EVALUATION OF RUSSIAN REGIONS SUSTAINABILITY USING THE MODIFIED PRINCIPAL COMPONENTS ANALYSIS

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Abstract

The study reflects an integrated approach to assessing the efforts of Russian regional authorities in the area of sustainable development. A quantitative sustainability indicator is calculated for each Russian region based on the methodology of generalized modified principal component analysis, which was approved by the authors' previous studies. This approach helps to avoid expert assessments when building a rating. All data for the indicator's calculation is taken from official statistics. The principal component loadings are calculated for 85 regions. The rating considers a number of indicators, which are grouped in 3 subsets (pillars), which reflect certain signs of regional sustainability (economic, social and environmental). The research lays the foundation for regular analysis of economic growth, social policy and environmental responsibility, and their dynamics in the Russian regions. The rating is designed to meet the need to assess the current state and potential of sustainability in Russian regions and can serve to improve regional environmental, social and economic policies.

Key words: principal components analysis, regional sustainability, rating of regions

JEL Code: C38, Q01, R11

Introduction and literature review

By adoption in 2015 «Transforming our world: the 2030 Agenda for Sustainable Development» United Nations and the world community has defined the vector for the next 15 years: social, economic and environmental priorities.

In contemporary world the conditions for social responsibility and sustainable development are applied in practice and become a real factor of competitiveness in world markets. At the basic level, countries and companies need to find ways to increase and maintain productivity and use resources to strengthen and maintain their competitive positions, while setting new goals.

Despite the fact that the principles of sustainable development have been enshrined in a number of official documents of the Russian Federation for more than 20 years, they have not yet become truly widespread in the country.

It can be illustrated, in particular, by the review of sustainable development ratings of territories and companies in Russia. Only a small number of them reflect the approach to sustainable development as a complex phenomenon. Most of them affect only certain areas of sustainable development: environmental parameters of microeconomic and regional (urban) activity or socio-economic indicators of companies and territories.

One can consider the best-known ratings of sustainable development in Russia (see tab. 1).

Tab. 1. Russian ratings of regional sustainable development

Rating	***Source***	***Features***
"Polar index. Regions. Rating of sustainable development of the Russian Arctic regions.	"PORA" agency and the Environmental Economics Chair, Lomonosov Moscow State University https://www.econ.msu.ru/sys/	Rating's been calculated since 2017. A comprehensive approach to the assessment of Arctic sustainable development
Rating of Russian cities	SGM Agency LLC http://www.agencysgm.com/projects/	Rating's been calculated since 2012. Assess of Russian cities in their development to identify promising areas for growth
Environmental, social and economic index of regions of the Russian Federation	RIA Rating and WWF https://riarating.ru/infografika/	Rating's been calculated since 2012. The index has revealed a number of patterns of development of Russian regions taking into account their economic orientation.
Rating of the socio-economic situation of the Russian Federation	RIA Rating https://riarating.ru/infografika/	Ratings've been calculated since 2011 and 2013. The methodology is based on a set of quantitative indicators from official statistics characterizing economic, social and budgetary sphere of a territory.
The quality of life rating of regions of the Russian Federation	RIA Rating https://riarating.ru/infografika/	
Rating of attractiveness of Russian regions	"General Director" Journal https://www.gd.ru/	Rating's been calculated since 2014. Takes into account six complex parameters. Each indicator was given the same weight.
Rating of investment attractiveness of Russian regions	National rating agency http://www.ra-national.ru/	Rating's been calculated since 2013. Investment potential and investment risk are used as the components of the investment climate: The investment potential consists of 9 private potentials: natural resources, labor, production, consumer, financial, institutional, infrastructure, innovation and tourism.
Rating of governors' efficiency	Civil Society Development Fund http://russia-rating.ru/info/category/gubernators	Rating's been calculated since 2014. The rating is based on the results of absentee surveys, absentee and face-to-face interviews with representatives of the expert community.
Rating of management efficiency in the subjects of the Russian Federation	Agency for Political and Economic Communications (APEC) and the Political Research Laboratory of the Higher School of Economics http://apecom.ru/projects/	Rating's been calculated for 2012- 2017. The methodology is based on three blocks: political and management, social and financial and economic. Both methods of mathematical analysis and expert assessments are used.
AV RCI regional competitiveness index - Russian growth poles	AV Group consulting company http://av-group.ru/wp-content/uploads/2015/10/AV_RCI_2015.pdf	Rating's been calculated since 2014. The regional competitiveness index reflects the actual implementation of competition factors, i.e. it evaluates the indicators reflecting the results of interregional competition.

Source: composed by the authors.

Unlike the overwhelming majority of existing ratings, the Polar Index project is methodologically based on the "triple bottom line" concept. Sustainable development is understood as a framework with three parts: social, environmental and economic, without "distortion" in one direction or another. In this regard, the criteria for evaluating regions and companies are grouped into three blocks, reflecting these key dimensions of sustainable development.

Among other ratings, conceptually and methodologically similar to the "Polar Index" is the rating of Russian cities, which is made by SGM Agency since 2012. The purpose of the rating is to identify leaders and outsiders of sustainable development, as well as the most balanced Russian cities in their development to identify promising areas for their growth. The rating includes cities with population exceeding 100 thousand people.

An important attempt in assessment of sustainable development of Russian regions was undertaken in 2012 when RIA and WWF released the Environmental, social and economic index of regions of the Russian Federation. The authors of the methodology (Bobylev et al, 2011) used the World Bank's Adjusted Net Savings Index as an integral indicator taking into account the environmental sustainability of Russia's regions in a broad framework, including economic, social and environmental factors.

Rating of the socio-economic situation of the Russian Federation has been compiled by RIA Rating agency since 2011. The calculations use a number of indicators of the scale and efficiency of the economy, as well as a limited list of parameters characterizing the state of the budget and social sphere (15 indicators in total). The results of the rating characterize the current situation of a territory rather than the progress and especially its development potential.

Rating of Russian regions on quality of life is made by rating agency "RIA Rating" annually since 2013. The authors aim to determine the quality of life in the regions and assess the existing imbalances in this area. The rating uses 72 indicators characterizing various aspects of living conditions in the region (from the level of economic development and the volume of income of the population to the provision of various types of services and climatic conditions).

Rating of attractiveness of Russian regions by Journal "General Director" takes into account six complex parameters: 1) labor force (number, value and qualification); 2) availability of demand for everyday goods and 3) durable goods (market volume and its dynamics); 4) economic situation in the region; 5) state of infrastructure (roads, real estate) and, of course, 6) regional tax policy. All the indicators, which were calculated using the specific formulae, are assigned equal weights.

By construction of this rating we make an attempt to reflect the current state of sustainable development in the regions of the Russian Federation. It is based on available data on significant

development factors. In essence, the index reflects the objectives and aggregate indicators of sustainable development.

As for international practices there is a vast number of approaches to regional policy evaluation. T. Beaussier, S. Caurla, V. Bellon-Maurel, and E. Loiseau analyze and compare the most promising methods of policies assessment (Beaussier et al, 2019).

The methodology of our research is based on principal component analysis (PCA), which is widely used in multidimensional statistics (see, for instance, Doukas, et. al., 2012) including sustainable development issues. We can mention the research of Ff. Tan and Zh. Lu who applied PCA-VAR model to implement a qualitative and quantitative analysis of relations among society, economy and environment subsystems, and provide proposals for the future set-ups of regional development (Tan and Lu, 2015). Y.N. Gavrilets, M.V. Chernenkov and S.A. Nikitin use PCA and data from sociological surveys as well as from official statistics for 47 Russian territories to calculate aggregate indices, that characterize the correspondence between regional economic growth and levels of population satisfaction and concern (Gavrilets, Chernenkov and Nikitin, 2019). T. Zhgun analyzes trends and quantitative characteristics of social dynamics on the basis of PCA. Her algorithm is based on a variance criterion and the selected signal-to-noise ratio that characterize data variability (Zhgun, 2017). A.-I. Petrişor, I. Ianoş, D. Iurea and M.-N. Văidianu implement PCA in conjunction with GIS modelling to build hierarchies of the adminstrative units and to identify underdeveloped regions (Petrişor et al, 2012).

Along with studies that try to avoid references to expert estimates when choosing weights when constructing a composite indicator (see, for example, Poledníková and Melecký, 2017), we offer a fairly simple but complex approach based on the analysis of the main components, which we've already used to make an assessment of environmental responsibility of Russian regions (see Verenikin and Verenikina, 2019).

1 Methodology, data and analysis

Sustainable development is a multidimensional characteristic that comprises a variety of indicators $X = \{x_i\}_{i=1}^{n}$ (n=32 in this case). Each, i-th indicator characterizes the performance of a j-th region (j=1,…,m; m=85 in this case). Overall we deal with a matrix of initial data $X = \begin{pmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{pmatrix}$.

The key issue is how to choose appropriate weighting coefficients for the particular economic, social and environmental activities x_i that will not rely on subjective judgments.

We use principal component approach - a multidimensional statistical technique allows to put together diverse, almost incomparable factors. It transforms a set of original variables into a

set of artificial uncorrelated variables: $Z = \begin{pmatrix} Z_1 \\ \vdots \\ Z_n \end{pmatrix} = \begin{pmatrix} z_{11} & \cdots & z_{1m} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nm} \end{pmatrix} = LX$, where $Z_1,\ldots,Z_m$ are the first to *m*-th principal component vectors, $L = \begin{pmatrix} l_{11} & \cdots & l_{1n} \\ \vdots & \ddots & \vdots \\ l_{n1} & \cdots & l_{nn} \end{pmatrix}$ is the matrix of linear orthogonal transformation.

Principal component loadings are eigenvectors of the covariance matrix of initial data Σ: $(\Sigma - \lambda I)l_1^T = 0$. The corresponding characteristic equation $|\Sigma - \lambda I| = 0$ has *n* real-valued nonnegative roots $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_n \geq 0$ (eigenvalues of the covariance matrix Σ). The first principal component loadings are determined as the eigenvector that corresponds to the largest eigenvalue λ_1. The following principal components $Z_k = (z_{k1},\ldots,z_{km})$ use as component loadings other eigenvectors that correspond to successively smaller eigenvalues λ_k, k=2,…,n. λ_k is equal to variance of the *k*-th principal component. Total variance of principal components coincides with total variance of primary data, thus $\rho_k = \lambda_k \Big/ \sum_{k=1}^{n} \lambda_k$ is the share of total primary data variance explained by the *k*-th principal component.

The first principal component score z_{1j} is known to be used as an aggregate indicator of activity of the *j*-th economic actor. Unfortunately it explains only ρ_1 share of the variance of initial data and thus yields a substantive loss in exposing capability.

We use the generalized principal component approach approved by our previous research (Verenikin and Verenikina, 2019) to calculate an aggregate measure of regional environmental impact as a weighted sum of all principal component scores: $I_j = \sum_{k=1}^{n} \rho_k y_{kj} = \sum_{k=1}^{n} \rho_k \sum_{i=1}^{n} l_{ki}^2 x_{ij}$.

Note that we use here modified principal component scores $y_{kj} = \sum_{i=1}^{n} l_{ki}^2 x_{ij}$ instead of ordinary principal components z_{kj} (Aivazian, Stepanov, Kozlova, 2006). This makes it possible to avoid negative principal component scores as constituting elements of the composite index. The modified principal components y_{kj} are weighted by the corresponding shares of explained variance ρ_k. There is no loss in variance of the considered data. The explaining capability of the proposed indicator is extended to the total variance of initial variables. The distinguishing feature of the proposed composite measure is that it is not sensitive to subjective preferences concerning the relative significance of specific factors of regional sustainability.

The data are normalized within the range from one to ten in order to obtain the uniform increasing impact of all the factors of concern on the level of the resulting aggregate index. If an indicator corresponds to the case “the more the better” then we adjust it to 1-10 ranking scale in the following way:

$$x_{ij}^{n} = 1 + 9\left(\frac{x_{ij} - x_{ij}^{\min}}{x_{ij}^{\max} - x_{ij}^{\min}}\right),$$

where x_{ij}^{n} is a normalized variable, $x_{ij}^{\max}$ and $x_{ij}^{\min}$ are correspondingly the "best" and the "worst" value of initial indicator x_{ij}.

In the case "the less the better" the following normalizing transformation is applied:

$$x_{ij}^{n} = 1 + 9\left(\frac{x_{ij} - x_{ij}^{\max}}{x_{ij}^{\min} - x_{ij}^{\max}}\right),$$

where $x_{ij}^{\max}$ and $x_{ij}^{\min}$ are correspondingly the "worst" and the "best" value of initial indicator x_{ij}.

The analysis is focused on data from open official statistics, mainly Federal State Statistics Service (www.gks.ru). We had to analyze both annual state and regional reports, available in official web sites for the year 2017.

Original data is grouped into a number of subsets or pillars that reflect definite attributes of regional sustainable development. The rating considers a number of indicators that reflect human development, capital and environmental factors. They were grouped into three pillars called: «Economical», «Social» and «Environmental» (see tab.2). Some indicators were weighted by gross regional product (GRP) to make data more compatible. Expenses on human capital development represent the sum of regional expenses for education, health care and physical culture and sports (in mln. rubles).

Tab. 2. Indicators and pillars

Pillar	***Indicator***
A. Economical	A1. Industrial production index, % to previous year
	A2. Investments in fixed capital, % to GRP
	A3. Net balance of enterprises profit and loss, mln. rubles per capita
	A4. Share of loss-making organizations in total number of organizations, %
	A5. Availability of fixed assets, mln. rubles per capita
	A6. Fixed assets depreciation rate, %
	A7. Gross domestic expenditure on R&D, thousand rubles per capita
	A8. Innovative goods and services as a percentage of total sales, %
	A9. Real accrued wages of employees of organizations
	A10. Employment rate, %
B. Social	B1. Number of inhabitants per 1 sq. km
	B2. GRP per capita, rubles
	B3. Average per capita money income of population, rubles
	B4. Unemployment rate, %
	B5. Share of populations with money income below the subsistence minimum
	B6. Life expectancy at birth (years)
	B7. Total area of dwellings, average per one inhabitant, sq. m
	B8. Hospital beds per 10 000 population
	B9. Number of crime victims per thous. population
	B10. Expenses on human capital development, % to GRP
C. Environmental	C1. Volume of goods, works and services in mining and quarrying, % to GRP
	C2. Volume of goods, works and services in water supply; sewerage, waste management and remediation activities, % to GRP

	C3. Environmental protection expenditures, % to GRP
	C4. The index of physical volume of environmental protection expenses, % to previous year
	C5. Change of wood reserves, mln m3
	C6. Current expenditures for woods reproduction and for afforestation, mln rubles/GDP, mln rub
	C7. Recycled and consistent use of water, mln.m^3/GRP, mln rub
	C8. Discharge of polluted sewage, mln.m^3/GRP, mln rub
	C9. CO emissions, thousand tones/GRP, mln rub
	C10. Emission of pollutants into atmosphere, % to the previous year
	C11. Atmospheric pollutants neutralized, %
	C12. Share of especially protected natural territories , % to the total area of territory

Source: composed by the authors.

2 Results and discussion

Moscow, Tver, Voronezh, Nizhny Novgorod and Leningrad regions are among the leaders of the index (see tab.3). These regions are the most economically developed industrial regions of the Russian Federation. Development of infrastructure, high level of economic and social development together with high potential for further progress are specific to these regions. These regions are among the most dynamically developing regions of Russia. Moscow city is on the 11th place.

Arkhangelsk region's 4th place can be explained by its high positions in A1, A8, B1, B4, B5, B9, C1, C3, C9, C10 indicators (see tab.2). It's one of the industrial regions of Russia and the center of nuclear shipbuilding in Russia. The Plesetsk cosmodrome is located in the region. The region has significant reserves of natural resources (forests, oil, gas, bauxites, titanium ores, gold, diamonds).

Belgorod region is among the leaders by B1, B5, B9 and C9 indicators. Kursk region is among the leaders by B1, B9 and C9 indicators. Belgorod and Kursk regions are industrial-agrarian regions whose economy based on large reserves of iron ore of the Kursk Magnetic Anomaly and fertile black earth agricultural land.

Mordovia Republic is the leader by C1 indicator and among the leaders by A8, B1, B9, C9 and C11 indicators. The main industries in Mordovia are machine building and metalworking, chemical and petrochemical industry, food industry. Mordovia is one of the leading regions in terms of the share of innovative products in the total volume of industrial products.

Yakutia Republic is the leader by B1, B9, C5 and C12 indicators and among the leaders by C9 indicator. It's the largest subject of the Russian Federation by area. Yakutia's industry is focused on extraction and enrichment of raw materials; the republic is rich in natural resources. The republic has a very powerful diamond mining industry. Yakutia has the largest uranium deposit in the country.

Tab. 3. The overall rating of regional sustainability: leaders and outsiders

Leaders		*Outsiders*	
Moscow Region	1	Tomsk Region	76
Tver Region	2	Buryatia Republic	77
Belgorod Region	3	Trans Baikal Territory	78
Arkhangelsk Region	4	Karelia Republic	79
Kursk Region	5	Chechen Republic	80
Voronezh Region	6	Yugra Area	81
Leningrad Region	7	Khakassia Republic	82
Mordovia Republic	8	Kalmykia Republic	83
Nizhny Novgorod Region	9	Tuva Republic	84
Yakutia Republic	10	Ingushetia Republic	85

Source: composed by the authors

Sustainability index is a linear combination of the whole set of modified principal component scores: $I_j = \sum_{k=1}^{n} \left(\lambda_k \sum_{i=1}^{n} l_{ki}^2 x_{ij} \right) \Big/ \sum_{k=1}^{n} \lambda_k$. So it can be considered as a composition of partial indices which sum up weighted modified principal component scores for each data pillar. These sub-indices generate the region's rankings with respect to particular pillars (see tab.4). They provide a glimpse of the factors of sustainable development and of the potential for its improvement.

Tab. 4. Pillars A. Economical, B. Social and C. Environmental: leaders and outsiders

		Economical	*Social*	*Environmental*
Leaders	*1*	Moscow City	Chukotka Area	Tver Region
	2	Saint Petersburg City	Nenets Area	Altay Republic
	3	Arkhangelsk Region	Magadan Region	Pskov Region
	4	Moscow Region	Yamal Nenets Area	Smolensk Region
	5	Amur Region	Sakhalin Region	Yakutia Republic
	6	Tatarstan Republic	Kamchatka Territory	Saratov Region
	7	Mordovia Republic	Moscow Region	Kursk Region
	8	Khabarovsk Territory	Belgorod Region	Murmansk Region
	9	Belgorod Region	Lipetsk Region	Mari El Republic
	10	Tyumen Region	Voronezh Region	Orel Region
		Economical	*Social*	*Environmental*
Outsiders	*76*	Tomsk Region	Khakassia Republic	Tuva Republic
	77	Crimea Republic	Altay Republic	Chukotka Area
	78	Kalmykia Republic	Karachayevo-Cherkessia Republic	Saint Petersburg City
	79	Khakassia Republic	Trans Baikal Territory	Chechen Republic
	80	Ivanovo Region	Kalmykia Republic	Ingushetia Republic
	81	Yugra Area	Kabardino-Balkaria Republic	Magadan Region
	82	Orenburg Region	Saint Petersburg City	Yugra Area
	83	Pskov Region	Moscow City	Yamal Nenets Area
	84	Komi Republic	Ingushetia Republic	Sakhalin Region
	85	Karelia Republic	Tuva Republic	Nenets Area

Source: composed by the authors

We also obtained sustainability index for districts of Russian Federation by summing up final scores of regions included in the certain aggregate district (see tab.5). The predictable leader here is Central federal district.

Tab. 5. The overall rating of districts sustainability

Central Federal District	1
Volga Federal District	2
Siberian Federal District	3
Northwestern Federal District	4
Far Eastern Federal District	5
Southern Federal District	6
North Caucasus Federal District	7
Ural Federal District	8

Source: composed by the authors

Conclusion

Unlike most of the existing sustainability ratings, our rating methodology reflects a comprehensive approach to assessing regional sustainability. The rating provides an integral assessment of the current state of sustainability of Russian regions. We used only official statistics published by federal agencies, so there are some disadvantages due to the lack of sufficient statistical information. We do not use any expert assessments, which require complicated and expensive research.

In fact, our research lays the foundation for regular (e.g., once in 5 years) consideration of sustainability of the Russian Federation regions. Investigation of the factors that determine the positions of the regions in sustainability ranking can be used to improve ecological, social and economic policy in Russian regions. It is obvious that in order to improve regional sustainability more attention and investments should be allocated to the projects which maintain environmental, social and economic development.

As a matter of further research, the inclusion of new environmental, economic and social components in our index, can serve to improve the comprehensive index of sustainable development of Russian regions.

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