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Анализ взаимосвязи между макроэкономическими показателями России и финансовыми рынками на основе модели VAR

Ян Цзяхэн, Ван Хао, Гусейнов Ш.Р.

В статье раскрываются вопросы построения и использования количественных моделей, объясняющих корреляцию различных экономических переменных. Цель: проведение анализа взаимосвязи между макроэкономическими показателями России и состоянием ее финансового рынка на основе модели VAR. Задачи: 1) описание спецификации авторегрессии VAR, адаптированной под анализ нескольких детерминант; 2) построение модели взаимосвязи ВВП России с показателями финансового рынка страны. Гипотеза: применение адаптированной VAR-модели с учетом байесовской оценки параметров позволяет рассмотреть в динамике одновременно нескольких детерминант, а также оценить их взаимодействие и спрогнозировать будущие значения. Методы: систематизация, регрессионное моделирование, синтез, обобщение, прогнозирование, сравнение. Результаты: в процессе исследования с помощью модели VAR проанализирована взаимосвязь между экономическим ростом и состоянием финансового рынка России, а именно банков и небанковских финансовых посредников. В качестве результативной переменной рассматривался ВВП, из числа объясняющих и влияющих факторов выбраны: процентные ставки в годовом исчислении по новым кредитам, квартальный прирост чистых активов коммерческих банков и квартальный прирост активов небанковских финансовых посредников. Установлено, что изменение объемов активов финансовых посредников имеет более тесную взаимосвязь с темпами прироста реального ВВП.

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КЛЮЧЕВЫЕ СЛОВА

ВВП, авторегрессия, активы, банк, ставка, кредит.

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Analysis of correlation between Russia's macroeconomic indicators and financial markets based on the VAR model

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The article reveals the issues of construction and use of quantitative models that explain the correlation of various economic variables. Objective: to analyze the correlation between Russia's macroeconomic indicators and the state of its financial market based on the VAR model. Objectives: 1) description of the VAR autoregressive specification adapted to the analysis of several determinants; 2) construction of a model of correlation between Russia's GDP and the country's financial market indicators. Hypothesis: the use of an adapted VAR model with account to the Bayesian estimation of parameters allows us to consider several determinants in dynamics simultaneously, as well as to evaluate their interaction and predict future values. Methods: systematization, regression modeling, synthesis, generalization, forecasting, comparison. Results: In the course of the study, using the VAR model, the correlation between economic growth and the state of the Russian financial market, namely banks and non-bank financial intermediaries, has been analyzed. GDP was considered as the outcome variable, and the following explanatory and influencing factors were selected: annual interest rates on new loans, quarterly growth in net assets of commercial banks, and quarterly growth in assets of non-bank financial intermediaries. It has been established that changes in the volume of assets of financial intermediaries have a closer correlation with the growth rate of real GDP.

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KEYWORDS

GDP, autoregression, assets, bank, rate, credit., Samara, critical factors, spatial components.

According to preliminary data from Russian Federal State Statistics Service (Rosstat), Russia's GDP has grown by 4% in 2024. The high growth reflects a significant increase in government spending, especially on sectors related to the military industrial complex. Growth slowed significantly in the second half of the year. Production capacity is approaching its limit, so it is becoming increasingly difficult to expand output. At the same time, structural imbalances in the economy have become more intense. The government has run deficits for three consecutive years, and consumer price inflation has accelerated to double digits. According to IMF forecasts, economic growth in 2025 is expected to be just 1.3%. Russia's dependence on high levels of government spending means that any significant reduction in such spending could trigger unemployment, GDP decline or even recession [1].

The sanctions regime imposed by the international community on Russia has a negative impact on the country's trade, finance and central bank operations. This is reflected in the accumulation of a significant amount of trade loans that Russian companies have provided to their buyers. As payment problems increase, Russian exporters are self-financing a significant portion of the country's exports by providing trade loans to their buyers. The resulting shortage of foreign exchange liquidity, along with other sanctions on the Russian foreign exchange market, gives rise to exchange rate volatility.

Separately, it should be noted that the risk of banking crisis is increasing as a result of high inflation, rising housing prices, credit expansion and high deposit rates. All these factors are known to be predictors of previous banking crises [2]. If either confidence in the financial sector or the government's ability to cover losses in case of more serious problems in the subsidized MIC weakens, systemic financial instability may occur.

Within the conditions mentioned above, of special interest are the models and methods used in empirical studies of macroeconomic problems and designated to serve as a basis for forecasts or for detecting crucially important interrelationships. Currently, in order to count distributional effects of economic shocks, dynamics of financial markets and macroeconomic indicators, scholars and experts use a new type of functional vector autoregressive model that facilitates joint specification of functional and aggregate time series. This is achieved by extending the functional VAR model by adding aggregate time series [3].

Thus, the issues related to how the updated VAR approach can be useful in analyzing the correlation between Russia's economic growth and condition of its financial sector under international sanctions pressure are of high scientific and practical importance, which predetermined the choice of the topic of this article.

The VAR methodology, its perceived shortcomings and opportunities for analyzing and forecasting macroeconomic indicators are described in the works of Y. I. Krotova, V. A. Balash, A. R. Faizliev, I. A. Sokolov, E. O. Matveev, K. Mahlstein, C. McDaniel, S. Schropp, M. Tsigas.

E. A. Fedorova, I. V. Pyltsin, Y. A. Kovalchuk, P. A. Drogovoz, C. Fohlin, and A. Gregg are developing identification assumptions that allow interpreting VAR model residuals in terms of underlying structural economic shocks.

At the same time, despite the available publications and developments, a number of key aspects related to the use of VAR approach to analyze and forecast the economic situation in the country still remain open. For example, the questions of how well simple econometric VAR procedures can describe the reaction of the monetary authorities to economic conditions and new market shocks caused by sanctions pressure still remain unclear. In addition, the ability of the VAR model to identify supply and demand shocks in the global commodity markets and to study their dynamic impact on the macroeconomic performance of a country deserves special attention.

Thus, the purpose of the article is to analyze the correlation between Russia's macroeconomic indicators and the condition of its financial market using VAR model.

So, the main idea of the study is to use a number of factors of the Russian financial market as regressors to determine their impact on GDP growth. Such factors are calculated from a relatively large set of variables.

Let $X_t = [X_{1t}, \dots, X_{Nt}]'$ - vector made of *N* observed times series describing the state of the Russian economy.

Each of its elements can be represented as:

$$X_{it} = \lambda_{i1} f_{1t} + \dots + \lambda_{iR} f_{Rt} + u_{it}$$

or in matrix form:

$$X_t = \Lambda F_t + U_t$$

where $U_t = [u_{1t}, \dots, u_{Nt}]'$ vector of eigen shocks of observed variables, $F_t = [f_{1t}, \dots, f_{Rt}]'$ – vector made from *R* non-observed general factors;

$$\Lambda = \begin{bmatrix} \lambda_{11} & \cdots & \lambda_{1R} \\ \vdots & \ddots & \vdots \\ \lambda_{R1} & \cdots & \lambda_{NR} \end{bmatrix}$$ – loading matrix.

Having reformulated the model for the whole data set [1...T] and vectorized it, we obtain the following equation:

$$y^{vec} = \bar{X}\beta + \varepsilon^{vec}$$

where $y^{vec} = vec(Y), Y = (Y_1, \dots, Y_T)'$

$$\bar{X} = I_n \otimes X, \quad X = \begin{pmatrix} Y_0 & \cdots & Y_{1-l} & X_1 \\ \cdots & \cdots & \cdots & \cdots \\ Y_{T-1} & \cdots & Y_{T-l} & X_T \end{pmatrix}$$

$$\beta = vec(B), B = (A_1, \dots, A_l, C)'$$

$$\varepsilon^{vec} = vec(E), E = (\varepsilon_1, \dots, \varepsilon_T)', \varepsilon^{vec} \sim N(0, \bar{\Sigma})$$

where $\bar{\Sigma} = I_T \otimes \Sigma$

Assumptions about multivariate normal distribution

$$(y^{vec}|\beta) \sim N((X \otimes I_T)\beta, I_T \otimes \Sigma)$$

Bayesian estimation of VAR model parameters consists in obtaining aposteriori distributions of β and Σ. It is assumed that β has a multivariate distribution with mean β_0 and covariance Ω_0:

$$\beta) \sim N(\beta_0, \Omega_0)$$

Ω_0 is considered as a diagonal matrix. The diagonal elements corresponding to endogenous *i* and *j* with lag I, are given through the following equation:

$$\delta_{0,i,j}^{l} = \begin{cases} \left(\frac{\lambda_1}{l^{\lambda_3}}\right)^2 \text{для } j = i \\ \left(\frac{\lambda_1 \lambda_2 \delta_i}{l^{\lambda_3} \delta_j}\right)^2 \text{для } j \neq i \end{cases}$$

where λ_1, λ_2 and λ_3 – hyperparameters, and δ_j – square root of the corresponding (i , i) element of the initial estimate Σ .

VAR models provide a credible structure for analysis, but are very vulnerable to the problem of scarcity of degrees of freedom [4,5]. A natural solution is to build models on estimated factors that effectively summarize information from many macroeconomic variables. The obtained specification looks as follows:

$$\begin{bmatrix} F_t \\ i_t \end{bmatrix} = F(L) \begin{bmatrix} F_{t-1} \\ i_{t-1} \end{bmatrix} + \vartheta_t$$

where ϑ_t – white noise, F_t – vector of factors estimated by the method of principal components, F(L) – lag polynomial, a i_t – bank interest rate.

In view of the above, to determine the correlation between Russia's macroeconomic indicators and the financial market in the country we use the proposed specification of autoregressive VAR, in which each variable is regressed on a constant, a certain number of its own lag values and lag values of other variables. The advantages of this model are the possibility of considering several determinants in dynamics, taking into account their interaction and predicting future values.

The model counts the quarterly growth (q/q) of real GDP as an indicator of economic growth (gdp), weighted average annualized interest rates on new loans granted to residents (crate), quarterly growth (q/q) of net assets of commercial banks (asset_banks) and quarterly growth (q/q) of assets of non-bank financial intermediaries (asset_NBFI), which include insurance companies, non-state pension funds, investment funds (joint investment institutions), credit unions, financial companies, other financial intermediaries and professional participants of the stock market.

All data are obtained from the website of the Central Bank of Russia and Rosstat; the analyzed period starts from Q2 2016 to Q2 2024 (Table 1).

Table 1

Input data for VAR model

Date	Quarterly GDP growth, %	Interest rates on loans, %	Quarterly growth of banks' assets, %	Quarterly growth of assets of non-bank financial intermediaries, %
2016 Q2	11.66937	14.8	1.964423	3.841439
2016 Q 3	12.50597	15.52	1.146193	2.203485
2016 Q 4	-5.56392	15.52	0.844961	12.83427
2017 Q 1	-10.4572	14.55	1.545213	1.114256
2017 Q 2	11.76655	13.483	4.156955	-0.29387
2017 Q 3	12.63903	13.58	3.069827	6.761617
2017 Q 4	-1.4295	14.55	3.58269	0.007771
2018 Q 1	-16.7308	16.102	2.910057	2.258929
2018 Q 2	8.096921	14.453	-0.7719	4.722794
2018 Q 3	11.54871	15.035	0.519567	4.972104
2018 Q 4	-10.6245	14.55	0.322409	3.126068
2019 Q 1	-9.5018	15.714	9.112151	2.513462
2019 Q 2	9.947665	17.557	-9.3039	0.818112
2019 Q 3	21.07197	17.945	-3.17074	0.338542
2019 Q 4	-6.38288	17.654	-0.40787	-3.8897
2020 Q 1	10.60224	16.684	3.454839	-0.06365
2020к2	11.65965	16.393	-2.87072	2.963188
2020 Q 3	22,23222	14.938	1.179329	1.867012
2020 Q 4	-4.78193	14.744	-1.49344	-8.70126
2021 Q 1	-7.77325	14.647	0.751215	5.654766
2021 Q 2	11.57001	13.871	-2.15328	-0.15405
2021 Q 3	21.65925	13.774	3.352679	2.925292
2021 Q 4	-4.86659	14.938	4.023265	-0.48781
2022 Q 1	-2.75414	16.102	-2.82245	-3.80235

Окончание табл.1

Date	Quarterly GDP growth, %	Interest rates on loans, %	Quarterly growth of banks' assets, %	Quarterly growth of assets of non-bank financial intermediaries, %
2022 Q 2	12.00918	16.49	0.299385	3.174278
2022 Q 3	20.21182	17.848	4.161014	6.486311
2022 Q 4	-3.95227	17.46	0.355281	1.895812
2023 Q 1	-8.53624	16.684	-1.31492	5.971304
2023 Q 2	13.87398	16.49	1.161595	3.152539
2023 Q 3	19.31309	16.781	1.161356	3.493452
2023 Q 4	-6.12846	15.714	8.536043	-0.46241
2024 Q 1	-16.3429	15.132	4.531439	5.88468
2024 Q 2	2.541435	12.707	1.573245	3.335325

The logic of the proposed model can be interpreted as follows: changes in interest rates of financial institutions as a result of the introduction of restrictive measures on new loans lead to changes in the volume of lending to industry and population of the country, which, in turn, causes changes in the volume of assets of bank and non-bank financial and credit institutions, as well as GDP growth rates in the country.

Before the model was built, it was checked for stationarity using the extended Dickey-Fuller test. All parameters turned out to be non-stationary – p-value for GDP is equal to 0.9513, for banks' assets – 0.7251, for assets of non-bank financial intermediaries - 0.5754, for lending rates – 0.5853, therefore, in order to make the series stationary, they were replaced by the corresponding time series of second-order differences (d.gdp, d.crate, d.asset_banks, d.asset_NBFI).

Further, the construction of the VAR model involves finding the optimal number of lags. For this purpose, the author used such criteria as: Schwartz criteria (SC), Hannah-Quinn (HQ), Akaik (AIC) and final prediction error (FPE) [6]. Under all criteria, the optimal number of lags was found to be 6. See Table 2 for the estimated equation coefficients.

The results obtained allow us to note that Russia's GDP is mostly affected by lag values of lending rates and lag values of banks' assets; lag values of GDP

Table 2

Estimated coefficients of VAR model equations

	d.gdp	d.crate	d.asset_banks	d.asset_NBFI
d.gdp.l1	-0.01652	0.285927	-0.05475	-0.63419
d.crate.l1	1.507826	-0.47416	-1.73882	-1.1479
d.asset_banks.l1	0.234245	-0.11452	-1.19145	0.363459
d.asset_NBFI.l1	0.673355	0.344845	-0.96216	-2.09792
d.gdp.l2	-1.04848	0.330324	-0.26127	-0.43058
d.crate.l2	5.268477	-0.12697	-1.20482	-0.566
d.asset_banks.l2	0.393869	-0.35332	-1.12185	0.322622
d.asset_NBFI.l2	-0.79	0.366573	-1.32877	-1.40349
d.gdp.l3	-0.73063	0.354613	-0.16173	-0.53961
d.crate.l3	-2.4353	-1.41223	-0.88172	2.315972
d.asset_banks.l3	-0.8585	-0.44774	-1.12827	0.378785
d.asset_NBFI.l3	0.429235	0.412493	-1.13714	-1.30387
d.gdp.l4	-0.23281	0.341877	-0.34888	-0.31418
d.crate.l4	-0.01652	0.285927	-0.05475	-0.63419
d.asset_banks.l4	1.507826	-0.47416	-1.73882	-1.1479
d.asset_NBFI.l4	0.234245	-0.11452	-1.19145	0.363459
d.gdp.l5	0.673355	0.344845	-0.96216	-2.09792
d.crate.l5	-1.04848	0.330324	-0.26127	-0.43058
d.asset_banks.l5	5.268477	-0.12697	-1.20482	-0.566
d.asset_NBFI.l5	0.393869	-0.35332	-1.12185	0.322622
const	-0.79	0.366573	-1.32877	-1.40349

and own lag values – lag values of loan interest rates; banks' assets – own lag values and lag values of loan interest rates; assets of non-bank financial intermediaries – own lag values.

This conclusion is confirmed by the constructed correlation matrix (see Table 3).

Table 3

Correlation matrix coefficients

	d.gdp	d.crate	d.asset_ banks	d.asset_ NBFI
d.gdp	1			
d.crate	-0.25108	1		
d.asset_ banks	0.030491	-0.17387	1	
d.asset_ NBFI	0.18353	0.106692	0.1380186	1

This article used out-of-sample pseudo-prediction to evaluate the predictive ability of the VAR model. The time horizon for the evaluation starts in the first quarter of 2014 and ends in the second quarter of 2024. Thus, we consider a total of 38 observations to investigate the predictive performance of the model. Graph 1 shows the first forecast available at the beginning of the target quarter and the last forecast available at the end of the 38th observation period.

As Figure 1 shows, the forecasting ability of the last iteration of the model is quite high both in relatively stable 2019 – 2020 and during structural changes in 2022 – 2023. The quality of the first iteration is worse; in particular, the model was unable to predict in a proper time the GDP contraction in 2021. However, the overall amplitude of the decline and further recovery are reproduced quite accurately.

In addition, a Granger causality test was performed to estimate the model.

According to Granger causality, if signal X1 "Granger-causes" (or "G-causes") signal X2, then past values of X1 should contain information that helps to predict X2, and the X1 data should then have greater predictive power than past values of X2. The mathematical formulation of this test is based on linear regression modeling of random processes. There are more sophisticated extensions for nonlinear cases, but these improvements are often more difficult to apply in practice. Granger causality was analyzed for different combinations of time series

The results of the Granger test are presented in Figures 2 and 3.

The test results confirmed the existence of interdependence between time series, i.e. according to Granger each series influenced at least one other.

Thus, in the course of the study, the correlation between economic growth and the state of Russia's financial market, namely banks and non-bank financial intermediaries, was analyzed using the VAR model. The proposed model took into account quarterly growth rates of real GDP as a measure of economic growth, weighted average annualized interest rates on new loans, quarterly growth of net assets of commercial banks and quarterly growth of assets of non-bank financial intermediaries.

According to the results of modeling it was found that the change in the volume of assets of financial intermediaries has a closer corelation with the growth rate of real GDP.

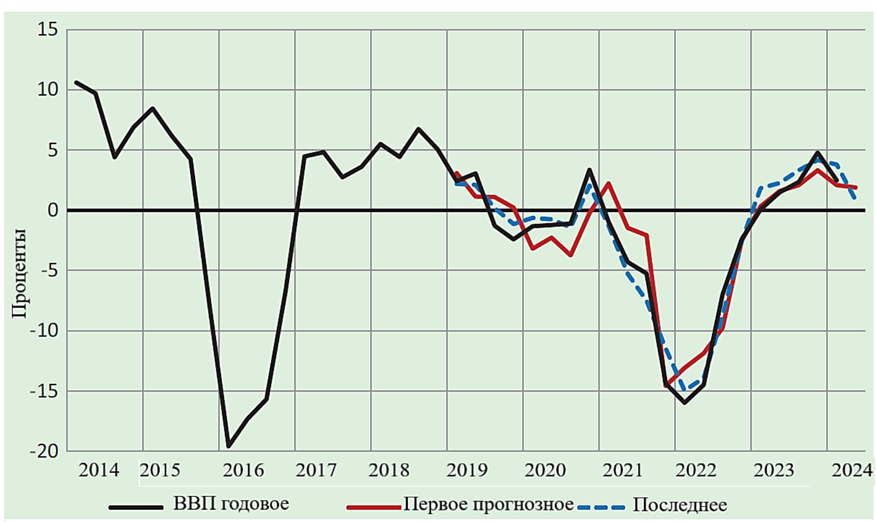

Figure 1. Forecasting ability of the first and last iterations of the VAR model

Predicted GDP Predicted interest rates

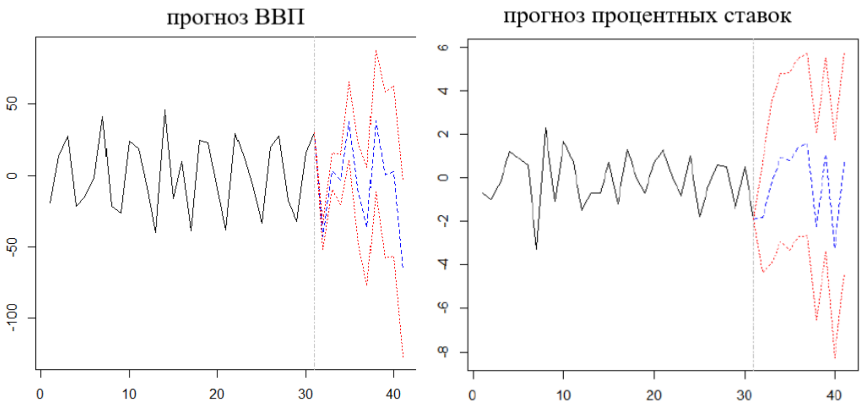

Figure 2. Results of Granger test for time series of GDP and interest rates

net assets of commercial banks net assets of non-bank institutions

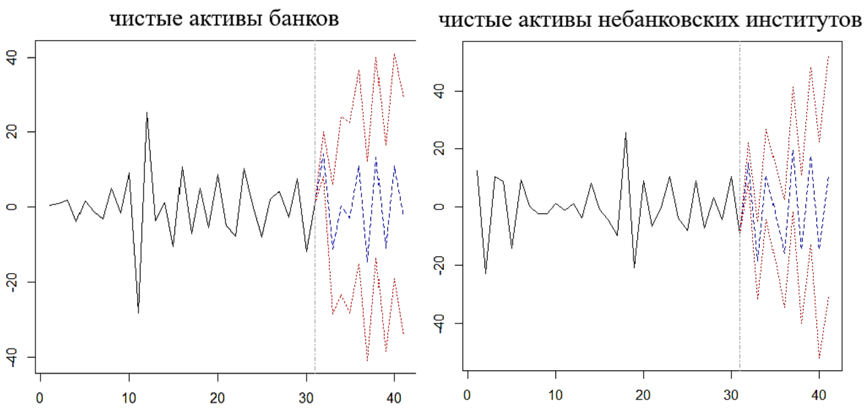

Figure 3. Results of the Granger test for time series of net assets of banks and non-bank institutions

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