RELAÇÕES INTERNACIONAIS NO MUNDO ATUAL

CENTRO UNIVERSITÁRIO CURITIBA - UNICURITIBA - VOLUME 3 - NÚMERO 36/2022 CURITIBA/PARANÁ/BRASIL - PÁGINAS 623 A 647- ISSN: 2316-2880

CLUSTER ANALYSIS OF RUSSIAN REGIONS BY ECONOMIC AND DEMOGRAPHIC INDICATORS TO IMPROVE THE STRATEGIES OF DEVELOPMENT INSTITUTIONS

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ABSTRACT

Objective: The aim of the study is to create a classification of the subjects of the Russian Federation by economic development and demographics. **Methods:** The classification of the subjects of the Russian Federation is performed using cluster analysis. The study of relationships focuses on the following indicators: gross regional product per capita, average per capita amount of fixed assets and investment, share of small and medium-sized entrepreneurship in gross regional product, labor productivity index, per capita gross regional product index, subsistence minimum, median income of the population, the excess of the median income over the subsistence minimum, and percentage of the population with incomes below the subsistence minimum. For each cluster group, Pearson and Spearman correlation coefficients are calculated, and the relationship of the indicators is evaluated. **Results:** Research into the economic conditions of the regions suggests five cluster groups similar in their economic situation and problems. In the presence of relationships, power regression models are constructed, on the basis of which the influence of factor attributes on the resultant is quantitatively evaluated. **Conclusion:** Clustering by demographic indicators reveals the division of the population of Russian regions into three cluster groups. The cluster with a poor demographic situation includes almost half of the Russian regions (40 constituent entities), characterized by low birth rates, high mortality, and negative migratory population growth. The study also touches upon the issue of regional unemployment, which rose in all Russian regions in 2021. Based on the conducted research, economic conclusions are derived for the purpose of developing an effective strategy for development institutions.

Keywords: Clustering of the regions of the Russian Federation; Economic development of the regions; Demographic development of the regions; Unemployment; Development institutions.

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

ANÁLISE DE AGRUPAMENTO DAS REGIÕES RUSSAS POR INDICADORES ECONÓMICOS E DEMOGRÁFICOS PARA MELHORAR AS ESTRATÉGIAS DAS INSTITUIÇÕES DE DESENVOLVIMENTO

RESUMO

Objectivo: O objectivo do estudo é criar uma classificação dos temas da Federação Russa por desenvolvimento económico e demográfico. **Métodos:** A classificação dos temas da Federação Russa é realizada utilizando a análise de agregados. O estudo das relações centra-se nos seguintes indicadores: produto regional bruto per capita, montante médio per capita de activos fixos e investimento, quota-parte de pequenos e médios empresários no produto regional bruto, índice de produtividade laboral, índice de produto regional bruto per capita, mínimo de subsistência, rendimento mediano da população, excesso do rendimento mediano sobre o mínimo de subsistência, e percentagem da população com rendimentos abaixo do mínimo de subsistência. Para cada grupo de agregados, são calculados os coeficientes de correlação de Pearson e Spearman, e é avaliada a relação dos indicadores. **Resultados:** A investigação sobre as condições económicas das regiões sugere cinco grupos de agregados semelhantes na sua situação e problemas económicos. Na presença de relações, são construídos modelos de regressão de poder, com base nos quais a influência dos atributos dos factores no resultante é avaliada quantitativamente. **Conclusão:** A agregação por indicadores demográficos revela a divisão da população das regiões russas em três grupos de agregados. O agrupamento com uma situação demográfica pobre inclui quase metade das regiões russas (40 entidades constituintes), caracterizado por baixas taxas de natalidade, elevada mortalidade, e crescimento populacional migratório negativo. O estudo aborda também a questão do desemprego regional, que aumentou em todas as regiões russas em 2021. Com base na investigação conduzida, são extraídas conclusões económicas com o objectivo de desenvolver uma estratégia eficaz para as instituições de desenvolvimento.

Palavras-chave: Aglomeração das regiões da Federação Russa; Desenvolvimento económico das regiões; Desenvolvimento demográfico das regiões; Desemprego; Instituições de desenvolvimento.

1 INTRODUCTION

The efforts of development institutions are aimed at solving strategic tasks related to the social, economic, and financial state of the country by creating favorable conditions for investment based on minimizing the cost of doing business, developing effective policies in the operation of critical sectors of the national economy, and improving the quality of management of regional economies.

The development of strategies for the operation of development institutions within the country is enhanced by the transition from analyzing the economic and social activities of an individual subject of the Russian Federation to a group of subjects (regions) that are homogeneous by the studied parameters. In this case, it becomes

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

possible to detect key patterns of the socio-economic development of the regions, which are difficult or impossible to detect when analyzing one constituent entity. Furthermore, it is much easier and more effective to develop the policies of development institutions for groups of similar regions rather than for each region separately.

In the present paper, we report the results of a classification of the constituent entities of the Russian Federation via cluster analysis methods by the level of their economic development and the demographic situation (mortality and birth rate), as well as provide some conclusions on the study of unemployment in the country.

The experience of studying the socio-economic situation of the regions based on cluster analysis of the subjects of the Russian Federation is described in a number of works of Russian researchers. N.V. Proskurina (2021) provides an aggregate assessment of the economic development of the regions of Russia based on the target indicators of the obtained cluster groups. A.N. Namgalauri (2019) examines the availability of innovation infrastructure elements in the regions of the Central Federal District using a cluster analysis of Russian regions by the availability of innovation infrastructure, which directly affects their competitiveness level.

A clustering of Russian regions according to the models of industrial-innovation development is proposed in the work of A. Doroshenko. The author considers four variants of the model: with low industrial development and low innovative efficiency; with low industrial development and high innovative efficiency; with high industrial development and low innovative efficiency; and with high levels of both industrial development and innovative efficiency (Doroshenko et al., 2022).

S.G. Bylina (2021) studies the classification of Russian regions from the point of comprehensive development of rural areas. The researcher concludes on the need to connect regional programs for the development of agriculture with programs for the informatization of rural areas, which are based on innovative approaches to the development of the agro-food complex and the structural reorganization of agricultural production.

A study by Shchukina et al. (2020) demonstrates the expediency of using cluster analysis to study regions in terms of the living standards of the population. A classification of Russian regions by living standards for the period from 2010 to 2018 is provided by N.A. Shchukina and A.V. Golub (2020) in a different study. It must be said that the improvement of living standards is often associated with the transition from the traditional model of the economy to a green economy model and the formation

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

of eco-innovation policies, as stated, for example, by E.A. Borkova et al. (2019).

The effects of the labor potential of the population on the economic growth of regional economies are investigated by Iu.N. Krivokora et al. (2021), V.V. Manuilenko and V.A. Butnar (2019). The authors propose a method for the study of these effects based on the clustering of the regions of Russia according to the level of development of the integral indicator of labor potential.

The directions of action of development institutions are more or less determined by the conclusions arising from scientific research on regions. S.A. Grebenkina examines the issue of the development of subsidized regions that do not have enough funds to implement major social and economic programs. The researcher argues for the need to create a typology of such regions and establish a universally approved classification of subsidized regions considering their specifics and prospects for development (Grebenkina, 2020). G.A. Gadelshina (2022) offers a method for the integral assessment of the level of development of the subject of the Russian Federation in its dynamics, considering a broad range of socio-economic factors. Instability in the development of the region is assessed based on outliers and residual variance, calculated after the construction of an approximating linear trend of the integral assessment.

M.V. Gogitidze (2021) examines the labor market in the regions of the Russian Federation based on the indicators of employment, unemployment, decent work indicators, and the distribution of graduates from educational institutions. It is worth noting that the need for such research exists and that it is also necessary to conduct additional research into competition in the labor market and the demand for specific professions.

The problem of creating an optimal mechanism for managing regional economies from the point of the theory of regional reproduction is considered in a study by E.A. Bazhutova (2020). G.A. Borshchevskii (2020) proposes a method for predicting the number of regional government staff considering the socio-economic development of the territory under different scenarios of the growth of labor productivity: conservative, innovative, and forced. Research into this issue is relevant for improving the effectiveness of management of the constituent entities of Russia.

2 METHODS

The classification of Russian regions by the level of economic development by

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

means of cluster analysis was performed by the following indicators calculated by Rosstat (Federal State Statistics Service, n.d).

Gross regional product per capita (2019 data; unit of measure – Russian ruble, indicator value for the year; the variable name in the following analysis is “GRP per capita”) was calculated as the ratio of the gross regional product (GRP) in current basic prices to the average annual number of the resident population.

The expediency of using such an indicator as GRP per capita in the clustering of the subjects of the Russian Federation is proved, for example, in a study by D.V. Kolechkov (2019).

Excess of median income over the subsistence minimum (2020 data; unit of measurement – times; hereinafter – “Income/minimum”) was calculated as the ratio of the median per capita monetary income (income of 50% of the population) to the subsistence minimum.

The volume of investment in fixed capital per capita in actual prices (2019 data; unit of measure – Russian ruble; hereinafter – “Investment”) was estimated as the ratio of the volume of investment in fixed capital for the year to the average annual number of the resident population (according to 2019 data).

The amount of fixed assets per capita (2019 data; unit of measure – Russian ruble; hereinafter – “Funds”) was defined as the ratio of the volume of fixed assets for the year to the average annual number of the resident population.

The number of people with incomes below the subsistence minimum as a percentage of the total population (2020 data; hereinafter – “Share of the poor”) was derived from data on the distribution of the population by the average monetary income per capita and its comparison with the subsistence minimum; the unit of measurement is the percentage of the total population.

The indicators not adopted for clustering but considered in the analysis included the following.

The share of small and medium entrepreneurship in the gross regional product (2019 data; the measurement unit is percent; the variable name in the following analysis is “Share of SE”), a relative indicator that characterizes the contribution of small and medium-sized businesses in the formation of gross regional product.

The index of the physical volume of gross regional product per capita (2019 data; unit of measurement – Russian ruble; hereinafter – “GRP index”) was estimated as the quotient of the division of the index of physical volume of GRP and the index of change in the resident population.

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

The labor productivity index in 2020 compared to 2015 (unit of measurement – times; the variable name in the following analysis – "Labor productivity") was derived through the chain growth rate of labor productivity for 2015-2020.

"The share of small and medium entrepreneurship in the GRP" was not included in the clustering, as its estimation does not reflect the direction of the region's development trends. For example, for a region with a large volume of GRP, a 2% increase in the share of small and medium-sized businesses in the structure of GRP would be more substantial than for regions with a small volume of GRP.

The "Index of the physical volume of gross regional product per capita" and "Labor productivity index in 2020 compared to 2015" were also excluded from clustering for the same reason. Interpretation of changes in these indicators is directly contingent on the absolute value of a 1% increase. Thus, the choice of these indicators is only appropriate when comparing regions with comparable size economies.

Since the overall sample of the assessed regions was fairly heterogeneous, the aforementioned indicators were considered in the analysis of development trends within cluster groups, since the regions included in one cluster are homogeneous and comparable.

We should emphasize that the classification of Russian regions was performed based only on the most considerable and influential indicators of economic development. This approach was taken so as to prevent the problem of a large number of indicators of secondary importance "clogging" the cluster analysis and devaluing the involvement of more significant indicators by participating in the clustering on par with them. The option of setting weights was not applied since the weight values are determined primarily based on an expert opinion, which may be erroneous.

Furthermore, a separate clustering of Russian regions was conducted according to demographic indicators of natural and migratory population movement.

The k-means method was chosen as the main clustering method. A hierarchical procedure (the k-nearest neighbor method) was preliminarily used to construct an association dendrogram in order to determine the optimal number of groups (clusters). Before the procedure, the values of the initial indicators were normalized (standardized) to eliminate the influence of units of measurement on the clustering results. The quality of the partitioning was assessed through analysis of variance, by testing the hypothesis of the equality of variance between clusters and within clusters. The Euclidean distance served as a measure of proximity.

The connection between the indicators was assessed via Pearson and Spearman

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

correlation coefficients. Their significance was tested by Student's t-test at the level of $p < 0.05$.

As regression models of dependencies, we applied the paired power function ($y = a_0 x^{a_1}$) and the multiple power function ($y = a_0 x_1^{a_1} x_2^{a_2} x_3^{a_3}$). The parameters a_0 , a_1, a_2 $and\ a_3$ were determined by the least-squares method using a linearization procedure via the logarithm method. The significance of the models was estimated based on Fisher's F-test, and the significance of regression coefficients was assessed by Student's t-test; the level of significance was taken as 0.05. The obtained regression models were tested for heteroscedasticity via the White test. The normality of the distribution of the model residuals was established using the Shapiro-Wilk criterion. The quality of the resulting regression models was determined by the value of the determination coefficient.

The calculations were performed in STATISTICA 13.0.

3 RESULTS

3.1 Results of the clustering of Russian regions by the level of economic development

The performed hierarchical clustering procedures suggested the optimal number of clusters to be 5.

Cluster 1 combines ten regions with well-developed extractive industries: Nenets Autonomous Okrug (Arkhangelsk Oblast), Khanty-Mansi Autonomous Okrug-Yugra (Tyumen Oblast), Yamalo-Nenets Autonomous Okrug (Tyumen Oblast), Sakhalin Oblast, Chukotka Autonomous Okrug, Magadan Oblast, the Sakha Republic (Yakutia), the Komi Republic, Murmansk Oblast, Tyumen Oblast (except for Khanty-Mansi Autonomous Okrug-Ugra and Yamalo-Nenets Autonomous Okrug). These regions demonstrate abnormally high (relative to the national average) values of the average per capita GRP. The average values of the indicators of cluster 1 are presented in Table 1.

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

Table 1. Mean values of the clusters

Indicator	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
GRP per capita, RUB	2,541,691	674,009	538,580	380,243	274,174
Share of small and medium entrepreneurship in GRP, %	10.7	24.7	24.4	28.2	27.2
GRP index, %	102.0	101.8	101.1	102.5	102.1
Labor productivity index, %	110.1	110.5	109.8	112.0	109.2
Share of the population with income below the subsistence minimum, %	10.5	10.2	12.7	13.5	20.4
Median income, RUB	45,515	29,502	24,541	22,497	18,627
Subsistence minimum, RUB	17,455	11,968	11,988	11,002	10,937
Excess of median income over the subsistence minimum, times	2.6	2.5	2.1	2.0	1.7
Average per capita investment in fixed capital, RUB	678,847	134,049	109,631	87,962	64,982
Amount of fixed assets per capita, RUB	8,687	2,331	1,960	1,542	1,179

Source: the authors' calculations

The constructed correlation matrix (Table 2) suggests the following conclusions about the regions in cluster 1:

- the higher the region's GRP, the larger is its industry (inverse correlation with the share of SE in the GRP);
- GRP is strongly contingent on the amount of investment and fixed assets;
- the growth of GRP goes almost in parallel to the rise in labor productivity.

It is worth noting that the study of the relationship between GRP and other indicators is covered in previous research by Russian scholars. For instance, I.A. Proshin (2022) examines the relationship between GRP and the subsistence minimum, unemployment rate, population, and minimum accrued salaries.

Table 2. Pearson correlation coefficients (above the diagonal) and Spearman correlation coefficients (below the diagonal) for cluster 1

Indicator	Correlation coefficients significant at the 0.05 level are highlighted									
	GRP per capita	Share of SE	GRP index	Labor productivity	Share of the poor	Median income	Subsistence minimum	Income /minimum	Investment	Funds
GRP per capita	1.000	**-0.742**	-0.094	-0.325	-0.527	**0.652**	0.329	**0.714**	**0.990**	**0.961**
Share of SE	**-0.873**	1.000	0.157	0.528	0.376	-0.468	-0.202	-0.560	**-0.731**	**-0.754**
GRP index	-0.164	0.342	1.000	**0.706**	-0.227	0.415	0.500	0.217	-0.041	-0.038
Labor productivity	-0.400	0.509	**0.683**	1.000	0.021	-0.044	-0.055	0.027	-0.249	-0.220
Share of the poor	**-0.655**	0.445	-0.182	0.027	1.000	**-0.775**	-0.382	**-0.875**	-0.474	-0.555
Median income	**0.691**	-0.500	0.364	-0.045	**-0.836**	1.000	**0.808**	**0.798**	**0.651**	0.584
Subsistence minimum	0.318	-0.136	0.524	0.091	-0.327	**0.745**	1.000	0.295	0.347	0.167

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

Income/minimum	**0.818**	**-0.636**	0.023	-0.145	**-0.936**	**0.845**	0.345	1.000	**0.695**	**0.772**
Investment	**0.918**	**-0.873**	-0.173	-0.255	-0.536	**0.655**	0.373	**0.718**	1.000	**0.956**
Funds	**0.855**	**-0.900**	-0.237	-0.391	-0.582	0.500	-0.027	**0.736**	**0.764**	1.000

Source: the authors' calculations

The analysis reveals that the share of the population below the subsistence minimum *(y)* shows an inverse nonlinear dependence on the average per capita GRP *(x)*. This dependence is best described by the following power equation of pairwise regression:

$$\hat{y}_x = 1025.8779 \cdot x^{-0.320404}$$

Statistical characteristics of the resulting equation: determination coefficient – 44%; the equation is significant based on Fisher's F-test at the p<0.02629 level; the regression coefficients are significant based on Student's t-test at the level of p<0.003291 (free member) and p<0.026288 (regression coefficient); heteroscedasticity is not observed.

Based on the obtained equation, a 1% increase in the average per capita GRP causes a 0.32% reduction in the share of the population below the subsistence minimum.

The connection between the average per capita GRP *(x)* and median income *(y)* is demonstrated by the following equation:

$$\hat{y}_x = 392.31614 \cdot x^{0.324985}$$

Characteristics of the model: determination coefficient – 53%; the equation is significant based on Fisher's F-test at the level of p<0.01083; the regression coefficients are significant based on Student's t-test with p<0.002856 (free member) and p<0.010834 (regression coefficient); heteroscedasticity is not detected.

The equation indicates that a rise in the average per capita GRP by 1% increases the median income by 0.32%.

The dependence of median income *(y)* on the amount of investment per capita *(x)* is described by the following equation:

$$\hat{y}_x = 1007.81611 \cdot x^{0.287573}$$

The determination coefficient of the obtained equation is 53%; the equation is significant based on Fisher's F-test at the level of p<0.0111; the regression coefficients are significant based on Student's t-test at the level of p<0.000245 (free member) and p<0.011097 (regression coefficient); heteroscedasticity in the remnants of the model is not observed.

Thus, a 1% growth of the average per capita investment results in a 0.23% increase

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

in the median income of the population.

The power equation of the dependence of the average per capita GRP *(y)* on the labor productivity index *(x)* is:

$$\hat{y}_x = 47.626532 \cdot x^{0.162137}$$

The characteristics of the resulting equation are as follows: determination coefficient – 47%; the equation is significant based on Fisher's F-test at the level of p<0.01987; the regression coefficients are significant based on Student's t-test at the level of p<0.00000001 (free member) and p<0.019868 (regression coefficient); heteroscedasticity is absent.

The obtained equation indicates that a 1% increase in labor productivity causes the average per capita GRP to rise by 0.16%.

The best approximation to describe the dependence of the average per capita GRP *(y)* on the average per capita investment (x_1) and fixed assets (x_2) is the following power equation of multiple regression:

$$\hat{y}_x = 46.973565 \cdot x_1^{0.640752} \cdot x_2^{0.258319}$$

The determination coefficient of the obtained equation is 97%; the equation is significant based on Fisher's F-test at the level of p<0.00000001; the regression coefficients are significant based on Student's t-test at the level of p<0.000684 (free member), p<0.00009 (regression coefficient for x_1), and p<0.015416 (regression coefficient for x_2), heteroscedasticity is absent.

The resulting model suggests that a 1% increase in the average per capita investment raises the average per capita GRP by 0.64%, and a 1% increase in the average amount of fixed assets per capita causes the average per capita GRP to grow by 0.26%.

The second cluster is comprised of 12 economic regions: Moscow, St. Petersburg, Moscow Oblast, Leningrad Oblast, Krasnoyarsk Krai, Kamchatka Krai, the Republic of Tatarstan, Irkutsk Oblast, Belgorod Oblast, Sverdlovsk Oblast, Perm Krai, Primorsky Krai, Kaluga Oblast, Samara Oblast, Nizhny Novgorod Oblast, Lipetsk Oblast, Yaroslavl Oblast, Kursk Oblast, and Voronezh Oblast.

The average values of the indicators in cluster 2 are provided in Table 1. Table 3 shows the coefficients of correlation between the indicators.

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

Table 3. Pearson correlation coefficients (above the diagonal) and Spearman correlation coefficients (below the diagonal) for cluster 2

Indicator	Correlation coefficients significant at the 0.05 level are highlighted									
	GRP per capita	Share of SE	GRP index	Labor productivity	Share of the poor	Median income	Subsistence minimum	Income/minimum	Investment	Funds
GRP per capita	1.000	-0.428	-0.271	-0.169	-0.121	**0.863**	**0.673**	0.404	**0.731**	**0.849**
Share of SE	**-0.551**	1.000	0.288	-0.119	-0.443	-0.119	-0.324	0.328	**-0.511**	-0.125
GRP index	-0.247	0.313	1.000	0.111	-0.053	-0.110	-0.114	-0.016	-0.243	-0.141
Labor productivity	-0.111	-0.075	0.240	1.000	0.240	-0.114	0.133	-0.374	0.097	-0.173
Share of the poor	-0.207	-0.271	-0.014	0.384	1.000	-0.319	0.266	**-0.919**	-0.188	**-0.473**
Median income	**0.623**	0.056	-0.076	-0.073	**-0.509**	1.000	**0.784**	**0.520**	**0.603**	**0.878**
Subsistence minimum	**0.635**	-0.428	-0.102	0.183	0.284	**0.484**	1.000	-0.100	0.413	**0.509**
Income /minimum	0.147	0.316	0.038	-0.402	**-0.964**	**0.467**	-0.332	1.000	0.347	**0.649**
Investment	**0.665**	**-0.712**	-0.200	-0.036	-0.201	0.298	0.386	0.135	1.000	**0.683**
Funds	**0.565**	-0.125	-0.137	-0.139	**-0.496**	**0.639**	0.440	0.396	**0.340**	1.000

Source: author's calculations

The principal conclusions from the correlation coefficient matrix of the second cluster are as follows:

- GRP has a close direct correlation with the amount of investment and fixed assets;
- the share of the population below the subsistence minimum is not contingent on GRP (unlike in cluster 1);
- the median income of the population is in a close direct correlation with the average per capita GRP.

The dependence of the median income of the population *(y)* от the average per capita GRP *(x_1)* and the amount of fixed assets per capita *(x_1)* is described by a power function:

$$\hat{y}_x = 22.042756 \cdot x_1^{0.300305} \cdot x_2^{0.409623}.$$

The statistical characteristics of the resulting model are as follows: determination coefficient – 77%; the equation is significant based on Fisher's F-test at the level of p<0.00001; the regression coefficients are significant based on Student's t-test at the

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

level of p<0.034095 (free member), p<0.040117 (regression coefficient for x_1), and p<0.011763 (regression coefficient for x_2), heteroscedasticity in the remnants of the model is not observed.

The calculated model indicates that a rise in the average per capita GRP by 1% causes a 0.3% increase in median income, and a 1% increase in fixed assets leads to a 0.41% growth in median income.

The dependence of median income *(y)* on the average per capita GRP *(x)* can also be described by a linear function:

$$\hat{y}_x = 10016.87 + 0.03x$$

The determination coefficient of the obtained equation amounts to 74%; the equation is significant based on Fisher's F-test at the p<0.000000012 level; the regression coefficients are significant based on Student's t-test at the level of p<0.003553 (free member) and p<0.000002 (regression coefficient), heteroscedasticity is lacking.

Therefore, an increase in the average per capita GRP by 100 thousand RUB leads the median income of the population to rise by 3 thousand RUB.

The dependence of the average GRP per capita *(y)* on the average per capita investment *(x_1)* and the amount of fixed assets per capita *(x_2)* is described by the following power function of multiple regression:

$$\hat{y}_x = 150.317541 \cdot x_1^{0.349644} \cdot x_2^{0.55145}$$

Characteristics of the model: determination coefficient – 68%; the equation is significant based on Fisher's F-test at the level of p<0.00013; the regression coefficients are significant based on Student's t-test at the level of p<0.00873 (free member), p<0.04146 (regression coefficient при переменной x_1), p<0.004924 (regression coefficient при переменной x_2), heteroscedasticity in the remnants of the model is not observed.

Accordingly, a 1% increase in average per capita investment entails a 0.35% growth of the average per capita GRP, and a 1% increase in the average per capita amount of fixed assets causes the average per capita GRP to rise by 0.55%.

The third cluster contains 11 regions with an average level of economic development: Khabarovsk Krai, Astrakhan Oblast, Tomsk Oblast, Orenburg Oblast, Vologda Oblast, Novosibirsk Oblast, the Republic of Udmurtia, Tula Oblast, Krasnodar Krai, the Republic of Bashkortostan, and Chelyabinsk Oblast.

The average values of the indicators of cluster 3 are included in Table 1. The correlation coefficients between the indicators are provided in Table 4.

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

Table 4. Pearson correlation coefficients (above the diagonal) and Spearman correlation coefficients (below the diagonal) for cluster 3

Indicator	Correlation coefficients significant at the 0.05 level are highlighted									
	GRP per capita	Share of SE	GRP index	Labor productivity	Share of the poor	Median income	Subsistence minimum	Income/minimum	Investment	Funds
GRP per capita	1.000	**-0.721**	0.108	0.122	0.431	0.389	**0.815**	**-0.788**	**0.682**	**0.629**
Share of SE	**-0.692**	1.000	-0.269	-0.411	-0.453	0.155	-0.320	**0.691**	-0.448	-0.330
GRP index	0.323	-0.316	1.000	**0.780**	0.486	-0.450	-0.258	-0.136	-0.174	-0.248
Labor productivity	0.182	-0.238	**0.847**	1.000	0.383	-0.368	-0.182	-0.197	0.055	-0.044
Share of the poor	**0.580**	-0.469	0.394	0.168	1.000	-0.391	-0.022	-0.546	0.026	-0.115
Median income	0.231	0.322	-0.376	-0.245	-0.378	1.000	**0.769**	0.049	0.443	**0.648**
Subsistence minimum	0.503	0.028	-0.397	-0.392	0.126	**0.811**	1.000	**-0.585**	**0.652**	**0.733**
Income/minimum	-0.503	**0.727**	-0.200	-0.056	**-0.699**	0.357	-0.161	1.000	-0.462	-0.273
Investment	**0.664**	-0.469	0.053	0.308	0.280	0.364	0.483	-0.266	1.000	**0.738**
Funds	0.399	-0.133	-0.077	0.196	-0.091	**0.636**	0.476	0.098	**0.629**	1.000

Source: the authors' calculations

Thus, in the third cluster group, direct correlations are observed between the average per capita GPR and the average per capita amounts of investment and fixed assets, as well as between the labor productivity index and the average per capita GRP. The link between the size of the median income of the population and the average per capita GRP is statistically insignificant (which disrupts the logical pattern of phenomena), yet the median income proves to be sufficiently related to the average per capita size of fixed assets, which indicates a close connection between the economic well-being of the population and the level of industrial development of the region.

The dependence of the average per capita GRP *(y)* on the labor productivity index *(x)* is described by a power regression equation:

$$\hat{y}_x = 63.094525 \cdot x^{0.100349}$$

The key statistic characteristics of the obtained model are as follows: determination coefficient – 63%; the equation is significant based on Fisher's F-test at the level of $p<0.00214$; the regression coefficients are significant based on Student's t-test at the levels of $p<0.00000003$ (free member) and $p<0.00214$ (regression coefficient); no heteroscedasticity is detected.

Thus, in the regions of the second cluster, a 1% increase in the labor productivity index results in a 0.1% rise in the average per capita GRP.

The fourth cluster comprises 25 constituent entities of Russia with a low level of

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

economic development: the Republic of Karelia, Amur Oblast, Kaliningrad Oblast, Arkhangelsk Oblast (except for the Nenets Autonomous Okrug), the Republic of Khakassia, Novgorod Oblast, Kemerovo Oblast - Kuzbass, Omsk Oblast, Vladimir Oblast, Ryazan Oblast, Rostov Oblast, Volgograd Oblast, Tver Oblast, Smolensk Oblast, Orel Oblast, Tambov Oblast, Penza Oblast, Saratov Oblast, Bryansk Oblast, Kostroma Oblast, Sevastopol, the Adygeya Republic, Ivanovo Oblast, the Republic of North Ossetia-Alania, and the Republic of Dagestan.

Average indicator values by cluster are demonstrated in Table 1. Pearson and Spearman correlation coefficients for links between the indicators are presented in Table 5.

Table 5. Pearson correlation coefficients (above the diagonal) and Spearman correlation coefficients (below the diagonal) for cluster 4

Indicator	Correlation coefficients significant at the 0.05 level are highlighted									
	GRP per capita	Share of SE	GRP index	Labor productivity	Share of the poor	Median income	Subsistence minimum	Income/minimum	Investment	Funds
GRP per capita	1.000	**-0.614**	0.230	0.080	0.251	**0.562**	**0.754**	-0.359	**0.427**	**0.714**
Share of SE	**-0.561**	1.000	-0.076	-0.062	-0.288	-0.180	-0.383	0.362	-0.324	-0.329
GRP index	-0.028	0.057	1.000	0.277	0.146	0.308	0.308	-0.025	**0.765**	0.349
Labor productivity	0.045	0.008	**0.409**	1.000	0.354	-0.012	-0.006	-0.005	0.007	0.040
Share of the poor	0.151	-0.136	0.044	0.342	1.000	-0.138	0.265	**-0.690**	0.154	-0.120
Median income	**0.398**	-0.044	0.070	0.057	-0.233	1.000	**0.836**	0.245	**0.500**	**0.604**
Subsistence minimum	**0.592**	-0.257	0.088	0.067	0.133	**0.682**	1.000	-0.324	**0.463**	**0.664**
Income/minimum	-0.279	0.210	0.041	-0.039	**-0.558**	**0.405**	-0.258	1.000	0.037	-0.145
Investment	**0.431**	-0.389	-0.012	-0.155	-0.167	**0.508**	0.191	0.314	1.000	**0.404**
Funds	**0.639**	-0.328	0.136	0.043	-0.131	**0.645**	**0.778**	-0.108	**0.377**	1.000

Source: the authors' calculations

Analysis of the Pearson and Spearman correlation coefficients suggests the following conclusions for cluster 4. The GRP is contingent on the size of fixed funds (quite a close connection) and weakly associated with the amount of investment per capita. The growth of the GRP (GRP index) is directly dependent on the amount of investment. The median income of the population shows населения has an average degree of correlation with the average GRP per capita and the amount of fixed assets and investment per capita (average correlation). Furthermore, the rise of the share of small and medium-sized enterprises in the structure of GRP in these regions leads to the reduction of GRP and not its rise. This suggests that the very organization of small and medium entrepreneurship in these territories is ineffective and requires assistance

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from development institutions.

The dependence of per capita GRP *(y)* on the share of small and medium-sized businesses in GRP *(x_1)* and the amount of fixed assets per capita *(x_2)* is described by a power function of multiple regression:

$$\hat{y}_x = 128763.1565 \cdot x_1^{-0.44662} \cdot x_2^{0.34908}$$

Statistical characteristics of the calculated equation are as follows: determination coefficient – 71%; the equation is significant based on Fisher's F-test at the $p<0.0000004$ level; the regression coefficients are significant based on Student's t-test at the $p<0.00000005$ level (free member), $p<0.001737$ (regression coefficient with x_1), $p<0.000049$ (regression coefficient with x_2), heteroscedasticity in the model residuals is not observed.

Thus, with a 1% increase in the share of small and medium entrepreneurship in the structure of GRP, the size of the average per capita GRP decreases by 0.45%. In turn, a 1% rise in the average per capita amount of fixed assets causes a 0.35% increase in the average per capita GRP.

Cluster 5 comprises the poorest regions of Russia (a total of 20 regions): Jewish Autonomous Oblast, Transbaikal Krai, Ulyanovsk Oblast, the Republic of Mordovia, the Republic of Kalmykia, Pskov Oblast, the Republic of Mari El, Stavropol Krai, Kirov Oblast, the Republic of Buryatia, Kurgan Oblast, the Chuvash Republic, Altai Krai, the Altai Republic, the Republic of Crimea, the Tyva Republic, the Karachay-Cherkess Republic, the Kabardino-Balkar Republic, the Chechen Republic, and the Republic of Ingushetia. The calculated average indicators of the cluster show the extreme economic disadvantage of these territories (Table 1).

The values of Pearson and Spearman correlation coefficients (Table 6) indicate a weak interrelatedness of the economic indicators, proving the current regional policy ineffective. In this group the influence of fixed assets on GRP is still evident, but the link with investment is no longer effective. The share of the poor is inversely correlated with the share of small and medium-sized enterprises in GRP (a marked degree of correlation). This allows for a conclusion that further development of SE will improve the overall economic situation of the regions' population. The work of development institutions in these regions should therefore focus on support for small and medium-sized businesses.

The labor productivity index in this cluster group does not show a significant correlation with the GRP index, which indicates the low effectiveness of production in general.

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

Table 6. Pearson correlation coefficients (above the diagonal) and Spearman correlation coefficients (below the diagonal) for cluster 5

Indicator	Correlation coefficients significant at the 0.05 level are highlighted									
	GRP per capita	Share of SE	GRP index	Labor productivity	Share of the poor	Median income	Subsistence minimum	Income/ minimum	Investment	Funds
GRP per capita	1.000	-0.151	0.168	0.384	**-0.476**	**0.544**	0.257	**0.446**	0.319	**0.667**
Share of SE	-0.245	1.000	0.260	0.286	**-0.615**	0.156	-0.327	**0.621**	-0.108	-0.280
GRP index	0.068	0.220	1.000	0.442	**-0.525**	0.185	-0.289	**0.572**	0.198	0.046
Labor productivity	0.116	0.289	**0.455**	1.000	**-0.519**	0.362	0.084	0.412	0.390	0.154
Share of the poor	-0.395	**-0.576**	-0.394	-0.301	1.000	**-0.509**	0.208	**-0.953**	-0.054	-0.222
Median income	**0.495**	0.230	0.302	0.220	-0.439	1.000	**0.707**	**0.484**	**0.446**	**0.616**
Subsistence minimum	0.051	-0.189	0.065	-0.008	0.314	**0.618**	1.000	-0.274	**0.530**	**0.574**
Income/minimum	0.353	**0.633**	**0.473**	0.253	**-0.937**	0.427	-0.338	1.000	-0.041	0.126
Investment	0.414	-0.185	0.351	0.391	-0.078	0.430	0.359	0.012	1.000	**0.532**
Funds	**0.750**	-0.203	0.129	0.295	-0.335	0.405	0.162	0.183	**0.457**	1.000

Source: the authors' calculations

The power equation of the dependence of the average per capita GRP *(y)* on the amount of fixed assets *(x)* takes the form:

$$\hat{y}_x = 17198.234 \cdot x^{0.394616}$$

Characteristics of the model: determination coefficient – 64%; the equation is significant based on Fisher's F-test at the level of p<0.00002; the regression coefficients are significant based on Student's t-test with p<0.00000001 (free member) and p<0.000023 (regression coefficient); heteroscedasticity is not observed.

The derived model suggests that in the regions of the fifth cluster, a 1% rise in fixed assets causes a 0.39% increase in the average per capita GRP.

3.2 Results of the clustering of Russian regions by the intensity of natural and migratory population movement

The growing mortality and dropping birth rate observed in almost all regions of Russia make the study of natural population movement one of the most topical problems. It is needless to mention the extent to which these processes affect regional economies and the country as a whole.

The dynamics of the key demographic indicators of Russian regions in 2018 were analyzed previously by L.P. Kleeva (2020). Our study concerns the indicators recorded in 2020. Summary statistical characteristics of the indicators of birth rate, mortality, and migration growth in Russia are presented in Table 7.

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

Table 7. Statistical characteristics of the birth and mortality rates of the Russian Federation in 2020

Indicator	Mean	Median	Minimum	Maximum	Variation coefficient, %
Total birth rate, ppm	9.9	9.5	7.0	20.2	24.2
Total urban birth rate, ppm	10.2	9.6	7.5	26.2	27.2
Total rural birth rate, ppm	9.6	8.9	5.4 Mordovia	22.6	35.6
Total mortality, ppm	14.4	15.4	3.8	19.0	22.1
Total urban mortality, ppm	14.0	14.7	3.7	19.3	22.6
Total rural mortality, ppm	15.5	16.4	3.9 Ingushetia	22.4	26.7
Migration growth rate, ppm	1.03	-0.69	-15.7	131.3	1'423.3

Source: the authors' calculations

Table 7 shows that the regions most notably differ from one another by the intensity of migration processes (variation coefficient of 1423%) and to a small degree by the intensity of natural population movement.

In the course of the study, the clustering of the regions of the Russian Federation was carried out by the k-means method. The number of groups (3) was determined based on the analysis of the association dendrogram constructed in the course of hierarchical clustering by the k-nearest neighbor algorithm.

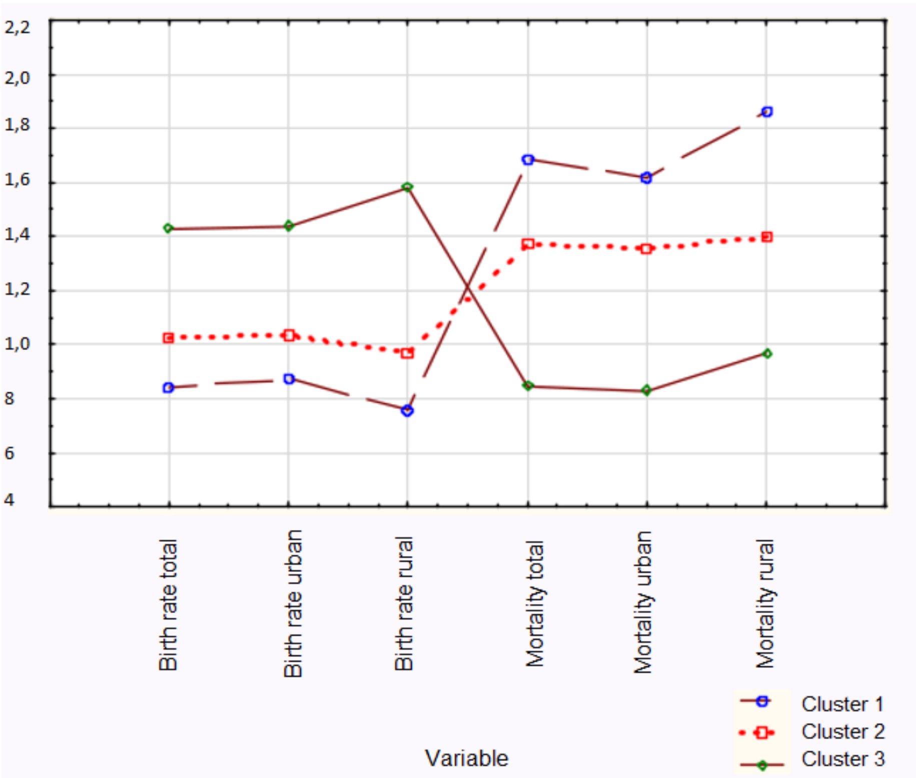

Figure 1. Graph of the mean values of clusters on a standardized scale
Source: compiled by the authors

The first cluster is characterized by the most favorable demographic situation in the country. It includes 11 regions: Moscow, Dagestan, Ingushetia, Kabardino-Balkaria,

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Chechnya, Altai, Tyva, Yakutia, Nenets Autonomous Okrug, Khanty-Mansi Autonomous Okrug-Yugra (Tyumen Oblast), and Yamalo-Nenets Autonomous Okrug (Tyumen Oblast).

Thirty-four subjects are included in the second cluster: Moscow Oblast, the Komi Republic, Kaliningrad Oblast, Leningrad Oblast, Murmansk Oblast, Saint-Petersburg, Adygea, Kalmykia, Crimea, Krasnodar Krai, Astrakhan Oblast, Sevastopol, Karachay-Cherkessia, North Ossetia-Alania, Stavropol Krai, Bashkortostan, Mari El, Tatarstan, Udmurtia, Perm Oblast, Tyumen Oblast (except for Yugra and Yamalo-Nenets Autonomous Okrug), Khakassia, Krasnoyarsk Krai, Irkutsk Oblast, Novosibirsk Oblast, Omsk Oblast, Tomsk Oblast, Buryatia, Transbaikal Krai, Kamchatka, Khabarovsk Krai, Sakhalin, Jewish Autonomous Oblast, and Chukotka.

The third cluster includes 40 regions: Belgorod Oblast, Bryansk Oblast, Vladimir Oblast, Voronezh Oblast, Ivanovo Oblast, Kaluga Oblast, Kostroma Oblast, Kursk Oblast, Lipetsk Oblast, Orel Oblast, Ryazan Oblast, Smolensk Oblast, Tambov Oblast, Tver Oblast, Tula Oblast, Yaroslavl Oblast, the Republic of Karelia, Arkhangelsk Oblast, Vologda Oblast, Novgorod Oblast, Pskov Oblast, Volgograd Oblast, Rostov Oblast, Mordovia, Chuvashia, Kirov Oblast, Nizhny Novgorod Oblast, Orenburg Oblast, Penza Oblast, Samara Oblast, Saratov Oblast, Ulyanovsk Oblast, Kurgan Oblast, Sverdlovsk Oblast, Chelyabinsk Oblast, Altai Krai, Kemerovo Oblast, Primorsky Krai, Amur Oblast, and Magadan Oblast.

The territories belonging to the first cluster have the highest birth rate and the lowest mortality rate compared to other Russian territories. Moreover, the relatively high birth rate is ensured by the high birth rate in rural areas, while in all other clusters the rural birth rate is lower compared to urban areas (Table 8).

Table 8. Characteristics of demographic indicators of the first cluster group

Indicator	Mean	Median	Minimum	Maximum	Variation coefficient, %
Total birth rate, ppm	14.5	13.4	9.9 Moscow	20.2 Tyva	22.1
Total urban birth rate, ppm	14.5	12.3	9.7 Moscow	26.2 Chechnya	36.2
Total rural birth rate, ppm	16.2	16.4	11.5 Yugra	17.6 Ingushetia	18.4
Total mortality, ppm	8.4	9.3	3.8 Ingushetia	11.9 Moscow	30.1
Total urban mortality, ppm	8.3	8.6	3.7 Ingushetia	11.8 Moscow	30.3
Total rural mortality, ppm	9.4	9.9	3.9 Ingushetia	14.9 Nenets AO	37.2
Migration growth rate, ppm	1.0	0.1	-2.2 Yamalo-Nenets AO	6.1 Yakutia	290.1

Source: the authors' calculations

In all cluster groups, rural mortality exceeds the death rate of urban areas. The highest mortality rate of above 18 ppm is found in the territories of the third cluster,

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which are also marked by extremely low birth rates (the lowest in the country), below 8 ppm in rural areas (in urban areas – 8-9 ppm). Thus, the territories of the third cluster demonstrate negative natural population growth of about 10 ppm.

The second cluster in terms of demographic indicators is close to the average Russian level (Table 9): the total birth rate is 10.2 ppm, the total mortality rate is 13.8 ppm, and the rate of natural growth is negative (-3.6 ppm).

Table 9. Characteristics of demographic indicators of the second cluster group

Indicator	Mean	Median	Minimum	Maximum	Variation coefficient, %
Total birth rate, ppm	10.2	10.2	7.1 Leningrad Oblast	12.9 Buryatia	10.8
Total urban birth rate, ppm	10.4	10.2	7.8 Leningrad Oblast	13.0 Tyumen Oblast	11.8
Total rural birth rate, ppm	9.7	10.0	5.6 Leningrad Oblast	14.3 Chukotka	25.9
Total mortality, ppm	13.8	13.7	10.5 Chukotka	16.1 Crimea	10.2
Total urban mortality, ppm	13.5	13.5	8.0 Chukotka	17.1 Crimea	13.6
Total rural mortality, ppm	14.0	14.6	8.5 Murmansk Oblast	17.6 Chukotka	23.3
Migration growth rate, ppm	2.91	-1.34	-15.73	131.34 Sevastopol 16.8 Leningrad Oblast	573.7 (without Sevastopol)

Source: the authors' calculations

The highest migration growth rate in the third cluster is observed in Kaluga Oblast – 6.75 ppm (see Table 10), which is explained by the region's geographic proximity to Moscow and, accordingly, its attractiveness for migrants. Next follow Novgorod Oblast (3.19), Rostov Oblast (2.85), Kursk Oblast (2.51), Belgorod Oblast (2.49), Pskov Oblast (1.67), and Volgograd Oblast (1.32). Positive migration in these territories partially compensates for the negative consequences of the low birth rate, since the migrating individuals are mostly of working age, and the majority of them have children. The remaining regions in the cluster have either a slightly positive balance of migration or a negative one. This further aggravates their demographic situation, since, as previously noted, the citizens leaving the regions are mainly those of working age and with children. Particularly precarious conditions are noted in Smolensk Oblast (the migration growth rate is -4.72 ppm), Mordovia (-4.67), Amur Oblast (-4.18), and

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Primorsky Krai (-3.67). Left empty is also Magadan Oblast with a migration growth rate of -4.84 ppm. These regions are in a dire need of assistance from development institutions to reduce the intensity of outgoing migration flows and prevent colossal shortages of the employable population not only due to their critically low birth rates and high mortality but as a result of migration-related population decline.

Table 10. Characteristics of demographic indicators of the third cluster group

Indicator	Mean	Median	Minimum	Maximum	Variation coefficient, %
Total birth rate, ppm	8.4	8.4	7.0 Mordovia и Smolensk Oblast	10.2 Sverdlovsk Oblast	9.3
Total urban birth rate, ppm	8.7	8.7	7.5 Smolensk Oblast 7.9 Mordovia	10.3 Sverdlovsk and Amur Oblasts	8.7
Total rural birth rate, ppm	7.6	7.3	5.4 Mordovia	10.4 Chelyabinsk Oblast	15.1
Total mortality, ppm	16.8	16.8	12.5 Magadan Oblast	19.0 Pskov Oblast	7.4
Total urban mortality, ppm	16.2	16.15	12.2 Magadan Oblast	19.3 Tula Oblast	9.3
Total rural mortality, ppm	18.6	18.7	15.9 Kemerovo Oblast	22.4 Karelia	8.7
Migration growth rate, ppm	-0.58	-0.65	-4.84 Magadan Oblast	6.75 Kaluga Oblast	398.5

Source: the authors' calculations

As part of the analysis, Pearson correlation coefficients were calculated for connections between the studied indicators in the third cluster group. Based on this, we derived the following conclusions.

The birth and mortality rates in cluster 3 have an inverse relationship, i.e. ss the birth rate goes up, the death rate goes down, and vice versa. This pattern is confirmed both for the overall population and for the urban and rural populations separately (the correlation coefficient for the total population is -0.55; for the urban population – -0.47; for the rural population – -0.53). The coefficients are significant according to Student's t-test at the level of 0.05. This finding suggests that low birth rates are most likely determined by the state of public health and healthcare in these regions, rather than by the economic situation. The activities of development institutions should therefore focus on measures to improve the functioning of the healthcare system in these territories and to improve the conditions of the development of childhood. This recommendation does not rule out measures to improve the economic situation of the

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population, but the priority of areas of action must be taken into account. In this context, we can mention T.F. Kreidenko (2020), who suggests an interesting method for assessing the regions of the Russian Federation in terms of the conditions for the development of childhood, which meets the country’s needs for improving the demographic situation. O.I. Bantikova (2021) mathematically proves the dependence of birth and death rates on regional ethnonational specifics: the greatest birth rates are found in regions with a high proportion of the titular population under the condition of low urbanization of the territory. S.A. Balashova (2020) finds that an increase in the share of the rural population leads to a rise in mortality, which can be explained by the migration of the young population to cities and an increase in the share of the elderly, remoteness from medical facilities, and inaccessibility of qualified medical care.

The migration rate has a direct relationship with the total mortality of the population (Pearson's coefficient is significant according to Student's t-test at the significance level of 0.05 and has a value of 0.32). Thus, people tend to leave the regions with high mortality. The same conclusion is made for cluster 2 (Pearson’s coefficient equaling -0.38). The measures that can be taken by regional development institutions to reduce mortality will also indirectly contribute to the reduction of the migration outflow of the population from the regions of the third cluster group.

Thus, almost half of the territory of Russia is in a grave demographic situation. These regions should be the primary beneficiaries of development institutions’ assistance in improving fertility and mortality rates.

4 CONCLUSION

The conducted study reveals that the regions of Russia are incredibly diverse and heterogeneous in terms of their economic development and demographics. It is advisable to continue their further study using the methods of cluster analysis, which will show general patterns and correlations of indicators in the groups of regions that are in a certain way homogeneous.

In all cluster groups, the average per capita GRP is found to depend on the amount of fixed assets. The connection of GRP with the amount of investment is also confirmed in almost all clusters except for the fifth one (the most economically disadvantaged). Meanwhile, the poorer the region, the weaker the relationships of the indicators with GRP.

The increase in the average per capita GRP goes almost in parallel with the growth

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in labor productivity in the regions of the first, third, and fifth cluster groups.

Interestingly, in all cluster groups, the rise of the share of small and medium-sized entrepreneurship in GRP leads not to an increase but to a reduction of the average per capita GRP. Moreover, the more developed a region is, the stronger this dependence. The finding could be explained by small and medium-sized businesses in Russia being ineffective. Improving the situation is one of the tasks of development institutions.

All of the regions are characterized by the rise in the median income of their population with the increase in the average per capita GRP. However, the percentage of the population below the subsistence minimum is observed to reduce with the rise in the GRP only in the regions of clusters 1, 2, and 3, i.e. in the groups with high and the lowest GRP. The gap between median income and the subsistence minimum grows with the increase in the average per capita GRP only in cluster 1, i.e. in the regions specialized in extractive industries.

Furthermore, in the most economically underdeveloped regions (cluster 5), the share of people below the subsistence minimum is found to be inversely related to the share of small and medium-sized enterprises in GRP. Therefore, further development of SE in these regions will provide for the improvement of the overall welfare of their population.

The study of the demographic situation based on the indicators of birth rate, mortality, and migration growth suggests that the regions of Russia can be clearly distinguished into three groups (as is evident from the graph of average indicator values of the clusters): regions with the relatively favorable, tolerable, and poor demographics. A poor demographic situation is observed in forty regions of Russia, which are marked by low birth rates, high mortality, and negative migration growth, which also reduces the region's population. Meanwhile, a close connection is observed between birth and mortality rates, i.e. regions with high birth rates also experience high mortality. Furthermore, the study reveals that the group of regions with a poor demographic situation is marked by a direct link between mortality and migration growth. This observation can in part be explained by the fact that the migrating individuals are mostly young, and the citizens remaining in the region are typically characterized by a higher mortality rate. The outlined dependencies are observed both in rural and urban populations. Thus, it is advisable that regional development institutions aim to improve the overall operation of the healthcare system and to create the conditions making the regions of residence attractive for young citizens.

In 2021, the registered unemployment rate rose in all constituent entities of the

[Received/Recebido: Março 10, 2022; Accepted/Aceito Maio 16, 2022]

Russian Federation, which largely owes to the detrimental effects of the COVID-19 pandemic on the labor market. In ten Russian regions, mainly those of the South and Central part of the country, there was an increase of more than eight times. The efforts of development institutions concerning the labor market should therefore focus on these exact regions.

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