UDC 338.27 DOI: 10.5862/JE.240.10

T.A. Belova, R.Kh. Bahitova, I.A. Lackman

DYNAMIC MODEL OF DIAGNOSIS AND FORECASTING OF ECONOMY IN THE CITY OF UFA

Т.А. Белова, Р.Х. Бахитова, И.А. Лакман

ДИНАМИЧЕСКАЯ МОДЕЛЬ ДИАГНОСТИКИ И ПРОГНОЗИРОВАНИЯ ЭКОНОМИКИ ГОРОДА УФЫ

The paper presents the results of building a model for diagnosing and forecasting the economic activities in the city of Ufa. This study was performed as the analytical support for creating an economic development strategy in a metropolitan city. The novelty of the approach is in the detailed analysis of the city-level indicators of the development of economic activity. This allows to identify the problems in the development of the social and economic spheres. A vector autoregression model which takes into account the correlations between the main macroeconomic indicators was chosen as a tool for diagnosing the economy. . A preliminary statistical data analysis was done and cause-effect relations were determined in the article. Vector autoregression models were made for the following branches of the city economy: industrial production, construction, wholesale and retail trade, transport and communication. The represented types of economic activities hold the main economic potential of the metropolitan city. The modeling period covers the period from the 1st quarter of 2009 till the 3rd quarter of 2014. As a result of this study we managed to determine the competitive advantages and specific problems of the economic system in the metropolitan city, analyze the basic factors and actions for overcoming adverse trends in the future. The obtained information could be useful for public authorities to solve problems connected with enhancing the welfare of the population, improving the living standards of citizens, developing the infrastructure, contributing to the effective prosperity of the social and economic spheres of the city, developing a competitive economy, expanding the external economic relations.

ECONOMETRIC MODELING; TIME SERIES ANALYSIS; VECTOR AUTOREGRESSION MODEL; FORECASTING; ECONOMIC SECTORS.

В статье представлены результаты разработки модели диагностики и прогнозирования видов экономической деятельности города Уфы. Данное исследование представляет собой аналитическую поддержку создания стратегии экономического развития столицы Башкортостана. Новизна данного подхода заключается в детализированном анализе индикаторов развития видов экономической деятельности на уровне города, что позволит выявить проблемы развития социально-экономической сферы. В качестве инструмента диагностики экономики выбрана векторная авторегрессионная модель, которая позволяет учесть взаимосвязи между основными макроэкономическими показателями. В работе проведен предварительный статистический анализ данных и выявлены причинно-следственные связи. Далее построены векторные авторегрессионные модели для следующих отраслей экономики города: промышленное производство, строительство, оптовая, розничная торговля; транспорт и связь. Представленные виды экономической деятельности составляют основной экономический потенциал мегаполиса. При этом период моделирование составлял с 1 квартала 2009 г. по 3 квартал 2014 г. На основе полученных адекватных моделей было выполнено краткосрочное прогнозирование макроэкономических показателей, которое подтвердило значимость моделирования. С помощью проведенного исследования удалось выявить конкурентные преимущества и специфические проблемы функционирования экономической системы мегаполиса, проанализировать основные причины, факторы и действия для преодоления неблагоприятных тенденции в будущей перспективе. Полученная информация может быть полезна для органов государственной власти в решении вопросов, связанных с ростом благосостояния населения, повышением и улучшением уровня и качества жизни горожан, развитием инфраструктуры, эффективном процветании социально-экономической сферы города, развитием конкурентоспособной экономики, расширением внешних связей.

ЭКОНОМЕТРИЧЕСКОЕ МОДЕЛИРОВАНИЕ; АНАЛИЗ ВРЕМЕННЫХ РЯДОВ; МОДЕЛЬ ВЕКТОРНОЙ АВТОРЕГРЕССИИ; ПРОГНОЗ; ОТРАСЛИ ЭКОНОМИКИ.

Introduction. At the present stage of development, one of the significant issues that many of the world's countries face is creating an efficient socio-economic urban development management mechanism that can coordinate the current processes to ensure all areas of life with the future long-term prospects. This problem is highly important in Russia, as the proportion of the urban population is 73.7 % according to the data gathered in 2010, also all factors forming the economic potential of the country are concentrated in the cities. Many urban districts of the Russian Federation analyze the current situation in the socio-economic sphere. Ufa, the capital of the Republic of Bashkortostan, is among the metropolitan cities [1]. The city is a center of culture, science and education, as well as the growth hub of the regional economy. About 200 large and medium-sized industrial enterprises are located in Ufa, with about 40 % of the republic's industrial potential concentrated there. The city is prospering and it is important to study the main types of its economic activity and to carry out comprehensive programs of social and economic development.

The results of creating an adequate dynamic diagnostic and forecasting model for Ufa's economy based on econometric modeling are presented in the article.

The novelty is that comprehensive research of economy of the city of Ufa as a separate territorial entity in view of the branches and taking into account the long-term response of investment and industrial components was carried out for the first time. The result was obtained by using vector autoregression models. This approach allowed diagnosing the main types of economic activities, making forecasts on the future prospects of the key macroeconomic indicators, detecting competitive advantages and problems of the functioning of a metropolitan economic system.

1. Research methodology and preliminary analysis of data. The econometric approach was chosen as a main method for diagnosing the economic activities, with a vector autoregression model (VAR-model) created, which is an efficient forecasting instrument capable of finding short-term forecasts and taking into consideration the influence of lagged values and factors on the dynamics of the main economy indicators [3, pp. 1590–1595; 4].

Modeling was carried out with the data for the period from the 1st quarter of 2009 till the 3rd quarter of 2014. The following industries: industrial production, construction, wholesale and retail trade, transport and communication were chosen for the analysis. These economic activities for Ufa are important in terms of contribution into the metropolitan economy. Indicators and their descriptions used in the study are shown in Tab. 1. The choice of factors was based on works by Sukhanova and Shirnaeva [3, pp. 1590–1595], and Deryugina and Ponomarenko [4], consultations with the city administration were held as well. Data from the territorial authority of the Bashkortostan Federal State Statistics Service [2] and the Central Bank of the Russian Federation [5] formed the information base. Since all of the considered time series followed the lognormal distribution occurring due to the smaller effect of additional units on the result, logarithms were found for all data sets before the analysis.

A preliminary data analysis was carried out at the beginning of the study:

1) with the help of the augmented Dickey–Fuller test (ADF-test) [6, pp. 427–431, 7] it was defined that all processes were static as conversion from initial data into growth rate was done (Tab. 2);

2) with the help of Granger causality test [8, pp. 424–438, 9, pp. 167–173] it was revealed that endogenous variables are logarithms of growth rate of shipped products and logarithms of growth rate of the volume of investment into the fixed capital aimed at all economic activities. The rest of the indicators are exogenous.

Thus, four vector autoregression models based on preliminary data analysis were created. They allowed estimating Ufa's economy efficiency by branch.

2. Vector autoregression models of Ufa's economy. The developed vector autoregression models of Ufa's economic activities were checked for adequacy and reliability of their indicators (Tab. 3). High t-statistics values of model parameters proved the statistical significance of the coefficients of the developed models, high F-test values of the models for each equation showed the connection of macroeconomic indicators, the values of determination coefficients close to unity showed the appropriate fit quality of the models.

Table 1

Initial data for the economy analysis of Ufa based on vector autoregressions

Designation	Description
lnVInd	Logarithm of the growth rate of the shipped industrial products (%)
lnNInd	Logarithm of the growth rate of the average number of industrial workers (%)
lnInvInd	Logarithm of the growth rate of the investment volume into the fixed capital aimed at the development of industrial production (%)
lnVCons	Logarithm of the growth rate of volume of the shipped construction production (%)
lnNCons	Logarithm of the growth rate of average number of construction workers (%)
lnInvCons	Logarithm of the growth rate of the investment volume into the fixed capital aimed at the development of construction (%)
lnVTr	Logarithm of the growth rate of the volume of products shipped in wholesale and retail trade (%)
lnNTr	Logarithm of the growth rate of the average number of wholesale and retail trade workers (%)
lnInvTr	Logarithm of the growth rate of the investment volume into the fixed capital aimed at the development of wholesale and retail trade (%)
lnVTC	Logarithm of the growth rate of the volume of shipped transport and communications goods (%)
lnNTC	Logarithm of the growth rate of the average number of transport and communications workers (%)
lnInvTC	Logarithm of the growth rate of the investment volume into the fixed capital aimed at the development of transport and communications (%)
lnOil	Logarithm of the growth rate of Brent oil price (%)
lnRer	Logarithm of the rate of growth of the real exchange rate, USD. / RUB (%)

Table 2

Dickey–Fuller test

Designation	Model type	Calculated value	Critical values	Series type	Integration order
lnVInd	with constant	−3.35	−3	DS	0
lnInvInd	with constant	−5.10	−3	DS	0
lnNInd	with constant	−5.39	−3	DS	0
lnVCons	with constant	−3.71	−3	DS	0
lnNCons	with constant	−3.56	−3	DS	0
lnInvCons	with constant	−4.44	−3	DS	0
lnVTr	with constant	−4.76	−3	DS	0
lnNTr	with constant	−6.03	−3	DS	0
lnInvTr	with constant	−5.66	−3	DS	0
lnVTC	with constant	−3.17	−3	DS	0
lnNTC	with constant	−5.93	−3	DS	0
lnInvTC	with constant	−5.64	−3	DS	0
lnOil	with constant	−3.36	−3	DS	0
lnRer	with constant	−4.66	−3	DS	0

Table 3

Statistical characteristics for each equation of the VAR-model

Statistical characteristics	Industry	Building	Wholesale and retail trade	Transport and communications
F-st.	6.15; 8.771	8.216;20.412	4.345; 7.157	9.134; 16.504
R^2	0.672; 0.745	0.606; 0.793	0.626; 0.734	0.682; 0.795

Additionally, residuals of each model equation were analyzed. The analysis showed that the mathematical expectation of the residuals equaled zero, that the dispersion was constant based on an augmented White test for equation systems [11, pp. 817–838, 12, pp. 325–333], that there was no autocorrelation between the residuals, based on the Box–Pierce/Ljung–Box Q-statistics [13], and that the residuals were distributed normally based on the Jarque–Bera test [10, pp. 96–129].

Thus, the obtained diagnostic models of Ufa's economic activities had acceptable statistical qualities.

The developed diagnostics models of Ufa's economy are the following (Student's t-statistics are in brackets in formulas (1)–(4)):

1) diagnostics model of the city industry:

$$\begin{cases} \ln VInd_t = \underset{[2.38]}{0.516} \ln VInd_{t-1} - \\ - \underset{[-3.104]}{0.648} \ln InvInd_{t-1} + \underset{[4.74]}{0.885} \ln NInd_t + \\ + \underset{[3.786]}{0.565} \ln Oil_t - \underset{[-2.234]}{0.314} \ln InvInd_{t-6} + \varepsilon_{1t}; \\ \ln InvInd_t = \underset{[4.122]}{0.813} \ln VInd_{t-1} - \\ - \underset{[-2.498]}{0.474} \ln InvInd_{t-1} + \underset{[2.576]}{0.437} \ln NInd_t + \\ + \underset{[3.527]}{0.478} \ln Oil_t - \underset{[-2.01]}{0.257} \ln InvInd_{t-6} + \varepsilon_{2t}, \end{cases} \quad (1)$$

where *lnVInd* is the logarithm of the growth rate of the shipped industrial products; *lnInvInd* is the logarithm of the growth rate of the investment volume into the fixed capital aimed at the development of industrial production; *lnNInd* is the logarithm of the growth rate of the average number of industrial workers; *lnOil* is the logarithm of the growth rate of brent oil price.

2) Ufa's construction diagnostics model:

$$\begin{cases} \ln VCons_t = \underset{[2.123]}{0.485} \ln VCons_{t-3} - \\ - \underset{[-2.512]}{0.814} \ln InvCons_{t-3} + \underset{[5.214]}{0.596} \ln NCons_t - \\ - \underset{[-2.619]}{0.417} \ln \mathrm{Re}\, r_t + \varepsilon_{3t}; \\ \ln InvCons_t = \underset{[6.712]}{0.626} \ln VCons_{t-3} - \\ - \underset{[-3.532]}{0.467} \ln InvCons_{t-3} + \underset{[7.998]}{0,289} \ln NCons_t - \\ - \underset{[-2.468]}{0,446} \ln \mathrm{Re}\, r_t + \varepsilon_{4t}, \end{cases} \quad (2)$$

where *lnVCons* is the logarithm of the growth rate of volume of the shipped construction production; *lnInvCons* is the logarithm of the growth rate of the investment volume into the fixed capital aimed at the development of construction; *lnNCons* is the logarithm of the growth rate of average number of construction workers; *lnRer* is the logarithm of the rate of growth of the real exchange rate, USD / RUB.

3) Ufa's wholesale and retail trade diagnostics model:

$$\begin{cases} \ln VTr_t = \underset{[2.875]}{0.577} \ln VTr_{t-2} + \underset{[3.282]}{0.526} \ln VTr_{t-4} - \\ - \underset{[-3.18]}{0.703} \ln InvTr_{t-2} - \underset{[-2.12]}{0.396} \ln InvTr_{t-4} + \\ + \underset{[4.107]}{0.859} \ln NTr_t + \underset{[2.547]}{0.141} \ln \mathrm{Re}\, r_{t-1} + \varepsilon_{5t}; \\ \ln InvTr_t = \underset{[3.378]}{0.603} \ln VTr_{t-2} + \underset{[2.642]}{0.376} \ln VTr_{t-4} - \\ - \underset{[-4.066]}{0.799} \ln InvTr_{t-2} - \underset{[-2.275]}{0.378} \ln InvTr_{t-4} + \\ + \underset{[3.534]}{0.657} \ln NTr_t + \underset{[2.365]}{0.542} \ln \mathrm{Re}\, r_{t-1} + \varepsilon_{6t}, \end{cases} \quad (3)$$

where *lnVTr* is the logarithm of the growth rate of the volume of products shipped in wholesale and retail trade; *lnInvTr* is the logarithm of the growth rate of the investment volume into the fixed capital aimed at the development of wholesale and retail trade; *lnNTr* is the logarithm of the growth rate of the average number of wholesale and retail trade workers; *lnRer* is the logarithm of the rate of growth of the real exchange rate, USD / RUB.

4) Ufa's transport and communications diagnostics model:

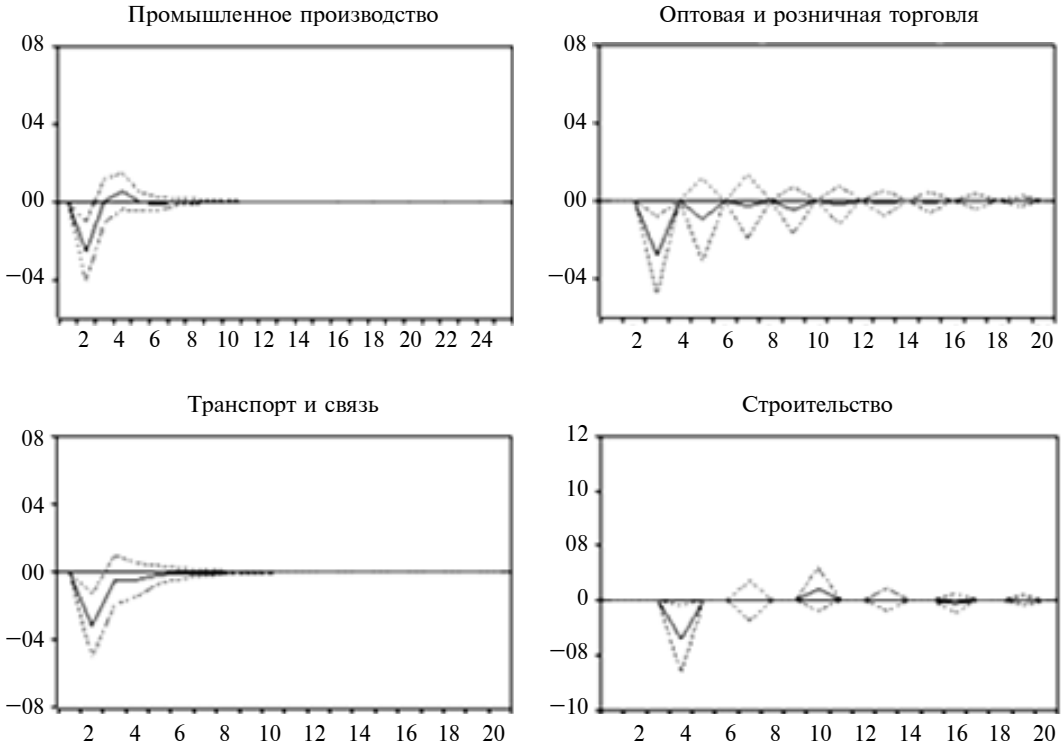
$$\begin{cases} \ln VTC_t = \underset{[4.746]}{0.774} \ln VTC_{t-1} - \\ - \underset{[-3.91]}{0.632} \ln InvTC_{t-1} + \underset{[2.236]}{0.643} \ln NTC_t + \\ + \underset{[2.44]}{0.396} \ln Oil_t + \underset{[2.011]}{0.535} \ln \mathrm{Re}\, r_{t-1} + \varepsilon_{7t}; \\ \ln InvTC_t = \underset{[4.292]}{0.581} \ln VTC_{t-1} - \\ - \underset{[-4.69]}{0.629} \ln InvTC_{t-1} + \underset{[3.708]}{0.493} \ln NTC_t + \\ + \underset{[3.836]}{0.516} \ln Oil_t - \underset{[-2.956]}{0.653} \ln \mathrm{Re}\, r_{t-1} + \varepsilon_{8t}, \end{cases} \quad (4)$$

where *lnVTC* is the logarithm of the growth rate of the volume of shipped transport and

communications goods; *lnInvTC* is the logarithm of the growth rate of the investment volume into the fixed capital aimed at the development of transport and communications; *lnNTC* is the logarithm of the growth rate of the average number of transport and communications workers; *lnRer* is the logarithm of the rate of growth of the real exchange rate, USD / RUB; *lnOil* is the logarithm of the growth rate of Brent oil price.

Thus, comparing these diagnostics models of Ufa's economic activities, we can conclude the following: first, lagged values of present variables influence the growth rate of the volume of investment and growth rate of volume of the shipped production at present. The growth rate of the shipped production volume of past periods has positive interrelation with endogenous variables, because output expansion and service spheres development take place with the increasing of this indicator. Additional capital investment with an effective economic growth is required to provide all branches of economy with modern equipment and new technologies, which allows reducing costs of production and improving the goods and services quality. Lagged values of the investment volume growth rates have a negative influence on endogenous variables. Less current investments are required provided that the past level of financing was high enough. However, investment must be carried out in effective forms. Investments into outdated means of production should not be made, otherwise inefficient capital utilization leads to resources restriction. It is obvious from the above that the reduction of shipped production volumes takes place. Diagnostics results of certain economic activities show that the effect of the depreciation of fixed assets surpasses that of innovative investments.

Functions of impulse responses, which describe the time it takes for the endogenous variable to return to the equilibrium curve at unit response of the exogenous variable, can be analyzed to confirm the adequacy of variable interrelation in the models [10, pp. 96–129; 14]. Figure shows the response of the logarithmic growth rate curves for the shipped production volume by type of economic activity to the 'shock' of the investment growth rate logarithm.



Response of the logarithmic growth rate of shipped products to the 'shock' of the investment growth rate logarithm

The curves presented in Fig. 1 indicate the negative response of the growth rate logarithm of shipped products to an increase in the investment volume growth rate logarithm for all types of economic activity. The effect from the change in the investing activities vanishes in 6–8 quarters of industrial production, transport and communication branches, but for the wholesale and retail trade and construction it can be seen for several years.

Secondly, the growth rate of the average number of workers affects the endogenous variables dynamics in all branches while the relationship is direct. It can be explained by the fact that additional funding for salaries and other deductions is necessary with an increase in the number of skilled and unskilled workers; the work force increasing assures the employment in the economy and expansion of the production. This factor has the greatest impact on the shipped products volume in the industrial branch (*lnVInd*), as the branch is one of the most perspective, and highly skilled specialists are involved in it. The factor has influence on the shipped products volume of wholesale and retail trade (*lnVTr*), related to the expansion of distributing facilities and creating workplaces.

Thirdly, the dependence of metropolitan economy on external factors is traced, that is, on the growth rate of oil price (*lnOil*) and the growth rate of exchange rate (*lnRer*). The growth rate of oil price has a positive influence on the development of industrial and transport and communication branches. It is the result of the influx of export petrodollars into the economy. The growth rate of exchange rate has a positive impact on the dynamics of wholesale and retail trade indicators (*lnVTr* and *lnInvTr*). Export goods bring a profit with the weakening of the national currency and support of domestic producers takes place as well. The growth rate of exchange rate has a negative impact on the construction variables (*lnVCons* and *lnInvCons*). It can be explained by the strong dependence of construction branch on the costs of import construction technologies and materials.

Internal and external factors affect the development of main economic activities in the capital of the Republic of Bashkortostan. The examined indicators with scientifically substantiated signs are present in the models.

Conclusion. Thus, a comprehensive study was carried out for all branches of Ufa's economy taking into account the long-term response of investment and industrial components with the help of vector autoregression models. We have drawn the following conclusions based on dynamic diagnostics models and made a forecast for Ufa's economic situation:

a) the problem of depreciation of fixed assets, which have a negative effect on economic growth, is peculiar for the city of Ufa;

b) the examined types of economic activities need structural and technological modernization, expansion of interactions with scientific and educational institutions, sources of additional investment.

In the current economic climate, it is necessary to develop an effective investment policy directed at modernizing and supporting all types of economic activities in Ufa and further improve them. Dynamic diagnostic and forecasting models of the city's economy allowed to obtain a qualitative assessment of the current economic situation of the metropolitan system.

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BELOVA Tat'iana A. – Department of mathematical methods in Economics, Institute of Economics, Finance and business, Bashkir State University, postgraduate.
450074. Zaki Validi str. 3. Ufa. Russia. E-mail: k.t.a.1991.1991@mail.ru

БЕЛОВА Татьяна Александровна – аспирант кафедры математические методы в экономике, институт экономики, финансов и бизнеса, Башкирский государственный университет.
450074, ул. Заки Валиди, д. 32, г. Уфа, Россия. Тел.: (987)101-91-97. E-mail: k.t.a.1991.1991@mail.ru

BAHITOVA Railia Kh. – Bashkir State University, Head of the Department «Mathematical Methods in Economics».
450074. Zaki Validi str. 3. Ufa. Russia. E-mail: bakhitovarh@mail.ru

БАХИТОВА Раиля Хурматовна – Башкирский государственный университет, заведующая кафедрой «Математические методы в экономике», д-р экон. наук.
450074, ул. Заки Валиди, д. 32, г. Уфа, Россия. Тел.: (927)351-11-88. E-mail: bakhitovarh@mail.ru

LACKMAN Irina A. – Ufa State Aviation Technical University, assistant professor of the department of «Computational Mathematics and Cybernetics».
450000. K. Marx str. 12. Ufa. Russia. E-mail: lackmania@mail.ru

ЛАКМАН Ирина Александровна – Уфимскиий государственный авиационный технический университет, доцент кафедры «Вычислительная математика и кикбернетика», кандидат технических наук.
450000, ул. К. Маркса, д. 12, г. Уфа, Россия. Тел.: (927)965-56-55. E-mail: lackmania@mail.ru