The Effects of Shocks on the Real Economy in Romania. A Bayesian FAVAR Approach

Andrei-Costin NEACȘU*
Bucharest University of Economic Studies, Bucharest, Romania
**Corresponding author, andrei.neacsu@fin.ase.ro*

Georgiana PLEȘA
Bucharest University of Economic Studies, Bucharest, Romania
georgiana.plesa@fin.ase.ro

George Alexandru NEACȘU
Bucharest University of Economic Studies, Bucharest, Romania
alexandru.neacsu94@yahoo.com

Abstract. *The last five years have marked the global economy with a series of shocks, such as the COVID-19 pandemic, the war in Ukraine, supply chain bottlenecks, the surge in inflation, and the energy crisis, whose magnitude and duration were challenging to predict. Moreover, the impact of those shocks significantly affected the accuracy of macroeconomic forecasts. Thus, assessing the effects of the shocks became extremely important and conditioned by the econometric models that can capture a large amount of information. This paper proposes a Bayesian Factor-Augmented Vector Autoregressive Model (FAVAR) to assess the effects of the most prominent shocks that recently hit the real Romanian economy. We use a high-dimensional data set of quarterly indicators from 2005Q1 to 2023Q3, covering the real sector, price indexes, sentiment indicators and financial variables. Our main results suggest that tightening monetary policy shock decreases both the real economic activity and prices, while a supply shock produces a delayed negative and persistent effect on real economic activity and on the majority of the indicators introduced in the model. The results of the uncertainty shocks are characterized by wider confidence intervals and the effects are estimated to have a lower magnitude.*

Keywords: monetary policy shock, vector autoregressive model, Bayesian estimation, supply shock.

Introduction

The recent adverse events that affected the global economy (e.g., pandemic crises, the war in Ukraine, supply chain bottlenecks, peaks in inflation and the energy crisis) have increased the interest of academic research and policymakers in assessing the effects of these shocks over the macroeconomic framework. This aspect is crucial for central banks to form their decisions, given the significant role of maintaining price stability and sustainable growth. Thus, policymakers need to know about the timing and the effects of changes in monetary policy instruments on inflation and economic activity to conduct the monetary policy process.

In the context of a multitude of shocks hitting the economy from both the demand and supply sides, dealing with uncertainty regarding the economic outlook and the state of the economy represents one of the main challenges for monetary policy. To address this issue, research should focus not only on the model specifications but also on the data set. On one hand, even if classical structural vector autoregressive models (VAR models) have been widely used to assess the impact of various economic shocks by impulse response functions, they sometimes lack empirical

DOI: 10.2478/picbe-2024-0033

evidence to support economic theory. These results are known in the literature on monetary policy transmission mechanism as "price puzzles", which, according to Kim and Rubinni (2000), represent an increase in prices after a monetary tightening shock or "overshooting puzzle" promoted by Eichenbaum and Evans (1995) being equivalent with a delayed effect in the exchange rate. Macroeconomic indicators have specific limitations in the assessment framework since most of them are measured quarterly and are available for less than two decades, especially in the case of most emerging markets. Therefore, to improve the accuracy of the estimates, one has to enlarge the information data set by adding additional variables. However, in a standard VAR framework, there is no rule to choose the exact number of indicators to include, and the problem cannot be easily solved.

We analyze the effects of recent dominant shocks on Romania's small open economy, such as monetary, domestic supply, energy prices, and uncertainty shocks. This state is an emerging economy from Central Eastern Europe, a European Union member, but not a eurozone one yet. In order to adopt the euro, the country has to meet a set of specific convergence criteria. The progress is conditioned by the impact of adverse economic events that hit the economy over the past five years, which have had direct implications on the trade flows and disruptions in global value chains, given the geographical proximity to the war zone in Ukraine. We adopt a Factor Augmented Vector Autoregressive Model (FAVAR) proposed by Bernanke et al. (2005), and we particularize it for the Romanian data from 2005Q1 to 2023Q3. We use a data set compounded by 37 quarterly variables grouped into three factors given by principal component analysis. The method allows estimating a model with an extensive data set into state space representation using Bayesian inference and extracting a group of unobserved factors that summarize the information in the data.

Romania, as well as other countries, suffered from a downturn in economic activity at the beginning of 2020 after the COVID-19 pandemic started. The unprecedented worsening in economic activity was mainly reflected by the negative contribution of domestic demand attributable to a contraction in final consumption and the one of net exports. At the same time, gross fixed capital formation recorded positive developments. After the rebound of economic activity in 2021, uncertainties and risks stemmed from the external environment, global supply chain bottlenecks, and a surge in energy prices and commodity prices on international markets. The war in Ukraine intensified all of these. Under these circumstances, inflationary pressures started to increase, and annual inflation followed an upward trajectory, reaching a peak only in November 2022. Subsequently, the global economy continued its recovery from the multiple adverse shocks, and the annual inflation started to decline while the central bank tightened monetary conditions. However, high uncertainties continue to be associated with the persistent effects of the war and the escalation of tensions in the Middle East, which add a possible worsening in bottlenecks in global production and distribution chains and persistent inflationary pressures associated with weather conditions. Therefore, analyzing the effects of shocks may be relevant for an overview of the economic conditions.

Our main results suggest that tightening monetary policy shock leads to a decrease in economic activity and prices, while a supply shock produces a delayed negative and persistent effect on real economic activity and on the majority of the indicators introduced in the model. Regarding the uncertainty shock, we observe the effects that are estimated to have a lower magnitude, but the results are characterized by wider confidence intervals.

The rest of the paper is organized as follows. The second section summarizes some of the research studies focused on these types of models and the assessment of the shocks. The third section briefly describes the model and the estimation algorithm. The fourth and fifth sections present the data and the main results, while the last section concludes.

Literature review

So far, several studies have examined the impact of monetary policy shocks on macroeconomic variables. Since the seminal work of Sims (1992), different variants of structural vector autoregressive models (SVAR) have been developed to assess the transmission mechanism and to outline the effects of monetary policy innovation on the real economy. However, the classical VAR model has some limitations, especially regarding the number of variables and lags used. Standard VARs seldom employ more than fourteen variables to conserve degrees of freedom. Thus, an econometrician often chooses a unique data series to measure a general economic concept such as "real economic activity" or "inflation".

In order to address this issue, Bernanke et al. (2005) propose a mix between the standard VAR and the factor analysis into a factor-augmented VAR (FAVAR) based on the estimation on principal components and a Bayesian method based on Gibbs sampling, enabling the use of a large number of variables from different economic sectors. The results provide some support that a "price puzzle" effect can be reduced if a researcher exploits a broad range of information in empirical modeling. Moreover, a large set of variables provides a more comprehensive outlook for the transmission mechanism of shocks. Besides that, this conclusion has become more critical in the last five years given that in times marked by uncertainty and data suffering from frequent revisions and it is difficult to correctly identify the effects of an adverse shock, restricting the analysis to a limited data set.

Mumtaz and Surico (2009) extend the model of Bernanke et al. (2005) to the open economy, using an international panel data set including 17 industrialized countries. The study assesses both the impact of an external unanticipated monetary shock and an external supply shock on the UK economy. The main results show little evidence regarding exchange rate and price puzzles. A few years later, from another point of view, Korobilis (2013) introduced a Factor-Augmented vector autoregressive model with time-varying coefficients and stochastic volatility on the US economy, investigating the impact of both endogenous and exogenous shocks on inflation volatility during the 1970s and early 1980s. These findings revealed that the proposed model produces impulse responses to inflation that significantly mitigate the price puzzle. In addition, the analysis demonstrates notable changes in the transmission of unanticipated monetary policy shocks, particularly concerning GDP, investment, exchange rates, and money.

Among other studies that focused on mitigation economic puzzles is Forni and Gambetti (2010), where the authors employed a structural factor model encompassing 112 US monthly macroeconomic series to examine the effects of monetary policy. To identify the monetary policy shocks are identified using a standard recursive scheme, revealing zero impact effects on both industrial production and prices. Key findings include the observation of maximal effects on bilateral real exchange rates immediately post-shock, thereby resolving the 'delayed overshooting' puzzle. Moreover, following a contractionary shock, prices decline across all time horizons, eliminating the associated price puzzle.

A comparative perspective between two different econometric methods, namely a relatively unrestricted Factor-Augmented vector autoregressive and a Dynamic Stochastic General Equilibrium (DSGE) model one can find in Boivin et al. (2010). In this study, the authors discuss the impact of the changing regulatory landscape on credit provision and subsequently they review empirical evidence concerning the evolving effects of monetary policy actions on real economic

DOI: 10.2478/picbe-2024-0033, pp. 378-390, ISSN 2558-9652 |
Proceedings of the 18th International Conference on Business Excellence 2024

activity and inflation. Findings offer similar results from both econometric perspectives: monetary policy innovations have had a less pronounced impact on real activity and inflation in recent decades compared to before 1980. The analysis attributes these shifts to changes in policy behavior and their influence on expectations, with little contribution from underlying shifts in private-sector behavior unrelated to changes in monetary policy.

Not only the impact of monetary policy on GDP and overall inflation was studied, but also the impact on real house price growth, which since the Global Financial Crisis this subject has become of great interest to researchers. Thus, Gupta et al. (2010) brought evidence related to the impact of monetary policy on the housing market and found that the latter responds, in general, negatively to a tight monetary shock. They also stood out by finding heterogeneity over the housing market as ‘the luxury,’ ‘large-middle,’ and ‘medium-middle’ segments responded much more than the ‘small-middle’ and the affordable housing market segments. Moreover, a large information data set can mitigate a less known puzzle, namely the "home price puzzle".

The transmission mechanism of monetary policy in the new member states of the European Union is developed in the literature, among others, by Creel and Levasseur (2005) and Balabanova and Brüggemann (2017). Their results from different approaches to the VAR model, including FAVAR extension, exhibit the "exchange rate puzzle" and demonstrate the importance of external economic developments for analyzing monetary policy.

In the context of the past few years' adverse events that hardly hit the global economy, it is essential to focus on various types of shocks beyond just monetary policy, especially demand and supply shocks. The latter, in particular, is pertinent in light of recent events stemming from the COVID-19 pandemic, which has led to significant disruptions to the global supply chains. Thus, Finck and Tillmann (2023) estimated the impact of supply chain shocks on international container trade. They applied constraints on the sign of certain responses of shocks during specific episodes, focusing on supply chain disruptions. Some findings suggest that supply chain shocks result in a notable surge in consumer prices and a decline in real economic activity within the euro area.

However, to the best of our knowledge, the previous research concentrated on FAVAR analysis in the context of the post-pandemic period has not yet been largely developed. Yang et al. (2023) extend a time-varying FAVAR, highlighting that monetary policies from developed countries produce spillover effects on emerging financial markets, particularly China. Klieber (2024) proposes a method to control for non-linearities between large panel data sets and latent factors able to deal with outliers from the COVID-19 pandemic.

Methodology

The method used in this paper relies on Bernanke et al. (2005), and the state space representation can be written as follows

$$X_{i,t} = b_i F_t + \gamma_i S_t + v_{i,t}, \quad VAR\left(v_{i,t}\right) = R \tag{1}$$

$$Z_t = c_t + \sum_{j=1}^{P} B_j Z_{t-j} + e_t, \ \ VAR(e_t) = Q$$

$$Z_t = \{F, S_t\}$$

Where $X_{i,t}$ denotes the $T\ x\ M$ matrix of variables (e.g. macroeconomic, financial variables or survey data), the F_t represents the vector of unobserved factors that summarize the information from the data. The S_t element is the variable of interest of which shock we want to study (interest rate for monetary policy shock, inflation for supply shock or supply bottlenecks indicator for supply bottlenecks shock) when we calculate impulse response functions for each element of $X_{i,t}$.

For the current analysis, we assume a vector autoregressive structure with two lags and three unobserved components $F_t = \{F_{1t}, F_{2t}, F_{3t}\}$. Therefore, the representation of observation equation from (1) can be rewritten as follows

$$\begin{aligned}&(X_{1t}\ X_{2t}\ \ X_{3t}\ \ \dots\ \dots\ \dots\ X_{Mt}\ S_t\ ) \\ &= (b_{11}\ b_{12}\ b_{13}\ \gamma_1\ 0\ 0\ 0\ 0\ b_{21}\ b_{22}\ b_{23}\ \gamma_2\ 0\ 0\ 0\ 0\ b_{31}\ b_{32}\ b_{33}\ \gamma_3\ 0\ 0\ 0\ 0\ \dots\ \dots\ \dots\ \dots\ 0\ 0\ 0\ 0\ \dots \\ &+ (v_{1t}\ v_{2t}\ v_{3t}\ \ \dots\ \dots\ \dots\ v_{Mt}\ 0\ )\end{aligned} \tag{2}$$

Where $X_{i,t}$ is related to the three factors via the factor loading $b_{i,j}$ for $i = 1, \dots M$ and $j =$ 1,2,3 and to the variable of interest for shock S_t via the coefficient γ_i. Bernanke et al. (2005) assume that γ_i are zon-zero only for financial variables (fast moving variables). The transition equation is

$$\begin{aligned}&(F_{1t}\ F_{2t}\ F_{3t}\ S_t\ F_{1t-1}\ F_{2t-1}\ F_{3t-1}\ S_{t-1}\ ) \\ &=\ (c_1\ c_2\ c_3\ c_4\ 0\ 0\ 0\ 0\ ) \\ &+\ (A_{11}\ A_{12}\ A_{13}\ A_{14}\ A_{15}\ A_{16}\ A_{17}\ A_{18}\ A_{21}\ A_{22}\ A_{23}\ A_{24}\ A_{25}\ A_{26}\ A_{27}\ A_{28}\ A_{31}\ A_{32}\ A_{33}\ A_{34}\ A_{35}\ A_{36} \\ &+\ (e_{1t}\ e_{2t}\ e_{3t}\ e_{4t}\ 0\ 0\ 0\ 0\ )\end{aligned} \tag{4}$$

We summarize below a few estimation steps for the Gibbs sampling algorithm. For a more detailed version, see Bernanke et al. (2005), and Blake and Mumtaz (2017). First, we set priors and starting values. We estimate an initial value of factors F_{1t}, F_{2t} and F_{3t} by using principal components analysis. The priors for factor loadings is normal. We note $H_i = \{b_{ij}, \gamma_i\}$ and we assume that $p(H_i) \sim N(H_{0,}, \Sigma_{H_0})$. The VAR coefficients from the matrix B (from equation (1)) are also Normal $p(B) \sim N(B_{0,}, \Sigma_B)$..The variance-covariance matrix R is diagonal with elements defined by an inverse Gamma prior $p(R_{ii}) \sim IG(R_{0,}, V_{R_0})$, while the variance covariance matrix Q have non-zero elements for the four transition equations ant these elements can be described by an Inverse Wishart prior $p(\Omega) \sim IW(\Omega_{0,}, V_0)$.

Second, conditional by F_t and R_{ii} we sample the factor loadings from their conditional distributions. The posterior for the VAR coefficients B are Normal given by $H(H_i|F_t, R_{ii}) \sim N(H_i^*, V_i^*)$, where

$$H_i^* = \left(\Sigma_{H_i}^{-1} + \frac{1}{R_{ii}} Z_t{}' Z_t\right)^{-1} \left(\Sigma_{H_i}^{-1} H_0 + \frac{1}{R_{ii}} Z_t{}' X_{it}\right) \tag{5}$$

$$V_i^* = \left(\Sigma_{H_i}^{-1} + \frac{1}{R_{ii}} Z_t{}' Z_t\right)^{-1}$$

Third, conditional on the factors F_t and the factor loadings H_i we sample the variance of the error terms from the observation equation R_{ii} from the inverse Gamma distribution with scale parameter $(X_{it} - Z_t H_i)'(X_{it} - Z_t H_i) + R_0$ and degrees of freedom $T + V_0$ where T is the length of the sample.

Fourth, conditional on the F_t and Ω, the posterior for the VAR coefficients are Normal distributed, $H(B|F_t, \Omega) \sim N(B^*, D^*)$

$$B^* = \left(\Sigma_B^{-1} + \Omega^{-1} \otimes \underline{X}_t' \, \underline{X}_t\right)^{-1} \left(\Sigma_B^{-1} vec\,(B_0) + \Omega^{-1} \otimes \underline{X}_t' \, \underline{X}_t vec\,(\hat{B})\right) \tag{6}$$

$$D^* = \left(\Sigma_B^{-1} + \Omega^{-1} \otimes \underline{X}_t' \, \underline{X}_t\right)^{-1}$$

Where $\underline{X}_t = \{F_{t-1}, S_{t-1}, F_{t-2}, S_{t-2}, 1\}$ and $\hat{B}$ is the OLS estimator for B.

Fifth, conditional on F_t and the VAR coefficients B we sample the error covariance Ω with the Inverse Wishart posterior form with scale parameter $\left(Y_t - \underline{X}_t B\right)' \left(Y_t - \underline{X}_t B\right) + \Omega_0$ and $T + V_0$ degrees of freedom.

Last, given H_i, R, B and Ω, the factors F_t are sampled with Carter and Kohn algorithm.

Results and discussions

The data set introduced to estimate the FAVAR model gathers 37 quarterly macroeconomic, economic sentiment, and financial indicators over 2005Q1 – 2023Q3, given that the inflation targeting regime was introduced in Romania in mid-2005. For a detailed overview of the evolution of these time series and sources, see Table 1 and Appendix. We represent the variables in standardized form, as they are included in the model. The data set include besides the GDP and its component other indicators representative for real economic activity (such as industrial production and retail trade), measures of inflation, economic sentiment indicators, index for commodities, price of oil and financial time series such as volatility implied index (VIX), Bucharest Exchange Trade index or exchange rate of euro to national currency.

The analyzed period covers two critical economic episodes: the global financial crisis and the COVID-19 pandemic. Apart from the significant effects of those crises on economic activity and financial markets, their specific characteristics have affected the accuracy of forecasts. After the financial international crisis, most indicators recovered and followed an upward trajectory with no major events until the pandemic outbreak at the beginning of 2020. At that moment, the Romanian economy experienced a significant decrease in economic activity due to social distancing policies but rebounded shortly after. However, the subsequent shocks (inflation, supply bottlenecks, energy crisis) continue to produce adverse and persistent effects.

To assess the effects of shocks, we consider the 3-month interest rate ROBOR for monetary policy shock, inflation as a percentage change of the Consumer Price Index to represent the supply shock, the inflation of energy prices that is a subcomponent of the Harmonized Index of Consumer Prices. For the uncertainty shock, we include the World Uncertainty Policy index developed by Ahir et al. (2018) that measures the frequency of "uncertainty" in the quarterly Intelligence Unit (EUI) reports. To estimate the model with a large data set, we assume that three unobserved factors summarize the economy's evolution under the factor model analysis. After estimating the model, we imply an impulse response analysis and represent in Figure 2 to Figure 5 the above-mentioned shocks' effect on real economic activity. For ease of illustration, we will represent only some of the indicators we included in the model, considering their importance in driving economic activity.

Table 1. Data set included in the FAVAR

Indicator	*Source*
Gross Domestic Product	National Institute of Statistics
Consumption	National Institute of Statistics
Capital	National Institute of Statistics
Exports	National Institute of Statistics
Imports	National Institute of Statistics
Industrial production	National Institute of Statistics
Industrial production of durable goods	National Institute of Statistics
Industrial production in energy	National Institute of Statistics
Industrial production of intermediate goods	National Institute of Statistics
Industrial production of nondurable goods	National Institute of Statistics
Industrial production euro area	National Institute of Statistics
Retail trade (excluding auto-moto)	National Institute of Statistics
Retail trade (services)	National Institute of Statistics
Retail trade (auto)	National Institute of Statistics
Retail trade (fuels)	National Institute of Statistics
Construction output	National Institute of Statistics
Inflation (Consumer Price Index)	National Institute of Statistics
Inflation (CORE)	National Institute of Statistics
Inflation (Harmonized Index of Consumer Price)	Eurostat
Inflation (energy prices)	Eurostat
Economic Sentiment Indicator (Romania)	European Commission
Economic Sentiment Indicator (euro area)	European Commission
Monetary aggregate	National Bank of Romania
Real wages	National Institute of Statistics
Unemployment	National Institute of Statistics
Oil Brent	Energy Information Administration
Commodity price index	Bloomberg
Baltic Dry Index	Bloomberg
Energy consumption	Transelectrica Romania
Sentix indicator	Bloomberg
Eurostoxx 600 indicator	Bloomberg
Bucharest Exchange Trade index	Bucharest Stock Exchange
Volatility Implied index	Bloomberg
Option Adjusted spread	Reuters
3-month interest rate Euribor	European Central Bank
3-month interest rate Robor	National Bank of Romania
World Uncertainty Indicator for Romania	Federal Reserve Bank

Source: Authors' own research.

Figure 2 illustrates the response functions to a monetary policy shock, equivalent to an increase by approximately 0.2 percentage points in the 3-month interest rate ROBOR. According to economic theory, a contractionary monetary policy shock negatively affects real economic activity and inflation. Thus, we see a decrease in the GDP of about -0.1 percentage points, reflecting the adverse effects in all GDP components. Moreover, industrial production and retail trade are also expected to decrease. At the same time the increase of the interest rate deteriorates the business expectations regarding the evolution of the activity, indicated by the drop in the Economic Sentiment indicator (ESI) for Romania. The negative effects on inflation are lagged due to the price stickiness and reach a maximum level in the medium term, after almost ten periods. In terms of labour indicators, a tight monetary policy causes a surge in unemployment rate, through the cost channel, and a drop in real wages owing to a larger supply on the labour market. Financial indicators react immediately after the shock, and the return is expected to happen faster than the real activity indicators.

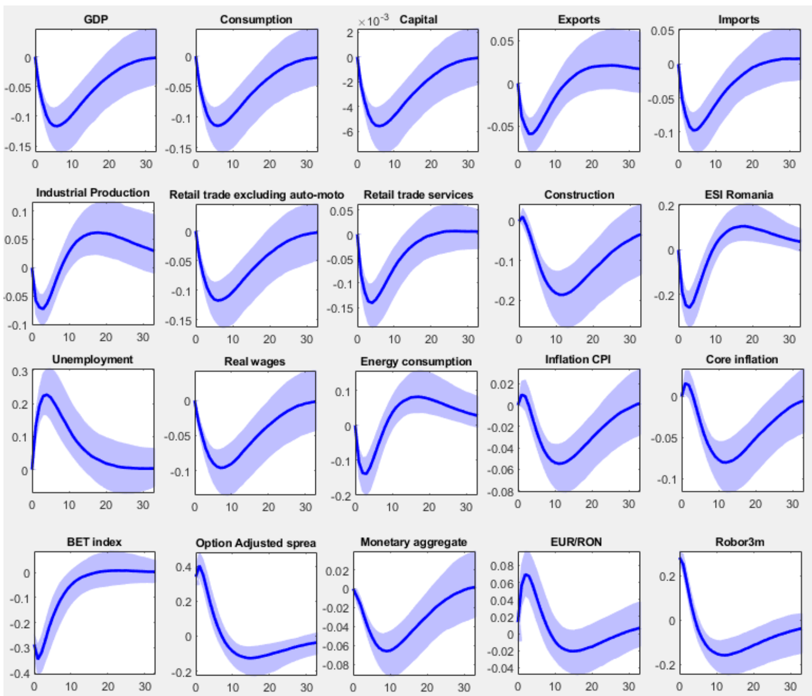

Figure 2. The effects of a monetary policy shock

Source: Authors' own calculations.

The effects from the supply side, an increase in consumer prices and an increase in the energy prices, are represented in Figure 3 and Figure 4. The pattern of the results is relatively similar for both shocks. The increase in prices is estimated to persist over the medium and long term. Therefore, the negative effect of a surge in inflation has a delayed effect on economic activity estimated through the model at -0.04 percentage points on GDP. However, we observe delayed effects on the majority of the indicators. Energy consumption decreases after almost 10 periods, probably due to the indirect transmission mechanism operating through costs. On the financial side, the country's risk premium increases, reaching a maximum effect after 10 periods and then starts gradually to decrease. It is worth mentioning that in the contemporary global landscape, where geopolitical tensions are escalating and conflicts such as the war in Ukraine persist, the imperative of monitoring energy price shocks has never been more pronounced.

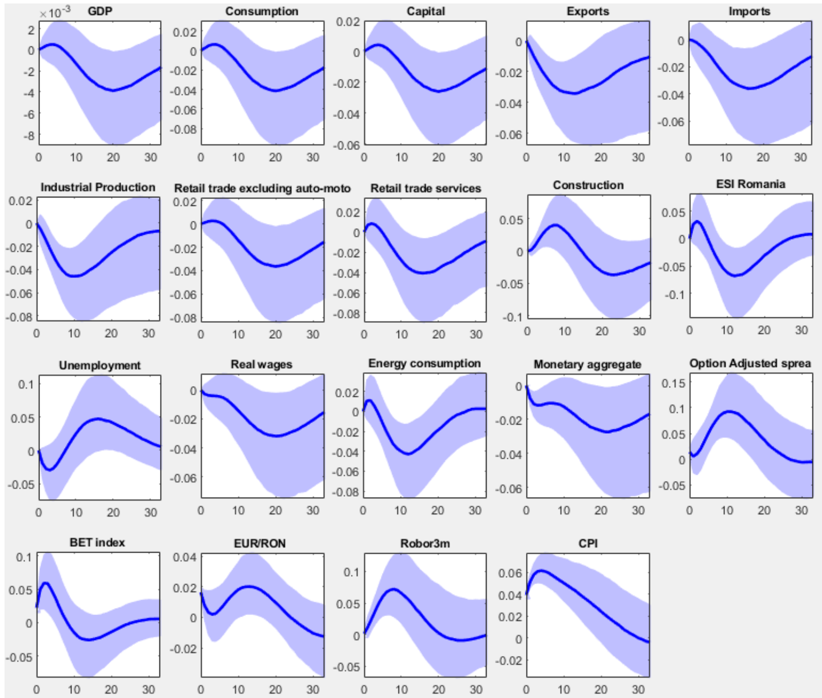

Figure 3. The effects of a supply shock

Source: Authors' own calculations.

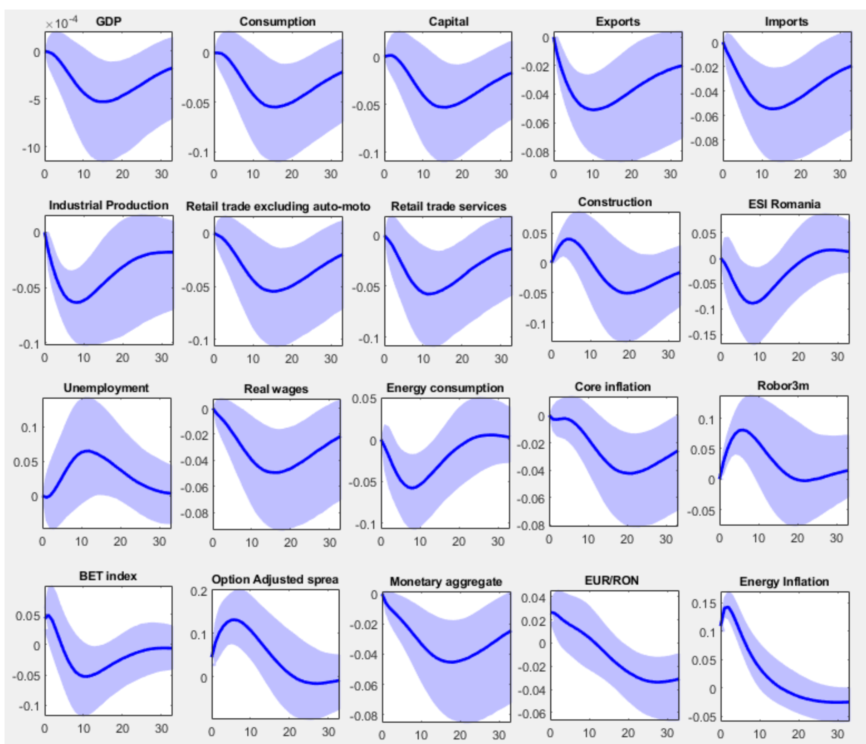

Figure 4. The effects of a supply price energy shock

Source: Authors' own calculations.

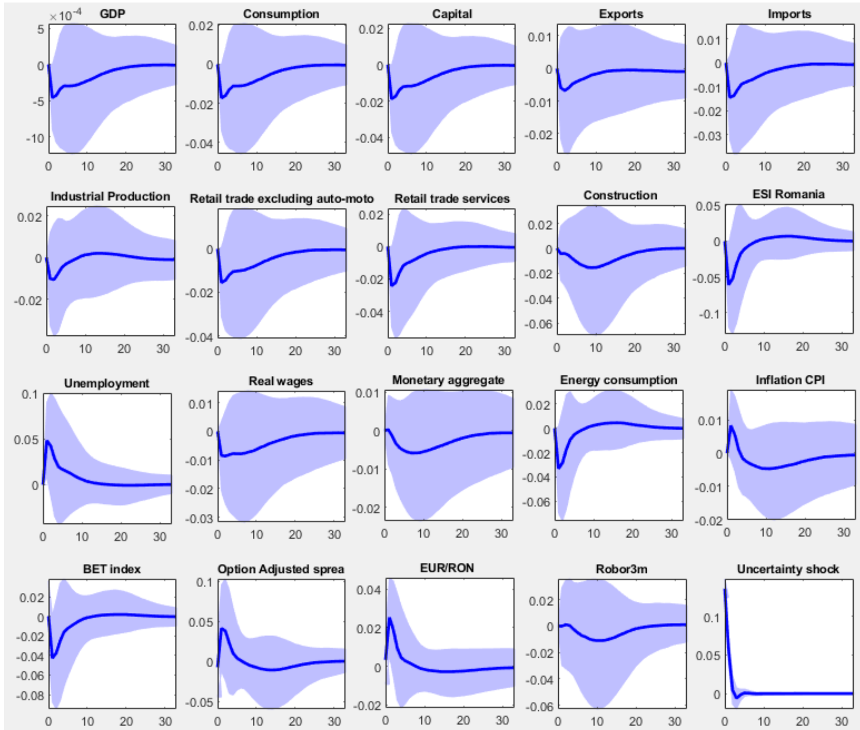

Figure 5. The effects of an uncertainty shock

Source: Authors' own calculations.

Finally, we conducted a scenario studying the impact of an uncertainty shock on macroeconomic variables. When the shock occurs, it quickly dissipates on most of the variables, and one can remark that its effect does not last as in the case of other shocks. As expected, the economic activity slows down, the labour market faces some turbulence and financial indicators are pricing in the instability from the market. However, the confidence intervals are wider than in other cases and the effects of the shock are not statistically significant in some figures.

Conclusion

In this paper, we adopt a Factor Augmented Vector Autoregressive Regression model having three common factors of influence and we study the impact of four shocks that have recently gained relevance in the economic activity: monetary policy shock, supply shock, energy prices shock and an uncertainty shock. We particularize the analysis on a representative small open economy, namely Romania. The main findings are consistent with economic theory, as a tight monetary policy leads to a decline in economic activity, a break in price dynamics, and a drop in both the stock market and economic sentiment. In addition, a surge in the price indexes coming from the supply side has an adverse effect on economic growth. These shocks have been analyzed separately but the recent events, from the outbreak of the war in Ukraine onwards, have influenced the economy simultaneously. As an extension of this study, we would like to analyze concomitantly, within a different model, the impact of the aggregate shock on these macroeconomic variables. However, there are some limitations related to the data sample as the time framework is limited compared to major states.

DOI: 10.2478/picbe-2024-0033, pp. 378-390, ISSN 2558-9652 |
Proceedings of the 18th International Conference on Business Excellence 2024

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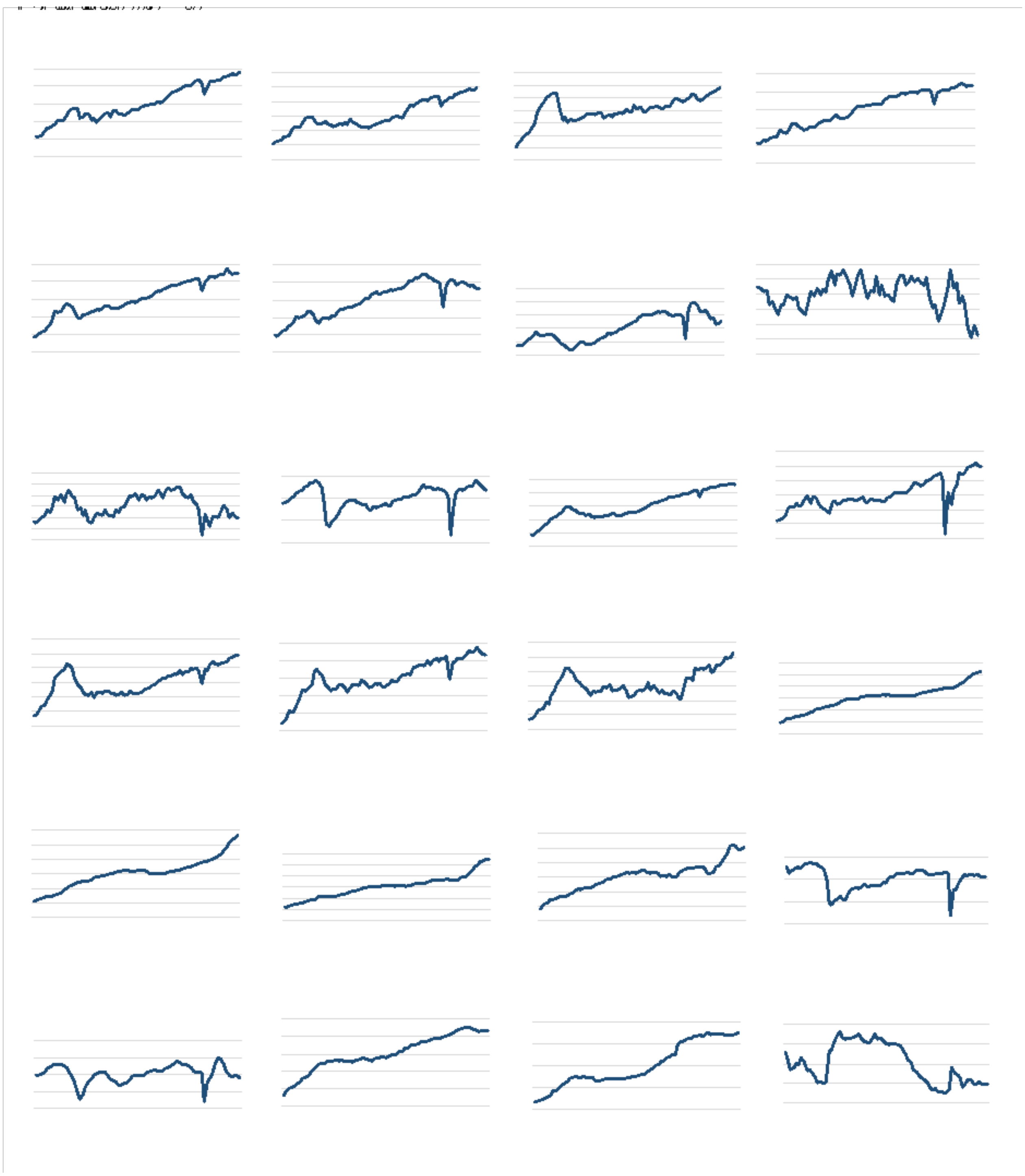
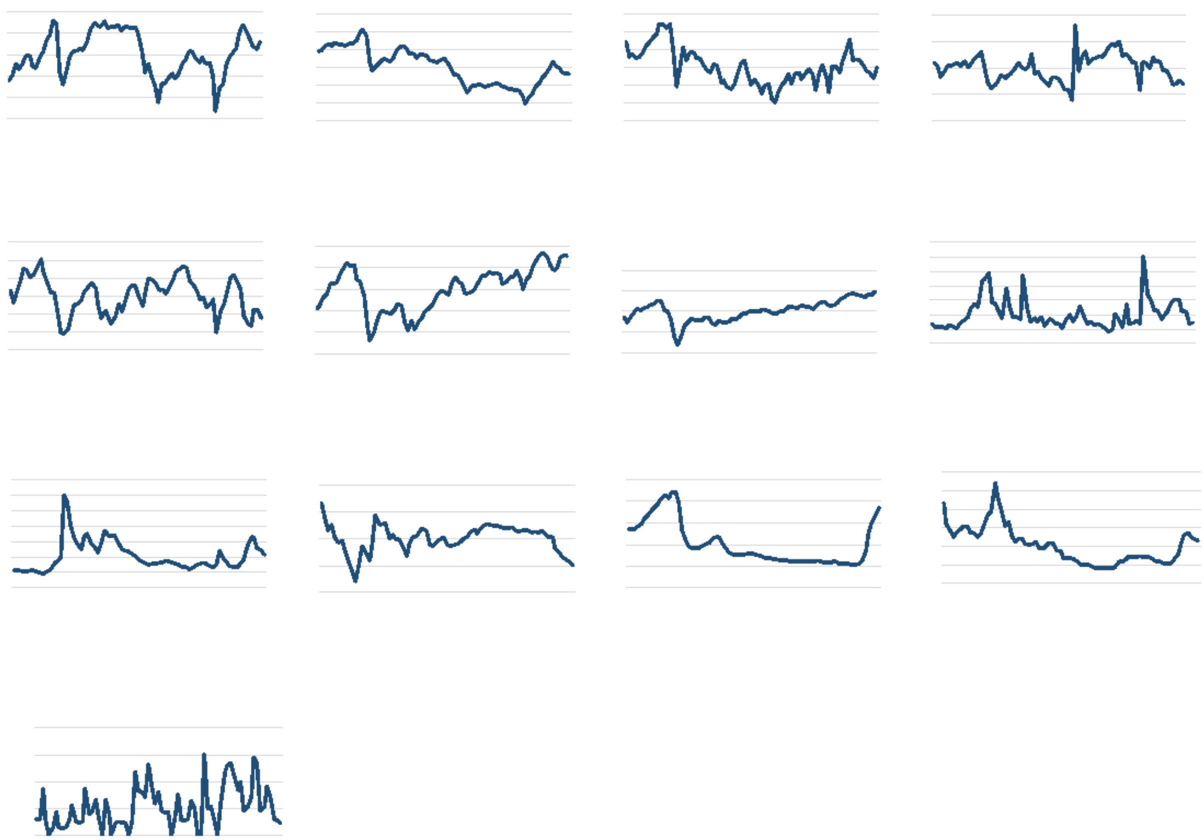
Appendix





Source: Authors’ own calculations.