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Research paper

A New Approach to Assessing the Science Contribution to the State Economy

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Abstract

The article is dedicated to the issues of assessing the science contribution to the state economy. The suggested author's approach to estimation the science impact on the economic growth. The authors carried out modeling of estimation the role of science in the country's economic development on the example of Great Britain. According to the models obtained, the volume of R&D expenditures has the most significant influence on the country's economic development, and in the long outlook this impact is almost twice as high as in the short-term one. The article conclusion contains advantages and limitations of author's approach to assessing the science contribution to the state economy.

Keywords: *science, science contribution, state economy, economic development, modeling.*

1. Introduction

Current rapid development taking place in the world is bases on knowledge. Developed countries economies robotics is occurring at considerable speed. Information becomes an important factor of production at the same level with capital and labor. The main producer of the information which then becomes an important factor of production is a country's scientific sector. A lot of countries enjoy more or less created mechanism of transforming the obtained knowledge into production. This knowledge is also a product which is exported, sold and which gives profit.

Problems of defining the role of science for economic growth are being studied in numerous works by various world scientists [1, 2, 3, 4], where they testify about its significant importance for the economy growth provision. But there is an alternative point of view that cast doubts on the effectiveness of an innovation policy that attempts to improve aggregate productivity only based on increasing R&D intensity [5]. In particular, investigation was carried out on the examples of such countries as follows:

- The USA [6],
- Japan [7],
- South Korea [8],
- China [2],
- Italia [9],
- Romania [10],
- Bangladesh [11],
- Ukraine [12],
- RF [13] etc.

In the works by [14, 15] Cobb-Douglas production function was applied for estimation the production factors influence on the country's economy in general.

Thus, the aim of the paper is developing author's approach to estimating the production factors influence on the country's economy in general.

2. Situation analysis

Comparing analyses of such indices as GDP per capita in different Europe countries (fig.1) and amount of R&D expenditure (fig.2) reveals a certain connection between them in a long-term period. Among the chosen countries are the EU leaders – Germany, Great Britain, France; the countries that are leaders by the standard of living – Finland, Sweden, Netherlands, Austria; the countries that are going through hard time due to the crisis – Portugal, Greece, Italy, and neighboring to Ukraine countries – Poland, Lithuania, Latvia, the Russian Federation and Hungary. Consequently, we can observe that among this selection Ukraine and Russia occupy the last place by the GDP level per capita in constant prices in 2000. In such countries as Sweden, Netherlands, Austria, Finland, Germany, France, Great Britain and Italy this indicator is above the average in Europe and Central Asia, which in 2017 was about 25 thousand dollars. Thus, Ukraine is behind this indicator from the average level by more than 8 times and from the level of leaders by more than 15-17 times.

Fig.2 represents the countries dynamics by the "R&D expenditure level" index. The same situation can be observed for the countries that provide their own economy with considerable level of the science expenditure and accordingly the majority of them have the analogue level of economic development. A conclusion can be made as follows: a low level of expenditure for their own R&D development by countries placed in the bottom part of graph 2 defines equal places in the bottom part of graph 1. And vice versa, the countries with high level of their own R&D development expenditure have higher indicator of their economic development (fig.1)

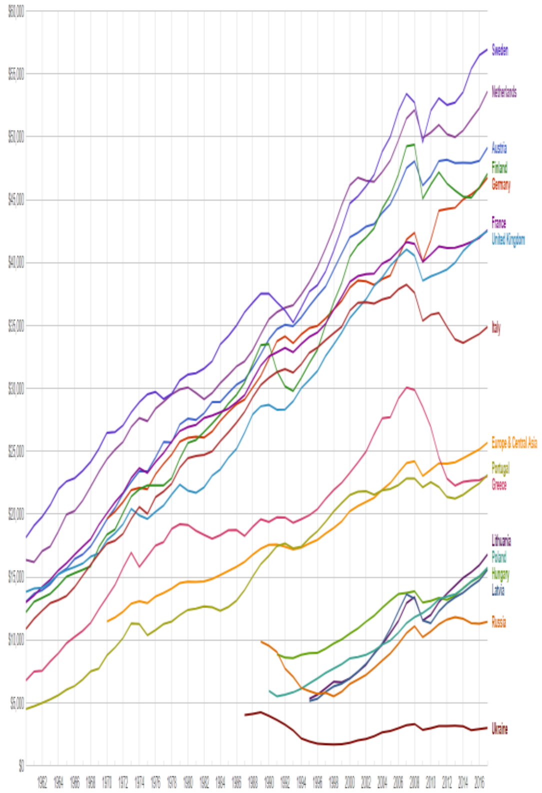

Fig. 1: GDP per capita (expressed in US dollars in 2000) in some European [1]

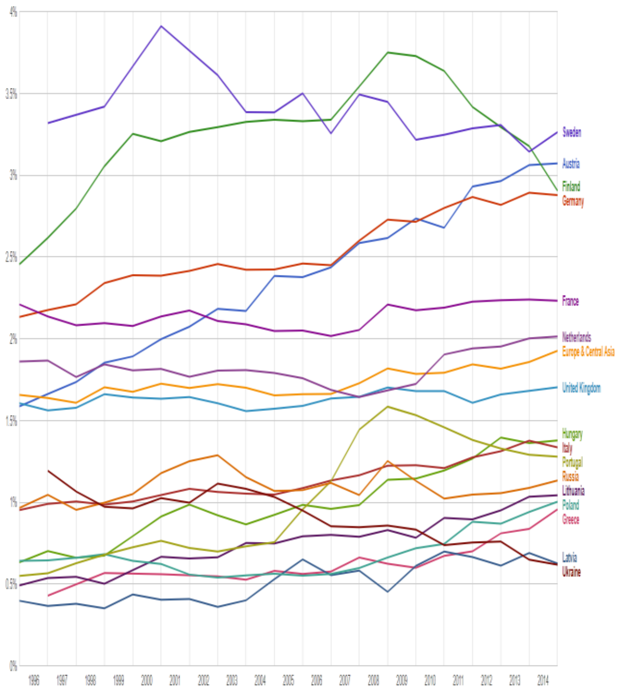

Fig. 2: Research and development expenditure in some European countries (% of GDP). [1]

3. Theoretical part

Cobb-Douglas production function was first calculated in 1928 in (Cobb-Douglas, 1928) [16]. It looks as follows:

$$Y = A \cdot K^{\alpha} \cdot L^{\beta} \qquad (1)$$

The function defines the dependence of created social product value from total living labor expenses L (within the country boundaries this indicator will be determined by the number of employed population in its economy - Labor force, total, according to the World Bank terminology), and the volume of productive assets being used K (current value of fixed assets, or according to the World Bank terminology - Gross fixed capital formation).

α and β are coefficients that take into account influence of each of the K and L factors on the production of a social product.

A is a coefficient that takes into account influence of factors that are not included in this equation, or factors that make up the external technological level of the economy (according to Solow [17]).

Specific values of α, β and A are determined on the basis of statistical data using mathematical statistics methods. It is considered that α and β should be less than unity, but their sum can take different values relatively to unity, which, accordingly, characterizes a different type of effect from the combined interaction of these factors.

In order to evaluate the information factor influence, we will take, firstly, because the main "producer" of such information is science, and secondly, the generally accepted methodology for evaluating the activities of science has not yet been adopted, we will make such an assessment on the level of the cost of this information, which can be determined as the amount of funding for science in the country. Consequently, equation (1) will look as follows:

$$Y = A \cdot K^{\alpha} \cdot L^{\beta} \cdot S^{\gamma}$$

Where S is amount of R&D expenditures in monetary units (Gross domestic **expenditure** on research and development – GERD. The given indicator includes **expenditure** on **research and development** by business enterprises, higher education institutions, as well as government and private non-profit organizations.), γ is a coefficient taking into account impact of information on social product production.

Provided α +β + γ = z, then in case of all the resources increases in n times we will receive:

$$A \cdot (nK)^{\alpha} \cdot (nL)^{\beta} \cdot (nS)^{\gamma} = An^{\alpha+\beta+\gamma} \cdot K^{\alpha} \cdot L^{\beta} \cdot S^{\gamma} = Y_n \qquad (2)$$

That is

$Y_n = n^z \cdot Y$ is a new index of GDP amount.

Thus if z=1, то $Y_n = n \cdot Y$, then proportional increase in all the resources by n times will lead to GDP increase in n times.

Provided z>1, то $Y_n > n \cdot Y$, then GDP increase will outrun the resources increase pace, which is characterized as a positive effect of economy stepping-up.

If z<1, то $Y_n < n \cdot Y$, then increase in resources will occur faster than GDP increase. That is characterizing for negative effect of economy stepping-up.

Each of the production factors is characterized by average and marginal values. If the equality is divided (2) by L, we will obtain the average labor productivity:

$$\frac{Y}{L} = A \cdot K^{\alpha} \cdot L^{\beta-1} \cdot S^{\gamma} \qquad (3)$$

Average labor productivity reflects the amount of GDP for the unit of the labor used. Two variants ought to be considered here. One of them is the following:

0<β<1, then β-1 <0 , it means than with increase in labor inputs L in n times (nL), average labor productivity will be changing in nβ-1times. It means, that β-1<n will decrease, given other equal conditions. In real production circumstances every additional labor unit will have to be provided with additional labor conditions and undergo appropriate training (that is, to be provided with the necessary information).

In terms of a state there may occur other situations:

Second variant.

β >1, then β-1 >0, which means that with increase in L labor productivity will continue growing, it means that economy possesses a certain amount of capital (fixed assets) that are not used, secondly a synergetic effect of such cooperation is observed.

4. Empiric part

4.1. Initial data for modeling

A hypothesis defining: information is an important factor of production as well as capital and labor. The question is whether it is possible to create production model in the country considering this factor. As a quantitative concept of "Information" factor we suggest taking the index of general expenditures for R&D in the country (GERD). As an example for modeling we suppose Great Britain as a modern European developed country. Initial data for building of such a model are presented in the table 1.

Table 1: Initial data for building Great Britain model, major indices.

Year	GDP, million current US$	Gross fixed capital formation, million current US$	Labor force, total thousand people	GERD , million current US$
2000	1 647 951	293 992	29 296	27 036
2001	1 621 510	279 784	29 259	26 474
2002	1 768 408	306 281	29 589	29 062
2003	2 038 395	343 125	29 869	32 710
2004	2 398 555	401 084	30 143	37 359
2005	2 520 702	427 418	30 590	39 603
2006	2 692 613	462 164	31 037	42 792
2007	3 074 360	542 977	31 241	50 228
2008	2 890 564	490 803	31 648	47 511
2009	2 382 826	363 600	31 826	40 545
2010	2 441 173	374 218	32 010	40 990
2011	2 619 700	402 811	32 192	44 004
2012	2 662 085	415 167	32 543	42 793
2013	2 739 819	433 369	32 852	45 467
2014	3 022 828	495 228	33 144	50 823
2015	2 885 570	478 483	33 408	49 142

Source: World Bank. Access date - September 2018p [1]

Initial data are represented by GDP in millions of US dollars – Y, amount of Gross fixed capital formation in millions of US dollars – K, number of labor force, total in thousands of people – L and amount of R&D expenditure (GERD – Gross domestic expenditure on R&D) in millions of US dollars were chosen as new information value – S.

The period under investigation covers 16 years from 2000 to 2015. Thus, for adequate statistical data comparing and creating a model, all the value indicators were corrected by us according to the dollar inflation level [19] and values are brought to the level of the US dollar in 2000. The results are presented in Fig. 3

The graph of the purified data is shown in Fig. 1

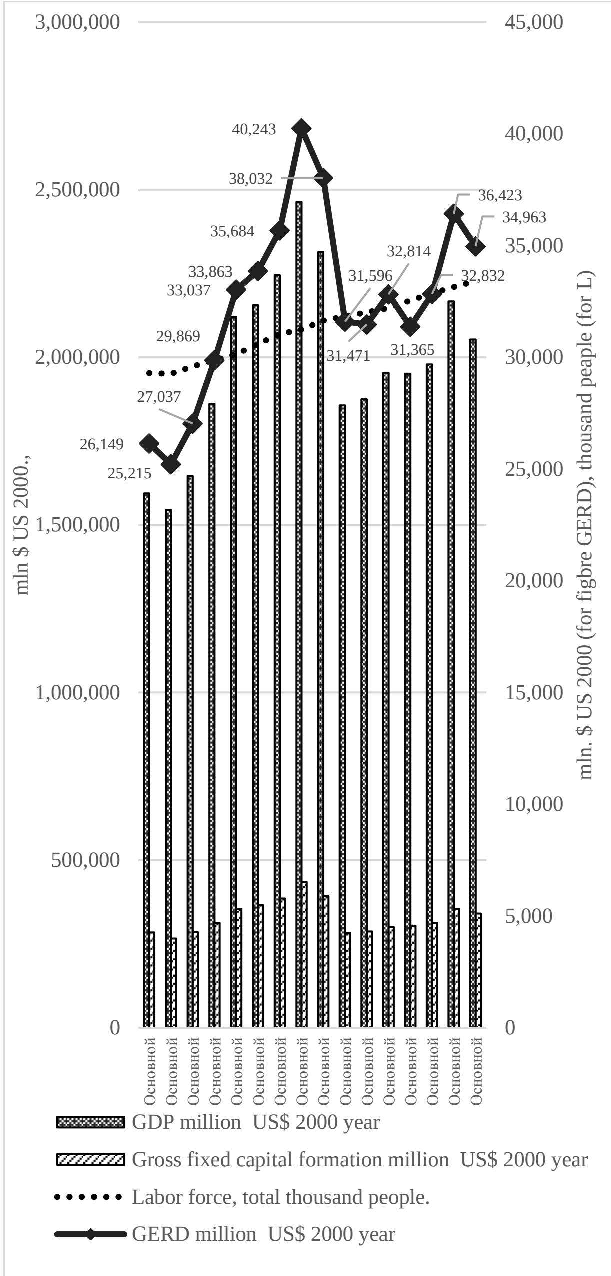

Fig. 3:. Dynamics of indicators for 2000-2015 in US $ 2000

The country's economy develops cyclically. We can observe two waves; the first was from 2000 to 2007, the second - from 2009 to 2014. This kind of development is related to GDP, Gross fixed capital formation and GERD indices. Labor Force Dynamics shows a gradual increase over the entire period under study.

4.2. Data analysis

The following stage of our investigation will include a brief analysis of these factors. In order to do this we suggest calculating their chain and basis growth rates and comparing them. The calculation results are represented in Fig.4 and Fig.5.

Dynamics of the chain growth rates for factors under study is of the following nature. Monetary factors-GDP, Gross fixed capital formation and GERD are characterized by synchronous nature of the changes, and the labor force factor is characterized with relative stability as well as the growth rate. The indicator is in the range from 1,006 to 1,014, i.e. fluctuations occur within 1-1,5% limits. At the same time, the first three factors range from 0.7 to 1.15, i.e. the oscillation amplitude is about 45%. Of course, the significant fall in 2007 and 2008 can be explained by the global crisis, but in 2014 descending waves are observed again.

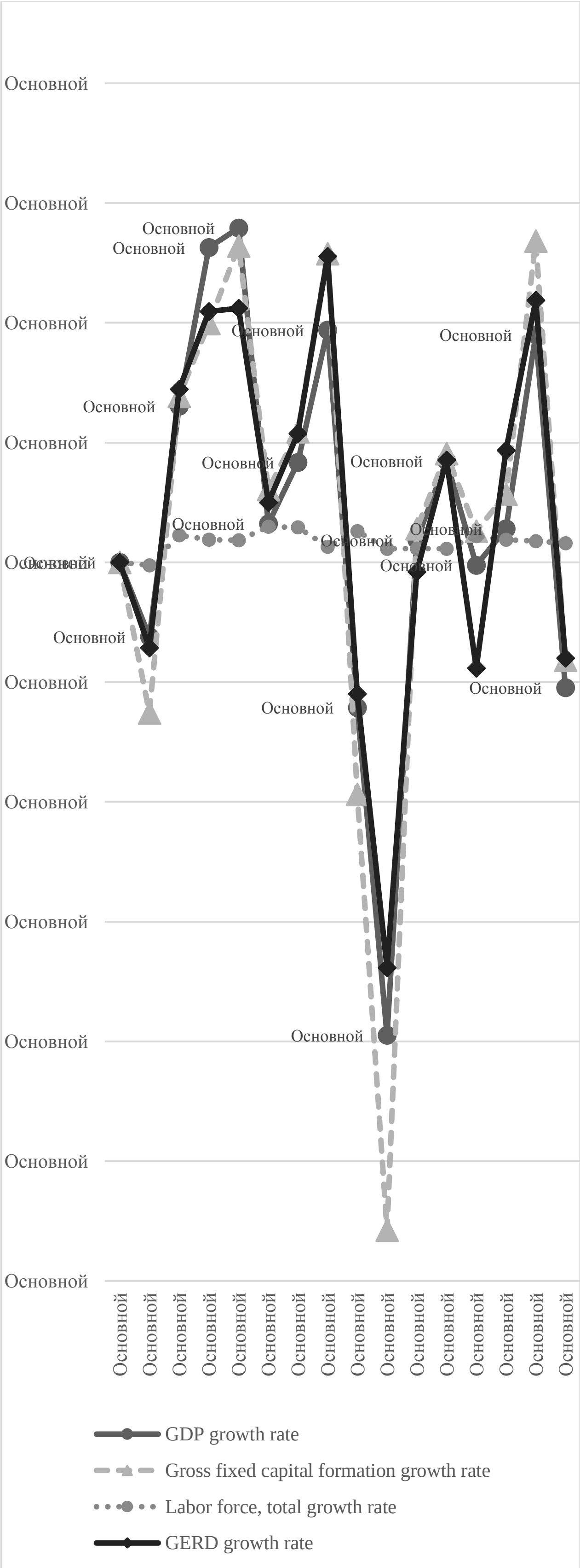

Fig.4: Indicators chain growth rates dynamics in 2000-2015

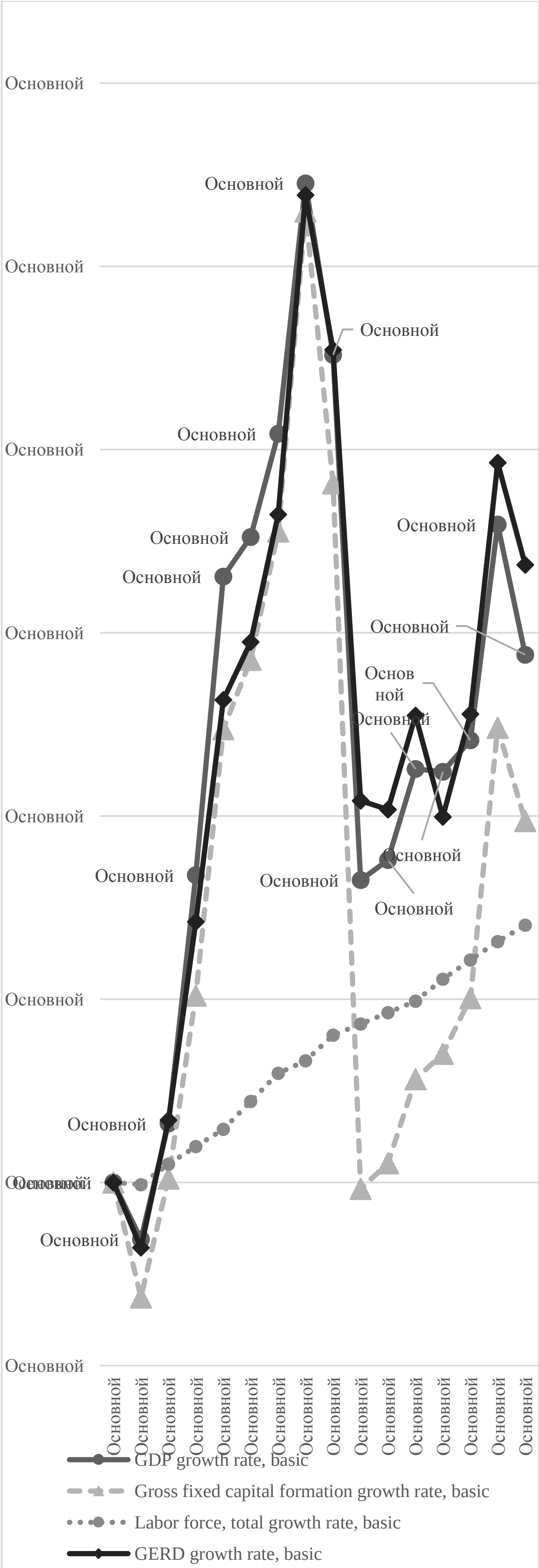

Fig.5: Comparing bases growth rates indicators in 2000-2015, calculated in $ US in 2000, 2000=100

In a long-term outlook reflected by bases growth rates indicators, dynamics of which is represented in fig.5, the following can be observed:

- Three growth waves occurred from 2001, from 2009 and from 2012 to 2014. And the same number of much shorter descending waves.
- General growth of GDP, Gross fixed capital formation and GERD indicators by 20-36% for the whole period under study, with Labor force indicator increase by 14%.
- Increase in GERD growth rates according to other factors.
- Maximum growth rates took place in 2007.
- Economy did not sustain its 2007growth rates in 2015.

The model coefficients calculation was carried out with the help of spreadsheet Excel 2016 built-in functions. The results are represented in Table 2.

Table 2: Building the models and their statistical estimation

	Initial data in $US in 2000		
	Absolute values	Growth rates	Bases growth rates
Model equation	Y=134,85K^(0,223)·L^(-0,166)·S^(0,818)	Y=1,01K^(0,449)·L^(-0,361)·S^(0,44)	Y=1,03K^(0,223)·L^(-0,166)·S^(0,818)
	Model statistical characteristics		
Multinomial R	0,9906	0,9826	0,9826
R-squared	0,9813	0,9656	0,9656
Standard error	0,0203	0,0177	0,0177
Observations	16	16	16
Fisher's criterion calculated	209,88	112,23	209,88
Fisher's criterion table	5,95	5,95	5,95
	Model is reliable	Model is reliable	Model is reliable
	Model's calculated indices		
A	135	1,01	1,03
α	0,22	0,45	0,22
β	-0,17	-0,36	-0,17
γ	0,82	0,44	0,82
Growth quality index α1+α2+α3	0,88	0,53	0,88
Conclusion on the development nature	negative outcome	negative outcome	negative outcome
	Statistical estimation of model indices by Student's criterion		
t0	1,8105	0,5875	1,7753
t1	1,5343	3,1911	1,5343
t2	-0,5805	-0,3459	-0,5805
t3	4,1482	2,229	4,1482
t-table under 90% value	1,356	1,356	1,356

In the short-term outlook the model has the following equation:

$$Y=1{,}01K^{0{,}449}\cdot L^{-0{,}361}\cdot S^{0{,}44} \quad (4)$$

The model for long-term outlook:

$$Y=1{,}03K^{0{,}223}\cdot L^{-0{,}166}\cdot S^{0{,}818} \quad (5)$$

It should be noted that checking for statistical criteria confirms the adequacy and reliability of the models obtained by us (see table 2).

Taking into account the global crisis, which significantly reduced the country's development rate, our models indices enable noticing the following: that the country is in the stage of t crisis recovering, because it has a negative outcome from all the factors under consideration.

According to the models obtained, the volume of R&D expenditures has the most significant influence on the country's economic development, and in the long outlook this impact is almost twice as high as in the short-term one. Also, a negative impact of the labor factor is observed, which, in our opinion, can be explained by the steady tendency for relocating most of the manufacturing enterprises to low-wage countries and use of emigrants' labor.

Isoquant plane of the factors under study is built on Fig.6.

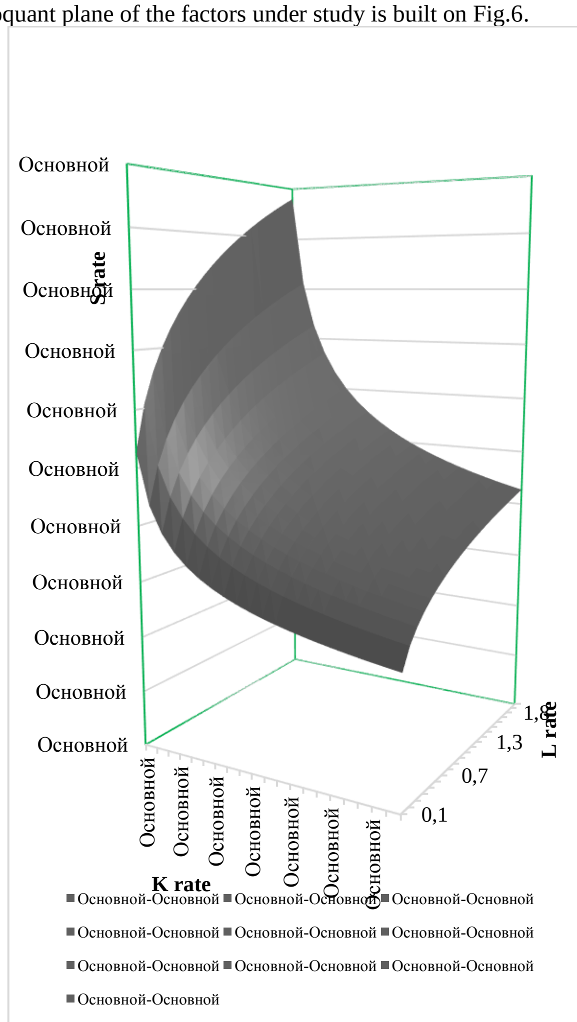

Fig.6: Isoquant plane of the factors of production for providing GDP bases growth rate in long-term outlook.

5. Conclusions

The carried out modeling of estimation the role of science in the country's economic development showed on the example of Great Britain that such impact is real and it is significant. For 2000-2015 period it shows that GERD growth rate increase by 1% will enable GDP increase by up to 4,4% in the short-term outlook and by up to 8,2% in a long-term one.

The suggested approach to estimation the science impact on the economic growth has certain advantages and limitations.

Thus the advantages include the fact that the model enables defining both exogenous (A coefficient which defines technologies development level according to which economy works) and endogenous impact (S index defining the impact of internal R&D development) of the science on economic development. Also by using different initial factors, which include chain and bases growth rates it is possible to testify to the model's ability to describe short-term and long-term periods in economy development. Limitations of its usage include necessity of taking into consideration the availability and development of scientific and technical infrastructure. In other words, this is the availability of mechanism for transferring the obtained knowledge from the scientific sector to the production one. In case of this infrastructure lack or being inefficient, the knowledge accumulated will not be used by the country for its development and consequently will have indirect influence for economic development.

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