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TECHNOLOGICAL MODERNIZATION OF THE OIL AND GAS INDUSTRY: THE CURRENT STATE AND PROSPECTS OF DEVELOPMENT

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ТЕХНОЛОГИЧЕСКАЯ МОДЕРНИЗАЦИЯ НЕФТЕГАЗОВОЙ ОТРАСЛИ: СОВРЕМЕННОЕ СОСТОЯНИЕ И ПЕРСПЕКТИВЫ РАЗВИТИЯ

In Russia today there is a gap between modern breakthrough technologies that should serve as an engine of economic development and industries that operate on technological equipment of the previous generation. At the same time, the modernization of production cannot be centered around renewing only the companies' fixed assets. The aim of the study is to analyze the current technological state of the oil and gas industry of the Russian Federation, the dynamics of investments in R&D by domestic and foreign oil and gas companies, the impact of sanctions on the modernization of the sector. The level of innovative activity in the oil and gas industry in 2013-2014 remained unchanged. The direction of technological innovation continues to depend on the future activities of the companies. The Russian company «Tatneft», which is one of the eight leading domestic vertically integrated companies and has been among the leading companies in the number of patents and inventions in the past five years but it is not the leader in the field of extraction and processing of hydrocarbons. From 2008 to 2014, there was an increase in the ratio of R&D to sales in virtually all oil and gas companies, but foreign companies remain the leaders in the volume of investment in R&D, both in absolute and relative terms. As a result of the analysis, the authors concluded that in Russia there is a reserve for the technological development of the industry, but the current high dependence on foreign technology in the commodity sector remains and is, unfortunately, unavoidable in the midterm. Production modernization in the oil and gas industry cannot consist only in updating the main funds of companies, as disregarding the implementation of new technologies by state and businessesleads to a loss of long-term competitive advantages of domestic companies.

TECHNOLOGICAL MODERNIZATION; IMPORT SUBSTITUTION; INTELLECTUAL PROPERTY; INNOVATION; POSTINDUSTRIAL ECONOMY.

Сегодня в России наблюдается некий разрыв между современными прорывными технологиями, которые должны послужить локомотивом развития экономики, и отраслями промышленности, функционирующими на поколении оборудования прежних технологических укладов. Вместе с тем модернизация производства не может заключаться только в обновлении основных фондов компаний. Целью исследования стал анализ текущего технологического состояния нефтяной и газовой промышленности России, динамики инвестиций в R&D отечественных и зарубежных нефтяных и газовых компаний, влияния санкций на модернизацию сектора. В 2013–2014 гг. уровень инновационной активности в нефтегазовой отрасли оставался неизменным. Выбор направления технологических инноваций продолжает зависеть от предстоящих областей деятельности компаний. Среди компаний-лидеров по числу патентов и изобретений за последние пять лет оказалась российская компания «Татнефть», которая входит в число восьми ведущих отечественных ВИНК, но при этом не является лидером в области добычи и переработки углеводородов. Нефтегазовые компании делают основной упор на развитие технологий в сегменте «добыча». С 2008–2014 гг. произошло увеличение показателя отношения расходов на НИОКР к выручке у большинства нефтегазовых компаний, однако зарубежные фирмы остаются лидерами в объемах инвестирования в НИОКР как в абсолютном выражении, так и в относительном. Сделан вывод, что в России есть резерв для технологического развития отрасли, но в настоящее время высокая зависимость от иностранных технологий в сырьевом секторе остается и, к сожалению, неустранима в среднесрочной перспективе.

ТЕХНОЛОГИЧЕСКАЯ МОДЕРНИЗАЦИЯ; ИМПОРТОЗАМЕЩЕНИЕ; ИНТЕЛЛЕКТУАЛЬНАЯ СОБСТВЕННОСТЬ; ИННОВАЦИИ; ПОСТИНДУСТРИАЛЬНАЯ ЭКОНОМИКА.

Introduction. The advanced technological development of nations, national companies and the private sector is now one of the key strategic vectors. Economies based on advanced technological structure allow to export modern goods and services in return for intellectual rent,

while recipient countries, often without advanced technologies, pay currency received from the exports of natural resources, taking away the resource rents some of which are non-renewable.

In the postindustrial society, the development of innovative productions is carried out with a «clean slate» and is not burdened with a mass of obsolete fixed assets that do not correspond to the spirit of modern times.

Completely rejecting industrial production and replacing it with the post-industrial service economy and clean energy is not possible in our opinion. One has only to refer to the experience of de-industrialization of the UK industry that was reduced in size by two thirds over the last 30 years. The country's leadership was confident that the priority of industries had been left in the past, and the future of the ascending branches was only associated with the knowledge-driven economy. As a result, a number of industrial sectors were destroyed and no alternatives to them have been found so far. The share of employees in manufacturing decreased by 2.7 times, the unemployment rate increased, because the economic system of the country was not prepared to train programmers and researchers from yesterday's workers [1]. It is obvious that the country's industry is the foundation of material production, and makes a fundamental contribution (from 25 to 40 %) to the gross domestic product [2].

Modernizing the Russian economy is extremely urgent and actively discussed at various levels of the institutional system. The modernization of the country is traditionally associated not only with permanent updating but a fundamental change in the direction and pace of economic development. The modernization of the Russian economy, the course of which was adopted by the Russian Government in 2006, should include its innovative development and new industrialization. Industrialization in the classic sense is the process of replacing the primitive, poorly equipped hand labor by machine work. New industrialization is the repetition of this process, but under new conditions, while the re-industrialization is the process of recovering industrial, technological systems, individual sectors and types of production, together with solving major problems related to the stock, technological and human resource base of the industry, as well as with a common vector for creating innovative domestic products with high added value [3]. In general, technological modernization is a change in the structure of the technological mode of various economic entities in favor of advanced technologies. Industry is the main subject for the changes.

A new financial and economic strategy aimed at accelerating economic growth on the basis of the new industrialization, a sharp increase in industrial investment, and import phase-out was offered by Glazyev [4, 5], Polterovich, Ivanter, Nekipelov, Primakov, Greenberg, Dmitriev, Kuzyk [6, 7] and other leading domestic economists. The problem of strategic development and reindustrialization of old industrial regions also has quite a serious scientific-theoretical basis. The works of both Russian scientists (Amosha, Novikova, Lyashenko, Makogon, Novak, Belinskaya) and foreign ones (Glonti, Boshmy, Lembuya, Steiner, Muller) have been dedicated to it.

Assessing the significance of the scientific research carried out not only by the above-mentioned scientists but also by many others, it should be noted that certain aspects of the problem remain largely controversial or do not find a clear solution under the conditions of a complex geopolitical situation.

In Russia today there is a gap between modern breakthrough technologies that should serve as an engine of economic development and industries that operate using technological equipment of the previous generation. At the same time, the modernization of production cannot be centered around only the renewal of companies' fixed assets, as both the state and the business completely neglecting to implement new technologies results in the loss of long-term competitive advantages of domestic companies.

The objective of the research. In this study, the aim was to analyze the current state of the technological portfolio of domestic oil and gas companies on the basis of the data of their inventive and innovative activities, and to assess the prospects of its development, based on the dynamics of investments in R&D in 2008-2014.

The questions of eliminating the technological backwardness of Russia were always relevant, and that is the reason why

borrowed advanced technologies were present both in the Russian Empire and in the Soviet Union. Even at the time of the Demidovs Russia exported metal and other manufactured goods to Europe, but in those years the Ural metallurgical industry was based on manual labor. Domestic industrialization started only in the late 19th and early 20th centuries. It featured massive urbanization, attraction of previously unused resources thanks to broad railway construction, as well as catch-up development, i.e., the purchase of already developed technologies from abroad using credits and the export of raw materials. In Soviet years, these characteristics have been supplemented by the extensive use of forced labor, the withdrawal of the surplus product of the agricultural complex, the focus primarily on the development of the military industry. Centralized state-run planning did not allow to close outdated production facilities and to develop private initiative [8].

The post-industrial approach actively highlights significant changes in the world economy, raising the questions of how the industry of the 21st century should look like, and what is its place among the variety of services and innovation of high-performance post-industrial regions in comparison to which the industries appear less efficient and hard to transform.

The need for innovative development of industrial production is dictated by the changes in economic conditions (tightening environmental regulations, the transition to a low carbon economy (reducing greenhouse gas emissions, energy efficiency, increasing the share of clean energy [9]), impossibility to ignore the social and political factors, as well as shifting whole sectors of the domestic economy, such as the oil and gas sector, to a new technological path (in the future). The concept of inclusive economic growth also emphasizes the need for a versatile, balanced approach to the economic development of countries.

According to the Thomson Reuters «2015 State of Innovation» report, the level of innovative activity in the oil and gas industry in 2013–2014 remained unchanged [10, p. 55]. The growth rate of innovation in the industry in 2014 compared to 2013 amounted to 1.0 % (Tab. 1). China is the leader in the field of «exploration, drilling, extraction and processing of oil and gas». The first places are occupied by the Sinopec and PetroChina companies(China), followed by Halliburton and Schlumberger (US). China National Offshore Oil Corp (China) is also ranked fifth. The Sinopec company focuses its innovation mainly on the downstream sector, namely on the fractionation of crude oil, cracking for production of heavy oil and diesel fractions, as well as the synthesis of polymers, aromatics, alcohols, acids and formaldehyde. PetroChina Corporation innovates mainly in the upstream sector of exploration, drilling, production, processing, and wellheads pipeline development technology. Currently, Sinopec and PetroChina are joining their efforts in the sector of processing hydrocarbons.

If we analyze the research in this area it is necessary to include the Imperial College of London (UK) and the US Department of Energy among the leaders. They are followed by Stanford University (USA) and the Technical University of Tallinn (Estonia).

Table 1

Investments in R&D for sub-sectors of the world oil and gas industry in 2013–2014 [10]

Subsectors	Share in total R&D volume	R&D volume		Change, %
		2013	2014	
Petroleum & Gas Exploration, Drilling, Production and Processing	62.5	15480	15589	0.7
Petroleum & Gas Fuels and Other Products	34.2	8464	8459	−0.1
Petroleum & Gas Transportation and Storage	2.6	664	658	−0.9
Petroleum Refining	0.7	178	183	2.8

Source: Thomson Reuters Derwent World Patents Index/

The methodology of the study. The study used scientific methods of research (comparison, generalization, analogy method, structural analysis and synthesis), logical techniques – theoretical analysis, methods of technical, economic and financial analysis.

The Russian company Tatneft (Tab. 2), which is one of the eight leading domestic vertically integrated companies, but it is not the leader in the field of extraction and processing of hydrocarbons, was among the leading companies in the number of patents and inventions in the past five years. It should be noted that the Thomson Reuters studies pointed to the great potential of this company, as it ranges among the leading oilfield service companies (Halliburton Energy Services, Schlumberger, Baker Hughes), for which the level of innovation is traditionally high, oil majors Exxon Mobil and Shell, as well as a number of scientific institutions. The latter are Korea Aerospace Research Institute, Harbin Institute of Technology, Beijing University of Aeronautics and Astronautics, and Beijing Institute of control technology, whose main task is developing and introducing appropriate innovations.

We have made an analysis of the dynamics of the innovative activities of the leading oil companies on the basis of the Federal Institute of Industrial Property database for the period from 2000 to 2015 (Fig. 1). The data demonstrates that vertically integrated oil companies PJSC Tatneft and PJSC Gazprom are leading at the level of the dynamics of registration of intellectual property in Russia with a considerable gap from other vertically integrated companies.

The structure of intellectual property by type of activity in the leading vertically integrated oil companies in 2000–2015 presented in Fig. 2 indicates that the companies' main focus is on developing technologies in the production segment. Rosneft is the only company for which the dynamics of patents and inventions in the recycling segment slightly predominates over its production segment. At this moment the current structure of the Russian vertically integrated oil companies in favor of investments in technologies that improve the efficiency and processing of hydrocarbons is in line with the trend of investment in R&D by the world oil and gas companies.

Table 2

The leading companies in innovation in the field of oil and gas in 2010–2014 [10]

Company	Country	The number of inventions, units
North America		
Halliburton Energy Services	U.S.	210
Schlumberger	U.S.	50
Baker Hughes	U.S.	41
ExxonMobil	U.S.	34
UOP LLC	U.S.	28
Europe		
Tatneft Stock Co	Russia	211
Shell Oil Co	Netherlands	103
IFP Energy Nouvelles	France	78
Saudi Aramco	Saudi Arabia	52
BASF SE	Germany	42
Asia		
Korea Aerospace Research Institute	South Korea	147
Harbin Institute of Technology	China	139
Aerospace Dongfanghong Satellite	China	97
Beijing University of Aeronautics and Astronautics	China	97
Beijing control technology	China	84
Mitsubishi Electric	Japan	77

Source: Thomson Reuters Derwent World Patents Index.

The focus on technological modernization of the Russian Federation was announced in 2008 but was not actually supported by either the government or by the business structures. The renewal of fixed assets in the industry will not occur rapidly due to the current Western sanctions, the limitation of provision of high-tech, low exchange rate and limited credit resources. However, in the present situation it is especially important to avoid the creating artificial problems which in the long run can disrupt the development of entire industries [11].

Structuring processes and tools related to the implementation and management of R&D in foreign companies is, as a rule, built in accordance with the business goals and objectives [12–14].

A systematic approach for adapting technologies virtually does not exist at the level of domestic industrial enterprises. Companies act based on the current situation often without any innovative programs. Therefore, they have to incorporate new technological solutions that have been created in-house or purchased earlier, in some cases using the concept of «open» innovation.

The innovative development programs of oil and gas companies (if these programs exist at all in a company) reflect the following information: the amount of R&D funding with respect to the company's level of revenues, target-based technologies and the base for creating them (the research department of an organization, outsourcing or trendy «open innovation»).

The indicator of investments in innovation as the percentage of R&D costs to the cash turnover is customarily used to assess the degree to which a company is integrated into the high-tech industry. If this ratio exceeds 5 %, the company can be attributed to the high-tech industry [15].

From 2008 to 2014, there was an increase in the ratio of R&D to sales in virtually all oil and gas companies, presented in Table 3, but foreign companies remain the leaders in the volume of investment in R&D, both in absolute and relative terms. Despite the fact that the majority of Russian companies have created innovation development programswith long-term technological priorities, the investments of Russian commodity companies in the technology, which in fact can be considered innovative, have not in most cases been a strategic priority for the companies in the period of high oil prices. Domestic oil and gas companies had had little interest in science before the EU and the US announced their sanctions, because the quality of their products had remained virtually unchanged and quite competitive. «The main R&D have been associated with the cost reduction for the extraction of minerals and their transportation. But such studies are poorly connected with high technology« [40]. In the current situation, to maintain the stability of the Russian economy, it is essential to maintain the volume of oil and gas at least at the current levels. Today, this problem has no simple solutions, as in the current crisis it is becoming more difficult and expensive to extract hydrocarbons, and the investments in the development of domestic innovations are still far from the desired level.

Table 3

Investments in R&D Russian commodity companies compared with foreign corporations in 2008–2014 [16–39]

Company	2008			2012			2014		
	R&D expenses, mln $.	Revenue, billion $.	The ratio of R&D expenses to revenue, %	R&D expenses, mln $.	Revenue, billion $.	The ratio of R&D expenses to revenue, %	R&D expenses, mln $.	Revenue, billion $.	The ratio of R&D expenses to revenue, %
Shell	1230	458.4	0.27	1307	467.2	0.28	1222	421.1	0.29
Exxon Mobil	847	459.6	0.18	1042	451.5	0.23	971	394.1	0.25
Surgutneftegaz	40.6	23.2	0.18	37.9*	27.97	0.16	38.9	15.83	0.25
Tatneft	26.7	17.9	0.15	19.9	14.62	0.14	7.1*	8.47	0.08
Gazprom	197.5	136.42	0.14	253.5	157	0.16	192	99.4	0.19
Lukoil	95	86.7	0.11	157	139.2	0.11	154	144.2	0.11
Rosneft	10.9	45.9	0.02	327	101.35	0.32	590.2	97.82	0.6
IBM	6000	103.6	5.8	6302	104.5	6.03	5437	98.8	5.5

Source: Our estimates for 2012 and 2014 based on the data from oil and gas companies* the calculations include data for the first three quarters of these years.

The problem of depending on foreign equipment in industry has aggravated because of the sanctions. The Energy Minister stresses the need for investments in R&D and engineering, noting that imported equipment is mainly used when developing offshore fields, due to the lack of Russian counterparts or because they do not conform to technical requirements. In his opinion, a weak point in the Russian market is the lack of domestic specialized software, compressor equipment and turbines [40]. In addition, Russian companies are the most dependent on the equipment for production of hydraulic fracturing, horizontal drilling, telemetry and technological support at angle and horizontal drilling.

Industry experts consider the need for tax reform in the oil and gas industry as an incentive to the innovative development of the industry [41–44][1]. Innovative methods of hydrocarbon extraction, which would help maintain current production levels, are very expensive and the existing tax system is inefficient economically. There are mechanisms of taxation in the sector that are being discussed now, according to which taxation should concern the financial results and not the physical production. Not only the mining companies and the representatives of the Government, but also the Ministry of Energy and the Natural Resources Ministry have supported the measure. It is expected that the relevant draft amendments to the existing legislation will be submitted to the State Duma in the spring of 2016. In addition, a tax on already depreciated property can become a specific driver for modernizing the companieshe in the industry.

Currently, the Government of the Russian Federation has approved the roadmap «The introduction of innovative technologies and modern materials in the fuel and energy complex» in which at least twenty national projects on introduction of innovative technologies and new materials in the fields of fuel energy complex will be implemented by 2018. The program also points out that the increase in the volumes of shipping (release) of products, works and services to customers and clients in the fuel and energy complex, produced with the use of innovative technologies and modern materials should be at least 5 percent per year compared to the previous year [45]. According to the project of the Energy Strategy of Russia, for the period until 2035 the share of imported machinery in the amount of purchased equipment could reach no more than 12 % by the end of the first stage of the strategy, no more than 8 % by the end of the second stage, and would drop to 3–5 % by 2035.

Experts point out that companies specializing in the promotion of innovative technologies need to beprovided with access to deposits forconducting tests. This means creating full-fledged test sites in which small innovative enterprises could develop their technology. Oil service companies are suggested to be used ss an integrator, as large vertically integrated oil companies typically strive to obtain a finished service instead of testing a new technology.

The novelty of the obtained results of the study is in the following:

1. the dynamics of the inventive activity of the leading Russian oil and gas companies has been proved;
2. the structure of the intellectual property rights of the Russian vertically integrated oil companies by type of activity has been revealed;
3. the investments in R&D for the leading Russian oil and gas companies in 2008-2014 have been analyzed.

Results. At the state level, the degree of preparedness for the innovations can be evaluated using the innovative ranking of UNESCO. In the global innovation ranking of 2014 prepared by UNESCO, the Russian Federation took the 49th place among 143 countries [46]. The UNESCO study has not identified any fall in the total costs in R&D resulting from the crisis of 2008–2009 in the majority of countries of Eastern Europe, and in major European countries, such as France and Germany, in some Asian economies with high

[1] More recently, there was a transition from a flat to a differentiated scale of taxation in the oil and gas industry of the Russian Federation. For example, the taxation mechanism of gas extraction and condensate has undergone dramatic changes after the introduction of amendments to the 01.07.2014 art. 342, Sec. 26 of the Tax Code on the basis of the Federal Law 263-FZ of 30.09.2013. However, the benefits resulting from these amendments lasted only 6 months and were virtually offset by the provisions of Federal Law 366-FZ of 11.24.2014 since 01.01.2015.

income (the Republic of Korea), and in countries with developing economies (China and the Russian Federation). However, the energy industry today faces serious challenges that require adequate attention, both from the government and corporations [14]. IEA and international patent offices noted a huge potential for scientific research in this area.

The experience of developed countries shows the special role of industrial and innovation policy in stimulating promotion and commercialization of new technologies in the market [47, 48].

In the 2008–2009 crisis and the subsequent recovery phase in 2010–2014, the level of costs in R&D from the state and business structures in the Russian economy was kept at a stable yet low level.

The ban on the technological transfer of technologies for deepwater drilling and LNG projects has shown the dependence of the domestic oil and gas industry on the advanced projects of Western suppliers. The analysis carried out by the experts of the Russian Ministry of Energy showed that most of the equipment imported by Russian oil and gas companies can be replaced today by Russian or foreign analogues produced in countries that do not support sanctions. However, only a partial replacement of such equipment can be performed within the three-year period. Full replacement will only be possible by 2020. Of course, there is a reserve for the technological development of the industry in Russia, but the current high dependence on foreign technology in the commodity sector remains and is, unfortunately, unavoidable in the midterm. *Further directions of research* include the study and analysis of the characteristics of financing innovations in oil and gas companies, as well as defining country specifics for the types of companies under consideration.

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