Formation of the knowledge economy in Russia: the role of university science

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Abstract. A significant feature of the knowledge economy is an updated education system aimed at the production of human capital capable of innovative activity in all sectors. The article deals with the scientific potential of the higher school in Russia and its ability to create the knowledge economy to form competitive Russian economy in the world market. There are interesting studies of foreign and Russian scientists on this topic. Many serious problems of higher education of the Russian Federation are still not resolved up to the present day. It refers to most higher education institutions that have not received the status of national research or federal institution, but they continue to carry out their mission of training young specialists for production under years of underfunding. The “optimization” process in education has made such universities weak, the profession of a teacher has become less attractive, the teaching staffs have an average age above 60 years, and it is deprived of renewal possibility. The scientific potential of Russia, including the higher education institutions, is significant and inexhaustible. The state should only use it correctly and rationally, take care of human resources, provide social protection for scientists and teachers. All these will attract young researchers to academic and university science, it will ensure the success of the knowledge economy in the country.

1. Introduction

A modern analysis of trends in the development of the world economy convinces that Russia will be able to overcome the raw materials specialization of the economy only based on its own knowledge economy formation. There is an established classification of types of economies in the world science – traditional, market, and planned. In 1962, the American scientist F. Machlup introduced into scientific circulation a new definition – “knowledge economy”. Up to date there is no clear understanding what this type of economy includes. Some scientists argue that such an economy is based on the effective use of the latest knowledge, knowledge becomes the main factor of economic growth and key social value [1-3], others consider knowledge to be a product that is the basis of production, and the knowledge economy is formed under the condition when knowledge becomes a product of sale, but with a certain weight and significance of this product in the market [4, 5, 6]. Most scientists recognize that significant features of such an economy are the complex renewal of the education system and the development of human capital, the rapid growth of innovative activity in leading industries, the development of the intellectual property market [7, 8]. The researchers associate the development of the economy of the regions with the results of scientific and innovative activities of research universities. Responding to the needs of the production sector of the region, the research universities,
interacting with the business community and government, form a unique entrepreneurial climate. The updated environment that, in turn, helps them to elicit their potential influences them themselves [9, 10].

So far, this problem in Russia has not been comprehensively and fully solved [11]. It seems that the knowledge economy should be based on the new knowledge industry, where the priority role belongs to the human capital, the latest technologies based on new developments of scientists, and active investment into the infrastructure of the innovative sector of the economy. These are the three drivers of sustained growth in the world economies. The authors of the report “On Human Development in the Russian Federation” note fairly that innovations as art are the most complex type of human activity. Therefore, it is not only important to learn how to use intellectual products of others, but also to create our own intellectual products. Thus, the strategic objective of the developing economies of the world is first to find effective measures to improve the quality of education [12].

The Soviet system of higher education until the collapse of the country and the reforms beginning in the political and economic spheres was one of the most stable and well-established mechanisms for training personnel for all sectors of the country economy. The graduates of Russian universities were invited to work at well-known corporations from all over the world. Over the years of reform, Russia lost its former model of education and needed to rebuild its new knowledge economy, where higher education could play a key role. This process is difficult, only Moscow State University possesses a modest but stable position in the world ratings.

Russia uses the experience of Western countries, where the main scientific forces are concentrated in research universities. There are 29 national research universities and 10 federal universities in Russia. They receive sufficient funding from government budget for research and development. There is a project to create a joint university in Tomsk, where educational, scientific and infrastructural resources are combined. Russian universities run research parks. Researchers work at the higher education sector in various scientific fields, but their patent activities in Russia and abroad are very modest.

The objective of this study is to analyse the state of the scientific potential of the modern higher institution of Russia, to identify its capacity to create the knowledge economy, to show success and problems in the formation of the modern knowledge industry, to conduct a comparative analysis and comparison with the leading countries of the world.

2. Methods and materials
The methodological basis of the study was the official documents of the Government of Russia, scientific works of Russian and foreign researchers on the formation of the knowledge economy in the world and the Russian Federation. The study was conducted using statistical, system, retrospective, comparative and logical analysis methods and tools.

The statistical base of the study was the data of the Russian Federal State Statistics Service, the reports of the Center for Strategic Research, the Center for Humanitarian Technologies, statistics of the World Bank, statistical reviews of the Higher School of Economics, international rating agencies.

3. Results
The international competition in the economy requires highly educated, professional, highly cultured personnel capable of continuous improvement, training and able to adopt and apply innovative technologies. A modern education system is required in the country that is ready cope with the most difficult challenges of the time to train such personnel. The higher education, in particular, can meet these requirements.

More recently, before the beginning of the political and economic reforms of the 1990s, Russian higher education was one of the most stable and well-established training mechanisms for all sectors of the country economy. Moreover, the graduates of Russian universities were invited to work at well-known corporations from all over the world. The economic crisis followed the political and economic
Restructuring of the country in the 1990s led to the crisis in all life-supporting systems of the society including the higher education system.

Over the years of reforms, Russia has lost its previous model of education. In the modern world, in order to have a competitive economy, Russia needs to rebuild its new knowledge economy, where the higher education system plays a key role. On the one hand, higher education trains labour resources for all sectors of production – human capital, that is already included in the scientific and production process at the universities, on the other hand, higher education acts as a generator of new ideas and technologies, thanks to the involvement of knowledge and scientific results in the production process.

This process is not simple in Russia, as everything that has first been destroyed or degraded, and then rebuilt again. Over the years of reforms, higher education in Russia has undergone many changes, the practice of state ordering for specialists at various sectors of the economy has been lost, the practice of guaranteed employment of graduates has been lost, state funding for universities has been greatly reduced, and the number of “state-funded places” has been reduced.

We studied the international rankings of higher education systems of different countries in the world. We present the results of one of them – Universitas 21 [13]. The rating estimates higher education systems of a large number of countries at different stages of economic and social development. It is calculated using the methodology of the Melbourne Institute of Applied Economic and Social Research at the University of Melbourne (Australia), and takes into account 24 main indicators, combined into four groups:

1. Resources (private and public sector investment) – 25%.
2. Results (research and publications, compliance with the needs of the national labour market, including subsequent employment of graduates) – 40%.
3. Communication (level of international cooperation) – 10%.
4. Environment (national policy and regulation, educational opportunities) – 25%.

The final calculations take into account the corrections for the population of the countries under study, the study is carried out in the countries with confirmed statistics on all indicators, and these measurements are summarized in the final indicator, which determines the position of each country in the world ranking.

We put some countries of the world ranking in the table that includes 50 countries, dated May 26, 2020 (table 1). Russia occupies 35th place among 50.

Table 1. Ranking of National Higher Education Systems 2019. Universitas 21: Ranking of National Higher Education Systems 2019. [13].

| Ranking | Country      | Indicator | Country  | Indicator | Country | Indicator | Country  | Indicator |
|---------|--------------|-----------|----------|-----------|---------|-----------|----------|-----------|
| 1       | USA          | 100       | 16       | Germany   | 69.6    | 30        | Italy    | 53.4      |
| 2       | Switzerland  | 88.6      | 17       | France    | 67.6    | 31        | Poland   | 51.3      |
| 3       | UK           | 84.5      | 20       | Japan     | 61.7    | 32        | Chile    | 51.3      |
| 4       | Sweden       | 82.9      | 23       | South Korea | 57.4  | 34        | South Africa | 48.7    |
| 5       | Denmark      | 82.5      | 24       | Spain     | 57.3    | 35        | Russia   | 48.5      |
| 6       | Canada       | 81.9      | 27       | China     | 54.7    | 42        | Turkey   | 43.3      |

Unfortunately, Russia has lost its own very good characteristics and traditions, and now modern Russia, reforming its knowledge economy, uses the experience of Western countries to incorporate university science into the innovative economy. Major scientific forces in Western countries are concentrated at research universities. Along with educational and research activities, the universities provide research and development services aimed at introducing into production, thereby ensuring the economic growth of industries and regions. Interacting with the leadership of the regions, they develop strategies for the political, economic, social and cultural development of cities and regions. The universities take on the function to generate non-standard solutions in order to create an innovative environment for productive partnership with the production sector.
Analyzing the experience of using the scientific activities of foreign research universities, Russia also creates modern research complexes on the basis of the largest Russian universities. To increase the role of universities as a producer of scientific knowledge requires improving the legal and regulatory framework of universities, change their structure; update the activity coordination and strategic planning of all higher education.

In October 2008, the President of the Russian Federation launched a pilot project on the creation of National Research Universities (NRU). Non-competitively, this status has been received by National Research Nuclear University (MEPhI) and the National University of Science and Technology (MISIS). In the concept of creating a network of national research universities, the Ministry of Education and Science of the Russian Federation defines the main mission of the research institute. It is to carry out educational and scientific activities equally and effectively on the basis of the principles of science and education integration.

At the same time the leading higher education institutions of the higher education system have obtained the special status: Lomonosov Moscow State University (MSU), St. Petersburg State University (St.PSU). Some universities in the regions have also obtained the special status: Baltic Federal University, Far Eastern Federal University, Kazan Federal University, Crimean Federal University, and Northern Arctic Federal University. Seven federal universities are formed. In October 2008, the President of the Russian Federation announced an open competition for the creation of national research universities. 110 universities of the country submitted applications for participation in this competition. According to the results, 12 universities received the status of the national research universities. In February 2010, other 128 higher educational institutions submitted their applications, 15 of them received the status of the national research universities. Thus, 29 large national research centers appeared in the country. Higher educational institutions of Moscow, St. Petersburg, Belgorod, Irkutsk, Kazan, Novosibirsk, Tomsk and other major scientific centers of the country were included. National Research Universities (NRU) were called upon to contribute to the implementation of the strategy of scientific and technical development of Russia. For the current year 2020, NRUs are the basis of the project 5–100. This project supposes five universities of the country entering the TOP-100 universities of the world. NRUs have become the leaders in terms of scientific activity and taken good positions in various international ratings, for example, according to QS World University Rankings 2016-2017, out of 916 universities, Russian universities took the following positions: Moscow State University – 108, St. Petersburg State University – 258, Novosibirsk State University – 291, Moscow State Technical University named after Bauman - 306, Moscow Institute of Physics and Technology (MIPT) and MGIMO University – 350 and others [14].

This process affected the number of staff engaged in research and development in the higher education sector of the Russian Federation. Since 2010, their number began to increase (table 2), and the volume of internal research and development costs in the higher education sector (table 3), they also show a sharp increase.

Table 2. Share of the higher education sector in the total number of staff engaged in research and development, % [15].

| Category            | 2000 | 2005 | 2010 | 2015 | 2017 |
|---------------------|------|------|------|------|------|
| Staff, total        | 4.6  | 5.3  | 7.2  | 8.6  | 8.4  |
| Researches          | 6.6  | 7.7  | 10.5 | 12.1 | 11.7 |
| Technicians         | 4.7  | 5.5  | 8.6  | 9.3  | 11.0 |
| Additional and other staff | 2.3  | 2.7  | 3.1  | 4.1  | 3.8  |

The integration of the Russian Academy of Sciences and higher educational institutions becomes an important task for the successful development of science. The process of reforming the Academy of Sciences and universities of the country coincides in time, and the objectives of the reforms pursue a single goal, it is to renew the knowledge industry on a new organizational basis using the integration of the powerful potential of academic science and the ability of universities to train qualified research
personnel. Much experience of such integration has been accumulated in Russia, for example, in Novosibirsk Akademgorodok, in the Urals, Krasnoyarsk, Tomsk and other cities.

Table 3. Internal research and development costs by activity sectors (billion, RUB) [Rosstat data].

|            | 2000 | 2005 | 2010 | 2015 | 2017 |
|------------|------|------|------|------|------|
| Total      | 76.7 | 230.8| 523.4| 914.7| 1019.2|
| by activity sectors: | | | | | |
| State      | 18.7 | 60.2 | 162.0| 284.1| 310.0|
| Business   | 54.3 | 156.9| 316.7| 541.5| 613.0|
| Higher education | 3.5 | 13.3 | 43.7 | 87.7 | 91.9 |
| Nonprofit organization | 0.2 | 0.4 | 1.0 | 1.3 | 4.2 |

At Novosibirsk State University, now the National Research University, from the first day of its organization, outstanding scientists of the Siberian Branch of the Russian Academy of Sciences teach at all faculties, and the students of NSU from the first year of study are included in the research process of the SB RAS. Having received a diploma of graduation, its graduates join the ranks of young researchers, so the scientists of the Russian Academy of Sciences prepare new scientific personnel, and they, in turn, having gained experience, and then become the teachers of NSU, organize joint laboratories, departments, educational and scientific centers with scientific research institutes. They hold joint scientific conferences, publish textbooks and publish scientific results.

There is an example in the Siberian region of combining infrastructure and capacities to strengthen the scientific potential of universities in the city of Tomsk. A so-called “Big University” is created there; all universities and research institutes of the city are included into this organization remaining legally independent. The integration aims to win the competition of the Ministry of Education and Science of the Russian Federation to create one of the 15 planned world-class scientific and educational centers (SEC). There is an inequality of infrastructure in Tomsk universities that developed historically, as well as insufficient efficiency in the use of resources, while the requirements for world-class scientific and educational centers from a technological and socio-economic point of view are increasing every day. Within the framework of the project, a service system will be created and the design of a digital platform for a multiple use of scientific equipment will be begun. This example is undoubtedly of a new knowledge economy creation of and worth of being repeated in different regions.

In order to provide small and medium-sized businesses with modern infrastructure that allows them to start production of high-tech products in the shortest possible time and with minimal costs, research parks are being created in many regions of Russia, including the higher educational institutions.

The first research parks appeared in the USA in early 1950s at Stanford University. Scientific teams and small firms were involved in free laboratories, which began to fulfill mainly military orders and work for the defense of the country. The cooperation of production companies with university scientists gave the first positive result, so regional specialized research parks appeared. The first research parks in the Soviet Union appeared in the universities in the late 1980s [16]. The cooperation of education, science and production was there begun. In 1990, the first research park of Russia was organized at Tomsk State University, then at Moscow Institute of Electronic Technology, at Moscow State University, at Moscow Engineering Physics Institute (MEPhI), and by the end of the 1990s research parks were almost in all universities of the country. Unfortunately, during the years of the country collapse and the reforms of the political and economic system, this experience was lost. Now it is being recreated in Russia on a modern, high-tech base, and this is a good condition for the development of innovative business at universities, although the experts are still discussing today whether the university needs a research park, what a modern research park should be, whose subordination it should be in, who should finance it, what organizational forms of the research park are the most effective [17].
It can be stated today that researchers in various scientific areas (table 4) work in the higher education sector and actively contribute to the knowledge economy.

**Table 4.** Number of researchers in the higher education sector by field of science (person).

| field of science:       | Total | 2008  | 2015  | 2016  | 2017  |
|------------------------|-------|-------|-------|-------|-------|
| Natural Science        | 13111 | 13175 | 13134 | 12165 |
| Engineering Science    | 10524 | 12858 | 12148 | 11025 |
| Medical science        | 2403  | 2018  | 2040  | 1696  |
| Agricultural Science   | 933   | 851   | 808   | 778   |
| Social Sciences        | 4309  | 11420 | 11199 | 10760 |
| Human Sciences         | 1880  | 5647  | 6568  | 5689  |

An important factor to create the knowledge economy is the use of the universities potential in the field of the intellectual property objects formation; in Russia it is still not fully used. According to 2016 data, 23.2% of all applications submitted for patent registration came from the researchers from higher education institutions, and the share of the received patents was 15.7%. The small share of patent applications for registration and the small share of patents received may be explained by the lack of policy on registration of intellectual property objects at the universities, a correct system of rewards for legal registration of rights to intellectual property results, as well as the lack of a clear procedure for working with patents. At the same time, the patent activity of Russian educational institutions abroad is even less optimistic: according to 2016 data there are only 14 filed patent applications or 1.5% of the total [18].

### 4. Discussion

The basis of the knowledge economy is the knowledge industry that represents the harmonious system of continuous education since comprehensive school, higher educational institutions of the country, the system of retraining scientific, research and educational personnel, the organization of advanced training. The practice has shown that in recent decades the education in Russia has undergone a complex transformation from a high-quality but closed educational system of the USSR to global educational trends. This transformation caught school teachers and university professors by surprise; it affected their personal and professional interests. There were contentious debates in the educational community between the adherents of “healthy conservatism” and the supporters of the introduction of new standards into education, a unified state exam, and the entry of Russia into the Bologna process.

The educational system of the Russian Federation has not been able to adapt to new conditions. There are many reasons of it. They are the underfunding of secondary and higher school institutions, low wages of the teaching staff and educators. The sphere of education in Russia remains unappreciated and is financed by 3 times less than the country’s GDP in comparison with the countries participating in the OECD. Having set the aim to create a modern knowledge economy, the state still allocates very little funds from the budget for it. In terms of domestic research and research costs, the positions of countries are distributed as follows: in 2018, the United States was in the first place, China was in the second place, Japan was in the third place, Germany was in the fourth place, the Republic of Korea was in the fifth place, France was in the sixth place, India was in the seventh place, the United Kingdom was in the eighth place, and Russia was in the ninth place [19].

In terms of funding from the state budget for research and development in terms of purchasing power parity of national currencies in US dollars in 2018, the Russian Federation was significantly inferior to the United States, China, Germany, Japan, that is, to all economic leaders of the world (table 5).

Savings in education and science have affected their quality characteristics and assessments. By the number of universities included in the TOP-100 (QS Rating of World Universities) in 2018, Russia’s position is very modest. If the United States in the TOP-100 universities in the world are represented...
by 31 universities, Great Britain - 16, Austria - 7, China - 6, Japan - 5, Germany - 3, France - 2, then Russia is represented by one university, i.e. Moscow State University. The first four places in the points of the QS Rating were occupied by the US universities, the next four places were occupied by the UK universities, Chinese universities were in the 25th, 38th, 40th places, and the best Russian university was only in 95th place out of a hundred [20]. In the international ranking of the best universities in the world according to Times Higher Education dated May 26, 2020, Moscow State University is only in 189th place out of 198, there are no other Russian universities in the ranking [21].

**Table 5.** Funding of research and development from the state budget by countries (millions of US dollars; based on purchasing power parity of national currencies) [19].

| Country                  | 2000       | 2010       | 2018       |
|--------------------------|------------|------------|------------|
| Russia                   | 4784.6     | 26076.7    | 27965.1    |
| Brazil                   | 8555.9     | 11570.2    | 13393.3    |
| UK                       | 9492.2     | 13315.8    | 15700.2    |
| Germany                  | 17234.0    | 28587.1    | 41032.0    |
| Italy                    | 9508.5     | 12348.8    | 12627.0    |
| Canada                   | 4589.6     | 8477.4     | 8189.3     |
| China                    | 11051.4    | 51275.2    | 98244.6    |
| Republic of Korea        | 5017.8     | 16293.9    | 22519.2    |
| USA                      | 72681.0    | 119382.0   | 130541.0   |
| Taiwan                   | 2978.7     | 7042.4     | 8217.2     |
| France                   | 14880.1    | 19141.6    | 20085.2    |
| Japan                    | 21227.8    | 32140.4    | 37244.3    |

Many acute problems of higher education in the Russian Federation remain unresolved up to date. It applies to most higher educational institutions that have not received the status of national research or federal university, but within the years of underfunding, these universities continue to fulfill their mission honestly in training young specialists for production and scientific activities. The maximum permissible annual educational load of research and teaching staff (hereinafter RTS) of the universities is one of the important problems. It is 900 hours per year. Such a maximum permissible load has been turned into an ordinary norm outside the universities of the capital. At the same time, every teacher is obliged to be engaged in research activities and publish its results in international rating journals; otherwise the salary is the lowest. To combine teaching and scientific activities with such an educational load is physically impossible.

Being short of modern equipment for research and experimental work, most universities in the country cannot turn into a modern industry of scientific knowledge. And although in 2018 the number of universities performing scientific research almost coincides with the number of higher educational institutions in the country (table 6), it is difficult to say that all universities have definitely become equal subjects of the knowledge economy.

**Table 6.** Research and Development Organizations [19].

| Total | 2000   | 2010   | 2018   |
|-------|--------|--------|--------|
|       | 4099   | 3492   | 3950   |

by science sectors:

| Higher Education | 526    | 617    | 998    |
| State            | 1247   | 1400   | 1511   |
| Business         | 2278   | 1405   | 1304   |
| Other organizations | 48    | 70     | 137    |

This fact reveals the following in Russia, the teaching staff being low paid is forced to make a research as the administration of most universities in the country fulfill the requirements of the Ministry of Education and Science. It is impossible to succeed working in such an algorithm and make a scientific breakthrough. But the reporting and information services of the universities work rather actively and give data on the progressive growth of university science. There is no doubt that many talented teachers and well-known scientists work at higher schools of the country. But the profession
of a university teacher has lost its former attractiveness, the teaching staff are of a solid age, and young graduates of the universities do not show interest in teaching. According to the Federal State Statistics Service, in 2019, the professors over 60 years old accounted for 66.3% of their total number at higher educational institutions and the candidates of sciences, the associate professors over 60 years old accounted for 25.6% who taught undergraduate, graduate, and postgraduate programs. The teaching staff training at postgraduate schools of the universities has consistently decreased since 2000 according to the Federal State Statistics Service. In 2000 the total number of postgraduate students was 117.7 thousand people, in 2018 there were only 90.8 thousand postgraduates, that is 26.9 thousand or 22.9% less. The admission to postgraduate school has decreased by more than 16 thousand people in 2018 in comparison with 2000.

Another indicator of the Russian education system is rather interesting. In 2019, the total number of the teaching staff of the organizations that carried out undergraduate, graduate, and postgraduate programs accounted for 236.1 thousand people, 17 thousand of them were scientific workers, while in 2010 the number of the teaching staff was 356.8 thousand people, and scientific workers were 21.6 thousand people. [22]. As a result the higher school lost 120.7 thousand people from the teaching staff or and 4.6 thousand vacancies of researchers over the past ten years.

It was caused by a so-called “optimization” policy, which was implemented during the last decade in the education sector, and it gave such a result: 33.8% of the teaching staff of the higher education were redundant. In many educational institutions, the departments were destroyed and blighted; the economies of scale were lost. Instead of huge scientific topics that were performed collectively, single researchers remained. The teaching staff of many universities still could not fully adapt to these new conditions. We should note that over the same years, the managerial staff of the universities increased from 22.9 thousand people up to 26.8 thousand people [22].

5. Conclusion
The main burden on the production of new scientific knowledge in modern Russia is on specialized scientific institutions subordinate to the Russian Academy of Sciences. The intellectual resources of the Russian Academy of Sciences are large, for many years large scientific centers have been successfully operating in the country. The regional departments of the Russian Academy of Sciences are the Urals, Siberian and Far Eastern. A successful integration of academic and university science resources into the scientific centers of Moscow, St. Petersburg, Novosibirsk, Tomsk, and Ekaterinburg gives a great synergetic effect. This integration should receive comprehensive support and be cultivated in all regions of Russia.

29 major national research universities and 4 federal universities are successfully working in the knowledge economy of Russia today. They are fully supported by the state and are making significant progress in the development of the universities as world-class educational and research centers.

In addition to the transformed national research and federal universities, there are many strong, professionally successful higher education institutions in the country those with the financial and institutional support from the state will be able to become large research centers in their regions and be the ideas generators for the entrepreneurial sector of the regional economy.

In Russia, there are also positive examples of the unification of the university science within one city or a region. It will help to combine resources and make it possible to solve problems corresponding to the challenges of the modern innovative economy on the scientific site of an entire city or a region.

The scientific potential of Russia, and the sphere of higher education, is significant and inexhaustible. The state should only use it correctly and rationally, take care of human resources, provide social protection for scientists and teachers; it will attract young researchers to academic and university science that will lead to the construction and successful development of the knowledge industry in the country.

When reconstructing the institutions of academic science and higher education, the reformers should not copy everything and transfer the experience of Western states to Russian reality, although
they undoubtedly have something to learn from. We need to build on our own experience. Russia itself has a powerful creative potential that can create an independent knowledge economy. This is proved today by successes in the military and defense sectors.

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