Analysis of the Influence of Factors on the Gross Regional Product of Russian Regions

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Abstract. The main indicator of socio-economic development of the region is still the gross regional product. It is most susceptible to changes in the methodological plan indicator. The relevance research of influence of factors on the dynamics of GRP is caused by the need for their systematic analysis. The purpose of this work is to determine the degree of influence of factors on the growth of GRP and identify the strengths and weaknesses of the economic development regions. To achieve this goal, four main factors were previously identified: agglomeration, labor, capital, and infrastructure, and for eight synthetic indicators that characterize them, their integral values were calculated, which, along with the GRP per capita indicator, were used in the classification of regions by the level of economic development based on cluster analysis. In accordance with the developed classification, coefficients of regression equations are calculated for each group of regions, in which the effective indicator is GRP per capita, and integral indicators of factors are used as explanatory indicators. In conclusion, based on the obtained regression equations, the factors that have the greatest impact on the GRP per capita are determined, and the features of economic development of the regions of the Russian Federation are revealed.

1. Introduction and problem description
The main indicator of socio-economic development of the region is still the gross regional product. He is most susceptible to changes in the methodological plan indicator. The relevance research of influence of factors on the dynamics of GRP is caused by the need for their systematic analysis. The purpose of this work is to determine the degree of influence of factors on GRP growth and identify the strengths and weaknesses of regional economic development. To achieve this goal, four main factors were previously identified: agglomeration, labor, capital, and infrastructure, and eight synthetic indicators that characterize them, their integral values were calculated, which, along with the GRP per capita indicator, were used to classify regions by the level of economic development based on cluster analysis. In accordance with the developed classification, coefficients of regression equations are calculated for each group of regions, in which the effective indicator is GRP per capita, and integral indicators of factors are used as explanatory indicators. In conclusion, based on the obtained
regression equations, the factors that have the greatest impact on the GRP per capita are determined, and the features of the economic development of the regions of the Russian Federation are revealed.

2. Review of previous research
Of Marx’s triad of factors of production [5]: land, labor, and capital, the first is present in the article as a factor of agglomeration [7] and a factor of infrastructure. A. Marshall noted [Volume 6, 2 p. 237] "... Land is on a different footing from man himself and those agents of production which are made by man; among which are included improvements made by him on the land itself." In this article, agglomeration and infrastructure are considered as human improvements to the land factor. These two factors, as well as labor and capital, were chosen to characterize the territory in terms of their impact on the dynamics of GRP. The production functions of Leontiev [4], Cobb-Douglas, or Allen as "early growth theories were mechanistic and physicalistic – not in a bad way, but in the sense that they fully described the flows and reserves of goods. In the neoclassical model, it is quite natural and customary to describe equilibrium paths and determine the price and dynamics of interest rates that would support the equilibrium path," Robert Solow noted in his Nobel speech [20]. The formula for economic growth considering technological progress, derived by him in his article from 1956 [15]

\[ \dot{K} = sF(K, L_0 e^{nt}) \]  

where: \( \dot{K} \) – the increment of capital stock; 
\( s \) is a constant that determines the share of output directed to accumulation; 
\( F \) – a function from...; 
\( K \) – total capital stock of the company; 
\( L_0 \) – the rate of labor costs conditionally equal to the subsistence minimum; 
\( e \) is the exponent; 
\( n \) – constant relative rate of increase in the employed labor force; 
\( t \) is the time path of capital that must be accumulated if all available labor is to be employed.

Formula (1) shows the function of exponential growth of accumulated capital with the technical progress of factors of production. Subsequent criticism of the Solow model pointed to a large amount of assumptions in formula (1), but recognized it as basic.

In the methodology of domestic economic measurements, with a very large differentiation of the economic development of Russian regions, there is a problem of leveling the development of regions by pulling the growth of those lagging behind to the level of the advanced ones. According to Granberg [1, p.115], three main approaches are used to reflect many characteristics of regional levels of economic development.

3. Research materials and methods
The article uses the algorithm of the first Granberg approach, which is described in the scientific article [14]. The integral indicators of agglomeration factors, labor, capital, and infrastructure were calculated using the linear scaling algorithm based on the list of indicators for 2002-2018 shown in Table 1.
Table 1. List of indicators of production factors that affect the dynamics of GRP and comparative columns of indicators of development of regions of the Russian Federation in 2002 and 2018, at the end of the year.

| 1. | The factor of agglomeration | 2002 | 2018 |
|----|------------------------------|------|------|
| 1.1 | Population density, people/km² | 8.18 | 8.09 |
| 1.2 | Share of the urban population in the total population, % | 70.37 | 70.98 |
| 1.3 | Number of public buses per 100,000 people | 69.35 | 119.01 |
| 1.4 | Availability of passenger cars per 1000 people | 135.55 | 310.37 |
| 1.5 | Density of public railway tracks, km/1000 km² of the region's territory | 52.66 | 53.23 |
| 1.6 | Density of paved public roads, km/1000 km² of the region | 34.27 | 67.72 |
| 1.7 | Share of paved roads in the total length of public roads, % | 91.11 | 70.30 |
| 1.8 | The share of roads with improved surface in total length of hard surface roads of general use, % | 68.30 | 62.2 |
|      | Integral indicator of the agglomeration factor | 42.27 | 37.91 |
| 2.  | Labor factor                  |      |      |
| 2.1 | The ratio of the average annual number of people employed in the economy to the number of economically active population aged 15-72 years, fractional | 0.883 | 0.898 |
| 2.2 | Per capita monetary income per month, RUB in 2002 prices (an increase of 2.36 times) | 3,170.5 | 7,485.23 |
| 2.3 | Labor productivity as the ratio of GRP to the number of people employed in the economy, thousand rubles per year in 2002 prices (increase of 2.48 times) | 100.13 | 248.68 |
| 2.4 | Average monthly nominal accrued wages of employees in the economy, RUB in 2002 prices (increase of 2.38 times) | 3,884.15 | 9,236.3 |
| 2.5 | Output of skilled workers and employees per 1000 people of the economically active population, people (reduced by 4.4 times) | 10.73 | 2.43 |
| 2.6 | The same for mid-level specialists, people (decreased by 23.3%) | 9.67 | 7.41 |
| 2.7 | The same applies to specialists with higher education, people | 10.06 | 10.45 |
| 2.8 | Number of employees engaged in research and development per 1000 people employed in the economy, people | 8.84 | 6.91 |
people (decreased by 21.9%)

| Integral indicator of the labor factor | 32.24 | 33.18 |
|----------------------------------------|-------|-------|
| Capital factor                         |       |       |
| 3.1 Gross regional product per capita, |       |       |
| RUB in 2002 prices (increase of 2.48  |       |       |
| times)                                 |       |       |
| 3.2 Capital strength – fixed assets in |       |       |
| the economy at the full accounting     |       |       |
| value per person employed in the       |       |       |
| economy, RUB (height 52%)             | 45,358| 112,460|
| 3.3 Capital return – GRP per ruble of  |       |       |
| fixed assets (growth 56%)              | 0.26  | 0.41  |
| 3.4 Degree of depreciation of fixed    |       |       |
| assets, %                              |       |       |
| 3.5 Share of fully worn-out fixed      |       |       |
| assets at full accounting value, % of  |       |       |
| total fixed assets                     | 17.1  | 18.7  |
| 3.6 Investments in fixed assets based  |       |       |
| on fixed assets (growth 83.6%)         | 0.048 | 0.089 |
| 3.7 Return on fixed assets – netted    |       |       |
| (profit minus loss) fin. result of     |       |       |
| the region on fixed assets              | 0.015 | 0.049 |
| 3.8 Tax return per employed person in  |       |       |
| the economy – consolidated regional     |       |       |
| budget revenues per employed person     |       |       |
| in the economy, thousand rubles in     |       |       |
| 2002 prices (growth 96.3%)             | 20.03 | 39.31 |
| Integral indicator of the capital factor|       |       |
| 4. Infrastructure security factor      |       |       |
| 4.1 Share of housing stock equipped    |       |       |
| with water supply, %                   | 71.3  | 81.0  |
| 4.2 Same with the sewer system, %      | 66.6  | 75.8  |
| 4.3 Same with central heating, %       | 72.1  | 84.7  |
| 4.4 Same with baths and showers, %     | 60.6  | 67.6  |
| 4.5 Same with gas, %                   | 71.8  | 69.0  |
| 4.6 Housing stock per inhabitant,      |       |       |
| excluding damaged and dilapidated      |       |       |
| housing, m²                            | 19.4  | 26.7  |
| 4.7 Income from communication services |       |       |
| to the population per inhabitant, RUB  |       |       |
| in 2002 prices (an increase 3.3 times) | 576.8 | 1,894.7|
| 4.8 Percentage of organizations that   |       |       |
| performed research and development     |       |       |
| in the total number of organizations,  | 0.098 | 0.097 |
| % Integral indicator of the           | 48.42 | 53.75 |
| infrastructure factor                  |       |       |

Calculated by the authors
The economic essence of the indicators is described in the methodological explanations of the corresponding sections of statistical collections [18].

For a comprehensive analysis of the economic development of the subjects of the Federation and their corresponding grouping, a cluster analysis was carried out taking into account five integral indicators of factors: agglomeration $x_1$, labor $x_2$, capital $x_3$, infrastructure $x_4$ and normalized values of GRP per capita $x_5$. Calculations were made for 80 subjects of the Russian Federation excluding Moscow, Saint Petersburg, Khanty-Mansiysk Autonomous Region, Yamalo-Nenets Autonomous Region, Nenets Autonomous Region, which stand out sharply in comparison to other regions in the country with a high GRP.

Cluster analysis was performed for 2018 using the following algorithm:

1. The arithmetic mean values of the integral indicators of 80 subjects of the Russian Federation for each of the five factors are calculated.
2. We also derive their maximum and minimum values from 80 subjects of the Russian Federation for each of the five factors.
3. Their adjusted maximum and minimum values are calculated as the arithmetic mean values between the maximum and average, minimum and average values, respectively.
4. Their adjusted average values are calculated as the arithmetic mean between their average and adjusted maximum values.
5. In accordance with the cluster analysis, the following parameters are calculated:
   a) distances from the values of the integral indicators of the $j$-th region to their average Russian values according to the formula:
   \[ R_{sr,j} = \sqrt{\sum_{i=1}^{5}(x_{i,j} - x_{sr})^2} \]  
   (2)
   b) the distance from the values of the integral indicators of the $j$-th region to their adjusted minimum values according to the formula:
   \[ R_{min,j} = \sqrt{\sum_{i=1}^{5}(x_{i,j} - x_{i,min})^2} \]  
   (3)
   C) distances from the values of the integral indicators of the $j$-th region to their adjusted average values according to the formula:
   \[ R_{vsr,j} = \sqrt{\sum_{i=1}^{5}(x_{i,j} - x_{vsr})^2} \]  
   (4)
   d) distances from the values of the integral indicators of the $j$-th region to their adjusted maximum values according to the formula:
   \[ R_{max,j} = \sqrt{\sum_{i=1}^{5}(x_{i,j} - x_{max})^2} \]  
   (5)
6. Among the four calculated distances for each region determined by the smallest value that allows to determine which value is closer to the integral characteristics of the region to the adjusted maximum, medium, minimum or average Russian value, i.e. this defines which group of regions by level of economic development it refers to.
7. According to the calculated minimum distance, the regions are divided into four groups: relatively low; average; above average and a relatively advanced economic development.
8. The following iterations calculate the arithmetic mean, adjusted average, minimum and maximum values of integral indicators for regions with an average level of economic development. Calculations using equations (2), (3), (4), (5) they are repeated until the calculated number of regions in the group with an average level of economic development stabilizes or stops decreasing.

Thus, based on the calculations obtained using cluster analysis, regions are grouped into the corresponding categories. If the smallest value is the distance to the adjusted maximum values, then the region is classified as a group of relatively highly developed subjects of the Russian Federation. If the smallest values are the distance to the adjusted average values, to the average values, and to the adjusted minimum values, then the region belongs to the groups of above-average, average, and relatively low levels of economic development, respectively.
4. Obtained result

The dynamics of Russia's GRP in comparable prices in figure 1 shows its growth in 2002-2008 by 2.3 times. The impact of the global crisis in 2008 was reflected in the fall of the Russian GRP in 2009 by 10.5%. In the period 2010-2014 GRP of the Russian Federation grew by 43.3%. Sanctions, the transition of the Central Bank of Russia to a floating ruble exchange rate from November 2014, and the subsequent doubling of import prices [14, Figure1], respectively, and technology transfer for small and medium-sized businesses, reduced the growth rate of Russia's GRP from 8% per year in 2009-2014 by four times-to 2% in 2015-2018.

![Figure 1](image1.png)

**Figure 1.** Dynamics of GRP of the Russian Federation and Federal districts for the period 2002-2018 excluding GRP of Moscow, Saint Petersburg, KHMAR, YNAR and NAR at comparable prices in 2002.

![Figure 2](image2.png)

**Figure 2.** Dynamics of the aggregate index of factors of production in the regions of the Russian Federation for the period 2002-2018.
Table 2. Classification of Russian regions by economic development.

| №  | Level of development | Subjects of the Russian Federation                                                                                                                                 |
|----|----------------------|---------------------------------------------------------------------------------------------------------------|
| 1  | Average              | Bryansk, Vladimir, Volgograd, Vologda regions, Sevastopol, Kabardino-Balkar Republic, Kemerovo, Novgorod, Omsk, Orenburg, Oryol, Penza regions, Perm, Primorsky Krai, Adygea, Karelia, Crimea, Mordovia, North Ossetia - Alania, Khakassia; Rostov, Ryazan, Saratov regions, Stavropol territory, Tambov, Tver regions, Udmurt Republic, Ulyanovsk, Chelyabinsk, Yaroslavl regions |
| 2  | Relatively low       | Altai territory, Amur, Arkhangelsk, NAO, Jewish Autonomous region, TRANS-Baikal territory, Ivanovo region, Karachay-Cherkess Republic, Kirov, Kostroma, Kurgan, Pskov region, Altai Republic, Buryatia, Dagestan, Ingushetia, Kalmykia, Mari El, Tuva, Smolensk region, Chechen and Chuvash Republic |
| 3  | Above average       | Astrakhan, Voronezh, Irkutsk, Kaluga regions, Krasnodar territory, Kursk, Lipetsk, Leningrad, Nizhny Novgorod, Novosibirsk regions, the Republic of Bashkortostan, Komi; Tomsk, Samara, Sverdlovsk, Tula regions and Khabarovsk territory |
| 4  | Relatively advanced | Belgorod, Kaliningrad regions, Kamchatka and Krasnoyarsk territories, Magadan, Moscow, Murmansk regions, the Republic of Sakha (Yakutia), Tatarstan; Sakhalin, Tyumen regions without AO, Chukotka Autonomous district |

Figures 1 and 2 show the dependence of trends in GRP of the Russian Federation in trillion rubles on the factors of production, calculated in integral indices. With the same weights of indicators of factors of production, the marginal aggregate index should aim at 320, and the integral index of the factor at 80. The integral factors of production and the gross regional product per capita of the regions were used to classify regions by the level of economic development using the algorithm of cluster analysis described above. The results of the cluster analysis are shown in Table 2.

In accordance with the developed classification of regions by economic development, regression equations are compiled. The resulting variable is GRP per capita $y$, which explains the agglomeration factors $x_1$, labor $x_2$, capital $x_3$, and infrastructure $x_4$. The arithmetic mean values of the resulting and explanatory variables for the corresponding groups of regions for the period 2005-2018 are calculated.

For regions with a relatively low level of economic development, the following regression equation is obtained:

$$ y = -19665.9x_1 + 422.6x_2 + 2308.2x_3 + 16543.6x_4 $$

For regions with an average level, the following regression equation is obtained:

$$ y = -25057.4x_1 + 7338.1x_2 + 9640.9x_3 + 14119.7x_4 $$

For regions above the average level, the following regression equation is obtained:

$$ y = -41763.1x_1 + 8334.5x_2 + 13210.9x_3 + 24566.4x_4 $$

For relatively high-level regions, the following regression equation is obtained:

$$ y = -94965.8x_1 + 18967.1x_2 + 11973.6x_3 + 52854.5x_4 $$
Determination coefficients for regression equations (6), (7), (8), (9) are 0.70, 0.65, 0.72, and 0.74, respectively, and show that the explanatory variables accurately describe the effective indicator. Calculated values of the Fisher criterion for coefficients of determination of regression equations (6), (7), (8), (9) are 5.48, 4.26, 5.84, 6.69 and all of them exceed the table value of the Fisher criterion $F_{0.05,4,9}=3.63$, which shows their overall significance.

5. Conclusions
As the economic development of regions improves, the coefficients of the regression equations (6)-(9) grow in magnitude, except for the coefficients before the variables of the integral capital factor and the integral infrastructure factor. So, for regions with a relatively low level of economic development, according to the calculations, the coefficient value before the variable of the integrated infrastructure indicator is $+16543.6$, which is more than the corresponding coefficient value ($+14119.7$) for regions with an average level of economic development. For regions with the above average economic development, the value of the coefficient before the variable of the integral capital indicator is $+13210.9$, which is higher than the same indicator for regions with advanced economic development ($+11973.6$). The obtained values of the coefficients show that the need to develop production and transport infrastructure in regions with relatively low level of economic development higher than in regions with medium levels of economic development, except in regions with the above average level of economic development, the need to attract investment capital in comparison with the regions of relatively high level of economic development. The calculations revealed general features of economic development in the regions of the Russian Federation:

- in all the considered regions of the Russian Federation, regardless of the level of economic development, the concentration of capital and labor resources in the capitals and large cities of the regions does not contribute to the overall economic development of the regions (a negative value of the coefficient before the variable of the integral indicator of agglomeration);
- the development of industrial and transport infrastructure and the creation of new jobs are particularly relevant for all the regions of the Russian Federation considered;
- in all regions, except for relatively highly developed ones, the need to attract capital is higher than the need for labor resources, which can be explained by the resource nature of the regional economy, the growth of mechanization and robotization of production, and a relatively high rate of unemployment in the regions;
- in regions with relatively high economic development, training for highly qualified personnel is becoming relevant, as evidenced by a sharp increase in the value of the coefficient before the variable of the integral labor factor.

Thus, for optimal economic development of the regions of the Russian Federation, it is necessary to reduce lending rates for production in the regions, decentralize the budget system of the Russian Federation with an increase in the revenue parts of regional and local budgets, and attract investment to create new jobs. Providing financial resources to municipal districts and cities will help solve the problem of equalizing the economic development of regions.

6. References
[1] Granberg A G 2004 Fundamentals of Regional Economics) High School of Economics Publ. M.: 495 p (In Russ.)
[2] Kataranova M 2010 The relationship between the exchange rate and inflation in Russia Voprosyjekonomiki I pp 44-62 (In Russ.)
[3] Kovalenko E G, Avtajkina E V 2013 Analysis of sustainable socio-economic development of rural territories of the Republic of Mordovia Systems management. Publ.Ogarev Mordovia State
University (Saransk) 1(19) URL: http://sisupr.mrsu.ru/2013-1/PDF/Avtaikina_Kovalenko.pdf (In Russ.)

[4] Leontief V 1990 Essays in Economics: theories, theorizing, facts and policies *Publ. Politizdat.* (M.:) 415 p (In Russ.)

[5] Marx K H 1958-1962 Capital. *Publ. Political Literature* M.: Vol 1 167 p Vol 2 649 p Vol 3 546 p Vol 4 Part 1 477 p Part 2 704 p (1958-1962) (In Russ.)

[6] Marshall A 1993 Principles of economics *Publ. «Progress»* (M) Vol 1 416 p Vol 2 310 p Vol 3 352 p

[7] Piven’ D A 2014 Regional Agglomeration and Premises for its Formation *Publ. Yaroslavl State University. Serial Human Sciences* 1(27) pp 133-138 (In Russ.)

[8] Solomonov M P 2018 Quantitative assessment of the influence of factors on the dynamics of shipped products in the region (for example Yakutia) *Theoretical and Applied Economics. Publ. Nota Bene* 4 (pp 30-40) (In Russ.)

[9] Solomonov M P, Pakhomov A A 2019 Assessment of the influence of factors on the volume of shipped products of economic zones and regions using the example of the Republic of Sakha (Yakutia) for 2006-2017 Certificate of Federal Service for Intellectual Property (M) (In Russ.)

[10] Solomonov M P, Turantaev S G 2018 Evaluation of the comfort of living in economic zones and regions using the example of the Republic of Sakha (Yakutia) for 2007-2016 Certificate of Federal Service for Intellectual Property (M) (In Russ.)

[11] Stiglitz Joseph, Amartya Sen, Jean-Paul 2016 Fitoussi.: The report by the Commission on the Measurement of Economic Performance and Social Progress *Publ. Institute Gaidar* (M) 212 p URL: https://klex.ru/rzv (In Russ.)

[12] Suslov V I, Ibragimov N M, Talysheva L P, Cyplakov A A 2005 *Econometrics Publ. SO RAN* (Novosibirsk) 740 p (In Russ.)

[13] Human development: a new dimension of socio-economic progress Faculty of Economics Moscow State University (M.: Prava cheloveka) 636 p (In Russ.)

[14] Solomonov M P, Pakhomov A A, Okhlopkov G N 2020 How Production Factors Affect Sustainable Development in a Region *IOP Conf. Series: Earth and Environmental Science* 459 062043 doi:10.1088/1755-1315/459/6/062043

[15] Solow 1956 Robert M.: A Contribution to the Theory of Economic Growth *The Quarterly Journal of Economics* Vol 70 1 pp 65-94 URL: http://www.econ.nyu.edu/user/debraj/Courses/Readings/Solow.pdf (In Russ.)

[16] The official website European Central Bank URL: www.ecb.europa.eu

[17] United States Federal Reserve Official Website URL: www.federalreserve.gov

[18] Official site Federal State Statistics Service Russian Federation. Regions of Russia socio-economic indicators URL: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog /doc_1138623506156

[19] Official site Central Bank of the Russian Federation URL: https://cbu.ru/

[20] Solow Robert S 1987 Growth Theory and Perspective Nobel lecture delivered December 8 Russian magazine URL: http://old.russ.ru/politics/20030228-solow.html (In Russ.)

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