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Methods for analyzing the impact of integrative activities of higher education institutions on the cultural and socio-economic components of regional development

Métodos para analizar el impacto de las actividades integradoras de las instituciones de educación superior en los componentes culturales y socioeconómicos del desarrollo regional

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ABSTRACT:
The article describes a new method for assessing the impact of the universities' educational and research activities on the cultural and socio-economic level of regional development, based on regression models. Statistical processing of indicators of research activities enabled to calculate the MAPE (mean absolute percentage error), Forecast Accuracy parameters, and the elasticity and determination coefficient. The effectiveness of the proposed method lies in the possibility of calculating the amount of financial resources needed to stimulate the universities' research activities to increase the GRP level by 1-2 or more percent.
Keywords: research activities, higher education systems, a correlation and regression model, gross regional product, regional development

RESUMEN:
El artículo describe un nuevo método para evaluar el impacto de las actividades educativas y de investigación de las universidades en el nivel cultural y socioeconómico del desarrollo regional, basado en modelos de regresión. El procesamiento estadístico de los indicadores de las actividades de investigación permitió calcular el MAPE, los parámetros de Precisión de Pronóstico y el coeficiente de elasticidad y determinación. La efectividad del método propuesto radica en la posibilidad de calcular la cantidad de recursos financieros necesarios para estimular las actividades de investigación de las universidades para aumentar el nivel de GRP en un 1-2 o más por ciento.
Palabras clave: Actividades de investigación, sistemas de educación superior, un modelo de correlación y regresión, producto regional bruto, desarrollo regional

1. Introduction

One of the important scientific problems lies in the development of methods for analyzing the impact of integrative educational and research activities of higher education institutions on the socio-economic component of regional development. In accordance with the global trends, the education system significantly affects the competitiveness and efficiency of national economies. In the context

of innovative economy, the cognitive resource is becoming the core element, whose main generation centers comprise higher education institutions. In the national economy, a major share of intellectual potential is concentrated in the university sector of science, which develops and transfers knowledge in various fields of activity.

The modern system of higher education is able to attract and develop talented young people, create new knowledge and ensure its practical implementation in relation to the real sector of the regional economy, which becomes the main tool for the development of the knowledge-based economy. At the same time, universities are a generator for innovative development of the region, a center for translation of best practices into the territorial education system. Regional higher education institutions have a significant impact on the level of the socio-economic indicators of regional development.

The development of the global and national economies is largely determined by their ability to produce, use and commercialize new knowledge and technologies. In the world practice, the partnership of universities and companies is mainly implemented through research and development; joint design and implementation of programs; intellectual property protection; creating business projects and participation of business representatives in university management. Such forms of cooperation between universities and the real sector of the economy have a positive integrative effect on the socio-economic component of regional development.

1.1. Literature review

Text Contemporary publications by B. Clark (1983), G. Sabato (1975), B.-A. Lundwala (1988), R. Nelson (1993), D. Charles (1995), D. Goddard and P. Chatterton (2000), G. Itskowitz (2000), Eidesdorf (2000), Altbach and Salmi (2012) state that a regional university shall be considered one of the main elements of the strategy for regional economic development.

The interaction processes that arise between the state, business and universities in the context of developing innovations for the purpose of knowledge economy are explained by the Triple Helix Model of H. Etzkowitz and L. Leydesdorff (2003).

The model of multifunctional and multi-level participation of the university in the regional development proposed by P. Arbo and P. Benneworth (2007) is based on the variety of functions of modern universities and the consequences of their implementation for regional development. Financing the universities' research activities creates a platform for their formation as the strongest drivers for the development of the regional economy.

J.B. Goddard and P. Chatterton (2000) believe that importance of universities for regional development lies in their ability to focus on regional development issues and involve other interested stakeholders. In addition, higher education institutions make a significant contribution to regional development; their importance is achieved by satisfying the needs of the regional labor market by training specialists, conducting relevant research, as well as through their ability to attract foreign investment and capital.

The following models of cooperation between universities and the real sector of the economy have currently been formed in the international best practice at the territorial level:

1. Cooperation in the development of joint research initiatives (Tynnikov, 2014);

2. Development of joint educational programs (Ramísio et al., 2019);

3. Student mobility (Shields, 2019; Hashim et al., 2018; Hamoud & Humadi, 2019).

An example of cooperation between universities and the real sector of the economy in the R&D field can be seen in the technology transfer centers in China. The Technology Transfer Center is an organization whose activity is aimed at introducing the results of scientific and technical activities into the real economy and is focused on making profit from the use of research results carried out in public universities and private companies (Xu et al., 2016).

The Chinese university system is one of the world's largest performers of high-tech research (Hu et al., 2018). Each university has its own technology transfer model in the form of a technology transfer center (university's associated private companies): programs for improving competitiveness of higher education; programs for improving university research standards; creating hybrid public-private partnerships; increasing the number of patents (Hanushek, 2016).

To assess the role of universities in regional development in economically developed countries today, various models are used to analyze the contribution of university science to the socio-economic, innovation and cultural development of regions. For example, the studies of B. Clark (2003), D. Goddard and P. Chatterton (2004), G. Etzkowitz and L. Leydesdorff (2003), D. Caffrey and H. Isaacs

(2012), E.A. Hanushek, and L. Woessmann (2015), Yao Yao (2019) determine that a regional university should be a core element of the economic strategy for regional development.

D. Caffrey and H. Isaacs (2012) proposed a generally accepted method for assessing the contribution of higher education to regional development, which suggests considering higher education as an industry. The essence of the approach is to assess the difference between the income base and the results of universities' activities affecting the development of the regional economy. As a rule, such impact is assessed through the following indicators:

- Cost of the real estate owned by the business associated with the university;

- Volume of state funding for the university;

- Number of jobs and their total cost created by the university (for example, employees of enterprises hired to work with universities);

- Size of deposits made by universities, university staff, and students in local banks;

- Funds spent by students (and teachers), who are not residents of the city, for the purpose of living in this city;

- Amount of taxes paid by the university, university employees, business entities and organizations affiliated with universities, to the city (regional) budget;

- Cost of business where the university is a co-founder or owner.

According to the model of J.B. Goddard and P. Chatterton (2004), the value of universities for the region lies in their ability to focus on the territorial problems, become a moderator of field discussions and form a pool of stakeholders to solve them. In addition, universities contribute to regional socio-economic development by meeting the needs of the regional labor market.

The regional system of higher education is a set of interrelated and interdependent education subjects, components that ensure professional training, retraining, and staff development at federal; and regional levels of the social order and at the level of employers (as a customer of R&D works).

2. Methodology

The systemic approach was used in this scientific study, which lies in studying objects as systems. The methods of systemic, comparative, statistical analysis, questioning and expert survey were also used.

The original proprietary method for studying the impact of the universities' research activities on the GRP level includes the following stages:

1. Determine the values of the key indicators of the universities' research activities in accordance with statistical data (factor attribute);

2. Determine the GRP values in accordance with statistical data (resulting attribute);

3. Carry out correlation and regression analysis based on calculation of the correlation coefficient, formation of the regression equation, Student's t-test, elasticity coefficient, and determination coefficient;

4. Build trend lines and find the forecast level for the indicators of the universities' research activities (factor attribute);

5. Use the found predicted values of the indicators of the universities' research activities in the regression equation and get the predicted GRP values (resulting attribute);

6. Then verify the accuracy of the predicted values based on the MAPE and Forecast Accuracy criteria and confirm the accuracy of the predictions and calculations.

The correlation coefficient (r) is the resulting indicator in the process of correlation and regression analysis. To calculate this coefficient, several intermediate values are calculated in accordance with the formulas specified below (Gromyko, 2015).

$$\sigma_x = \sqrt{\overline{x^2} - \left(\overline{x}\right)^2}, \quad (1)$$

$$\sigma_y = \sqrt{\overline{y^2} - \left(\overline{y}\right)^2}, \quad (2)$$

$$r = \frac{\overline{xy} - \overline{x}\,\overline{y}}{\sigma_x \sigma_y}, \quad (3)$$

$$a_1 = \frac{n\sum xy - \sum x * \sum y}{n\sum x^2 - \left(\sum x\right)^2}, \quad (4)$$

$$a_0 = \overline{y} - a_1 \overline{x}, \quad (5)$$

$$\overline{y_x} = a_0 + a_1 x, \quad (6)$$

$$t_{calculated} = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}, \quad (7)$$

where:
y - individual values of the resulting attribute;
x - individual values of the factor attribute;
n – the number of observations

The linear regression is reduced to an equation in the form: $\overline{y_x} = a_0 + a_1 x$, where *x* is the individual value of the factor attribute; a_0, a_1 are parameters of the equation of line (regression equation); $\overline{y_x}$ is the theoretical value of the resulting factor.

This equation shows an average value of changing the resulting attribute *x* by one unit of its measurement. The parameter index indicates the direction of such a change. In practice, construction of linear regression consists of assessing its parameters a_0 and a_1.

Using the classical approach, the equation parameters a_0, a_1 are found by the least squares method (formulas 4 and 5), which allows one to obtain such assessments of the parameters so that the sum of squares of the deviations of the resulting attribute actual values from the calculated, theoretical ones ($\overline{y_x}$) would be minimal.

The attributes under investigation often have different units of measurement; therefore, the elastic coefficient is used to assess the impact of the factor attribute on the resulting one. It is calculated for each point and on average for the whole variety by the formula:

$$Э = Y_x' \frac{X_i}{Y_x}, \quad (8)$$

where y'_x is the first derived regression equation.

The average elasticity coefficient is determined for the straight line equation by the following formula:

$$\overline{Э} = a_1 \frac{\overline{x}}{\overline{y}} \quad (9)$$

The elasticity coefficient shows the percentage change of the resulting attribute when the factor attribute changes by 1%.

The linear determination coefficient is an alternative indicator of the dependence degree between two variables, which is the square of the linear correlation coefficient (r^2). Its numerical value is always in the range from 0 to 1. It characterizes the proportion of variation (scatter) of the dependent variable. The value of the determination coefficient directly demonstrates the degree of impact of the independent factor on the resulting attribute.

To evaluate the used method of correlation and regression analysis and the predicted values of the indicators of the universities' research activities found on its basis, statistical assessment is used. In particular, the MAPE indicator (average absolute error) is calculated for each factor attribute (indicator of the universities' research activities) and the resulting attribute (GRP). The MAPE indicator is calculated by the following formula:

$$MAPE = \frac{1}{N}\sum_{t=1}^{N}\frac{\left|Z(t)-\hat{Z}(t)\right|}{Z(t)}, \quad (10)$$

where Z(t) is the actual value of the temporal series;

$\hat{Z}(t)$ is the predicated value of the temporal series;

N is the number of periods.

In this case, the value of the calculated MAPE indicator tends to 0 (MAPE → 0).

The forecast accuracy is estimated using the Forecast Accuracy indicator, which is calculated by the following formula:

$$Forecast\ Accuracy = (1- MAPE)\times 100\% \quad (11)$$

In this case the value of the calculated Forecast Accuracy indicator should tend to 100% (Forecast Accuracy → 100%).

The Penza region included in the Volga Federal District was used as a reasonable sample, since this area has a sufficient number of higher education institutions - 4 large universities, 5 research institutes, and 6 branches of Moscow universities.

There are the following research institutes in the Penza region:

- OJSC "Research and Development, Design and Technological Institute of Chemical Engineering";

- "NIIFI and VT", a branch of NIIFI JSC (research, development and manufacture of electronic equipment for various purposes, computer equipment for automated control systems and specialized control systems);

- JSC "Research and Development Institute of Electromechanical Instruments";

- JSC "Penza Scientific Research Electrotechnical Institute".

Higher education institutions of the region conduct scientific research and development in the field of technical, natural, humanitarian, public and other sciences. A significant amount of scientific research is supported by national and regional funding; some projects are implemented jointly with JSC Development Corporation of the Penza Region. Over the past three years, universities in the region have been considered effective as a result of state monitoring conducted by the Ministry of Education and Science of the Russian Federation.

3. Results

One of the purposes of the study was to identify a set of indicators of regional development, which are subject to the influence of the universities' activities in the field of research, development and innovation. At the same time, the gross regional product (GRP) should be considered as the most important indicator of regional development, directly and indirectly dependent on the universities' activities. In order to identify the impact of key indicators for the purpose of evaluating the effectiveness of universities' activities on the GRP indicator, the authors conducted a correlation and regression analysis of the socio-economic indicators of the region (as a case study of the Penza Region).

Table 1 presents the results of the correlation-regression analysis of the dependence between the size of the GRP in the Penza region and the amount of expenses for research and development.

Table 1

Correlation-regression analysis of the dependence between the GRP in the Penza region and the amount of internal expenses for research and development (Federal State Statistics Service of Russia, 2019

Year	Internal expenses for R&D, million rubles, *x*	GRP in the Penza region, billion rubles, *y*	x^2	*xy*	y^2	y_x
2013	4539.5	270.4	20606697.1	1227470.0	73116.2	377.6
2014	3518.5	295.2	12379594.5	1038650.8	87143.0	294.1

2015	3645.2	343.3	13287483.0	1251397.2	117854.9	304.4
2016	3793.6	348.9	14391401.0	1323587.0	121731.2	316.6
2017	3962.0	365.2	15697444.0	1446922.4	133371.0	330.3
Sum	19458.7	1623.0	76362619.6	6288027.4	533216.3	1598.3
Average value	3891.7	324.6	15272523.9	1257605.5	106643.3	324.6
Average square	15145678.8	105365.2	233249987134015.0	1581571539784.6	11372786609.7	1239216.6

In accordance with the above formulas (1 - 7) we calculated the intermediate values: $\sigma_x = 356.153$, $\sigma_y = 35.751$, $r = 0.815$, $a_1 = 0.082$, $a_0 = 6.18$, $\overline{y_x} = 6.18 + 0.082x$, $t_{calculated} = 9.875 >$ t_{table}, and this means that the calculated correlation coefficient r is significant, and the relation between the variables x and y is also significant. Table 2 contains interpretation of the correlation coefficient values.

After that the average elasticity coefficient was calculated using formula 9:

$$\overline{Э} = 0.82\frac{3891.7}{324.6} = 0.98$$

The elasticity coefficient of 0.98 shows that an increase in the volume of expenditure on research and development by 1% will lead to an increase in the gross regional product by 0.98%.

The determination coefficient r^2 is 0.66. This means that the variation in the formation of GRP is by 66% explained by the variation in the volume of expenditure on research and development and by 44% - by other factors.

Table 2
Interpretation of the correlation coefficient values (Gromyko, 2015)

Value of the correlation coefficient *r*	**Interpretation characterizing the strength of relationship**
0 < r ≤ 0.2	Very weak direct correlation
0.2 < r ≤ 0.5	Weak direct correlation
0.5 < r ≤ 0.7	Average direct correlation
0.7 < r ≤ 0.9	Strong direct correlation
-0.2 ≤ r < 0	Very weak inverse correlation
-0.5 ≤ r < -0.2	Weak inverse correlation
-0.7 ≤ r < -0.5	Average inverse correlation
-0.9 ≤ r < -0.7	Strong inverse correlation

In accordance with the data of Table 2, the determined value of the correlation coefficient r=0.94 corresponds to a strong direct correlation between the size of the GRP and the expenses for research and development in the region. The result obtained allows us to conclude that the amount of expenditure on research and development spent by organizations within the scientific and educational cluster has a direct impact on the size of the resulting gross regional product.

The study included a correlation-regression analysis of the dependence between the size of the GRP of the Penza region and the number of universities conducting research and development (Table 3).

Table 3
Correlation-regression analysis of the dependence between the size of the GRP and the number of universities conducting research and development

Year	Number of universities conducting R&D, pieces, *x*	GRP in the Penza region, billion rubles, *y*	x^2	*xy*	y^2	y_z
2013	2	270.4	4.0	540.8	73116.2	169.8
2014	4	295.2	16.0	1190.8	88625.3	312.8
2015	4	343.3	16.0	1304.4	106341.2	312.8
2016	5	348.9	25.0	1812.5	131406.3	384.2
2017	6	365.2	36.0	2271.6	143338.0	455.7
Sum	21.0	1635.3	97.0	7120.1	542826.9	1527.6
Average value	4.2	327.1	19.4	1424.0	108565.4	327.1
Average square	17.6	106968.2	376.4	2027833.0	11786440431.8	1287.5

In accordance with the calculations, we obtained the intermediate values: $\sigma_x = 1.327$, $\sigma_y = 35.751$, $r = 0.902$, $a_1 = 70, a_0 = 29$, $\overline{y_x} = 29 + 70x$, $t_{calculated} = 7.532 > t_{table}$, therefore, the calculated correlation coefficient r is significant, and the relationship between the variables x and y is also significant.

After that the average elasticity coefficient was calculated using formula 9: $\overline{Э} = 70\frac{4.2}{324.6} = 0.91$.

The elasticity coefficient of 0.91 shows that an increase in the number of universities performing research and development by 1% will lead to an increase in the gross regional product by 0.91%.
The determination coefficient r^2 is 0.81. This means that the variation in the formation of GRP is explained by 81% by the variation in the number of universities performing research and development and by 19% - by other factors.

Leading Penza universities have introduced an effective innovation infrastructure, which includes technology transfer centers, innovation and analytical departments, student research and production business incubators, and management of organizational and methodological support for R&D. At the same time, technology transfer centers contribute to the integration of science and industry in the region.

Personnel potential is an important factor in the innovation activities of universities. Table 4 shows the results of the correlation-regression analysis of the dependence between the size of the GRP and the number of universities' staff engaged in research and development.

Table 4
Correlation-regression analysis of the dependence between the size of the GRP in the Penza region and the number of staff engaged in research and development (Federal State Statistics Service of Russia, 2019)

Year	Staff engaged in R&D, thousand people, x	GRP in the Penza region, billion rubles, y	x^2	*xy*	y^2	y_z
2013	5.583	270.4	31.2	1509.6	73116.2	328.8
2014	5.684	295.2	32.3	1677.9	87143.0	216.0

2015	5.79	343.3	33.5	1987.7	117854.9	220.4
2016	4.69	348.9	22.0	1636.3	121731.2	175.0
2017	5.81	365.2	33.8	2121.8	133371.0	221.2
Sum	27.6	1623.0	152.8	8933.4	533216.3	1119.0
Average value	5.5	324.6	30.6	1786.7	106643.3	208.9
Average square	30.4	105365.2	933.4	3192239.7	11372786609.7	1235.4

In accordance with the calculations the intermediate values were found: $\sigma_x = 0.419$, $\sigma_y = 35{,}751$, $r = 0.682$, $a_1 = 58.277$, $a_0 = 3.411$, $\overline{y_x} = 3.411 + 58.277x$, $t_{calculated} = 4.958 > t_{table}$, therefore, the calculated correlation coefficient r is significant.

After that calculate the average elasticity coefficient was calculated using formula 9: $\overline{Э} = 58.277 \frac{5.51}{324.6} = 0.99$.

The elasticity coefficient of 0.99 shows that an increase in the number of personnel engaged in research and development by 1% will lead to an increase in the gross regional product by 0.99%.

The determination coefficient r^2 is 0.47. This means that the variation in the GRP formation is explained by 47% by the variation in the number of personnel engaged in research and development, and by 53% - by other factors.

Universities and research institutes have a significant impact on the level of regional development, because they implement comprehensive fundamental and applied research and development for state and non-state customers, including projects on the basis of grants provided by domestic and foreign foundations, they also render scientific, educational and consulting services to legal entities and individuals. At the same time, the effective activity of research and educational organizations contributes to:

- Performance of research, expert, analytical and other works for state and municipal customers, executive bodies and local government, as well as private companies;

- Implementation of international scientific cooperation, participation in joint research with Russian and foreign partners, holding of all-Russian and international conferences, meetings, symposia with a view to entering the world system of science and education and presenting their own scientific products;

- Formation of an attractive investment and business climate, and a favorable reputation of the region.

According to the calculation results, it can be concluded that the socio-economic development of the region depends largely on the number and quality of work of the universities' staff engaged in research and development. At the same time, universities are centers for broadcasting cultural heritage and research centers; they form small innovative enterprises, enjoy grant support from various scientific foundations and accumulate significant funds in research and development.

The study results allow us to conclude that higher education institutions make an integrative contribution as a driver for the economic development of the region, which can be shown as follows:

- Multiplier effect of economic development (tax deductions of universities in the regional budget, income received from foreign students and teachers);

- Universities prepare qualified workers for the labor market, whose salaries are generally higher than those who do not have university education, which directly and indirectly provides a higher tax income for the region and a higher level of consumption from a part of the population;

- Innovative development (production of new technologies and knowledge, commercialization of developments, number of licenses and patents);

- From the point of view of the state, the number of citations of publications in the databases of the Russian and international scientific indices is also important.

The results of the correlation-regression analysis of the impact of indicators of the universities' performance assessment on the size of the GRP in the Penza region are presented in Table 5.

Table 5

Summary results of the correlation-regression analysis of the influence of the integrative activities of universities on regional development indicators

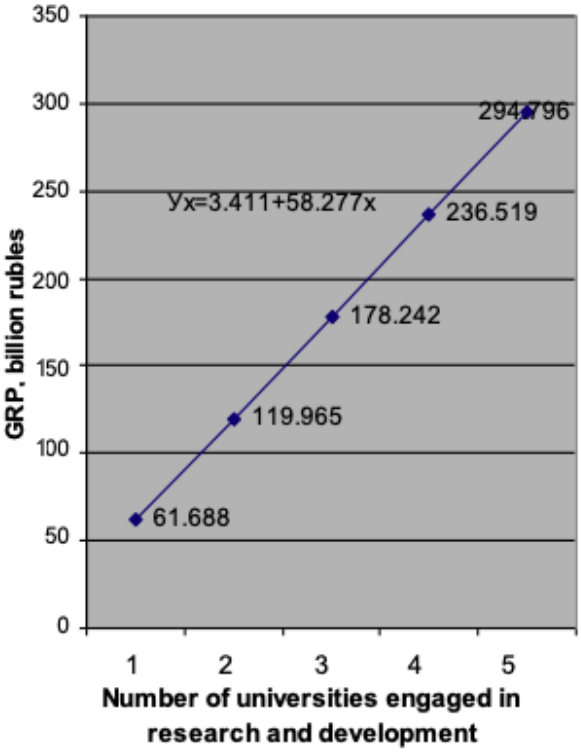
Socio-economic development indicators in the Penza region (X – impact factor)	GRP in the Penza region, billion rubles (Y – dependent factor)					
	Correlation coefficient *r*	Characteristics of the relation	Significance of *r* according Student's *t*-Test	Regression equation $y=a_0+a_1x$	Average coefficient of elasticity $\overline{Э}$	Linear coefficient of determination r^2
Internal expenses for R&D, million rubles.	0.815	Strong direct (0.7 < *r* <= 0.9)	Significant $t_{calculated}$ (9.875)> t_{table} (2.1604)	$\overline{y_x} = 6.18 + 0.082x$	0.98	0.66
Number of universities performing R&D, pieces	0.902	Strong direct (0.7 < *r* <= 0.9)	Significant $t_{calculated}$ (7,532)> t_{table} (2.1604)	$\overline{y_x} = 29 + 70x$	0.91	0.81
Staff engaged in R&D, thousand people	0.682	Average direct correlation (0.5 < r ≤ 0.7)	Significant $t_{calculated}$ (4.958)> t_{table} (2.1604)	$\overline{y_x} = 3.411 + 58.2$	0.99	0.47

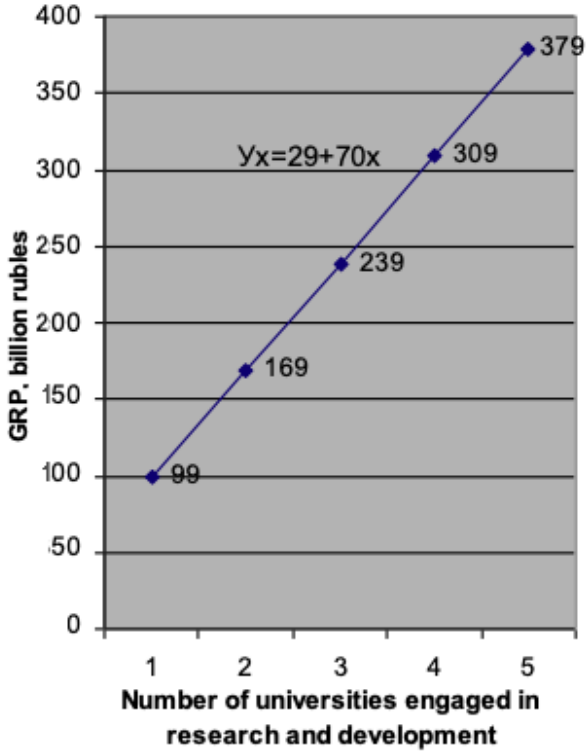
Thus, due to the revealed strong correlation between the key economic indicator of the region's GRP and the universities' research activities based on calculation of correlation coefficients (*r*), elasticity coefficients ( ), and determination coefficients (*r*2), it is possible to influence the economic development of the region. We illustrate this aspect with the help of the trend predicted values of factor attributes (indicators of the universities' research activities) and calculation of the productive attribute value (GRP) based on the obtained regression equations.

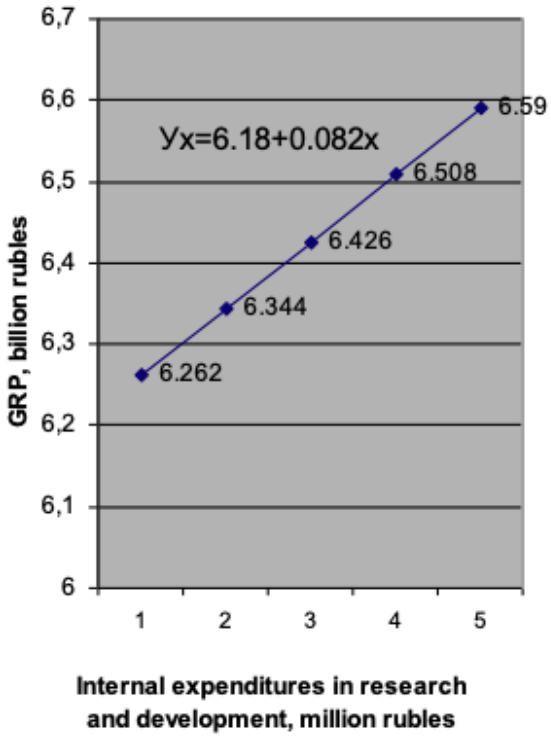
Figure 1 presents a graphical interpretation of the obtained regression equations reflecting the dependence of the GRP on the results of the universities' research activities.

Figure 1

Graphical interpretation of the obtained regression equations reflecting the dependence of the GRP on the results of the universities' research activities.



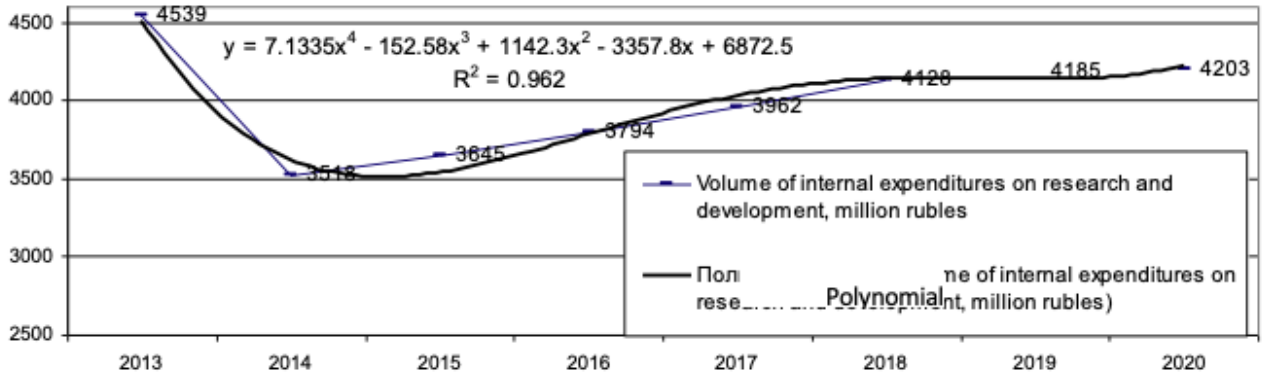


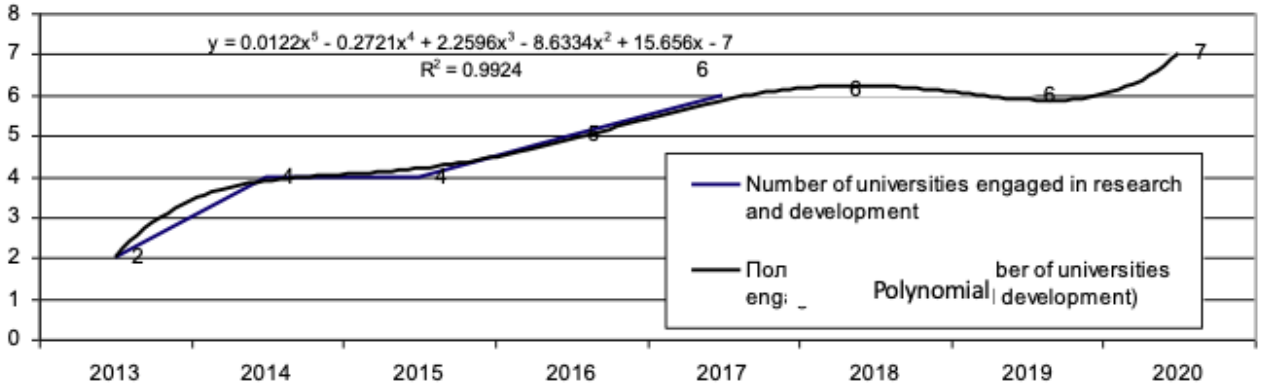


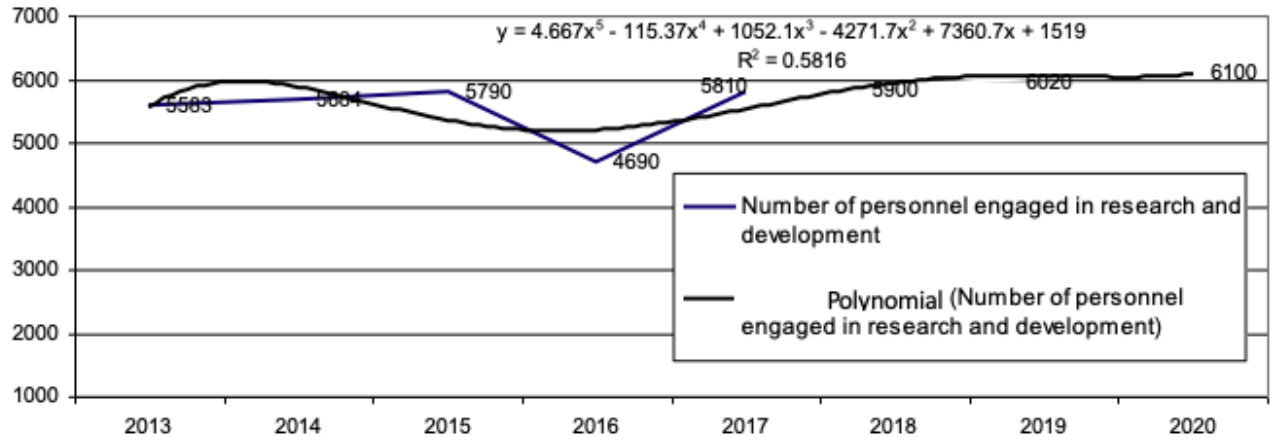
Thus, due to the revealed strong correlation between the key economic indicator of the region's GRP and the universities' research activities based on calculation of correlation coefficients (r), elasticity coefficients ( ), and determination coefficients (r2), it is possible to influence the economic development of the region. We illustrate this aspect with the help of trend predicted values of factor attributes (indicators of the universities' research activities) and calculation of the value of the productive attribute (GRP) based on the obtained regression equations.

Figure 2 shows the trend lines and the predicted values of the indicators of the universities' research activities.

Figure 2
Trend lines and predicted values of epy
indicators the universities' research activities







Based on the obtained predicted values, the GRP indicator for 3 years was calculated based on the obtained regression equations (Table 6).

Table 7

Calculation of predicted values of the resulting attribute (GRP) based on the obtained predicted values of factor attributes (indicators of the universities' research activities) and regression equations

Indicators of the universities' research activities	Predicated values of indicators of the universities' research activities			Regression equations	GRP predicted values calculated using the regression equations		
	2018	2019	2020		2018	2019	2020
Volume of internal expenditures for R&D, million rubles	4128.0	4185.0	3805.0	$\overline{y_x} = 6.18 + 0.082x$	344.676	349.35	318.19
Number of universities engaged in R&D	6	6	4	$\overline{y_x} = 29 + 70x$	449	449	309
Number of personnel engaged in R&D, thousand people	5.9	6.02	5.7	$\overline{y_x} = 3.411 + 58.277x$	347.2453	354.2385	335.5899

The data of table 7 show that the predicted values of factor attributes (indicators of the universities' research activities) have a positive trend in the next two periods, and that they will decrease in the third predicted period (2020). At the same time, the indicators of the resulting attribute (GRP) obtained on the basis of the regression equation also have a positive trend in the next two periods, and this indicator will also slightly decrease in the third predicted period.

To assess the reliability of the forecasts made, the MAPE and Forecast Accuracy indicators were calculated (Table 8). At the same time, correctness of the predicted values of the indicators was assessed for 2020, and the indicator $\frac{1}{N} = \frac{1}{5} = 0.2$, since the assessment concerned five periods of the temporal series.

Table 8

Calculation of MAPE and Forecast Accuracy indicators for factor attributes
(indicators of the universities' research activities) and the resulting attribute (GRP)

Indicators	2013	2014	2015	2016	2017	(MAPE→0)	Forecast Accuracy →100%
Actual value of the temporal series (internal expenditure for R&D, million rubles). The predicted value for 2020 is 3805 million rubles.	4539.5	3518.5	3645.2	3793.6	3962.0		
$\lvert Z(t) - \hat{Z}(t) \rvert$	734.46	286.5352	159.8	11.4	157		
$\frac{\lvert Z(t) - \hat{Z}(t) \rvert}{Z(t)}$	0.161795	0.081438	0.043838	0.003005	0.039626	0.06594	93.41
Actual value of the temporal series (number of universities engaged in R&D). Predicted value for 2020 is 4	2	4	4	5	6		
$\lvert Z(t) - \hat{Z}(t) \rvert$	2	0	0	1	2		
$\frac{\lvert Z(t) - \hat{Z}(t) \rvert}{Z(t)}$	1	0	0	0.2	0.33	0.3	70
Actual value of the temporal series (number of personnel engaged in R&D, people). Predicted value for 2020 is 5700 people	5583.0	5684.0	5790.0	4690.0	5810.0		
$\lvert Z(t) - \hat{Z}(t) \rvert$	117	16	90	1010	110		
$\frac{\lvert Z(t) - \hat{Z}(t) \rvert}{Z(t)}$	0.020956	0.002815	0.015544	0.215352	0.018933	0.05472	94.53
Actual value of the temporal series (GRP, billion rubles). The predicted value for 2020 calculated in accordance with the internal expenditures for R&D is 318.9 billion rubles	270.4	295.2	343.3	348.9	365.2		
$\lvert Z(t) - \hat{Z}(t) \rvert$	48.5	23.7	24.4	30	46.3		
$\frac{\lvert Z(t) - \hat{Z}(t) \rvert}{Z(t)}$	0.179364	0.080285	0.071075	0.085985	0.12678	0.108698	89.13%
Actual value of the temporal series (GRP, billion rubles). The predicted value for 2020 calculated in accordance with the number of universities engaged in R&D – 309 billion rubles	270.4	295.2	343.3	348.9	365.2		
$\lvert Z(t) - \hat{Z}(t) \rvert$	38.6	13.8	34.3	39.9	56.2		
$\frac{\lvert Z(t) - \hat{Z}(t) \rvert}{Z(t)}$	0.142751	0.046748	0.099913	0.114359	0.153888	0.111532	88.85%
Actual value of the temporal series (GRP, billion rubles). The predicted value for 2020 calculated in accordance with the number of the personnel engaged in R&D, people – 335.59 billion rubles	270.4	295.2	343.3	348.9	365.2		
$\lvert Z(t) - \hat{Z}(t) \rvert$	65.19	40.39	7.71	13.31	29.61		
$\frac{\lvert Z(t) - \hat{Z}(t) \rvert}{Z(t)}$	0.241087	0.136822	0.022458	0.038148	0.081079	0.103919	89.61%

Thus, based on the calculated MAPE and Forecast Accuracy indicators for the obtained predicted values, we can conclude that the predicted level of factor attributes (indicators of the universities' research activities) and the resulting attribute is highly accurate, for all factor attributes MAPE ≤ 0.3, and Forecast Accuracy ³ 70%, and for the resulting indicator (GRP level) MAPE ≤ 0.11, and Forecast Accuracy ³ 88%. The obtained MAPE and Forecast Accuracy values confirm the reliability of the proprietary method for assessing the impact of the universities' research activities on the GRP level and the predicted values of such indicators.

Based on the analysis performed, it can be concluded that the indicators of assessing the impact of the universities' integrative activities on the socio-economic component of regional development have a direct impact on the level of gross regional product. At the same time, formation of an effective system of regional universities in each constituent territory of Russia should ensure growth of socio-economic indicators of the regional development, which will contribute to the formation of a

knowledge-intensive innovative economy and development of industries and complexes of great priority for the region.

Assessing the impact of universities on the socio-economic and cultural component can contribute to the typology of regional higher education systems: drivers of regional development; higher education systems with high, moderate and low levels of influence.

This ranking shows the degree of contribution of regional higher education systems to the specific socio-economic situation in the region. At the same time, regional higher education systems make different contributions to the local economy, which is determined by the influence of various factors: geographical, historical, social, etc.

3.1. Discussion

Socio-economic development is influenced by the relationships between the university and the key groups of stakeholders, and only interaction with other education institutions and civil society organizations is aimed exclusively at solving their internal problems. The impact can be either direct, for example, in the case of regional authorities and the labor market, or indirect, through the development of commercial enterprises (located in the region) and the innovation component of their activities.

The existing models for assessing the region's economic potential, such as Economic Development Report Card 2018 (2018) (DRC), EU Regional Competitiveness Index (Annoni and Dijkstra, 2013) use a significant number of factor indicators that determine the increase or decrease in the GRP value. As a rule, such models use indicators for assessing the natural resource potential, general development level of entrepreneurship and market in the territory, personnel, etc. However, despite a fairly large number of indicators, such methods for assessing the development of the regional economy based on the systematic approach do not take into account the importance of assessing the impact of R&D of educational organizations on the GRP.

The method proposed by the authors complements the Model of multifunctional and multi-level participation of the university in the regional development of P.Arbo and P. Benneworth (2007), proving that financing of the universities' research activities contributes to the achievement of positive socio-economic results in the regional economy and enables to calculate the quantitative parameters of such impact.

4. Conclusions

Based on the study results, it was revealed that the results of the universities' integrative activities have a direct impact on the socio-economic and cultural component of regional development. At the same time, higher education institutions are large and bona fide taxpayers; promote the growth of federal funds in the region through subsidies; act as a customer and consumer of goods and services, stimulating the economic activity of regional enterprises; are research centers; create innovative enterprises, thereby stimulating tax revenues to the regional budget and the growth of GRP; contribute to the financial development of the regional economy through stimulating consumer demand (including by attracting foreign students and teachers) and through paying high (in terms of the region) wages to the teaching staff.

Thus, formation and implementation of integrative activities by regional universities within the system of regional development institutions allows to increase the economic efficiency of the region and achieve positive socio-economic results: increase in the number of small and medium-sized businesses; growth of GRP and indices of industrial production in the region; increase in the investment attractiveness of the region; growth of the level of health care, standards of life, employment rate and incomes of the population in the region, and as a result - increase in the income level of the consolidated budgets of the constituent entities of the Russian Federation.

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