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Comparative analysis of National Innovation Systems through an Indicator of R & D Expenditures

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ABSTRACT: Moving in the direction of achievement of sustained economic growth the majority of countries is following a way of innovative development. Innovations are the driving force of competitiveness development. Increase in national welfare positively affects on all spheres of human activity and allows to achieve the social, economic and political objectives. Any development assumes not only actions in the direction of the purpose, but also the constant analysis and control of the received results to correct the plan and to minimize new risks in time.
Scientists and economists of the international organizations accumulated considerable experience in drawing up statistics for assessment of results of the activity directed to improvement of the innovative environment for the purpose of improving competitiveness of regions.
There is no uniform standard of carrying out the analysis and granting objective and indisputable assessment of efficiency of the innovative policy pursued by the state nowadays.
The article describes the approaches to assessment of innovative development and competitiveness used by the international organizations. The countries chosen for the analysis are distributed on the key indicators reflecting the level of development of national innovation system. Level of efficiency of expenses on research and development is determined by the technique offered by the authors, conclusions are drawn on the applied nature of this analysis.

Keywords: innovation; innovation system; efficiency; competitiveness; rating.

I. INTRODUCTION

In the modern world the majority of the countries recognized an innovative way of development as the main strategic direction in the economy. There is the wide experience by determination of the level of development of innovative systems at various levels in scientific community. The largest international organizations have the systems of indicators and a technique of assessment characterizing the level of social security, education level, market competitiveness and the level of an innovation system.

II. METHODS

The World Bank within the long-term program "Knowledge for Development" worked out the generalizing indicator "Knowledge Economy Index" (KEI). The KEI is calculated based on a 10-ball scale and is divided into 4 pillars: Economic and Institutional Regime estimates the level of the created conditions for conducting business activity; Education and Training characterizes degree of literacy of the population and structure of the population on education level; Information and Communication Technology reflects degree of a computerization and degree of coverage telephone communication and the Internet; Innovation and Technological Adoption shows the level of innovative activity [1].

The world rating made by analysts of the World Economic Forum (WEF) is based on a combination of results of survey of heads of the large companies and public data. Researches are conducted annually, since 2004. The index is based on 12 control indicators, one of which is an indicator of innovative potential. Existence of such ratings is very important for development of innovative business as investors will introduce new technologies only being sure that in the country the necessary environment and an innovation system allowing to get the profit exceeding the sum of investments is created.

One more index reflecting level of development of an innovation system is developed by the international business school INSEAD. The global index of innovations includes 82 parameters which fully characterize the level of innovative development of various countries.

As the main factors characterizing innovative development in a technique of the Organization for Economic Cooperation and Development (OECD) the size of expenses on research and development, labor productivity and decrease in emission of greenhouse gases is used.

Table 1: Comparison of Innovative Development Level of Russia, the USA and China according to the main international ratings.

S. No.	Country	KEI, 2012 [a]	Global Competitiveness Index, 2018 [b]	Global Innovation Index, 2017 [c]
1	Russia	54th place	38th place	45th place
2	USA	13rd place	2nd place	4th place
3	China	83rd place	27th place	22nd place

Despite a large number of the used parameters, as a key indicator of level of innovative development the international organizations use expenses on research and development. Russia on this indicator occupies 34th place at a share of expenses in science from GDP in 1.1% [2]. These indicators at the USA and China for 2016 are 2.74% and 2.12% [3].
In the USA and China fixed assets for research and development are allocated by business (62% and 79% respectively), in Russia fixed assets are allocated from the state – 68%, business – 28% [4].

The fixed assets on research and development allocated by business of the USA are concentrated on the following industries:
–production of the main pharmaceutical products and pharmaceutical medicines – 16% (58.6 billion dollars in 2015);
–production of electronic components and payments – 9% (30.5 billion dollars in 2015);
– production air and spacecrafts and the related cars – 8% (27.5 bln. dollars in 2015)[(e)].
The U.S. Government on a straight line invests through the ministries (agencies). The main shares of expenses on research and development in 2018 fall on the Ministry of Defence (41%, 58,557 mln. dollars) and on the Ministry of Health (26%, 37,057 mln. dollars). On the third place expenses of the Ministry of Energy (13%, 18,359 mln. dollars).
For the last 10 years decrease in expenses on research and development by federal departments of the USA is observed.
In the priority directions, such as defense and health care, funds are allocated directly from the relevant ministries, in other directions of researches funds are allocated through financing of the universities.
Expenses of the U.S. Government on research and development tend to decrease since 1960 – since the midst of Cold War and Space Race – and for these years the share of these expenses from GDP decreased by 25%. [6]
In China business directs the investments generally to production of computer, electronic and optical products (16% or 57.5 bln. dollars in 2015) and on production of machines and the equipment (10% or 35.8 billion dollars in 2015).

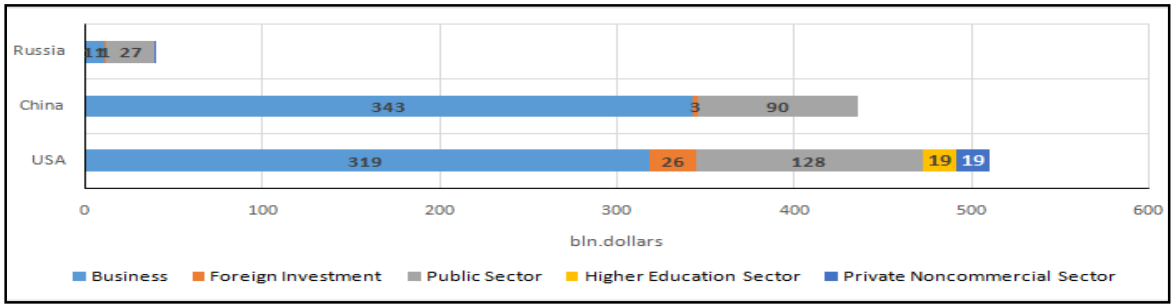

Fig. 1. Data on expenses on research and development in Russia, the USA and China in 2016 [4].

Table 2: Financing of research and development in the USA on sources, mln. Dollars[d].

S. No.	Source	2010	2011	2012	2013	2014	2015	2016	Percent
1	Business	233456	250873	258572	277974	295422	309653	318527	62%
2	Foreign Investment	15296	16305	17732	20348	24054	24 858	26427	5%
3	Public Sector	133742	134384	128725	125232	123611	126654	128203	25%
4	Higher Education Sector	12105	12 949	14 300	15378	16217	17 334	18686	4%
5	Private Noncommercial Sector	15494	15282	15019	15891	17156	18086	19246	4%
	Total	**410093**	**429793**	**434348**	**454823**	**476460**	**496585**	**511089**	**100%**

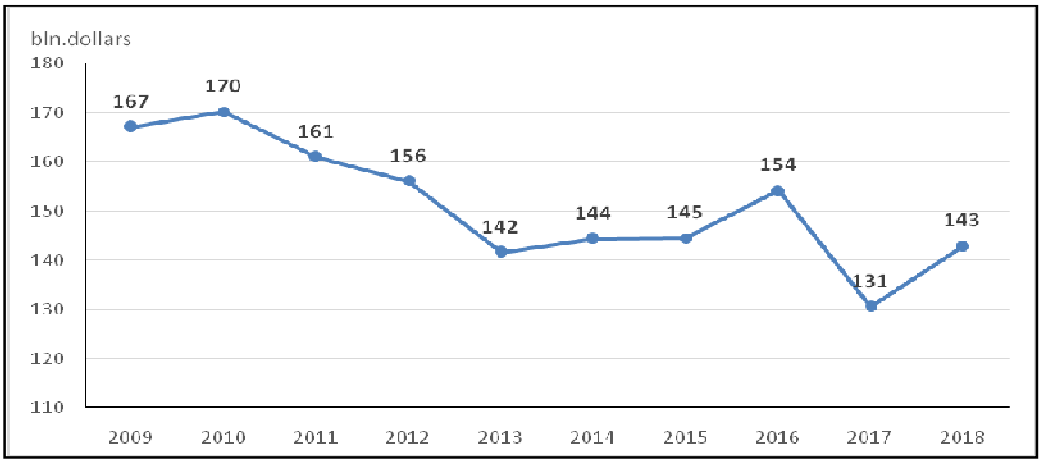

Fig. 2. Dynamics of expenses federal departments of the USA on on research and development [5].

Table 3: Financing of research and development in China on sources, mln. Dollars[f].

S. No.	Source	2010	2011	2012	2013	2014	2015	2016	Per cent
1	Business	153047	183157	216344	249255	279502	304445	343178	79%
2	Foreign Investment	2785	3315	2849	2986	3062	3024	2971	1%
3	Public Sector	51275	53714	63028	70525	75056	86636	90397	21%
	Total	**207108**	**240186**	**282221**	**322766**	**357621**	**394105**	**436547**	**100%**

Table 4: The number of the submitted patent applications on PCT in 2013[g].

S. No.	Field	USA	China	Russia
1	Biotechnology	4758	522	56
2	Information and communication technologies	18488	12774	309
3	Nanotechnologies	362	40	31
4	Medical technologies	6679	748	57
5	Pharmaceuticals	5001	733	90
6	Environment technologies	4704	1341	94
7	A61K (preparations for medical, dental, or toilet purposes)	3026	344	52
8	C12N (Microorganisms, genetic engineering)	922	142	7
9	IPC H: Electricity	11 065	9 453	174
	Total	**55006**	**26096**	**871**

Similar to volumes of the allocated funds the structure of patent activity where it is focused on information and communication technologies in all three analyzed countries is distributed.

The indicator of level of research and development costs plays an important role at decision-making of financial assistance to the states from the international organizations.

At allocation of money under implementation of the innovative project by specialists of the World Bank the solvency of the organization and the country in general is estimated and also the level of readiness for introduction of innovations is analyzed. Respectively the general economic analysis intertwines with the analysis of a national innovative system.

In the analysis of the project on granting 88 mln. dollars to the Republic of Kazakhstan in 2014 on increase in scientific potential the analysis of a national innovative system was carried out[h]. The following indicators were analyzed:

– a share of costs of research and development from GDP;

– the number of the organizations which are carrying out research and development;

– number of staff, occupied with research and development;

– the number of lecturers in higher education institutions, etc.

Quantitative index of achievement of necessary level of efficiency was increase in a share of costs of research and development within 10 years up to 3% of GDP. The purpose and the recommendation are standard for the World Bank. The same recommendations were for Chile, Colombia, Senegal, Tunis.

However, one of reports of the World Bank informs about incorrect use of an indicator - the share of costs of research and development from GDP - as it does not reflect the level of efficiency of national innovation systems and social rate of return. Use of this indicator is explained by the fact that to count profitability of investments in science rather difficult, and presence of high level of investments in research and development is better, than their absence [7].

By consideration of results of any activity it is necessary to analyze this phenomenon from directions: effectiveness, efficiency and stability.

The effectiveness is understood as extent of realization of the planned activity and correlation of actually received results with planned ones [8].

There is a set of interpretations of a concept efficiency. For example, D. Ricardo defined efficiency as extent of excess of results over the spent resources [9, 12].

Stability is understood as ability to achieve result in the set limits of the purposes and resources [8].

Research and development are the engine of progress and development of innovations because we see these results in everyday life, in production and finance. Importance of such works consists of obtaining new knowledge and practical application of results of intellectual work [10, 11]. Assignment for research and development involves development of new technologies, demand for competent employees, development education and as a result formation of innovative infrastructure. The comparative analysis of expenses on research and development allows to draw conclusions on results of the carried-out work in the field of formation of innovative economy.

If we consider the state as separate economic unit, all expenses need to be correlated to income gained thanks to them. It is necessary to analyze efficiency, that is to consider a ratio of income with expenses. The efficiency can also reflect extent of influence of the spent resources on a target indicator.

In the inter country comparative analysis of efficiency of innovation systems as a resource factor the volume of expenses on research and development was used, and GDP per capita was chosen as a resultant indicator. GDP indicator per capita characterizes effectiveness of economy and including effectiveness of a national innovation system as "engine" of economic growth.

Between the considered indicators over three countries correlation connection with correlation coefficient more than 0.9 is established.

For the description of communication we make regression models where an endogenous factor is GDP per capita, and exogenous one is expenses on research and development. The analyzed period was from 2002 to 2015.

Regression models confirm the importance of factors and communications between the chosen indicators.

The efficiency of expenses on research and development was defined as a ratio of average gain in 14 years on GDP per capita to average gain of expenses on research and development.

$$EFF^c = \frac{I^c_{GDP}}{I^c_{R\&D}} \quad (1)$$

I^c_{GDP} - geometric mean of gain of GDP per capita in the country *c*;

$I^c_{R\&D}$ - geometric mean of gain of expenses on research and development about the country *c*.

This indicator can also be used on an annual basis that allows to monitor regularly change of efficiency dynamics of expenses on research and development.

Table 5: Distribution of correlation coefficient.

	Expenses on research and development, mln. dollars	Number of applications for patents on PCT (by date of application)	GDP per capita, dollars	Number of researchers on 1,000 workforce
1. Russia				
Expenses on research and development, mln. dollars	1			
Number of applications for patents on PCT (by date of application)	0.871711	1		
GDP per capita, dollars	0.981217	0.91153	1	
Number of researchers on 1,000 workforce	-0.93383	-0.79942	-0.9544	1
2. USA				
Expenses on research and development, mln. dollars	1			
Number of applications for patents on PCT (by date of application)	0.90814	1		
GDP per capita, USD	0.99292	0.935892	1	
Number of researchers on 1,000 workforce	0.959611	0.893829	0.954947	1
3. China				
Expenses on research and development, mln. dollars	1			
Number of applications for patents on PCT (by date of application)	0,990468478	1		
GDP per capita, dollars.	0,994106063	0.974225	1	
Number of researchers on 1,000 workforce	0.836430854	0.775585	0.881439	1

Table 6: Regression models.

S. No.	Country	Regression equation
1	Russia	У = 5,18 + 0.66 × X, R^2 = 0.96 (0.99) (6.09×e^{-10})
2	USA	У = 16 801 + 0.079 × X, R^2 = 0,97 (3,6 × e^{-7}) (3,2 × e^{-10})
3	China	У = 2655 + 0,029 × X, R^2 = 0.99 (1,1 × e^{-8}) (2.37×e^{-13})

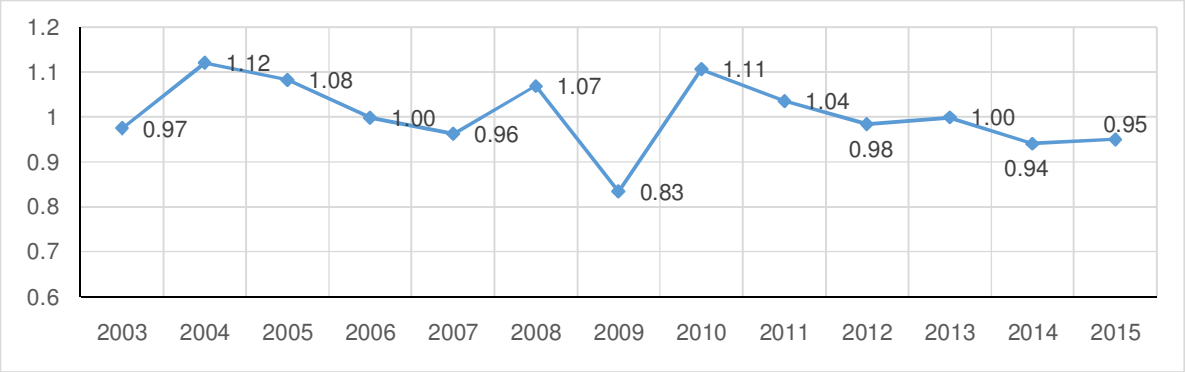

Fig. 3. Dynamics of an efficiency indicator of expenses use on research and development in Russia.

The formula for calculation of an annual efficiency indicator of expenses use on research and development is following :

$$EFF^n = \frac{I^n_{GDP}}{I^n_{R\&D}} \quad (2)$$

I^n_{GDP} - GDP deviation per capita by a year of *n* of previous year;

$I^n_{R\&D}$ - deviation of expenses on research and development by a year of *n* of previous year.

III. RESULTS

The efficiency indicator of expenses on research and development is 0.94 in China, 1.001 in Russia, 0.99 in the USA. It is possible to draw a conclusion that in Russia the efficiency of expenses use on research and development is higher. However average gain in a year on both indicators is much higher in China (on expenses on research and development 18% and on GDP per capita of 11%) that confirms a phenomenon of the Chinese economic miracle.

In Russia considerable decrease in efficiency indicator of expenses on research and development is observed in 2009 that it is connected with considerable reduction of gain on GDP as a result of crisis of 2008.

IV. DISCUSSION

The offered method of the analysis allows to draw conclusions most quickly and visually correctly about ability of the state or region effectively use the funds allocated for development. Achievement of good results in absolute measures gives a one-sided idea of readiness of an economic system for development of innovations. Therefore the considered method will be able to add the estimates system of the level of development of an innovation system in the country and region. At all variety of the studied assessment methods of the level of development of innovation systems a concrete assessment of ability to receive the maximum result with the smallest investments is not given anywhere. Usability of this method is also that data for its realization can be found, as well as in national statistical sources, and in bases of the international organizations.

V. SUMMARY

The USA and China considerably advance Russia on a number of economic indicators and also on the indicators reflecting the level of innovative activity. The same picture is reflected by the key ratings of the international organizations (Table 1). A key indicator, reflecting innovation level of the region, is the size of expenses on research and development. However, this indicator reflects only the level of the activity directed to creation of an innovation system, but it does not reflect its current efficiency. The method of efficiency assessment offered in the article can be used both for the comparative intercountry analysis and operational assessment of use of the means spent on research and development. Falling of efficiency indicator shows need of decrease in expenses on research and development as they are spent not effectively, and need of a national innovation system correction with the purpose to increase return from investments.

VI. CONCLUSIONS

Comparison of China, the USA and Russia is always of particular interest as these states are three world powers having high military potential that strengthens also the competition in the economic sphere. So far the USA is on the first place on the GDP level, but rates of development to China allows to shoot ahead. To realize the ambitions in the economy of Russia it is necessary to increase pace on the way of innovative development and to increase both efficiency and stability of the national innovative environment.

ACKNOWLEDGEMENTS

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FOOTNOTE

[a]. Source: website World atlas of data [https://knoema.ru/atlas/topics]

[b]. Source: website Humanitarian technologies [https://gtmarket.ru/ratings/global-competitiveness-index/info]

[c]. Source: website Humanitarian technologies [https://gtmarket.ru/ratings/global-innovation-index/info]

[d]. Data are obtained from the official site of the Organization for Economic Cooperation and Development (OECD): https://stats.oecd.org

[e]. https://stats.oecd.org/

[f]. Data are obtained from the official site of the Organization for Economic Cooperation and Development (OECD): https://stats.oecd.org

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