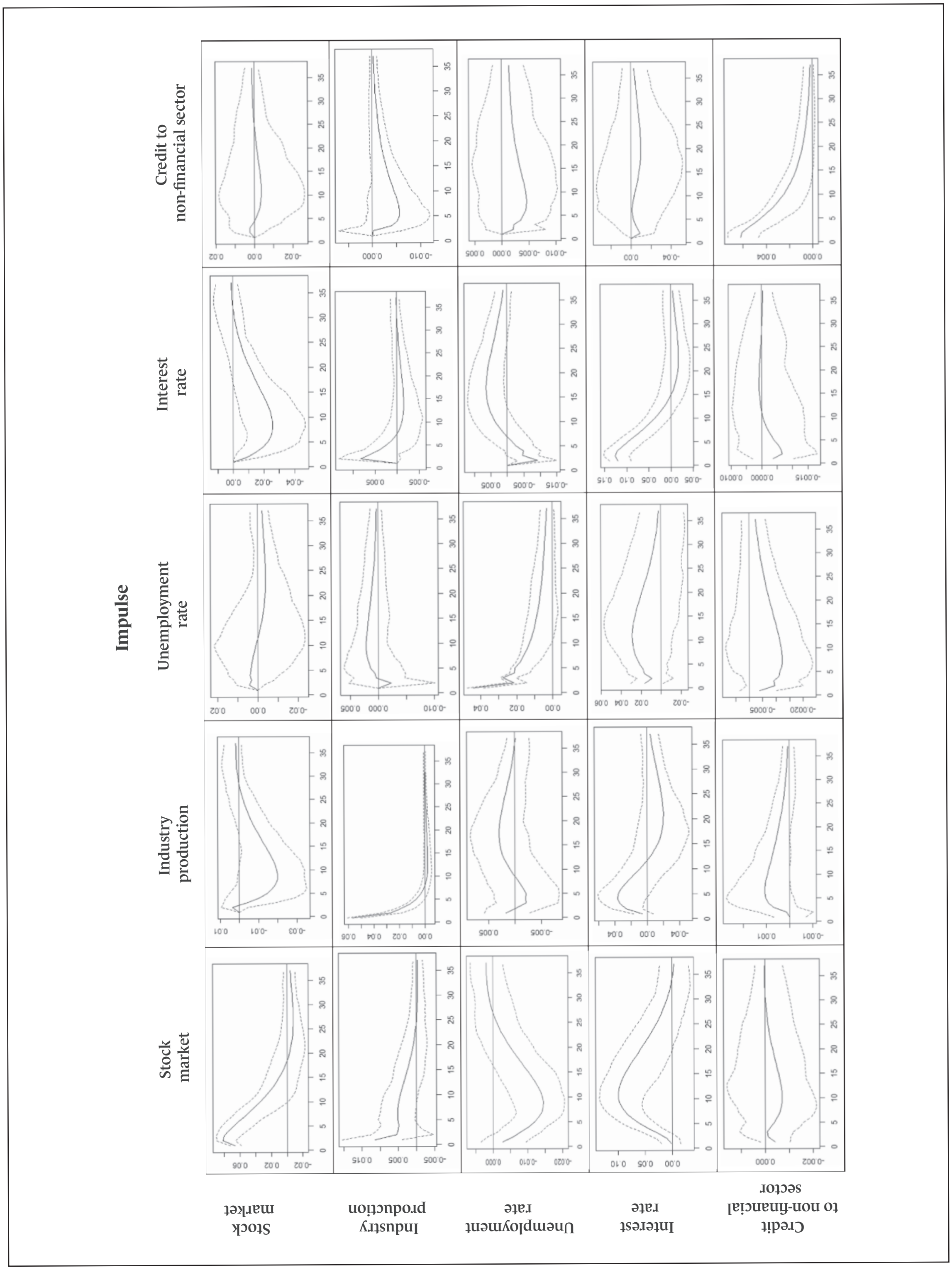

Figure 11

Impulse response function Germany VAR model M1 for the period between January 2000 and December 2008

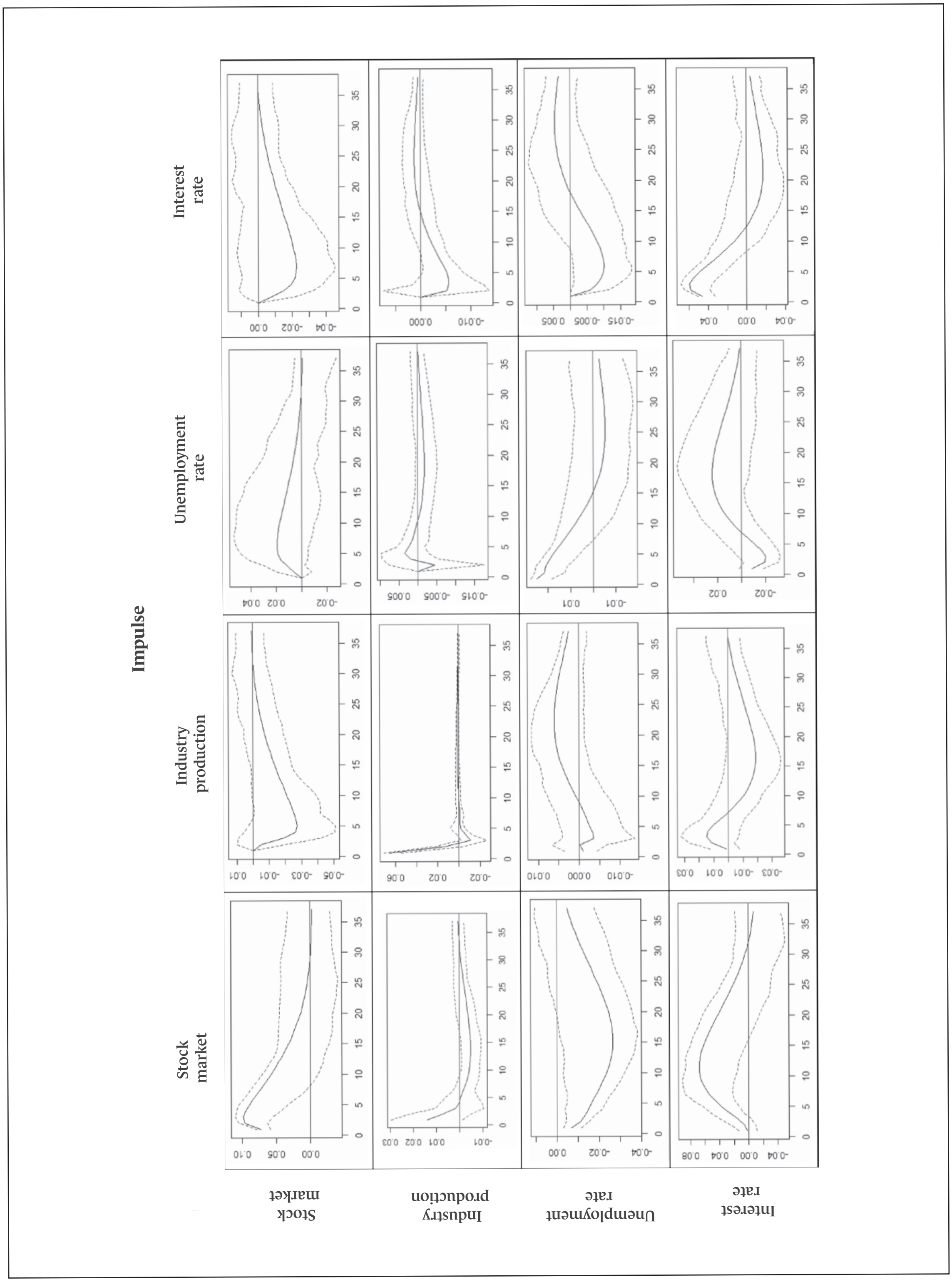

Figure 12

Impulse response function Germany VAR model M2 for the period between January 2000 and December 2008

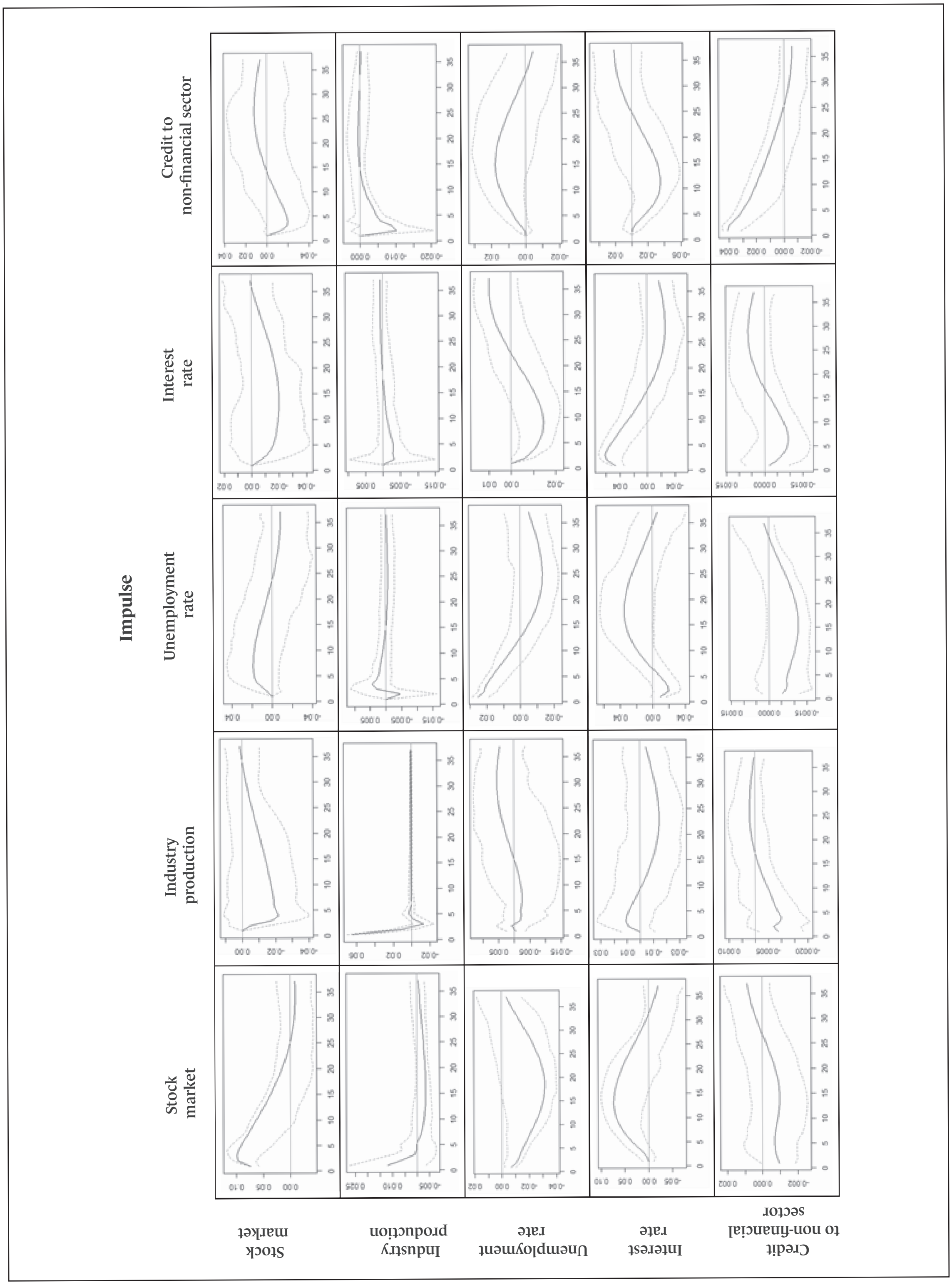

Figure 13
Impulse response function Germany VAR model M1 for the period between January 2009 and December 2019

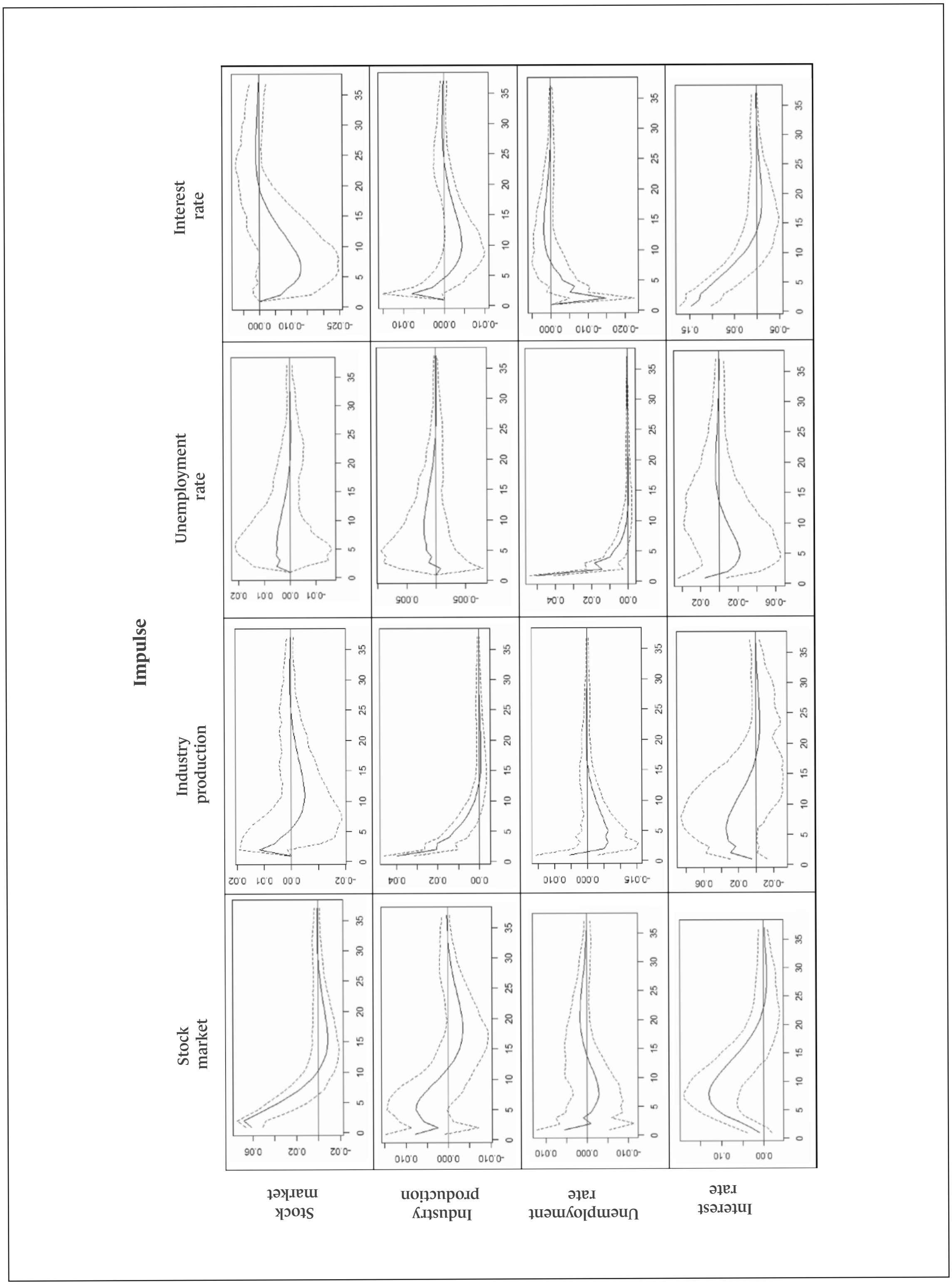

Figure 14

Impulse response function Germany VAR model M2 for the period between January 2009 and December 2019

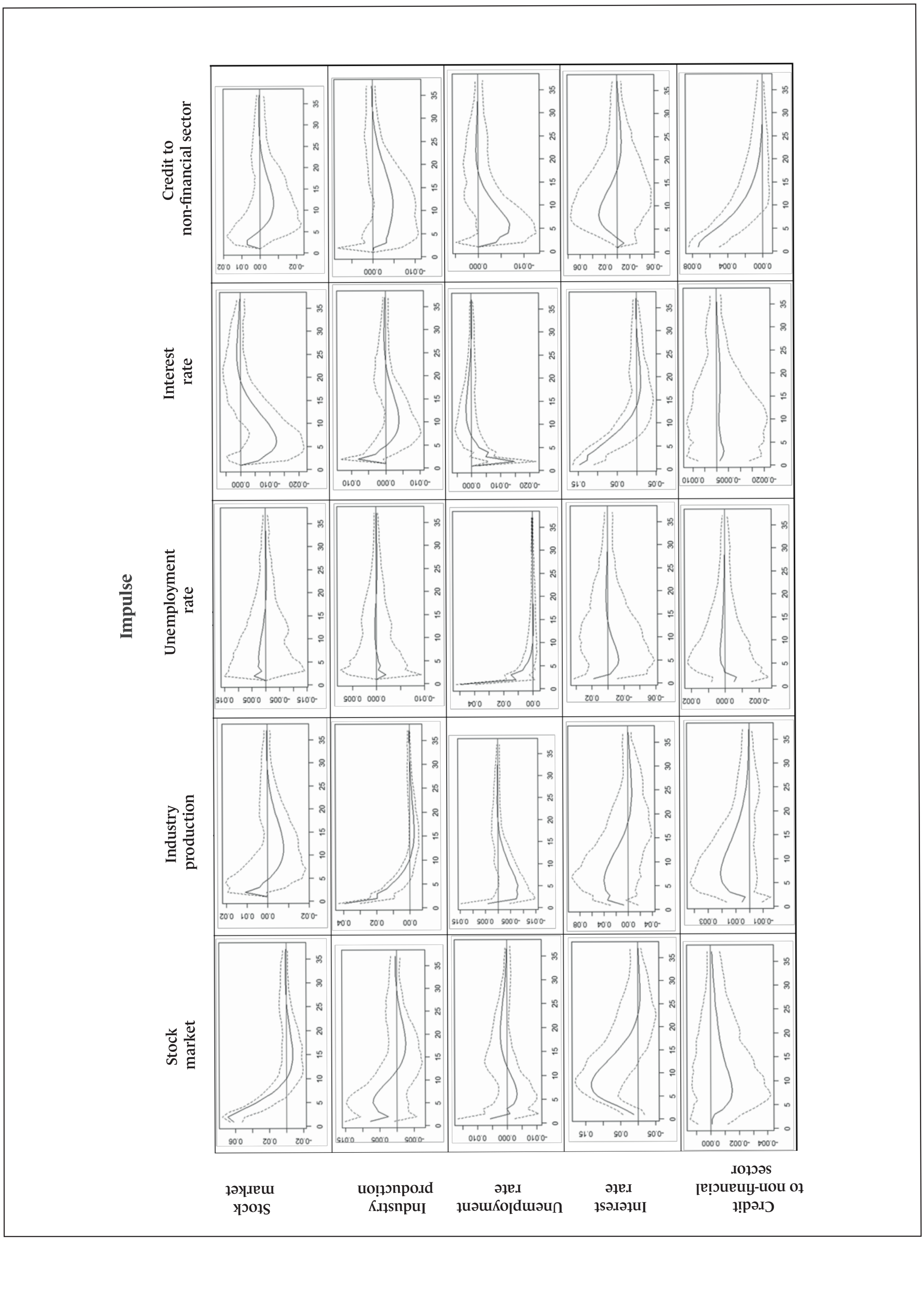

Figure 15

Impulse response function United Kingdom VAR model M1 for period between January 2000 and December 2019

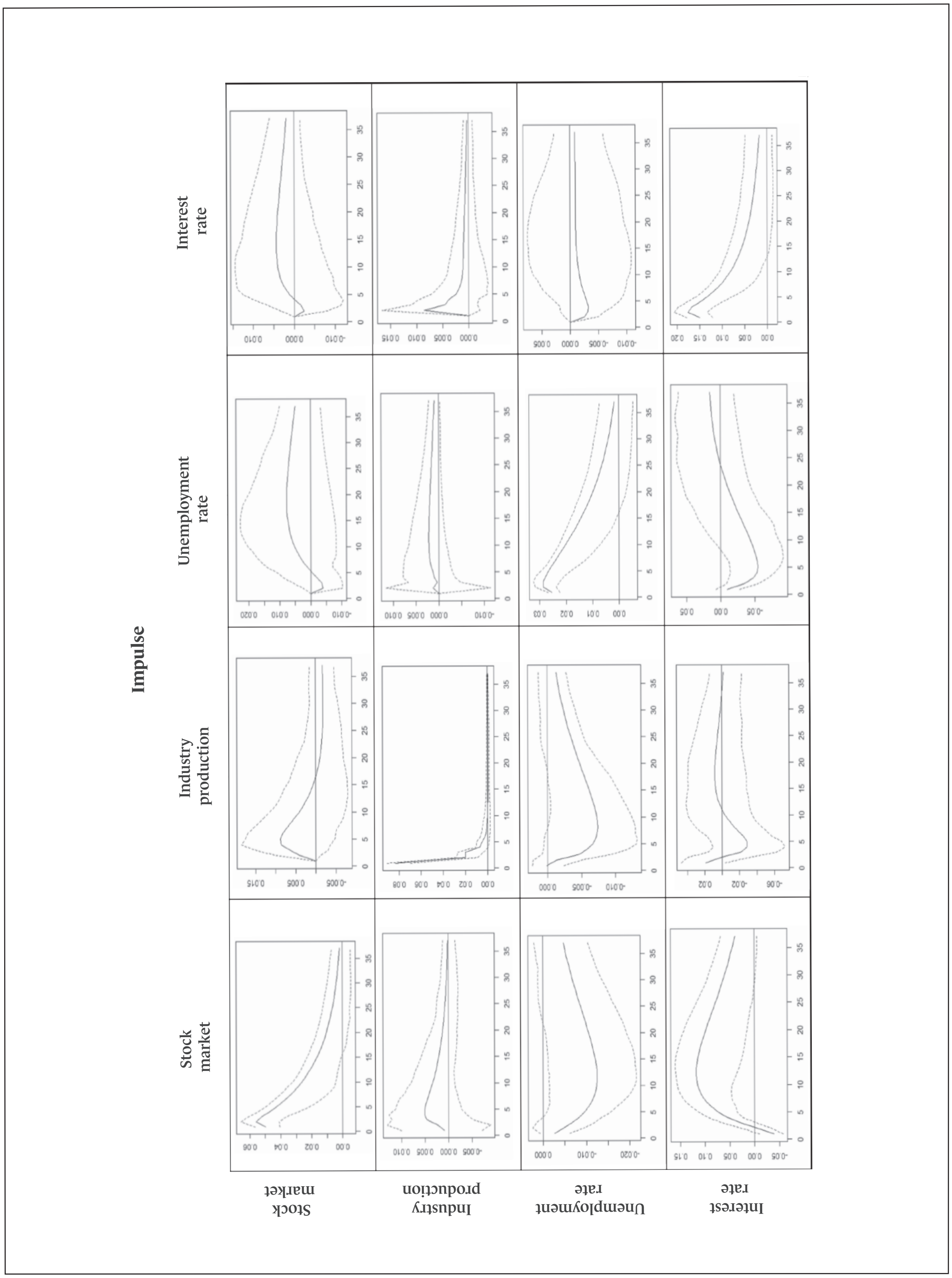

Figure 16

Impulse response function United Kingdom VAR model M2 for the period between January 2000 and December 2019

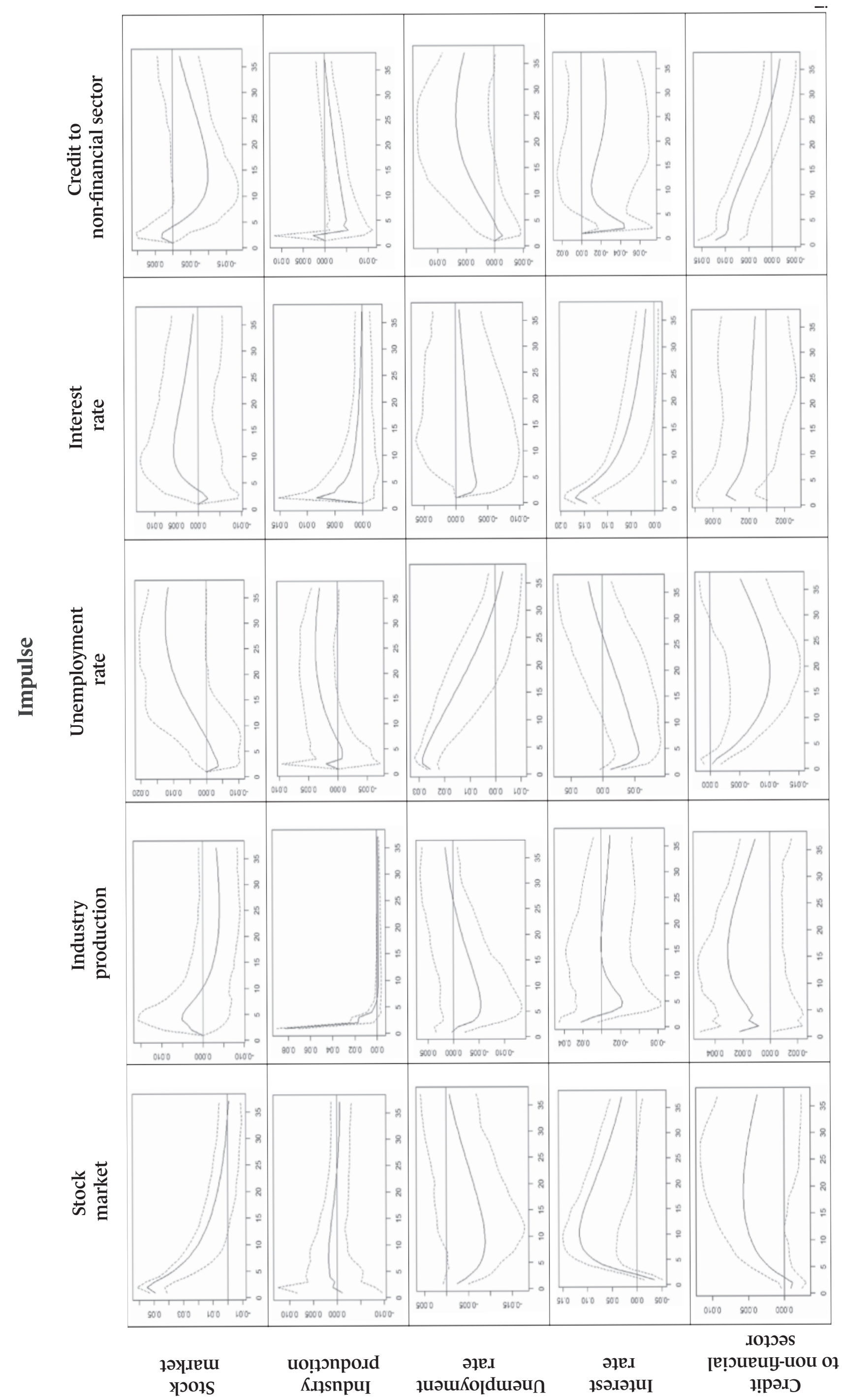

Figure 17

Impulse response function United Kingdom VAR model M1 for the period between January 2000 and December 2008

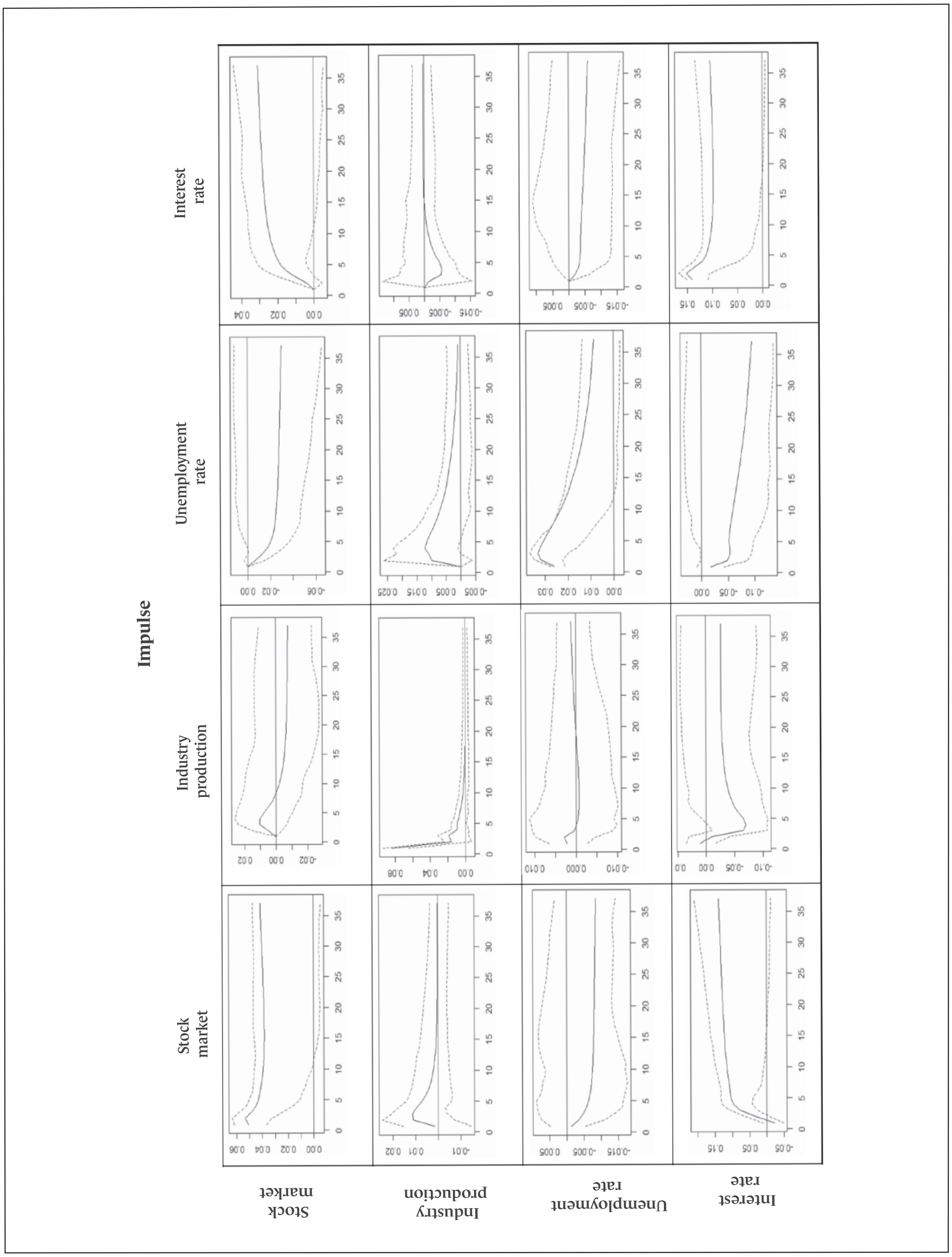

Figure 18

Impulse response function United Kingdom VAR model M2 for the period between January 2000 and December 2008

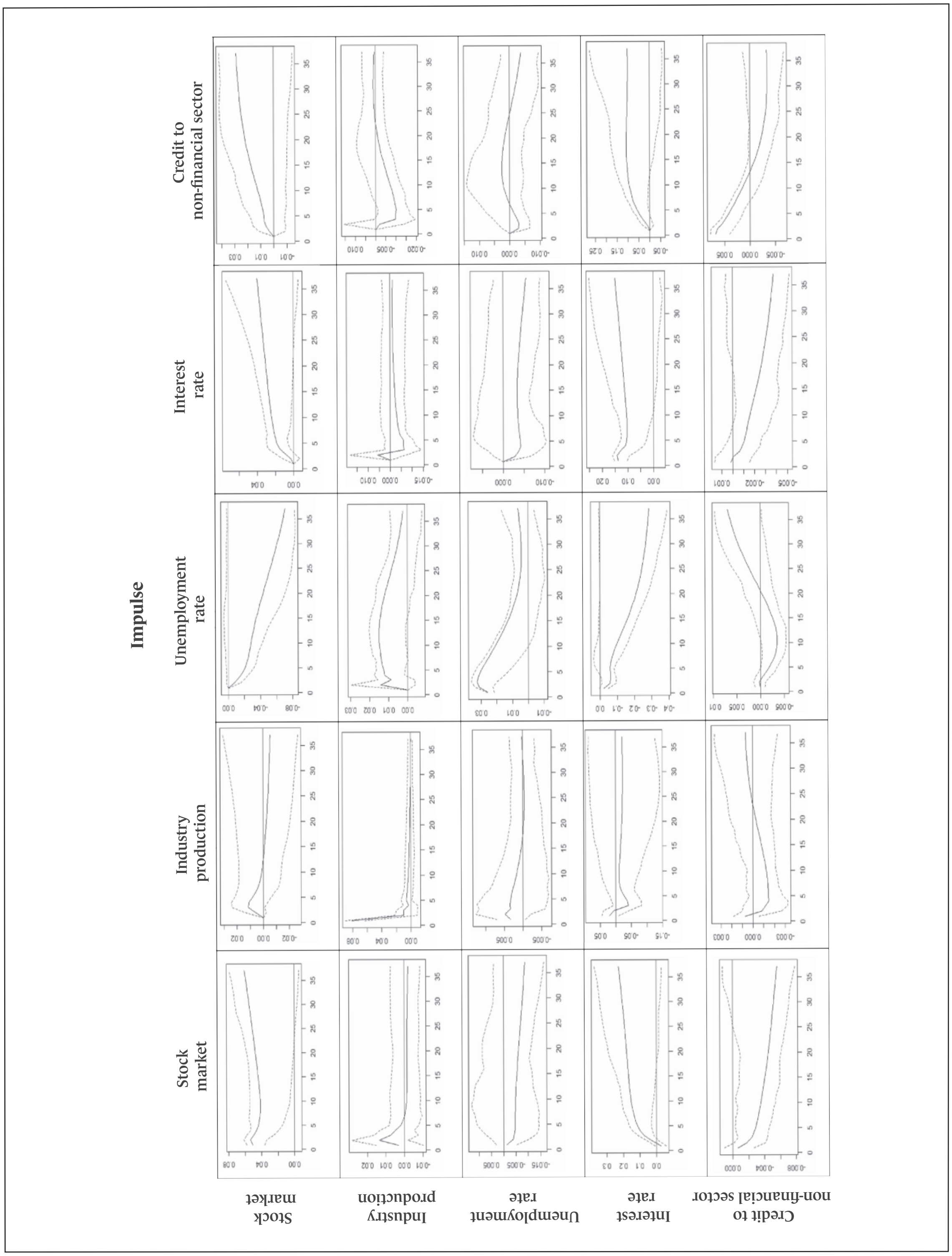

Figure 19

Impulse response function United Kingdom VAR model M1 for the period between January 2009 and December 2019

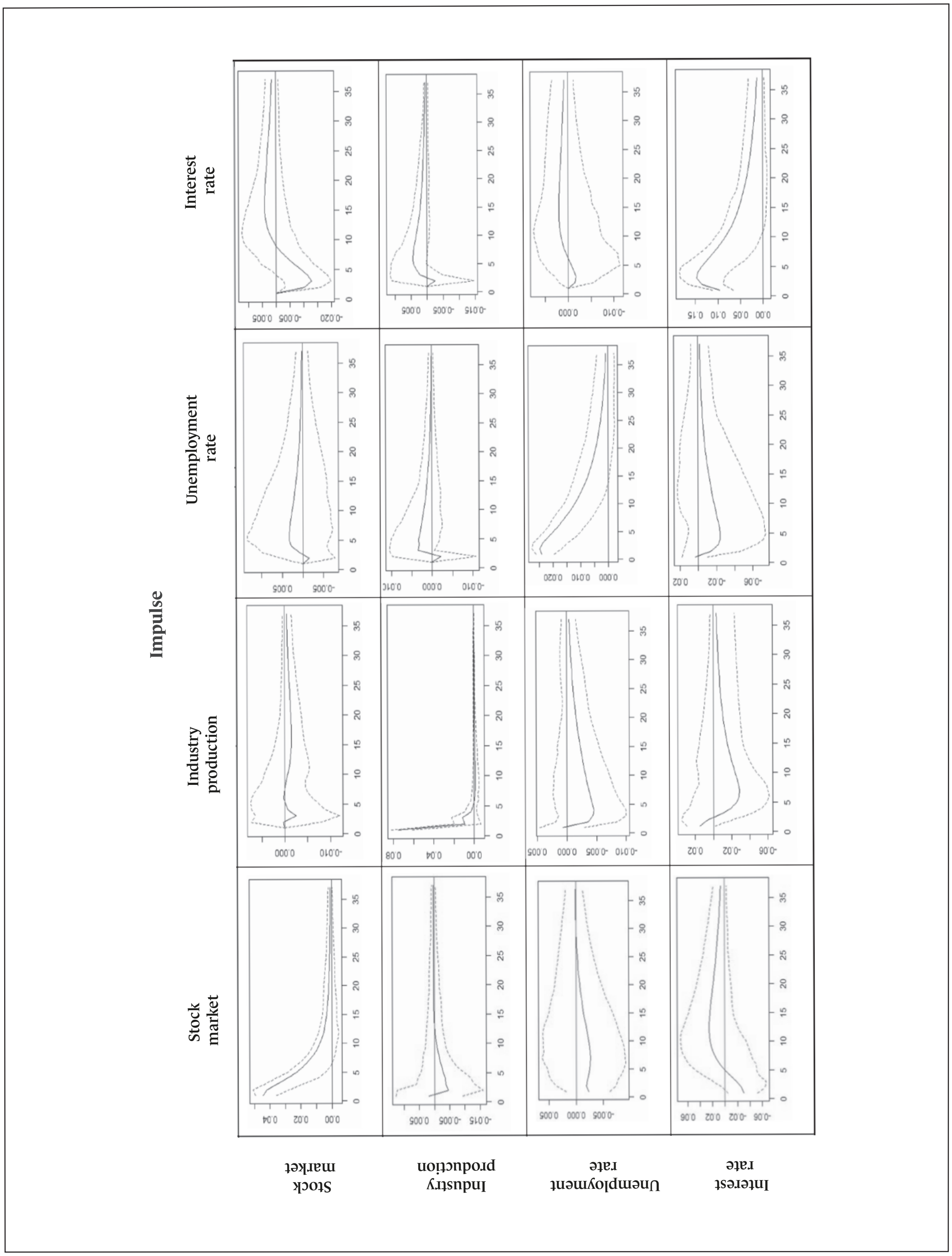

Figure 20
Impulse response function United Kingdom VAR model M2 for the period between January 2009 and December 2019