bounded coefficients [5]. S.N. Popova obtained weaker condition of uniform global reducibility for discrete-time periodic systems [6]. A.A. Kozlov proved uniform global attainability for linear non-stationary periodic systems with piecewise continuous and bounded coefficients [7].

In this paper necessary and sufficient condition of uniform global attainability of non-stationary discrete-time periodic system, i.e. we proved

Theorem 1. *A linear discrete-time periodic control system* (2) *is uniform global controllable iff the corresponding linear closed system* (3) *has the property of uniform global attainability*.

Conclusion. The obtained results can be further used in the theory of control over asymptotic invariants of dynamic systems of arbitrary types.

1. Horn, R. Matrix analysis / R. Horn, C. Johnson. – Cambridge: Cambridge University Press, 1988. – 655 p.
2. Gaishun, I.V. Discrete-Time Systems / I.V. Gaishun. – Natsional'naya Akademiya Nauk Belarusi, Institut Matematiki, Minsk, 2001. – 400 p.
3. Zaitsev, V.A. Uniform consistent linear discrete-time systems with incomplete feedback / V.A. Zaitsev // IFAC. – 2018. – P. 110–114.
4. Makarov, E.K. Controllability of asymptotic invariants of non-stationary linear systems / E.K. Makarov, S.N. Popova. – Minsk: Belarus. navuka, 2012. – 407 p.
5. Ints, I.V. On uniform global attainability of two-dimensional linear systems with locally integrable coefficients / I.V. Ints, A.A. Kozlov // Vestnik Udmurtskogo Universiteta. Matematika. Mechanika. Comp'uternye nauki. – 2017. – Pp. 178–192.
6. Popova, S.N. Global Lyapunov reducibility of periodic linear controlled systems with discrete time / S.N. Popova, I.N. Banshchikova // XII Belarusian mathematical conference: materials of the Int. conf. sc. Conf., Minsk, September 5-10, 2016 Part 2. – Mn.: In-t matematiki NAN Belarusi, 2016. – Pp. 42–43.
7. Kozlov, A.A. Criterion of uniform global attainability of periodic systems / A.A. Kozlov // Vestnik Udmurtskogo Universiteta. Matematika. Mechanika. Comp'uternye nauki. – 2019. – Vol. 29. №. 4 (in print).

MODELING THE REGIONS OF BELARUS COMPETITIVENESS THE BASED ON PANEL DATA

Katsiaryna Karpuk
GrSU named after Y. Kupala, Grodno, Belarus

Comparative analysis of the regions of Belarus competitiveness was conducted. A system of indicators that reflect the competitiveness in the regions under study was built. It consists of five units: quality of the population, living standards, quality of social services, quality of the ecological niche, cultural condition of society, investment attractiveness. Integral indicator of the competitiveness for regions was built using the factor analysis. All baseline indicators were sorted according to their impact.

Countries competitiveness is estimated annually by international non-governmental organization, the World Economic Forum (WEF). The Republic of Belarus has not taken part in the WEF ratings. Improving the Republic of Belarus competitiveness and the participation in the WEF ratings is scheduled for 2016–2020 by the Government program.

The competitive advantages of the country directly depend on the competitiveness of its regions. In this regard, forming of region competitiveness is the main goal in the task of improving the competitiveness of the country.

Material and methods. The system of indicators consists of five units.

Quality of population: rate of natural increase; infant mortality rate; age dependency rate; share of workers with higher education (%); number of marriages (per 1000 persons); number of divorces (per 1000 persons); rate of migration increase (%), life expectancy.

Standard of living: The ratio of per capita income to the minimum subsistence budget ; population provision with housing (m^2 of total area per 1 resident); paid services for population (in actual prices, one thousand rubles per capita); retail turnover of trade (in actual prices, one thousand rubles per capita).

Quality of social sphere: registered unemployment rate (in % of the economically active population); number of injuries at work including death or disability at 1day and more (per 1000 workers); provision with doctors in all specialties (per10000 persons); provision with paramedical personnel (per 10000 persons).

Quality of the environment: air polluting emissions from stationary sources (per1000 persons, tons); share of the captured air pollutants in the total pollution from stationary sources (%); fresh water use (per persons, m^3).

Investment attractiveness: fixed capital investments per person employed in the economy (million rubles per person employed in the economy); industrial production volume per capita (million rubles); share of loss-making entities (% of the total number of entities); ratio of exports to imports of products (%); profitability of sales (%); share of the shipped innovative products (works, services) in the total volume of own production by industry enterprises (%), the number of employees engaged in research and development.

Official statistics, published in the collections of National Statistical Committee of the Republic of Belarus are used for selected indicators. The study was conducted on panel data for 2013-2017. Comparability of data carried out by bringing the minimum consumer budget by the end of the year.

The integral indicator of the Grodno region districts competitiveness was built in [1] according to the 2008–2010 period based on panel data. A technique based on the methods of applied statistics was used for the construction of integral indicator.

Original 25 indicators were scaled on the interval [0, 1] for comparability of indicators, measured in different units. The indicators were then transformed according to the principal components method of factor analysis into the 4

principal factors. The total percentage of variance, saved by them, is 82%. The first principal factor saves 44,8% of the variance, second factor – 16,8%, third factor – 11,3%, fourth factor – 9,1%. The factor loadings values of the first principal factor are listed in table 1.

Table 1 – Factor loadings of indicators related to the first principal factor

N	Indicator	Factor 1
1	Number of research staff	**0,970**
2	Percentage of employees with higher education organizations	**0,969**
3	Volume of paid services	**0,958**
4	The ratio of per capita income with BMP	**0,943**
5	Retail trade turnover	**0,923**
6	Demographic load factor	**0,915**
7	Gross regional product	**0,879**
8	Housing provision	**-0,851**
9	Natural growth rate	**0,748**
10	The number of practitioners	**0,730**

Integral indicator of the competitiveness was obtained using the equation

$$R = 44,8\ F1 + 16,8\ F2 + 11,3\ F3 + 9,1\ F4,$$

where R is the competitiveness integral indicator, *F1*, *F2*, *F3*, *F4* – values of the first principal factors. The percentage of the dispersion, saved by them, is taken as weight.

The rating of the regions of Republic of Belarus for each year is given in table 2.

Table 2 – Rating regions of Belarus on Competitiveness for 2013–2017

Region	2013	Region	2014	Region	2015	Region	2016	Region	2017
Minsk c	116.93	Minsk c	108.15	Minsk c	121.31	Minsk c	115.29	Minsk c	108.93
Vitebsk	-15.6	Vitebsk	7.21	Minsk	24.83	Minsk	13.18	Minsk	9.14
Gomel	-17.15	Minsk	-7.93	Vitebsk	-13.84	Vitebsk	2.99	Vitebsk	2.37
Minsk	-29.35	Gomel	-20	Gomel	-23.11	Gomel	-4.71	Gomel	-8.47
Mogilev	-29.86	Mogilev	-30.44	Mogilev	-28.54	Mogilev	-21.55	Mogilev	-20.88
Grodno	-34.7	Grodno	-33.71	Grodno	-34.91	Brest	-27.29	Brest	-30.42
Brest	-44.8	Brest	-44.18	Brest	-36.35	Grodno	-34.05	Grodno	-32.4

Findings and their discussion. The permanent leader in competitiveness for 2013-2017 is the city of Minsk and the Minsk region. Vitebsk and Gomel and Mogilev take 2-5 places. Permanent outsiders are the Brest and Grodno regions. As can be seen from the table, the best indicators for all regions were in 2015 and 2016, and the worst in 2013 and 2014. Thus, in 2015, there was a slight increase in the economy of the regions.

The most important competitiveness growth factors of Belarus regions for the period under review were revealed (table 1).

The quality of population: the proportion of employees with higher education organizations, age dependency rate, rate of natural increase, rate of migration increase, life expectancy.

The investment attractiveness: share of innovation-active organizations in the total number of surveyed companies.

The standard of living: population provision with housing, the ratio of per capita income to the minimum subsistence budget, paid services for population, retail turnover of trade.

Quality of social services: provision with doctors.

Conclusion. In order to solve the identified problems it is, first of all, necessary to create new jobs and thus attract young working population to regions, as well as to implement a package of measures stimulating the development of small and medium businesses in the fields of material production, innovation and provision of public services.

1. Lialikava, V. Methodological aspects of economic objects ranging by applied statistics methods / V. Lialikava // Vestnik of Yanka Kupala State University of Grodno. – 2010. – Series 5. Num. 2, pp. 29–35.

APPLICATION OF FUZZY DECISION TREES FOR TEACHING THE SYSTEM OF RECOGNITION OF OBJECTS OF INTELLIGENCE AND THEIR STATES OF ACTIVITY BASED ON THE FUZZY APPROACH

Andrey Khvisevich, Alexander Bekish
Military Academy of the Republic of Belarus, Minsk, Belarus

In [1] in the interests of automated recognition of intelligence objects and their activity states with insufficient accumulated statistical information, the authors showed the feasibility of applying an approach based on the theory of fuzzy sets and the fuzzy logic method, in which each of the «arguing» recognition objects is assigned its own degree accessories on the basis of which the duty officer makes a decision. After assessing the reliability of the recognition result obtained, this information is taken into account as accumulated statistical data, which are then used in the formation and refinement of the rules of the fuzzy knowledge base. To train this knowledge base, both statistical data accumulated from the experience of conducting intelligence and expert assumptions (method of expert estimates) are used. However, in view of the subjectivity of the assumptions made, the training of the knowledge base will take a long time and with a deterioration in the quality of decisions regarding the recognition result.

For training a fuzzy knowledge base (both at the initial stage and in the systematic refinement of fuzzy rules), it is proposed to use fuzzy decision trees